Assessing Climate Change Risk at the Kam Kotia Mine Site

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Disclaimer

Data used in the assessment and development of this risk assessment report represent the best available information at the time the study was conducted. The data may change as further information is identified or becomes available. Climate risks and associated actions determined throughout this report are for illustrative purposes only and do not represent an exhaustive or recommended course of action to mitigate specific risks. Instead, this report concludes that further detailed analyses are necessary to address potential emerging climate risks. Results in this report are based on the level of feedback received from stakeholders involved throughout the project, which at times was limited.

Executive Summary

This report presents the findings of a Climate Change Risk Assessment (CCRA) of the Kam Kotia mine site, a former copper and zinc mine located near Timmins, Ontario. Kam Kotia has been the focus of significant remediation for decades and work on the site is still ongoing.

The purpose of a CCRA is to systematically identify potential climate change risks and opportunities, assess them, and consider options for mitigating or benefitting from them. A risk assessment framework is presented that provides a possible method for a screening-level assessment that is applicable for abandoned sites across Canada. The process consists of six main steps: project scoping, information gathering, vulnerability identification, risk ranking system, risk assessment and adaptation.

Background research and data gathering focused in three main areas: a literature review on abandoned mine sites and climate change, a review of site documentation and reporting, and climate data. Climate information was developed both for historical trends and future projections. This information, together with the site documentation and reporting, enabled preliminary identification of potentially relevant hazards for the site, currently, and for two future time periods. In total, 19 climate parameters were selected to inform the analysis and characterize climate conditions of most concern for Kam Kotia.

Climate change vulnerabilities are present when a climate condition or event interacts with a physical component, or the operations of a mine site, in a way that could increase risk. Vulnerability scenarios were used to identify and characterize climate change risks on site by developing a sequence of events that represent how climate events may impact site components, and how vulnerabilities, likelihoods and consequences interact to estimate risk. The likelihood of each vulnerability scenario was estimated for the most recent normals period with available data (1981-2010) and, using the outputs of a large ensemble of climate models, for two future time periods (2050's and 2080's). Consequences were established across four categories: 1) Financial, or socio-economic; 2) Physical damage to property; 3) Environmental; and 4) Public health. Consequences were estimated using an expert-based, consensus-driven approach.

Scenarios were subsequently scored and grouped into four classes, for the purpose of prioritization, as follows:

- Class I risks are those that fall well below the risk acceptance-intervention threshold and require no further intervention at the time of analysis.

- Class II risks are those that lie close to or on the risk acceptance-intervention threshold and require active monitoring and/or further evaluation.
- Class III risks are those that exceed the risk acceptance-intervention threshold and require active intervention.
- Class IV are risks that significantly exceed the risk acceptance-interception threshold and require urgent intervention.

In total, six scenarios were identified and categorized as Class IV under current climate conditions, 10 under projected 2050s climate conditions, and 12 under projected 2080s conditions. The majority of Class IV risks relate to the potential for surplus water on site that are driven by severe precipitation events, including spring freshet, rapid snowmelt, and rain-on-snow, and subsequently impact or damage components like the NUT impoundment dam or the water treatment plant. ENDM stakeholders also noted that the existing poor water quality was a high risk at the site. Intervention does not always indicate the need for immediate remedial measures, however, does require additional investigation and consideration.

During the risk ranking activity, risks were assessed based on a "business as usual" assumption, assuming the current performance of the site is consistent in current and future timelines and no additional remedial measures are in place. However, throughout the exercise, note was made of adaptation options that could be considered in the future to help manage key risks. Adaptation has been generally categorized as: improving information and knowledge, bolstering remedial actions, and building management capacity.

A key recommendation with respect to "improving information and knowledge" is to develop an individual landform and drainage design for the NUT and a site-wide drainage pattern plan that can better identify risks and opportunities for the management of flow. Among other potential "remedial actions," installation of a backup diesel generator would reduce the risk of water treatment pumps losing power and provides a clear, tangible adaptation opportunity for the near future. Finally, "building management capacity" for the site could include ensuring that significant institutional knowledge is not lost through effective documentation and ongoing reporting on the conditions of the site and performance of remedial measures.

Transferable lessons learned were identified that may be valuable for future CCRAs conducted for abandoned and orphaned mine sites. These include a list of resources and references to acquire to effectively complete the background information review, the process of assigning likelihood and consequences, a discussion on temporal boundaries and climate conditions that were not included for Kam Kotia but may be relevant to other sites, like permafrost thaw and wildfires.

Glossary

Term	Definition
Abandoned / Orphaned Mine Sites	An abandoned site refers to one at which the operator has rejected custodial responsibility for decommissioning and/or on-going remediation or reclamation. An orphaned site refers to one for which a responsible party (custodian) within the private sector can no longer be located or does not exist (NOAMI, 2016).
Acid Rock Drainage (ARD)	Base metal, precious metal and uranium mines contain sulphide minerals, either in the ore or the surrounding waste rock. When these sulphide minerals, particularly pyrite and pyrrhotite, are exposed to oxygen and water, a process of conversion of sulphide to sulphate takes place. Water in contact with these oxidizing minerals is made acidic, and in the absence of calcareous materials, such as calcite, the acidic water carries with it toxic metals and elevated levels of dissolved salts. As the reactions proceed, temperature and acidity increase, resulting in an increased rate of reaction. Rainfall and snowmelt flush the toxic solutions from the waste sites into the downstream environment. (NOAMI, 2016)
Adaptation	The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2014).
Bituminous Geomembrane (BGM) Cover	BGMs covers are a composite of different materials (geotextile, glass fibre fleece, bitumen, sand surfacing and anti-root film) used to provide a low permeability membrane (MEND, 2012).
Capillary Break / Capillary Barrier	A capillary barrier is created when a finer textured material overlays a coarser texture material, such that the finer texture material increases negative pore-water pressure (MEND, 2012).
Climate	Climate is defined as an area's long-term weather patterns. The simplest way to describe climate is to look at average conditions (e.g., temperature, precipitation, etc.) over time. Other useful elements for describing climate include the type and the timing of precipitation, amount of sunshine, average wind speeds and directions, number of days above freezing, and/or weather extremes (IPCC, 2012).
Climate Change	Refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the statistical properties (e.g., mean and/or the variability) in weather and atmospheric conditions that persists for an extended period, typically decades or longer (IPCC, 2012)

Term	Definition
Climate Change Hazards Information Portal (CCHIP)	CCHIP is an interactive source of information that provides customized historical and future climate data outputs based on geographical area, sector, theme, and timeframe of interest. It can be accessed here: https://go.cchip.ca/
CRI	Climate Risk Institute.
Crown Pillar	A rock mass of variable geometry that is situated above the uppermost underground workings of a mine and that serves to ensure the stability of surface elements and underground workings (NOAMI, 2016).
Risk	Refers to the potential for consequences arising from a given hazard where something of value is at stake and where the outcome is uncertain, measured as a function of the likelihood and consequence of adverse effects to health, property and other things of value (IPCC, 2014; NOAMI, 2016).
Climate Normals	Refer to arithmetic calculations based on observed climate values for a given location over a specified time period and are used to describe the climatic characteristics of that location (Environment and Climate Change Canada, 2020). A 30-year period is typically used to smooth out extremes, and ensure that particularly wet, dry, hot, or cold years do not dominate the climate conditions overall.
Dry Cover	The NIT area was capped with a composite engineered dry cover to prevent infiltration and limit oxygen diffusion into waste (SENES, 2000).
ENDM	Ontario Ministry of Energy, Northern Development and Mining.
Engineered Structure	A constructed facility or structure (i.e. building, dam/dyke, overflow channel, concrete shaft cap, etc.) for which engineered plans or drawings are available and include the appropriate accreditation of the author (NOAMI, 2016).
Ensemble Approach	The ensemble, or multi-model, approach to projecting climate refers to capturing a range of possible climate scenarios and representing those projections using a statistical distribution (e.g., percentiles). Research has indicated that the use of an ensemble approach has the advantage of accounting for all possible biases associated with individual climate models and can therefore provide the user with the most robust analysis of overall trends in climate (Auld et al., 2016).
Freeze-Thaw Cycles	A freeze-thaw cycle occurs when the daily maximum temperature is higher than 0 °C and the daily minimum temperature is less than or equal to -1 °C (Prairie Climate Centre, 2020).
Geosynthetic Clay Liner (GCL)	Geosynthetic Clay Liners are geo-composites containing a thin layer of sodium bentonite between two geotextiles and used as part of a

Term	Definition
	cover system design to reduce water infiltration and oxygen ingress (MEND, 2012).
Global Climate Models (GCMs)	Global climate models, sometimes termed general circulation models, represent physical processes in the atmosphere, ocean, cryosphere and land surface, are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations. GCMs have the potential to provide geographically and physically consistent estimates of regional climate change which are required in impact and risk analysis (IPCC, 2014).
Hazard	A source of potential harm, or a situation with a potential for causing harm, in terms of human injury, damage to health, property, the environment and other things of value; or some combination of these (NOAMI, 2016)
Impoundment Dam	An embankment constructed to contain wastes, contaminated materials and to divert flows or to prevent flooding (NOAMI, 2016).
North Impounded Tailings (NIT)	Located in the northwest area of the site, the 70ha NIT area contains tailings impounded by natural topography, the east-west dam, the north-south dam, and a dyke along the south eastern boundary. A dry cover is used to prevent the underlying tailings from being exposed to air and generating acid leachate.
North Unimpounded Tailings (NUT)	Located in the northeast area of the site, the NUT area has been impounded by a 2km impermeable perimeter to contain tailings and maintain them in a saturated state as part of the remediation process.
Open Pit	The open pit was used during mining operations, however, has since been filled with sand, tailings, contaminated soil, waste rock and other items from the site and capped.
Probable Maximum Flood (PMF)	The largest theoretical possible flood for a watershed that considers a combination of flood factors like maximum rainfall, initial soil state and snow melt (Ouranos, 2015).
Probable Maximum Precipitation (PMP)	The largest amount of precipitation that could accumulate in a given watershed, for a specific duration and for a particular time of year (World Meterological Organization, 2009).
Remediation	Remediation focuses on removing and reducing hazards and improve safety by removing, isolating or reducing pollution from soil, groundwater, sediment or surface water to achieve a decontaminated or contaminant-free site (Lima et al., 2016, NOAMI, 2016).

Term	Definition
Representative Concentration Pathway (RCP)	A Representative Concentration Pathway (RCP) refers to a future scenario used to inform future climate projections, indicating the radiative forcing. In the case of this assessment, RCP8.5 was used (8.5 Watts/m^2) and is associated with high emissions ("worst case scenario") continuing through the 21st century.
Risk Scenario	A risk scenario (or vulnerability scenario) refers to a tool used to identify and characterize climate vulnerabilities and risks. It is a sequence of events that provide a representation of how climate events may impact site components, and how vulnerabilities, likelihoods and consequences interact to estimate risk.
Risk Intervention Threshold	The acceptable level of risk before intervention is required. Intervention does not always indicate immediate remedial measures, however, does require additional investigation and consideration.
Sludge Settling Pond	An open pond where process water is allowed to stand while suspended material settles out (CANMET, 2013).
South Unimpounded Tailings (SUT)	Located in the southern area of the site, the area previously received discharged to the environment without containment. Unconfined tailings from the SUT were relocated to the NUT impoundment in September 2011.
Spillway	Spillways are in place in numerous locations on the site such that during severe precipitation, spring freshet, rapid snowmelt and other events, impoundment dams are not overwhelmed.
Tailings	Materials remaining after the economically valuable elements are removed from the ore, typically a slurry of sand/silt sized particles in water that are typically stored in an impoundment (MEND, 2009).
Vulnerability	The propensity or predisposition of a system or place to be adversely affected by climate change (IPCC, 2014). Adapted for Kam Kotia: when a climate condition interacts with a particular site component or the operations of the mine site in a way that could increase risk, especially considering a changing climate.
Wet Cover	Also referred to as elevated water table or moist cover. An elevated water table is developed by constructing perimeter dams to allow the water table to rise such that tailings are sufficiently saturated to inhibit sulphide oxidation (SENES, 2000).

Contents

List of Figures

List of Tables

1 Introduction

This report was completed as part of Project AP720, "Assessing Climate Change Risks of Abandoned or Orphaned Mine Sites in Ontario, Yukon and Northwest Territories," under a funding agreement with Natural Resources Canada (NRCan). A Climate Change Risk Assessment (CCRA) was completed for the Kam Kotia site, an abandoned mine located on the outskirts of Timmins, Ontario.

This report includes background on the Kam Kotia site, including the history of remediation and the main site components. Background research and data gathering focused in three main areas: a literature review on abandoned mine sites and climate change, a review of site documentation and reporting, and climate data. A risk assessment framework is presented and the findings of this CCRA are summarized, including transferable lessons to other abandoned mine sites.

1.1 Project Objectives

The objective of this report is to conduct a Climate Change Risk Assessment for the Kam Kotia abandoned mine site. This risk assessment is intended to:

1. Identify and assess the potential impacts of severe weather and climate change on the Kam Kotia Mine site;

2. Help inform future remediation work on the site; and

3. Specify and pilot a risk assessment framework for use in the screening-level assessment of climate risks related to abandoned mine sites.

1.2 Project Selection

The Kam Kotia mine site was selected for the CCRA as part of the AP720 project based on the following considerations:

1. **Interest of the jurisdictional partner in accommodating a climate change risk assessment of the site.** It became evident over the course of the main project on abandoned mines (AP720) that many sites would poorly lend themselves to climate change risk assessment due to time constraints among personnel of the oversight agencies, logistical considerations, or other potential obstacles. Personnel within Ontario's Department of Energy, Northern Development and Mines (ENDM) were interested in accommodating an assessment focused on Kam Kotia.

2. **Ability of the jurisdictional partner to collaborate.** Not only was ENDM interested in Kam Kotia being the focus of a climate change risk assessment, but

agency personnel also indicated an ability to collaborate. An important first step in this regard was ENDM's provision of data, past studies, and other documents related to the site and its remediation.

3. **Availability of site remediation and performance data.** Compared to many abandoned mine sites, Kam Kotia is data and information rich. Details with respect to data and information products provided for the assessment are included in **Section 4.1.**

1.3 Site Description

The Kam Kotia Mine site is a former copper and zinc mine located near Timmins, Ontario (**Figure 1**). The site was previously mined from 1943-44 and from 1961-72 and was abandoned after closing in 1972 and subsequently ownership of the site was transferred to ENDM. The site has been the focus of significant remediation work (see **Section 2.1**) after a remediation plan was completed in 2000. Additional remediation is ongoing at the site.

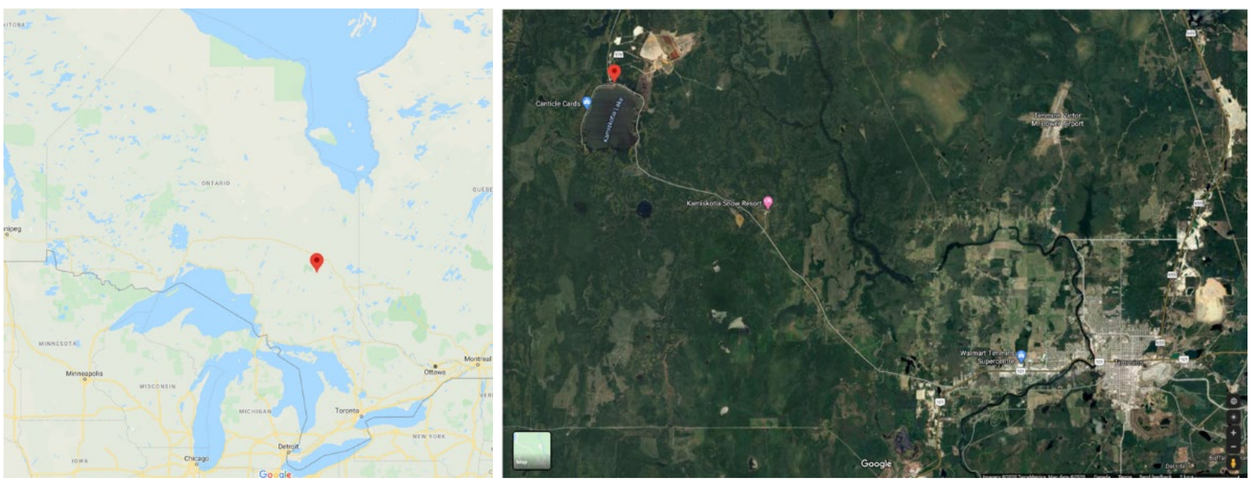

Figure 1: *Location of the Kam Kotia Mine Site in Northern Ontario. (Photo Credit: Google Maps, 2020).*

2 Background

To conduct a climate change risk assessment for the Kam Kotia site, background information pertaining to the site was reviewed.

2.1 Remediation History of Kam Kotia

Kam Kotia was mined from 1943-44 and from 1961-72. During this time, six million tonnes of highly sulphide-rich, acid generating tailings were deposited in three areas, two of which were unimpounded:

1. The “North Impounded Tailings” or “NIT” located in the northwest area of the site, and
2. The “North Unimpounded Tailings” or “NUT” located in the northeast area of the site;
3. The “South Unimpounded Tailings” or “SUT” located in the southern area of the site.

Until 2001, the site was left largely abandoned. Over time, acid mine drainage and metal leachate were produced from all three of the tailing areas, considerably impacting surrounding lands and waters.

Figure 2: *Aerial view of the Kam Kotia site prior to remediation (ca. 2000) (Photo credit: ENDM).*

Ultimately, surface rights for most of the site reverted to the province and remediation of the site became a public responsibility. Before remediation, the site footprint was approximately 500 hectares and has subsequently been reduced to 200 hectares through covering, sealing and controlling tailings. Beginning in 2001, a five (5) phase remediation plan was implemented, as follows:

> **Phase A:** Construction of a lime addition treatment plant and related infrastructure, completed in 2002. Construction of an impoundment dam around the Northern Unimpounded Tailings (NUT) area, completed in 2002.
>
> **Phase B:** Relocation of the Southern Unimpounded Tailings (SUT) to behind the new NUT impoundment dam, and application of Envirolime to the relocated tailings and the SUT removal area. This work was completed in 2003.
>
> **Phase C:** Relocation of additional NUT tailings to within the footprint of the new NUT impoundment area. This work was completed in 2004.
>
> **Phase D:** relocation of tailings from the north and east creeks to the NUT impoundment area completed in 2008. The construction of the "moist" cover over the NUT impoundment area, completed in 2009.
>
> **Phase E:** construction of a new dry cover over the Northern Impounded Tailings (NIT) impoundment area, completed in 2005. Rehabilitation of physical hazards on site (e.g., open pit, re-capping the main shaft and thin crown pillar).
>
> **Post Phase E**: general cleanup of the site and ongoing maintenance.

Figure 3 provides an illustration of the phases of rehabilitation (described above) completed from approximately 2002 to 2008. The majority of the remediation plan was carried out by 2010, however remediation remains an ongoing process. Most of the records and reporting that was available and distributed for the purpose of undertaking this CCRA was limited to remedial work conducted as part of the phased approach described above. Additional work was noted by ENDM staff in workshops include changes to sludge handling, the fill and cover of the open pit, and ongoing work related to vegetation and erosion control. These details have been provided wherever possible; however, knowledge gaps on the current state of remediation were present and have been outlined in additional detail in **Section 3.2**.

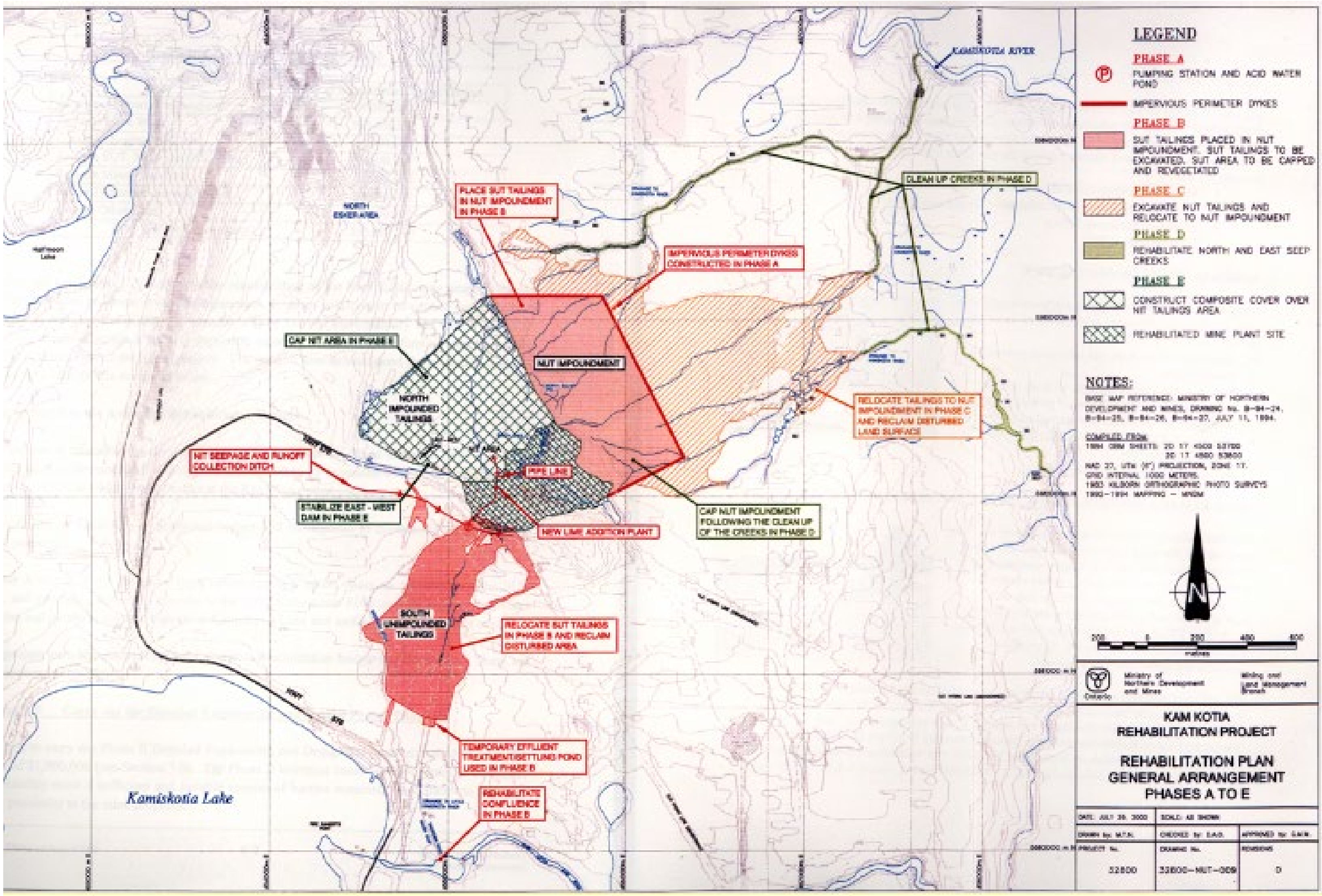

Figure 3: *Map of Kam Kotia showing the five phases of rehabilitation (SENES, 2000).*

2.2 Key Components of Kam Kotia Site

For the purpose of the current assessment, each site component has been described and either assessed for relevant climate risks or removed from scope. **Figure 4** presents an overview of the Kam Kotia site and relevant components in 2012**.**

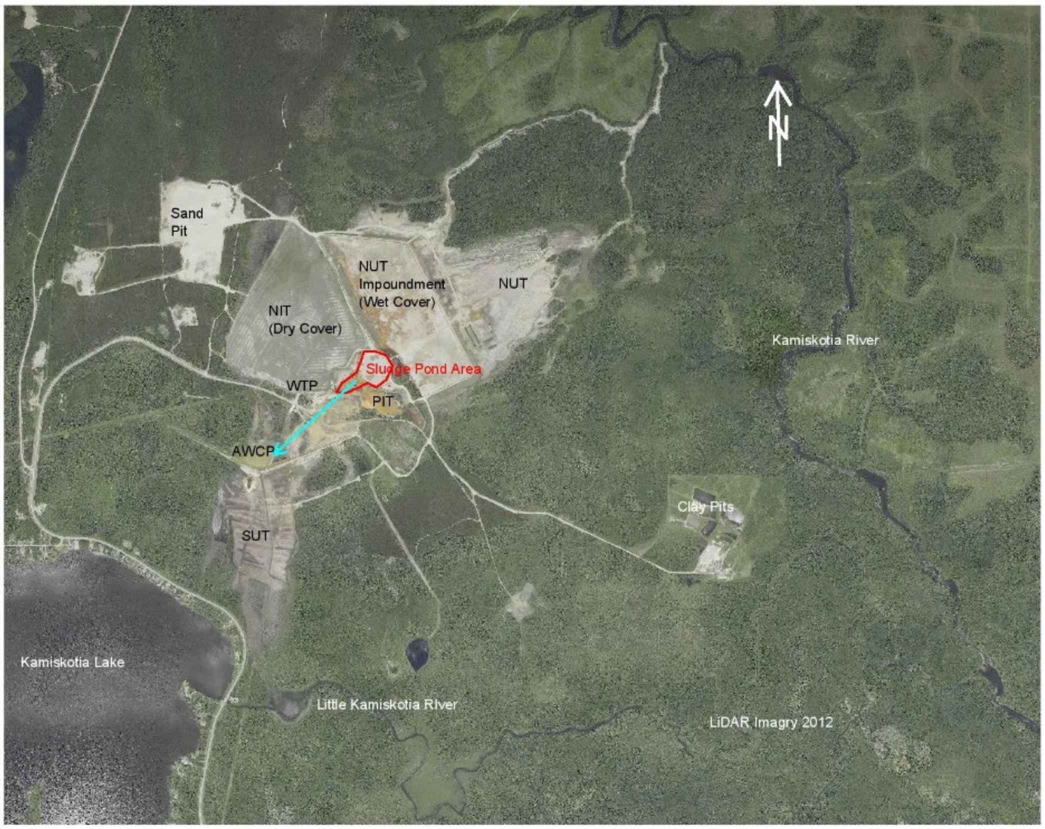

Figure 4: *Overview of Kam Kotia Site Components After Rehabilitation as seen in 2012 (Photo Credit: provided by ENDM).*

2.2.1 NUT Impoundment Area

The "North Unimpounded Tailings" (NUT) Area has been impounded as part of the remediation process and by 2009 the majority of NUT and SUT tailings had been relocated to the NUT Impoundment Area.

The area is enclosed by the 'NUT Impoundment Dam', a 2km impermeable perimeter used to create the NUT impoundment by containing the tailings and maintain them in a saturated state. The original design (constructed in 2003) had a maximum height of 4m and consisted of Granular B fill placed at a 3:1 slope with a 1.5m thick clay core on the upstream end, with compacted earth fill and vegetation on the downstream end.

In 2012, the impoundment dam was breached and partially washed out during a rapid snowmelt event discussed in **Section 4.3**. The dam was subsequently repaired and raised in 2014, along with the construction of a new spillway and concrete flow control structure (see **Figure 5**). The dam was raised using Granular B fill, a geotextile liner and rip rap along the upstream face. At the completion of construction, AMEC recommended that a hydraulic analysis be completed for the NUT spillway and monitor discharge water from the NUT spillway weir.

Figure 5: *NUT spillway after 2014 construction. (Photo Credit: erosion monitoring provided by ENDM, 2016.)*

The NUT impoundment area was also designed to have a moist cover– a thick, water saturated layer of sand – established to prevent the underlying tailings from being exposed to the air and generating acid leachate. Since the construction of the moist cover, there have been challenges with the reality on site not meeting the requirements of the design and it is now believed to function as a wet cover as it is frequently flooded. This is believed to be due to the complexities in accounting for the groundwater table and represents a considerable unknown in assessing the risks associated with the cover. The cover can be overwhelmed by too much water (e.g., as the result of rapid snowmelt events). It can also be damaged or rendered ineffective in the event of too little water, once the moist layer is no longer saturated.

ENDM staff also noted that the existing water quality in the NUT is already poor and not meeting water quality targets.

The NUT impoundment area is connected to the NIT impoundment area by a spillway, such that surface water from the NIT discharges to the NUT.

2.2.2 NIT Impoundment Area

The "North Impounded Tailings" (NIT) area was impounded before remediation, however, has had additional remedial efforts since 2001. The tailings in the NIT area are contained by the natural topography to the north and the east-west dam, the north-south dam, and a dyke along the south eastern boundary. The area is approximately 70ha.

The NIT area has a dam ("East-West Dam") and is connected to the NUT impoundment. A spillway was constructed in 2014 to direct surface water from the NIT to the NUT. Seepage from the NIT also drains by gravity and is collected by the Acid Water Collection Pond (AWCP).

Figure 6: *View of the NIT spillway including riprap, facing the NUT area (Photo Credit: AMEC Dam Raise As-Built Report, 2015).*

The NIT impoundment area has a dry cover, established to prevent the underlying tailings from being exposed to air and generating acid leachate. The lower-most layer of the cover is a capillary break layer that is designed to stop acid water from wicking upwards and affecting the barrier layer and is comprised of two layers of coarsely crushed rock and granular "B". A geosynthetic clay liner (GCL) forms the barrier layer of the cover and overlays the capillary break. On top of the GCL is 30 cm of clay, 50 cm of granular fill and 15 cm of topsoil and vegetation, as shown in **Figure 7**. In Hamlin (2007), the topsoil layer was noted to be less than 15cm due to insufficient quantities of topsoil on site. Maintaining vegetation on the cover is important for moderating erosion and surface water runoff.

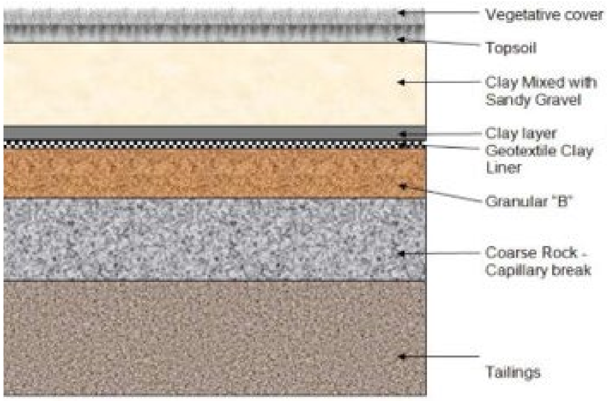

Figure 7: *NIT dry cover diagram (Photo Credit: ENDM), Aerial view of the NIT during construction of the cover (Photo Credit: Hazco, 2006).*

2.2.3 South Unimpounded Tailings (SUT) Area

The SUT area was approximately 48 ha in the southwest area of the site and previously received tailings that were discharged into the environment without containment. The majority of the unconfined tailings from the SUT were relocated to the open pit area in September 2011. A 2019 study showed that some areas of the SUT had potentially acid generating rock and tailings, however this may be trending away from being acid generating over time. Long term monitoring was recommended to adapt vegetation plans and add additional lime treatment. Any discharge in the SUT is driven by surface water runoff and groundwater inflows, particularly in the springtime. An emergency overflow ditch is located at the Acid Water Collection Pond, discharging to the SUT area.

2.2.4 Water Treatment System

Acid Rock Drainage (ARD) is collected from waste rock piles and the NIT tailings impoundment and drains to the Acid Water Collection Pond (AWCP) as seen in **Figure 8**. An emergency overflow ditch is located at the Acid Water Collection Pond, discharging to the SUT area. Water from the AWCP is pumped via the pump house to the wastewater treatment plant where it is treated with hydrated lime before discharging east of the water treatment plant. At the time of the analysis, pumps are powered by the Hydro One powerline and no backup system is available.

The water treatment plant was constructed on top of waste rock that has been classified as "ARD generators". The treatment plant is located near the open pit, however, is located outside of the hazard zone for stability issues associated with the open pit and underground mine.

Sludge generated from the treatment was previously released into the open pit mine, where it acted as a sludge settling pond. A 2015 preliminary study on sludge handling recommended construction of new sludge settling outside of the open pit. ENDM staff indicated that this was completed and sludge is now being released into sludge management cells and ponds, however this information was not available for review as part of the CCRA.

Figure 8: *Water Collection Ponds and Water Treatment Plant (Photo Credit: provided by ENDM, 2016).*

2.2.5 Underground Mine and Open Pit

The underground mine has received sludge generated from the treatment plant since 2005. The former open pit has been backfilled with sand, tailings, acid generating material, waste rock and other items from the site and has been covered with a bituminous geomembrane (BGM) cover, soil, and vegetation. Currently, work is ongoing at the open pit and new infrastructure will impact the capacity of the NUT, however the degree of this impact has not established. As part of this CCRA, the relationship between the underground mine and open pit, including potential discharge to and from other components (including the NUT impoundment area and water treatment plant) generally had less information available for research and analysis.

2.2.6 Adjacent Lands and Ecosystems

The adjacent lands and ecosystem of the site were considered out of scope for the risk assessment, however components that interact with the lands and ecosystems were considered. The Little Kamiskotia River, Kamiskotia Lake and Kamiskotia River are all nearby the site and can be impacted by surface and groundwater drainage and discharge.

2.2.7 Aggregate Extraction

Clay and sand pits remain active on the site and have been used to supply material for some remediation efforts on site. These components are subject to ongoing planning for remediation and permitting.

3 Approach and Methodology

This section provides a climate change risk assessment framework for the Kam Kotia mine site.

3.1 Overall Process

Climate change risk assessments (CCRAs) are used to systematically identify potential climate change risks and opportunities, assess them, and consider options for mitigating or benefitting from on them. The overall CCRA process for the Kam Kotia mine site was broadly developed based on guidance by the Mining Association of Canada for the assessment of climate change risks related to mining sites and operations as summarized in **Figure 9**.

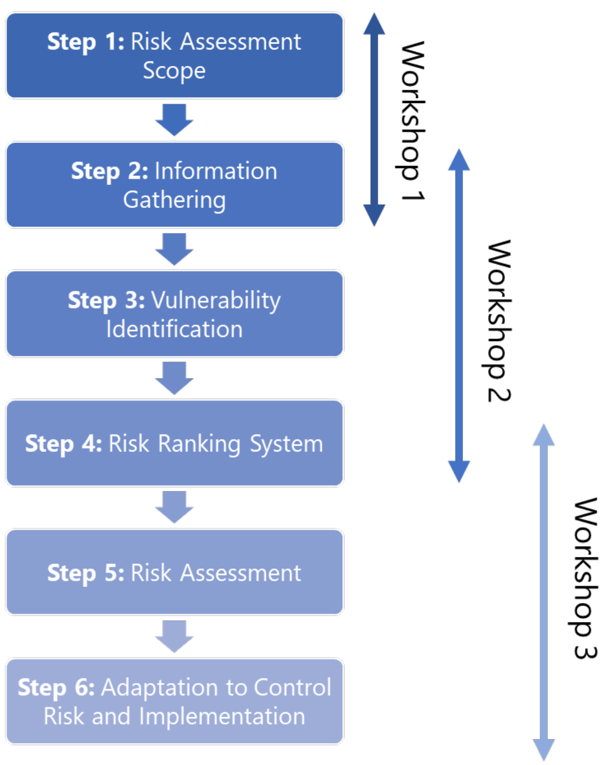

***Figure 9:** Overview of Risk Assessment Process. (Adapted from Mining Association of Canada).*

Three workshops were held with representatives from ENDM and CRI as outlined in **Table 1**. Workshop meeting notes are included in **Appendix B**.

***Table 1**: List of Workshops*

Workshop #	Content Covered
1 – October 15th 2020	Establish project objectives, overview of climate science, introduction to risk assessment approach and scoping of infrastructure components.
2 – November 5th 2020	Presentation of preliminary climate data findings, overview of vulnerability scenarios, introduction of risk ranking system.
3 – November 30th 2020	Presentation of final climate data findings, risk ranking exercise, discussion on adaptive measures.

3.1.1 Step 1: Risk Assessment Scope

The scope of the Kam Kotia CCRA was first defined by identifying the specific features of the site, operations, communities, and surrounding environment the assessment should address. **Section 3.2** provides additional details on the results of the scoping process.

The scoping process provided clarification on:

- Objective(s) of the Kam Kotia CCRA;
- Geographical and temporal boundaries of the CCRA;
- Relationship of the CCRA with Kam Kotia risk management efforts more generally;
- Specific features and components for inclusion, exclusion;
- Human, information, and financial resources required;
- Time constraints; and,
- Involvement of ENDM and other stakeholders.

3.1.2 Step 2: Assembly of Data, Information and Assessment Team

Determining the data, information and human resource requirements of the Kam Kotia CCRA was an iterative process. The data and information resources listed below are generally required for climate change risk assessments of abandoned mine sites:

- **Climate** - historical normals and trends, projected ensemble data, climate-related impact events.
- **Environmental** - including soils, topography, groundwater, surface water, vegetation, fauna, stream flows, lake levels, erosion.
- **Asset/infrastructure** - including types, locations, designs, physical components, ages, physical conditions, operations and maintenance practices.
- **Regulatory and financial** - including water discharge requirements, insurance requirements.

The Kam Kotia CCRA includes:

- A description of historical site-specific climate conditions, characterized over a 30-year period from 1981 to 2010);
- A characterization of future climate trends, based on ensemble (meaning numerous climate models) projections of changes in mean conditions and extreme events in the future, including assessments of the uncertainties inherent in these projections; and,
- Statistics related to weather conditions at the time and leading up to any known and past climate-related impact events at the Kam Kotia site.

CCRAs also require people who are knowledgeable of:

- Local historical and current climate;
- Local environmental conditions more broadly;
- The design and/or operation of the different components of the mine site, including key remediation processes;
- Future climate projections and climate hazards;
- The site-specific risk register; and,

- Risk assessment processes.

Section 4 provides a summary of research and data collection and **Section 5** provides the characterization of climate conditions. **Table 2** presents an overview of the assessment team responsible for conducting the CCRA.

Table 2: *Overview of Assessment Team and Key Areas of Knowledge*

Area of Knowledge	Team Member	Affiliation
Risk Assessment	J. Richard, E. Sparling, G. Milner, K. MacMillan	CRI
	T. Brown	Envision Strategic Environmental Consulting
Climate Information	A. Zaytseva, E. Sparling, G. Milner	CRI
Local Environmental Conditions	J. Gimon, T. Sulatycky, J. McFarling, K. McAlpine	ENDM
Site Design	J. Gimon, T. Sulatycky	ENDM
Site Risk Register	J. Gimon, T. Sulatycky	ENDM

3.1.3 Step 3: Vulnerability Identification

Vulnerability identification is an iterative process that identifies and describes the potential interactions between climate conditions and/or weather phenomena and specific infrastructure components, operations, communities, and/or the surrounding environment.

A climate change vulnerability is present when a climate condition or event interacts with a physical component, or the operations of a mine site, in a way that could increase risk (see **Figure 10**), especially in light of the changing climate.

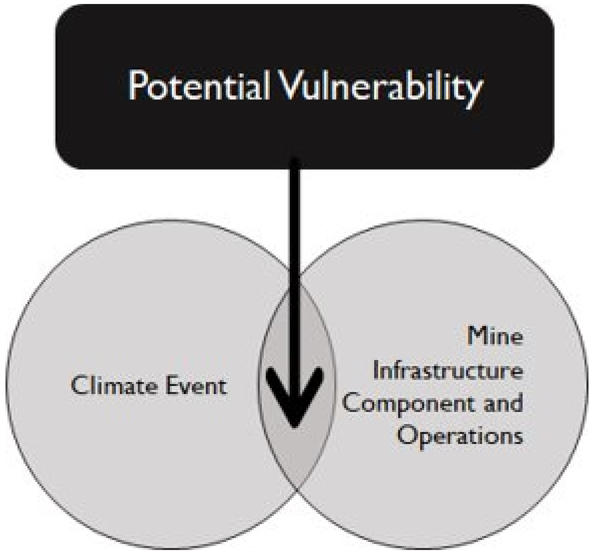

Figure 10: overview of climate vulnerabilities at of a mine site (figure adapted from Engineers Canada).

Climate-related vulnerabilities are always a consideration when designing and managing remediated mine sites, however these vulnerabilities can become more pronounced or alter as the result of a changing climate.

A vulnerability scenario is a tool used to identify and characterize the basis of climate change risks. Each scenario conveys a sequence of events, beginning with a climate hazard, that depicts how a climate or weather phenomena may impact site components, and how vulnerabilities, likelihoods and consequences interact to estimate risk.

An example of a vulnerability scenario includes the following: “rapid snowmelt at the Kam Kotia site leads to over topping of the NUT impoundment dam, resulting in the flow of tailings and contaminated water to the surrounding environment”.

This example scenario includes both direct impacts (damage of the impoundment dam) and indirect impacts (environmental). The scenario is supported by climate data and indicators to represent the scenario. For example, indicators for rain -on-snow can include the number of days per year where temperatures are greater than 0°C in winter and total winter precipitation. **Table 6** in Section 5.3 provides a listing of all climate hazards for which vulnerability scenarios were developed.

3.1.4 Step 4: Risk Ranking System

To move from the identification of vulnerabilities to the assessment and ranking of risks, likelihood and consequence criteria must be developed and agreed upon by the assessment team, and other key stakeholders, for each vulnerability scenario.

The following methodology, as described in **Table 3** and **Table 4** has been adapted to the Kam Kotia site based on a report from the National Orphaned/Abandoned Mines Initiative (2016) titled: *Orphaned/Abandoned Mines: Risk Identification, Cost Estimation and Long-term Management*. Criteria established within NOAMI (2016) were reviewed, presented to ENDM for discussion, and finalized to identify likelihood and consequence scoring.

Likelihoods were established based on climate conditions within a given time horizon and are assigned a numerical value from 1 (rare) through 5 (almost certain). Each climate event of concern for the Kam Kotia site was paired with available climate parameters, described historically and for the 2050s and 2080s. Likelihoods were assigned by members of the climate information team (CRI) and validated by ENDM. For example, it is historically *unlikely* ("not expected to occur over a decade") that drought will persist and pose risks onsite based on a small average water deficit across Summer and Fall seasons. However, by the end of the century (2080s), average water deficit is projected to increase by 182% relative to historical conditions, indicating it is *likely* that drought could occur several times over the course of a decade in the Summer and Fall seasons. **Section 5.3** describes in further detail the climate data used to inform the likelihood rating process.

It is important to note that the project team made the simplified assumption that occurrence of a given climate event (e.g., extreme precipitation) necessarily results in all other portions of the vulnerability scenario also occurring. This assumption enabled a precautionary approach and was made based upon the project scope and available data for Kam Kotia. However, it may introduce high degree of conservatism (overestimating risks) that could be reduced to more reasonable levels if a more comprehensive assessment were feasible.

Table 3: *Estimating Current and Future Likelihood of Climate Event*

Score	Definition
5	Almost Certain – Expected to occur more than once per year.
4	Likely – Expected to occur several times during the next decade.
3	Possible – Expected to occur once during the next decade.
2	Unlikely – Not expected to occur during the next decade.
1	Rare – Extremely unlikely to occur during the next 100 years or longer.

The consequences of a given scenario were then established and used to inform risk scoring. Consequences were defined across four categories:

1. Financial, or socio-economic;
2. Physical damage to property;
3. Environmental; and
4. Public health.

For any given scenario, the most severe of these categories was carried forward to estimate overall risk (e.g., "maximum consequence"). This takes a precautionary approach when considering the highest risks. Consequences were assigned using a consensus-driven approach with ENDM and CRI staff in attendance at workshop 3 and subsequently circulated among all project stakeholders for validation.

For example, based on the example vulnerability scenario provided above, the consequences of a rapid snowmelt could include overtopping of the NUT impoundment dam, thereby requiring costly repairs (financial), damage to physical property (physical damage), and cascading impacts to the surrounding site environment (environmental). For this example, it is not expected to result in any loss of life or injury (public health).

Table 4: *A Framework for defining Categories of Consequence and their Severity*

Category	Very Low 1	Low 2	Moderate 3	High 4	Very High 5
Financial / Socio-Economic	Little or no impact on site budget, minimal interruption of socio-economic activity	Able to accommodate within site budget, temporary interruption of socio-economic activity	Able to accommodate within broader Ministry funds. Short term, on-site loss of socio-economic activity	Able to accommodate within broader Ministry funds but only with cuts or reserve funds. Short term, on-site and off-site loss of socio-economic activity	Unable to accommodate within reserve funds. Permanent loss in socio-economic activity.
Physical Damage to Property	Minor, isolated, and/or cosmetic damage to property	Moderate, or limited loss of physical property	Significant, localized loss of property or moderate damage or loss on a wider scale.	Significant loss of property on a wide scale.	Widespread severe damage or loss of key assets, leading to cascading impacts.
Public Health	Minor incident (cuts and scrapes). Little or no impact on injured person's ability to carry on regular activities.	Medical aid required. Disruption to injured party's daily activities/quality of life.	Permanent disability. Isolated lengthy lost time injury. Significant disruption to injured party's daily activities/quality of life.	Fatality; permanent disability for several individuals. Significant disruption to multiple injured parties' daily activities/quality of life.	Multiple fatalities; permanent disability for numerous individuals. Catastrophic impact on quality of life.
Environment	Impact not likely measurable within ecosystem.	Negligible impact on local environment. Exceeds natural variability.	Localized or reversible environmental damage.	Widespread or irreversible environmental damage.	Widespread and irreversible environmental damage.

3.1.5 Step 5. Risk Assessment

This step provides the summation of the information collected and assessed to develop a comparative analysis of each identified risk. **Table 5** is a summary of the risk scores developed from the likelihood and consequences established in **Table 3** and **Table 4**.

The highest consequence score across the four categories was assigned for each scenario, such that a scenario with a "very high" consequence in one category, would be rated "very high" even if consequence ratings in other categories were lower.

Table 5: *Climate Risk Matrix*

Likelihood	Consequence				
	Very Low	**Low**	**Moderate**	**High**	**Very High**
Certain	Class II	Class III	Class IV	Class IV	Class IV
Likely	Class II	Class III	Class III	Class IV	Class IV
Possible	Class I	Class II	Class III	Class IV	Class IV
Unlikely	Class I	Class I	Class II	Class III	Class IV
Rare	Class I	Class I	Class II	Class III	Class III

The following classes were established to categorize risk:

- Class I risks are those that fall well below the risk acceptance-intervention threshold and require no further intervention at the time of analysis.
- Class II risks are those that lie close to or on the risk acceptance-intervention threshold and require active monitoring and/or further evaluation.
- Class III risks are those that exceed the risk acceptance-intervention threshold and require active intervention.

- Class IV are risks that significantly exceed the risk acceptance threshold and require urgent intervention.

Note that intervention as it is defined for Class III and Class IV does not always indicate the need for immediate remedial measures, however, does require additional investigation and consideration.

The definitions of likelihood, consequences and classes were circulated to ENDM for review and confirmation. No additional comments were received, and this procedure was therefore considered acceptable and consistent with internal ENDM risk processes.

3.2 Scoping and Knowledge Gaps for Kam Kotia

The following components were removed from scope due to a lack of data or limited knowledge of climate associated risks:

- Aggregate extraction
- Wildlife in adjacent ecosystems
- Underground mine - crown pillar
- Open pit rim, slope and wall
- Gates, chain link fence
- Roads and access points
- Non-hazardous waste material
- Building foundations

This was done in collaboration with ENDM personnel in Workshop #1 and all components removed were confirmed by ENDM prior to proceeding with the risk ranking exercise. **Table A-1** in **Appendix A** provides rationale for components removed from scope.

In general, there were gaps in available resources to ascertain the current conditions on site due to the complexity of work completed over the last 20 years of remediation. These are summarized as:

- Reports on site conditions completed before the 2000 phased rehabilitation were generally considered informational only and did not factor into the analysis as conditions have changed substantially.
- Reporting for the design and construction of the phased remediation (approximately 2001-2008) was generally very detailed. There were, however, gaps in the information:

- As-built drawings and reports were not available for most of the components. Instead, a high-level, non-technical report (Hamblin 2007) provides a summary of challenges faced in construction and changes to the scope of work.
- A detailed design report was prepared for the NIT Dry Cover as referenced in the Hamblin (2007) report; however, this was not available. The impact of temperature, freeze-thaw cycles and other climate and weather considerations therefore was inferred based on known and general information.
- In some examples, components are not performing as designed (e.g., NUT Wet Cover) or have had additional remediation (open pit) and this was ascertained from workshop feedback and incorporated into the analysis.

- Reporting for remediation actions taken after 2008 was sparse or unavailable, with the exception of the NUT impoundment Dam re-construction and upgrades in 2014.
  - A detailed design report for the Acid Water Collection Pond (AWCP), pumping house and water treatment plant was not available. Instead, design drawings from the raise of the AWCP and a high-level document from OCWA were consulted. It was therefore not possible to establish thresholds, like the maximum flow the treatment plant can handle or the maximum volume of the AWCP before the spillway is activated.
  - The design report prepared by EXP for the NUT dam repairs and NIT spillway was not available. Instead, an as built report prepared by AMEC was used. The as-built report includes valuable information, however, does not have detailed design rationale (e.g., the storm events that the dam was designed for). This information was obtained verbally during workshops with the ENDM team where possible.
- Remediation is ongoing at the site. This includes planned work to the open pit and underground mine, clay and sand pits, and sludge handling. In some cases, the current status of the remediation was not available to the CRI team and therefore assumptions were made based on the most recent information or confirmed in workshops.
- Typically, components like dams, spillways, water treatment plants and covers have frequent engineering inspections to confirm the integrity of critical remedial infrastructure. These were not available for this analysis of the Kam Kotia site.

- Some long-term monitoring and reporting were available, however data collected in the last 10 years were limited. Insufficient data was provided to be able to assess environmental data trends, like surface water and groundwater quality and quantity. Raw data is generally not considered sufficient for a CCRA unless it spans an extended period and multi-year trend analyses are available.
- ENDM staff indicated that water quality in the NUT impoundment area is already poor and not meeting water quality objectives. It is unclear how water quality may change over time and how climate change may impact this process.

4 Research and Data Collection

4.1 Review of Site-Specific Documents

Table **A-2** in **Appendix A** provides an overview of all site-specific documents that have been provided and reviewed. Specific details for site components and risks have been incorporated into the analysis.

4.2 Review of Research and Literature

The performance of mine closure sites and the influence of climate change is an emerging and complex field. The following section provides a brief summary of research conducted on some potential interactions between a changing climate and abandoned mines. This is not intended to be an in-depth or comprehensive research project, however, provides some illustrative examples and recommended further reading.

The Suzuki Foundation funded a study to look at climate change impacts and research on a national scale for Canada's mining sector (Pearce et al., 2009). This included a literature review of both industry publications and the scientific literature, as well as surveys of industry representatives and practitioners that identified the perception of climate change impacts, vulnerabilities, and adaptation opportunities.

The report discusses the role of climate change on orphaned or abandoned mines, noting the need for retrofitting with climate change. Abandoned and decommissioned mines have been designed for past climatic loads, indicating that they may be under designed for future climatic values and many have further degraded from a lack of maintenance since closure or abandonment (Pearce et al., 2009).

Specific exposure and risks adapted from the report to guide this analysis include:

- Warmer average temperatures leading to acid mine drainage
- Altered freeze-thaw cycles exposing previously frozen tailings

- Evaporation of water covers on tailing pond exposing raw tailings
- High intensity precipitation causing saturation of tailings impoundment, overtopping, and erosion increasing risk of failure
- Wind and wave action of extreme weather events causing re-suspension of tailings and formation of ice dams
- Greater precipitation frequency and intensity may cause flooding and/or dilution of effluent
- Altered freeze-thaw cycles forming ice dams
- Erosion induced by greater frequency and intensity of precipitation and/or permafrost thaw of slopes, berms, and mine pit walls.

The Mining Association of Canada has a forthcoming report on the climate variables and impacts on abandoned and remediated mining sites. The findings of this report have been summarized in **Table A-3** in **Appendix A**.

The terminology for Remediation, Reclamation, Rehabilitation, and Restoration ("4Rs") are often used interchangeably by policy makers, however, have specific targets and definitions. While remediation focuses on specifically treating or removing contamination, restoration can be defined as restoring an ecosystem to the extent where the original fauna and flora are restored (Lima et al., 2016). These have different climate implications, particularly when considering the time scale and legacy of implementation. This research demonstrates the need to define specific objectives and targets during planning and implementation.

Tailings dams are a significant area of interest, including understanding the complexity of managing uncertainty and remediation (Kossoff et al., 2014; Oboni & Oboni, 2020). Tailings stored under water reduce contact with the atmosphere and therefore reduce the risk of oxidation, and watertight tailings that do not interact with the floodplain can be an effective storage method given financial and environmental constraints (Brett, 2009; Kossoff et al., 2014). Water covers require adequate water to maintain continuous saturation (Brett, 2009).

The historic design of tailings dam structure has changed considerably and is an area of uncertainty when looking at abandoned mine sites, as closure practices for tailings are a relatively new and evolving subject (McLeod, 2017; Schafer et al., 2019). Much of the existing research on climate change and mining has focused on operational mines, however abandoned mines are a focus of significant concern and require more analysis (Anawar, 2013; Clemente & Huntsman, 2019). Research on known failures found that active impoundments are more likely to fail, with only 10-15% of known failures occurring in inactive or abandoned dams (Kossoff et al., 2014; Rico et al., 2008). In a study of 146 tailing dams failures, overtopping was found to be the primary cause of failure for inactive mines (Rico et al., 2008).

The impacts of increased precipitation and rainfall due to climate change and possible adaptations are of considerable concern for the mining sector (Clemente & Huntsman, 2019; Labonté-Raymond et al., 2020; Pearce et al., 2011).

A recent study on the impact of climate change on extreme rainfall events in the Abitibi region in Quebec found that the intensity of Probable Maximum Precipitation (PMP) is projected to rise up to 30% by 2100 in high emissions scenario, affecting mining infrastructure including berms, dams and spillways (Labonté-Raymond et al., 2020). The study highlights the need for considering the probable maximum flood (PMF), the largest theoretical possible flood for a watershed that considers a combination of flood factors like maximum rainfall, initial soil state and snow melt (Labonté-Raymond et al., 2020).

A 2017 study outlines methods for deriving PMF and PMP with consideration for climate change, including in the Mattagami watershed where the spring PMP was found to increase by approximately 6% by 2100 in high emissions scenarios (Clavet-Gaumont et al., 2017; Ouranos, 2015). The analysis also showed that spring freshet was found to occur earlier in the spring in future scenarios.

Water stress is one possible source of failure for vegetation in reclaimed mine lands, particularly where root growth is limited due to topsoil depth limitations (Guittonny-Larchevêque et al., 2016; Guittonny-Larchevêque & Pednault, 2016).

The "first flush" is a phenomenon where a gradual increase in acid and metal concentrations is found during prolonged dry periods followed by a sudden increase in concentration after precipitation, and this could be exacerbated by climate change with both increasing drought periods and extreme weather events (Clemente & Huntsman, 2019; Nordstrom, 2009) Reduced groundwater recharge from longer and warmer summers can also cause water tables to lower that may allow for migration of contaminated groundwater or increased oxidation for soils and minerals (Clemente & Huntsman, 2019).

Changes to water levels and hydrology from both precipitation and drought can impact concentrations of toxic dissolved metals. Clemente and Huntsman (2019) presents a summary of 15 case studies demonstrating how dry conditions can expose sites to oxidizing conditions, rainfall and high-water levels can reduce concentrations of contaminants, and where wet-dry cycles result in dissolution.

Climate conditions determine the volume and rate of evapotranspiration and precipitation, and projects are further influenced by site hydrology, the volume and rate of surface runoff, near surface seepage and ground water. Whether the ground is saturated and/or frozen may also be an important factor in determining the amount of drainage that infiltrates versus runs off, especially during snow melt and large rain events (Rykaart & Hockley, 2009).

Engineered dry covers minimize the influx of water and limit the intake of oxygen by creating an impermeable layer that prevents the oxidation of the tailings, limits erosion, and provides a surface for vegetation to regrow (Mine Environment Neutral Drainage Program, 2004). Subaqueous disposal is the process where tailings are disposed beneath water and is very effective to prevent oxidation, though not applicable everywhere and there is potential for trace metals in the tailings to leach into the water column.

Mining covers that use capillary barrier effects are useful to limit the generation of acid mine drainage, however require maintaining a fine-grained material layer overlain with a coarse-grain material, and damage can expose tailings to air and are sensitive to climate change (Hotton et al., 2020). Increased precipitation can positively impact these covers, as this can improve saturation of the moisture retaining layer and drought conditions can negatively impact saturation (Hotton et al., 2020).

Modelling and analysis completed at the Lorraine mine site in western Quebec simulated future drought conditions using the relative change in projected drought conditions between the historical period (1981-2010) and future period (2071-2100) to the longest historical drought (42 days), resulting in a future drought scenario of 51 days. The study found that at this site, the cover design is robust to withstand future drought conditions under climate change, however recommends hydrogeologic modelling is completed for individual sites due to the site-specific conditions and climate scenarios (Hotton et al., 2020).

Water balance models have been used to simulate the long-term performance of reclamation soil covers in oil sands mines in Alberta, however these typically use field monitoring and historic data and do not account for climate change (Alam et al., 2018). Downscaled precipitation and evapotranspiration modelling to simulate climate conditions on soil water dynamics for a site north of Fort McMurray found increases are expected in future net percolation (NP) and actual evapotranspiration (AET), which can lead to increased base flow in surface water resulting in contamination and rising water tables within mine waste that could increase the risk of geotechnical instability (Alam et al., 2018).

Landscape evolution modelling (LEM) can also be used to predict soil erosion with rehabilitated landforms with climate change considerations, as demonstrated at a mining site in Northern Australia (Hancock et al., 2017). Erosion is highly dependent on rainfall amounts and intensity, with higher rainfall associated with greater sediment outputs, demonstrating the need to incorporate future precipitation conditions in modelling engineered landforms (Hancock et al., 2017).

Mining sites that rely on year-round frozen conditions or permafrost have numerous additional concerns regarding climate change. Permafrost is not discussed in detail in this risk assessment, however future assessments can consult additional literature from Mine Environment Neutral Drainage Program (MEND 2004, 2009, 2011, 2012), the Mining Environment Research Group (EBA Engineering Consultants Ltd., 2004), and Bjelkevik (2005).

Specific guidance that addresses climate and weather impacts on mining drainage is currently available. The Mine Environment Neutral Drainage (MEND) program generated a guide for better prediction and management of chemical drainage from mines (CANMET Mining and Mineral Sciences Laboratories, 2009). This guide was investigated for climate sensitive components. It specifically mentions future atmospheric conditions and flooding in dealing with post closure uncertainty in mine drainage prediction. Practitioners are encouraged to consider the impacts of climate and weather on site drainage over all time scales, from discrete weather events long-term climate change, mainly beginning with sensitivity analysis.

4.3 Review of Information on Known Vulnerabilities

While implementing the phased remediation plan, and shortly thereafter, two major climate-related events affected the site. First, a substantial, unplanned leachate pond formed during construction of the NUT impoundment area, as the result of anomalously high precipitation during the summers of 2002 and 2003 (Hamblin, 2007). This pond required establishment of a de-sedimentation and treatment process, including the development of a temporary water treatment facility. **Figure 11** provides a view of the pond as it grew to fill the area that was to become the NUT Impoundment Area.

Figure 11: *Aerial view of the Kam Kotia mine site in 2005, with "the pond" of contaminated water covering much of the NUT impoundment area. (Hamblin, 2007)*

Second, the NUT impoundment dam was breached during a period of rapid snowmelt in March 2012. The breach resulted in the discharge of contaminated water and sediment onto surrounding lands, and ultimately into the Kamiskotia River. The dam was reconstructed shortly thereafter. **Figure 12** shows the aftermath of the breach.

Factors identified that contributed to the breach were reported as follows:

- In January 2012, a 0.75 m thick sand cover was placed over the NUT impoundment area, to improve its moist cover function. Work on the sand cover was completed in early March 2012.
- In late February 2012, warm weather had caused melt water to flow across the NUT's frozen sand cover toward the north end of the dam. Workers began constructing a drainage swale from the NIT spillway across the NUT cover to the NUT Impoundment spillway, to prevent runoff from crossing the NUT cover and overtopping the dam. At the same time, a ditch was dug to intercept the runoff and re-direct it toward the NUT Impoundment spillway.
- However, by early March warm air temperatures considerably softened the ground and prevented construction equipment from accessing the NUT Impoundment cover. This interrupted construction of the swale. Daytime high temperatures

ultimately rose to over 20°C, which are considered extreme conditions relative to historical March temperature records. This led to a sudden influx of melt water, overwhelming the ditch. Runoff from the NIT and NUT Impoundment areas then flowed over the face of the containment dam, eroding the dam and causing the breach.

- Most of the material lost from the impoundment as a result of the breach was sand that had been used in the construction of the cover and containment dam. The tailings themselves were exposed but were still frozen in place. A sediment plume comprised mostly of sand entered the Kamiskotia River (**Figure 13**).

Figure 12: *Kam Kotia NUT tailing retention dam after March 19, 2012 breach (Photo Credit: ENDM)*

Figure 13: *North Creek discharge to Kamiskotia River (March 20, 2012)*

Figure 14 demonstrates the die-off of the vegetation on the NUT dam in 2016. These photos were collected during erosion monitoring. While these conditions are not the result of climate conditions and are associated with soil acidity, they represent existing vulnerability of the vegetation on site.

Figure 14: *Comparison of NUT North-East Dam in 2014 with vegetation (left) and with vegetative die off in 2016 (right). (Photo credit: AMEC Dam Raise As-Built Report, 2015; erosion monitoring provided by ENDM, 2016.)*

Finally, the water quality in the NUT impoundment area is already poor quality and not meeting water quality objectives.

5 Characterizing Historical and Future Climate Conditions

The use of robust climate information, including both historical trends and future projections, is foundational in support of risk assessments. Climate data analysis can identify the most relevant hazards that a given geography is exposed to now and in the future, as well as the likelihood of those hazards occurring (NOAMI, 2016). To identify a suite of climate parameters tailored to the Kam Kotia site, the project team undertook literature review to identify 1) the state of knowledge relating to mining and climate change, 2) potential known thresholds of impact, and 3) climate or extreme weather impacts that occurred historically. A longer list of climate parameters was ultimately refined to characterize climate conditions of most concern for Kam Kotia. This refinement was completed based on climate model data availability and the extent to which certain parameters are less certain. A total of 19 climate parameters were selected for further analysis, which are contained within the broad categories below.

- Air temperatures;

- Total precipitation;
- Extreme precipitation;
- Dry conditions and/or drought;
- Freeze-thaw conditions; and
- Winds.

This section provides a description of the methodological approach used to obtain, analyze, and interpret climate data, and a brief historical and future climate characterization for the Kam Kotia site.

5.1 Approach used in Developing Climate Information

Climate information was obtained and developed via the Climate Change Hazards Information Portal (CCHIP)[1]. CCHIP is an interactive source of information that provides customized historical and future climate data outputs based on geographical area, sector, theme, and timeframe of interest. For the purposes of this Kam Kotia climate change risk assessment, the closest station with a sufficient period of record was identified to be the Timmins Victor Power Airport (Station Id #6078285), which had historical daily observations from 1955 to 2010 for most climate parameters. This monitoring station is located approximately 20 kilometers from the mine site and is considered to be representative of the site (e.g., due to no major topographic features, coastlines, or great lakes in the vicinity).

Figure 15 provides an illustration of the overall approach to obtain, develop, and interpret climate information as part of this project.

[1] https://go.cchip.ca/

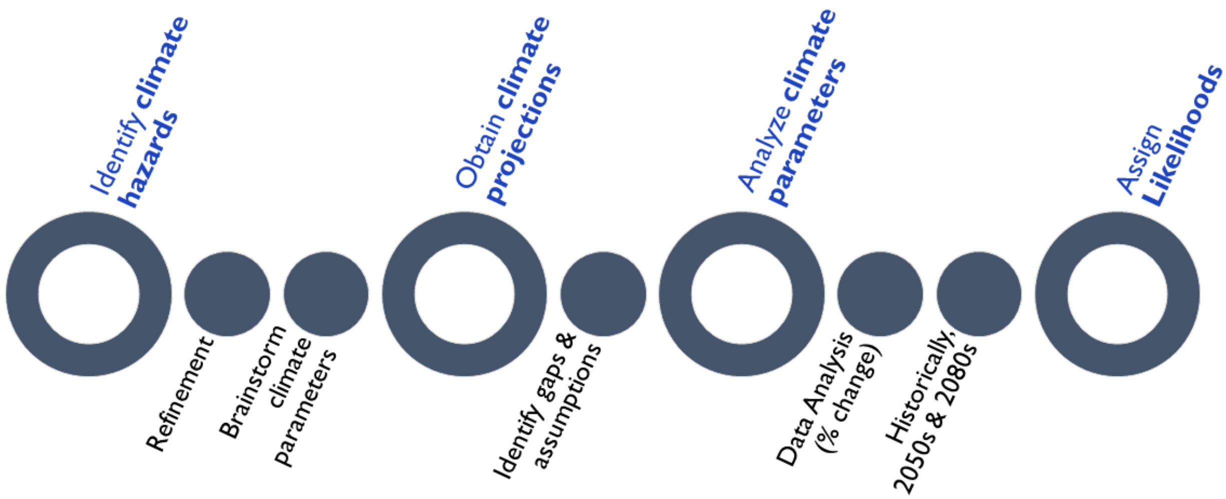

Figure 15: *Approach used to obtain, develop and assess likelihoods as part of the Kam Kotia risk assessment*

Once climate data analysis and characterization were complete, climate parameters were paired with individual risk scenarios (described in Section 3) and used to estimate a likelihood rating for historical conditions (1981-2010), mid-century (2041-2070), and end of century (2071-2100). By taking this approach, future climate projections were used to assess how current risks may shift over the coming decades to enable forward-thinking adaptation opportunities.

The remainder of Section 5.1 describes in further detail sources of climate data, how they were obtained and analyzed. Section 5.2 provides an historical and future climate characterization and Section 5.3 identifies the likelihood ratings based upon this climate information.

5.1.1 Historical Data Source

Historical data are based upon Environment and Climate Change Canada (ECCC) and Natural Resources Canada gridded datasets, as well as ECCC's Climate Data Archive[2]. It is important to note that errors or omissions in climate datasets as released by ECCC may therefore also be present in the datasets used for our analyses, although effort has been made to recheck values used for this risk assessment. Data were obtained and summarized based on a historical climate normal period, recommended to be 30-years in length by the World Meteorological Organization[3], of 1981 through 2010. Notably, a subset of climate parameters did not contain all 30-years of data within this baseline period. For example, precipitation data were missing some values within 2001, 2003, 2009, 2010 and therefore the results should be interpreted with caution if specific thresholds are needed. The trends and overall characterization of historical and future climate, however, are expected to be consistent.

5.1.2 Future Projections Source

Future climate projections used in this assessment are based upon global climate models (GCMs) produced as part of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The suite of climate models used in AR5 is from the Fifth Coupled Model Intercomparison Project (CMIP5), coordinated by the World Climate Research Program. In this assessment, climate parameters were analyzed based on the ensemble output of 40 GCMs, resulting in a robust range of estimates from which to calculate possible future conditions. A high emissions ("worst case") scenario was used for obtaining future projections – the Representative Concentration Pathway (RCP) 8.5. RCP8.5 refers to the radiative forcing (8.5 Watts/m^2) associated with high emissions continuing through the 21st century. This scenario is often employed in climate change risk assessments to account for potential feedback loops in future climate that are not yet well understood, and to add a degree of conservatism into projected climate conditions used to inform future climate risk likelihoods.

5.1.3 Statistical Downscaling of Climate Projections

As part of obtaining climate projections, the team used the Climate Change Hazards Information Portal (CCHIP). CCHIP uses a statistical downscaling approach referred to as the "delta method". The delta method is one of several methods which can be used to downscale climate projections of future climate from a climate model (e.g., at resolutions

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[2] https://climate.weather.gc.ca/

[3] https://www.wmo.int/pages/prog/wcp/wcdmp/GCDS_1.php

of 100km or larger) to a scale that enables meaningful adaptation decision making. It is perhaps the simplest approach, the easiest to understand, and has been widely used for impacts and adaptation studies. It has also been shown to compare well, in most cases, with the accuracy of other approaches. The following steps describe this approach as to how it was applied for the Kam Kotia risk assessment:

1. Obtain historical baseline (observed) climate conditions for the Victor Power Airport station (1981-2010);
2. Using the ensemble of all available AR5 climate models, obtain the average for the same historical baseline period (1981-2010) through re-gridding model runs to a common resolution;
3. Obtain future climate conditions for mid-century (2041-2070) and end of century (2071 to 2100);
4. Determine the difference ("delta") between the modeled baseline and future periods, representing the change in the specified climate condition (the 'climate change signal');
5. Apply this delta value to the station baseline condition to "bias correct" for any differences in climate models.

5.1.4 Uncertainty in Climate Projections

The use of the AR5 climate model ensemble not only allows for the calculation of an average projection of future climate conditions (representing a consensus of all independent models), it also allows for the estimation of projection uncertainty that could not be determined from a single climate model (Auld et al., 2016; Charron, 2016). Based upon the 'spread' of an ensemble of climate models, one can speculate on the uncertainty in projections. In other words, a climate parameter which shows less spread among many climate models is likely to be more reliable than a variable which has a very large range of projected outcomes. **Figure 16** illustrates the extent to which different climate conditions can be more or less certain, depending upon factors such as climate model ability and data availability.

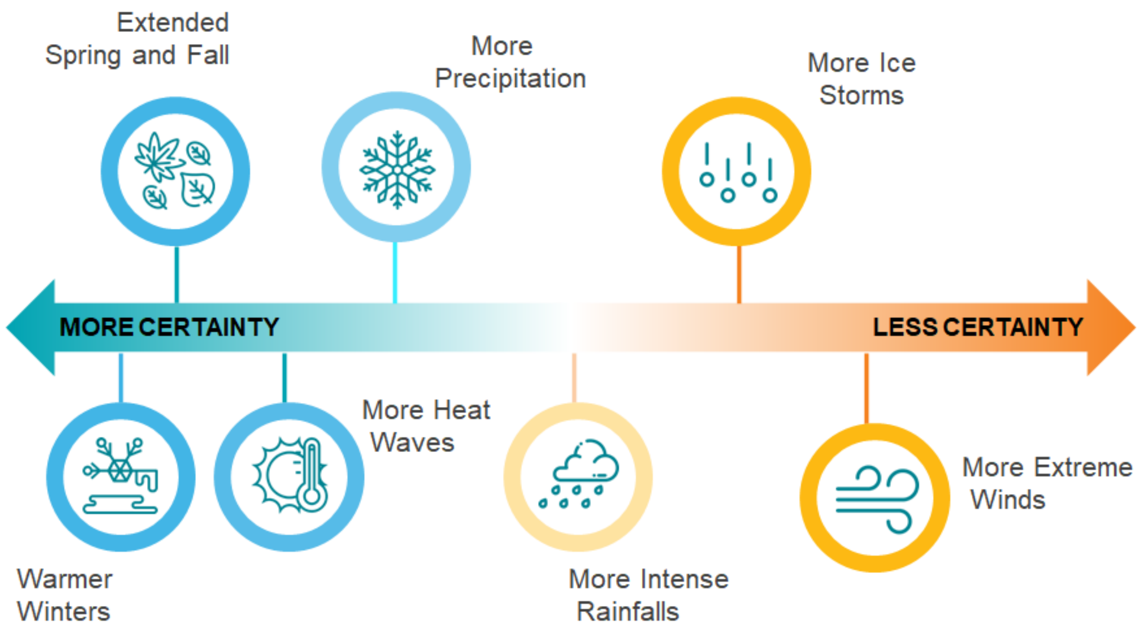

***Figure 16:** Representation of confidence in climate projections, based on the conditions being simulated*

To inform this risk assessment, each climate parameter was graphed and interpreted based on each climate normal period. Where available, the range in projections was interpreted; however estimated likelihoods used to inform risk scenarios were based upon ensemble averages, and the degree of change between climate normal periods. **Figure 17** illustrates ensemble projections for one climate parameter (maximum daily temperature). The range between climate modeled values by end of century is noticeably larger than those in the short-term, indicating uncertainty increases further out into the future.

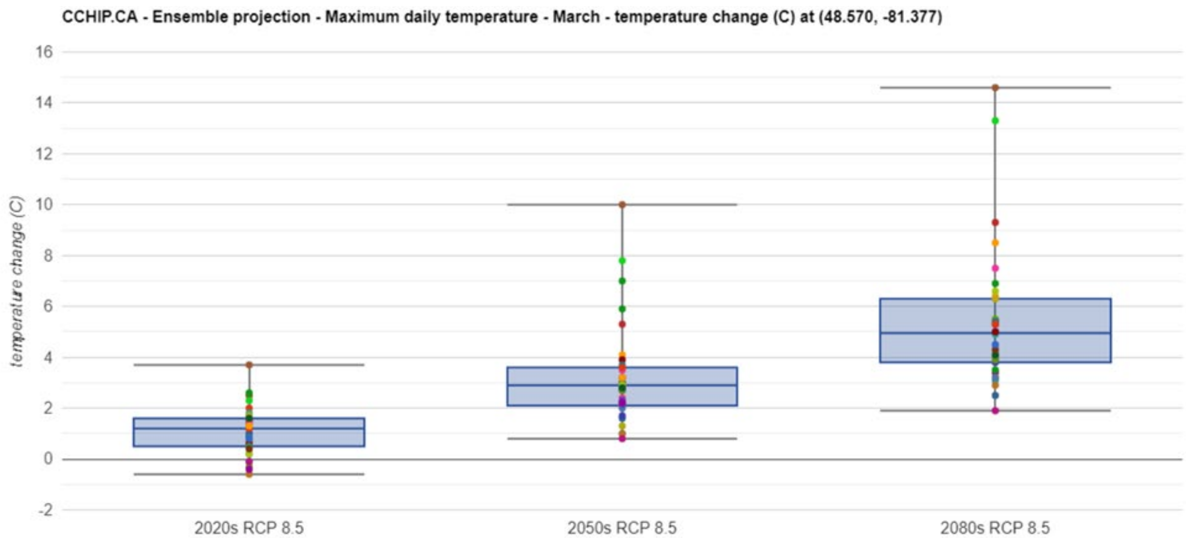

Figure 17: *Future maximum daily air temperature in March, indicating the 25th to 75th percentile range (shaded box areas) and full range of modeled values (vertical black lines). Ensemble averages are indicated by dark blue horizontal lines.*

5.2 Historical Trends and Future Projections

Climate conditions in the vicinity of the Kam Kotia mine site are expected to shift significantly by mid-century (2050s) and even more so by the end of century (2080s). Average annual air temperatures, historically at 1.8°C, are projected to increase to 5.3°C by mid-century and to 7.7°C by the end of century. In other words, based on the latest climate model projections, the climate is expected to warm by an additional 3.5°C by mid-century, well over the 2°C commitment specified in global climate agreements (e.g., the Paris Accord[4]). Seasonally, the rate of warming is increasing the fastest in the winter, with minimum temperatures projected to increase from -20°C (historically) to -15°C (2050s), and -12°C (2080s). The number of days where minimum temperatures exceed 0°C were also analyzed, particularly in the winter season where rapid thawing and melting is of concern. Historically, just under 2 days in the winter season meet this condition, but modeling indicates significant increases to 6 days in the winter by mid-century and over 11 days in the winter by end of century.

Historically, 840mm of precipitation annually is observed in the area near the site, which is projected to increase by 8% (2050s) and 12% (2080s). In the future, the highest increases in precipitation are projected for the winter season, then spring. Summer precipitation is anticipated to receive similar amounts of precipitation, with potentially drier conditions

[4] https://www.canada.ca/en/environment-climate-change/services/climate-change/paris-agreement.html

by end of century. Total precipitation was also analyzed monthly for all time horizons, to identify conditions that may be particularly problematic for Kam Kotia (e.g., increased precipitation on frozen ground, in winter or during the spring freshet). **Figure 18** illustrates the projected change (as a percent) in total March precipitation.

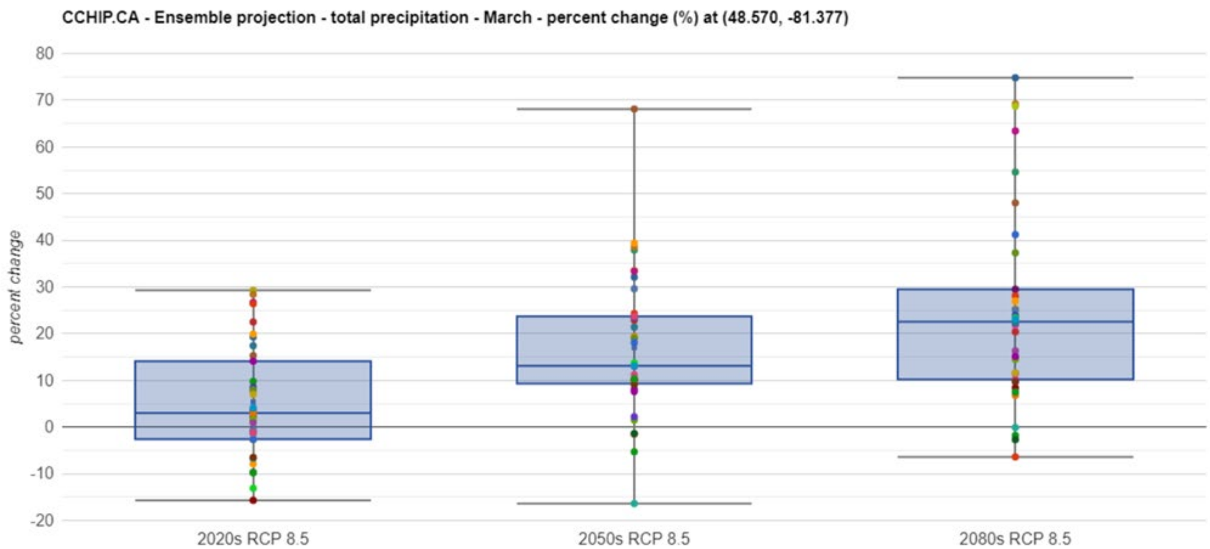

Figure 18: *Projected change (%) in total precipitation for Kam Kotia, relative to historical conditions*

Extreme precipitation was also characterized as part of this assessment. The highest amount of historical 1-day, 3-day and 7-day precipitation has historically been delivered as rain in the summer season. Annual maximum 1-day precipitation (37 mm historically) and the number of days where precipitation exceeds 20mm (6.3 days historically) indicate increases in extreme precipitation by mid-century of 8% (to 44mm) and 17% (to 7.9 days), respectively.

While total and extreme precipitation conditions are projected to increase annually and across most seasons, dry conditions, or potential drought, were also considered during summer and fall. Dry conditions are particularly important at the Kam Kotia site in relation to drying or degradation of vegetation, and during periods of low flow in the Kamiskotia River, where it may be more of a sensitive receptor to acidic site runoff. The number of annual dry days is not projected to change through time, but average water surplus and deficit do indicate notable changes. **Figure 19** illustrates the monthly water balance for Kam Kotia, historically and for future time horizons. One can interpret this graph reading from left to right and by focusing on the bars (columns) and their colours. Blue-shaded columns indicate water surplus in each month, while orange-red shaded columns indicate a water deficit. The average water deficit is increasing across the year overall (88% increase by 2050s), but this change looks very different depending on the season. For example, average water deficit from summer to fall is projected to increase 90% by mid-century and by more than 180% in the end of century. This indicates that there is potential for drier conditions and/or drought particularly from July through September.

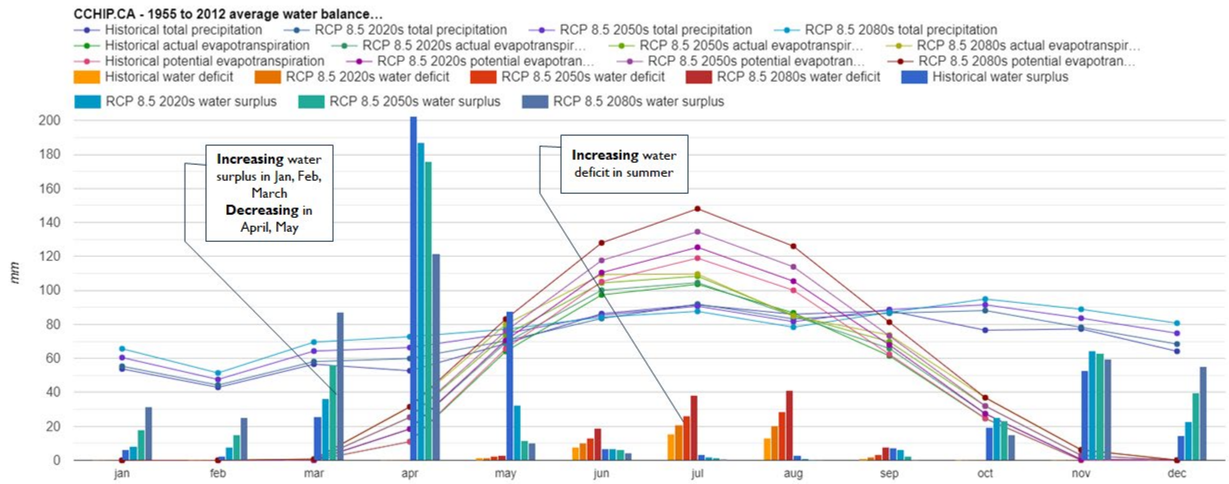

Figure 19: *Projected monthly water surplus and deficit for Kam Kotia, in millimetres (blue denotes surplus, orange denotes deficit)*

On the other hand, water surplus is projected to increase in winter months specifically (200% higher by mid-century). Combined with rises in precipitation and extreme events, this indicates a higher likelihood of winter or spring flood conditions on site.

Wind conditions were characterized based on historical data from Environment and Climate Change Canada; however, future projections were unavailable at the time of this assessment. Historically, the highest average windspeeds occur in spring and winter. However, the highest maximum (recorded) wind gust ever was noted in the summer season of 158km/hr. To account for uncertainties in climate modeling and a lack of data, the likelihood ratings assigned for this condition remained the same through time. In other words, historical conditions are applied in future time horizons such that large assumptions are not made without substantiated information. However, Kam Kotia does experience existing impacts due to windy conditions and thus risks associated with downed power lines, among other site components, should still be a focus for risk reduction measures.

Finally, freeze-thaw cycles were analyzed for Kam Kotia. **Figure 20** illustrates the number of days where this condition occurs historically and through future time horizons.

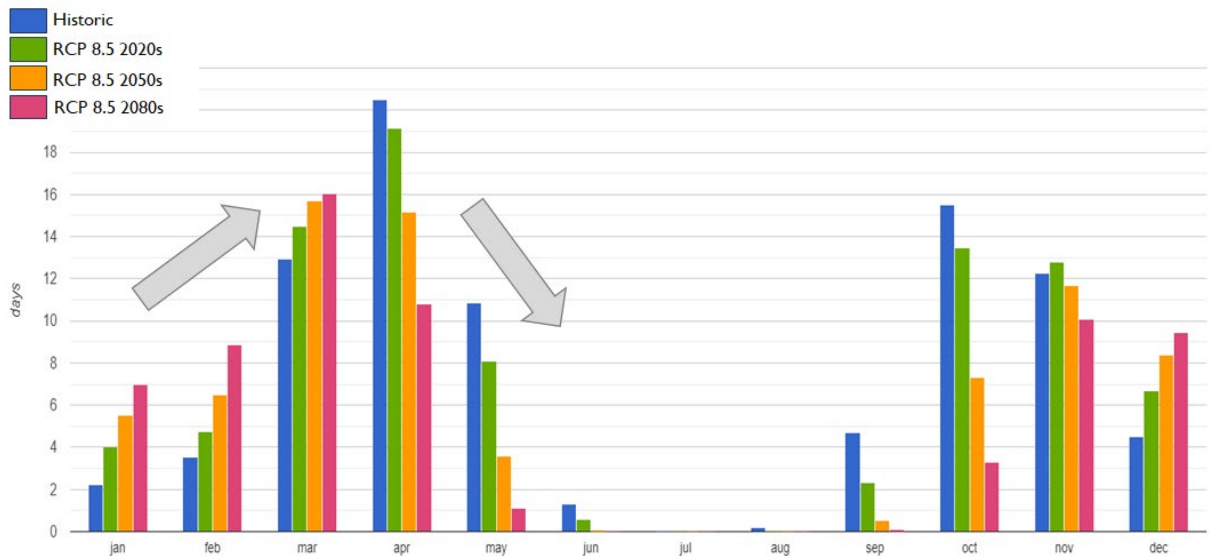

Figure 20: *Historical and future average monthly freeze-thaw cycles (# of days) for Kam Kotia, indicating increases in winter months and decreases throughout much of the rest of the year*

As indicated above, freeze-thaw cycles are generally decreasing across most months, with the exception of winter months. In winter, freeze-thaw conditions are increasing rapidly, indicating a higher likelihood of impact during winter through spring as it relates to snowmelt and/or flooding.

A full summary of all climate parameters analyzed in support of the Kam Kotia risk assessment are contained in **Appendix C**.

5.3 Likelihood Ratings Assigned based on Climate Information

Once climate information was analyzed, it was used to inform likelihoods of a given scenario occurring. It is important to note that the likelihood of a given climate event occurring was assumed to be representative of an entire risk scenario. This assumption enabled a precautionary approach and was made based upon the project scope and available data for Kam Kotia. It is important to add that while this is a precautionary approach, it introduces a very high degree of conservatism that could be reduced to more reasonable levels if a more comprehensive assessment were feasible. In other words, it is anticipated that some of the climate risks determined (see **Section 6**) may be overstated as a result. In future assessments, if detailed thresholds of failure and engineering data are more available, one could assess the likelihood of both the climate event and the entire risk scenario occurring to inform risk ratings.

Section 3.1.4 defines the criteria used in establishing the scale of likelihoods (ranging from rare to almost certain). Each likelihood rating is based on climate conditions within a given time horizon and is assigned a numerical value from 1 (rare) through 5 (almost certain). **Table 6** provides a summary of the climate parameters used in assigning likelihood ratings. Each parameter is paired with a given climate event of concern for the Kam Kotia site, along with historical and future climate information. This table can be interpreted from left to right, where likelihood ratings are assigned based on the degree of change projected in particular climate parameters and based on best judgment. For example, it is historically *unlikely* ("not expected to occur over a decade") that drought will persist and pose risks onsite based on a small average water deficit across Summer and Fall seasons. However, by mid-century, average water deficit is projected to increase by 90% across these seasons, and a result the likelihood is raised to *possible* in this time period ("expected to occur once over a decade"). By the end of the century (2080s), average water deficit is projected to increase by 182% relative to historical conditions, indicating is *likely* that drought could occur several times over the course of a decade in the Summer and Fall seasons.

Table 6: *Summary of likelihood ratings and climate parameters used in the Kam Kotia risk assessment. Projected changes (by 2050s and 2080s) represent the ensemble average condition.*

Climate Event / Condition	Climate Parameter(s)	Observations & Projections			Likelihood Ratings		
		Historical Condition	Change by 2050s	Change by 2080s	Historical	2050s	2080s
Dry Conditions / Drought	Average water deficit in Summer - Fall (mm)	6.3 mm	90%	182%	Unlikely	Possible	Likely
Rain-on-snow	Days Min Temp >0C in Winter	1.95 days	208%	469%	Possible	Likely	Almost Certain
	Total Precipitation Winter (mm)	157.2 mm	16%	26%			
Extreme precipitation	Maximum 1-Day Precipitation Annually (mm)	37.1 mm	8%	18%	Likely	Almost Certain	Almost Certain
	Days precipitation >20mm	6.3 days	17%	25%			
Combined Events	Maximum 1-Day Precipitation Annually (mm)	37.1 mm	8%	18%	Possible	Possible	Likely

Climate Event / Condition	Climate Parameter(s)	Observations & Projections			Likelihood Ratings		
		Historical Condition	Change by 2050s	Change by 2080s	Historical	2050s	2080s
	Max Wind Gust Speed (km/hr)	158 km/h	N/A	N/A			
Freeze-thaw cycles	Freeze-Thaw Cycles - Winter Season	10.2 days	100%	148%	Likely	Likely	Likely
Shifting hydrology / groundwater conditions	Average water surplus in Winter (mm)	23.5 mm	209%	377%	Unlikely	Possible	Possible
Extreme Winds	Days with average windspeed >= 52 km/hr	2.3 days	N/A	N/A	Likely	Likely	Likely
	Max Wind Gust Speed (km/hr)	158 km/h	N/A	N/A			

These likelihood ratings were used to inform risk scoring, described further in Section 6 below.

6 Risk Assessment Results

Table B-1 in **Appendix B** has the summary results of the risk assessment, including the 20 vulnerability scenarios with supporting research, sensitivity, and scoring. An excel document accompanies these results for additional details. Risks are discussed for the current, 2050s- and 2080s-time horizons. A summary of the risk assessment results is presented in the following sections.

6.1 Risks by Class

Figure 21 demonstrates the distribution of risk classes by the number of scenarios identified. This indicates that the number of risks requiring intervention increases with time due to increasing likelihood of climate events occurring. As discussed in **Section 3,** the likelihood assigned refers to the likelihood of the climate event occurring, not the likelihood of the scenario occurring.

The following section includes a discussion on the results of the scenarios by risk class.

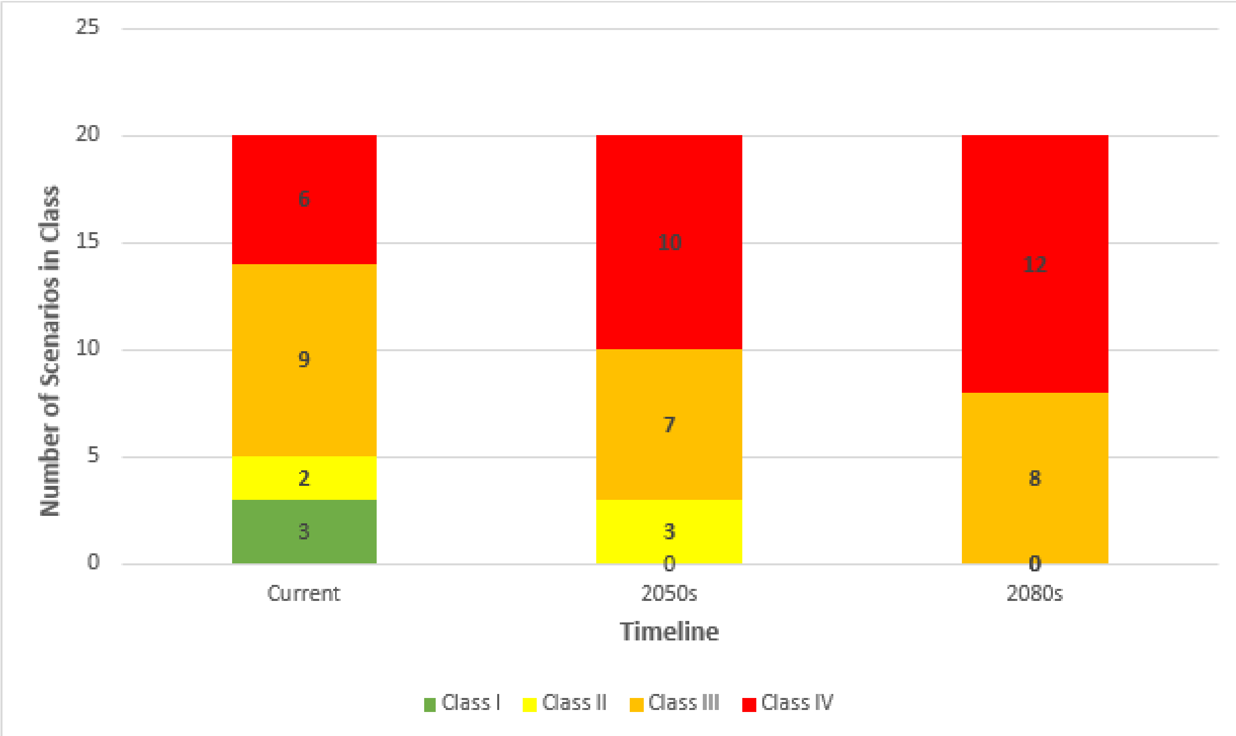

***Figure 21**: Distribution of climate risks by class*

6.1.1 Class IV Risks

Class IV risks are those that significantly exceed the risk acceptance threshold and require urgent action, which includes undertaking additional investigation to better quantify the risk and possible mitigation actions. Six scenarios were identified and categorized as Class IV, increasing to 10 scenarios in 2050s and 12 scenarios in 2080s. Stated otherwise, four additional risks are elevated between current conditions and mid-century, and six additional risks are elevated by end of century compared to current conditions.

Many of the Class IV risks under current climate conditions are broadly described as scenarios where the interconnected components of the Kam Kotia site are over capacity when the volume of water exceeds the capacity of the system. This may be the result of multiple events, such as extreme precipitation, spring freshet, rapid snowmelt, or rain-on-snow. This can subsequently impact and damage critical components like the NUT impoundment dam or the water treatment plant.

For the NUT Impoundment area, the greatest risks identified are triggered by a climate event where water exceeds the capacity of the system and there is a blockage of the spillway or failure to discharge quickly enough. In these scenarios, the dam could potentially be breached in one or more locations (like in the March 2012 event). A breach of the dam was identified as having a higher consequence than overtopping of the dam due to the costs and risks associated with more extensive damage and repairs. The breach of the dam was also estimated to lead to greater environmental consequences.

The performance of the spillway from the NUT dam that could prevent a breach is therefore critical when considering increasing precipitation and more frequent warm days in the winter that could lead to unexpected and rapid snow melt.

As per ENDM, the NUT impoundment dam was raised in 2014 and was designed for a "Timmins storm", equivalent to a 1:200-year event. A more conservative approach, where dams are sized to a 1:1000 event or the Probable Maximum Flood (PFM) would certainly reduce some of the risks associated with dam failure. However, various types of more detailed analyses would be required before undertaking such an initiative that balance the benefit of improvements with the possible consequences and cost of any additional design and construction. At the completion of construction, the consultant responsible for the design and construction of the dam raise recommended that a hydraulic analysis be completed for the NUT spillway and to monitor discharge water from the NUT spillway weir. In the interim, periodic dam safety reviews are beneficial for establishing the performance of the dam compared to designs and to identify any emerging risks.

Additionally, ENDM staff indicated that water quality in the NUT impoundment area is already poor and not meeting water quality objectives. Without a more detailed analysis, it is not possible to determine if water quality will improve over time as contaminants settle, and how climate change may impact this process. This demonstrates the uncertainty that is inherent in the risk assessment process.

For the NIT Area, the greatest risks were associated with the downstream infrastructure. Under frozen or thawing ground conditions, the NIT cover area has limited infiltration and can therefore exceed capacity and spill to the NUT impoundment area and/or Acid Water Collection Pond (AWCP). The consequences are more severe to downstream components onsite; however, it is beneficial to consider these components together when assessing risk in the NIT.

The water treatment system relies on continuous electrical power to pump water from the AWCP to the treatment plant. In a storm event where power is lost, the consequences are highest when the system is already at or near capacity due to increased precipitation, spring freshet or snow melt.

In the 2050s-time horizon, four scenarios increase from a Class III to a Class IV scenario. This includes the possible loss of wet cover on the NUT impoundment area due to drought conditions as the average water deficit in summer and fall is expected to increase.

Scenarios where the NUT spillway is not blocked or the dam overtops (instead of a more severe breach) also have elevated risk scores as the likelihood of extreme precipitation, rain on snow and storms increases over time.

6.1.2 Class III Risks

Class III risks are those that exceed the risk acceptance threshold and could potentially require intervention, including investigation and remedial action.

Similar to the Class IV risks, numerous scenarios were identified where the system is over capacity due to an extreme precipitation event or storm. In contrast with Class IV risks, consequences are reduced if the NUT impoundment dam can discharge effectively from the spillway and does not result in the breach of the impoundment dam.

Although the wet cover is currently more saturated than the design intended, drought scenarios demonstrate the risk of both too much and too little water to be able to adequately cover and store tailings. The likelihood of drought conditions is unlikely under current climate conditions; however, this is expected to increase with time. Additional research may be required to establish the length of dry periods or the fluctuation in groundwater that could possibly dry out the NUT cover and expose tailings.

6.1.3 Class I & II Risks

Class I risks are those that are below the risk threshold and do not require action or investigation. **Class II** risks are those that lie on the risk acceptance threshold and may require active monitoring.

Drought related scenarios, including the degradation of vegetation on the NUT impoundment dam and the NIT dry cover, had relatively low likelihoods and consequences. These increase to a Class III risk in the 2080s.

In general, vegetation and rip rap that can be damaged due to drought conditions are not engineered structures and therefore while degradation is detrimental, it is less likely to result in immediate severe consequence like a dam breach. There are limitations to the possible adaptive measures for vegetation, as vegetation must also meet criteria like being suitable for the soil acidity environment and have shallow roots due to potential damage to liners.

A possible risk scenario associated with the underground mine and open pit is the long-term shifts in hydrology and groundwater fluctuations resulting in surface subsidence in backfilled areas that could increase hazards for access and collapse. This scenario was ranked as a ‘medium’ consequence for public health, due to possible hazards if the public or staff access the area.

7 Discussion

7.1 Adaptation Opportunities

During workshop discussions and risk ranking, scenarios were assessed based on a "business as usual" assumption, assuming the current performance of the site is consistent in current and future timelines and no additional remedial measures are in place. Specific adaptation measures that apply to individual site components were not identified and considered not relevant at this scale (e.g., adaptation measures are not only influencing one site component at a time, but rather the site as a whole). To adopt a precautionary approach, each risk was assigned an adaptive effectiveness of *Not Effective* (the lowest possible score) to ensure that risk scoring was conservative. Overarching adaptation strategies were subsequently identified throughout the engagement process.

Adaptation opportunities are generally categorized as: improving information and knowledge, bolstering remedial actions, and building management capacity and are described in the following sections.

The actions discussed are provided for illustrative purposes only and do not represent an exhaustive or recommended course of action to mitigate specific risks. Instead, this report concludes that further detailed analyses are necessary to address potential emerging climate risks.

7.1.1 Improving Information and Knowledge

NOAMI (2016) recommends using a 'Risk Library' that is frequently updated and provides a record of remediation activities on site, the results of post-remediation monitoring and maintenance, and schedules for future monitoring and maintenance requirements.

Following the dam breach in 2012, a report by AMEC (the engineers responsible for construction supervision, contract management and geotechnical engineering support for the dam repairs) noted that no as-built drawings were available for the NUT impoundment dam completed in 2003. The dam appeared to deviate from design specifications, with a crest elevation 30 – 40cm lower than required and a larger volume of tailings stored such that the water level could exceed the elevation of the dam's clay core. While the dam was raised in 2014, this example demonstrates how the lack of as-built reports or unknown site conditions can increase risk. Both investigation and a strong record keeping system are useful tools to better understand the conditions on site and identify areas that require further action.

The majority of the Class IV risks identified pertain to flooding events that could overwhelm the system. Presently, there are challenges with identifying the flow path on site due to limited information or recent changes to the site that have changed hydraulic connections. There is therefore an adaptation opportunity to improve information and study the bathymetry of the site. This can include the development of a site-wide drainage pattern plan to identify risks and opportunities to manage flow on site, and individual landform and drainage designs for critical components, like the NUT impoundment area. These studies can compliment other recommendations, like the completion of a hydraulic analysis on the NUT spillway.

Other areas where information and knowledge building could support in site-specific adaptation include groundwater conditions. There is currently limited information related to the groundwater systems and pathways on site, as well as possible impacts of long-term fluctuations on ground subsidence and the performance of components that require saturation. A study on the relationship between contamination and groundwater flow on site could significantly improve adaptive capacity and risk reduction.

Likewise, the NUT moist cover is not currently functioning as designed as it is frequently flooded instead of maintaining a saturated state and therefore there are unknowns and risks associated with this. Undertaking a site-wide drainage plan could also support future work on how to improve the function of the cover or potentially replace with a new cover option that is more effective.

In many cases, identifying the risks and mitigating earlier on can prevent more severe consequences, like erosion of the vegetation and rip rap.

Additional upgrades have been made to the sludge management process, including the construction of sludge settling ponds. As part of this CCRA, detailed information on these changes was not available and therefore additional investigation may be required to determine any climate change related risks. Work is also ongoing at the open pit that may impact the capacity of the NUT impoundment area. This work could benefit from additional investigation and if a new design is proposed, consideration for climate related risks.

In many cases, identifying the risks and mitigating earlier on can prevent more severe consequences, like erosion of the vegetation and rip rap. Generally, there can be significant challenges and risks associated with a lack of information and the limited use of monitoring and assessments to inform decisions. This is particularly challenging where work has been completed over several decades and with different ownership and management. It is therefore recommended to improve data collection and knowledge via ongoing monitoring and reporting on site.

Overall, site management could be improved through the acquisition and periodic updating of further key types of information.

7.1.2 Bolstering Remedial Actions

In addition to the drainage plan identified above, there is an opportunity to bolster remedial action now and into the future. For example, scheduling consistent inspection of assets provides an opportunity to assess the performance of components like the NUT impoundment dam and proactively identify concerns on site. This includes dam safety inspections as recommended by the Canadian Dam Association. NOAMI (2016) further outlines how regular inspections can ensure that site conditions do not deteriorate and provides opportunities for early detection of issues, reducing costs of further rehabilitation if failure should occur.

Spillways (including from the NUT dam, between the NIT and the NUT and from the AWCP) were identified as a critical component to prevent the most severe consequences associated with the system exceeding capacity. Future maintenance of spillways, including ensuring that there are no blockages or damage at critical times of year like before a rapid snowmelt is a beneficial, proactive measure.

The water treatment plant is currently powered by electrical lines from Hydro One and Class IV risks were identified if the pumps are shut down and the system is at or near capacity. Installing a backup diesel generator can reduce this risk and provides a clear, tangible adaptation opportunity in the near future.

A “closed loop” system for treatment is frequently used on other mining sites, where tailings are enclosed with perimeter ditches that collect overflow and seepage in a polishing pond for treatment. This does not currently happen at the Kam Kotia site. As identified in workshop engagement, a closed loop system could be explored in further detail to determine if any of the risks identified could be mitigated.

The open pit has a BGM liner that has 0.60m of cover. Currently, vegetation is limited to grasses instead of vegetation with deep roots and may require more long-term maintenance due to erosion and loss of vegetation. The use of a deeper fill cover on top of the liner and vegetative plants that are more resilient to drought and erosion could be explored to mitigate risks.

Finally, an adaptation opportunity could be to ensure that any plans to change or improve the vegetation on site could consider the possibility and implications of drought at the site in the future.

7.1.3 Building Management Capacity

One final type of adaptation pertains to building institutional memory and capacity among those managing the Kam Kotia mine site. Due to the extended nature and timeline of the remediation process over more than 40 years, there is a need to maintain knowledge of site components and operations. Otherwise, significant institutional knowledge may be at risk of being lost. As noted in previous sections, a centralized and "living document" that includes a list of available documentation, a summary of remediation activities on site, the results of post-remediation monitoring and maintenance, and schedules for future monitoring and maintenance requirements is a valuable management tool.

This document would require the personnel and funding to continue documenting the current site conditions, frequent reporting on how remediated measures are performing and a record of monitoring and maintenance. These can allow for more frequent interventions and the ability to revisit risk assessments from an elevated foundation of data availability. Having a designated Engineer of Record (EoR) may also be beneficial to ensure accountability.

Finally, there is an opportunity within ENDM and among site management and stakeholders to establish a "final goal" with climate change in mind. Setting remediation targets over time with consideration for climate change will allow ENDM and site management staff to identify gaps, plan for the future and ultimately be more adaptive moving forward.

7.2 Transferable Lessons Learned

Future risk assessment work completed for orphaned and abandoned mine sites can benefit from the following information to inform the risk assessment process:

1. **Design and As-Built Reports.** Wherever possible, design and as-built reports should be used in conjunction to understand why aspects of the design were considered, if any relevant climate conditions or thresholds are available, and how the design may defer from what is on site.
2. **Final Closure Reports.** Where remediation has been completed, reports and regulatory submittals provide a strong basis to understand what has been constructed, the intended performance and any deviation from design. Reports completed after construction that note how remedial measures are performing also help to identify risk scenarios.

3. **Engineer of Record.** Having an EOR available for the workshops and review of material is a valuable resource to ensure institutional knowledge is available and incorporated into the analysis.
4. **Operations and Maintenance Reporting.** Site experience that provides details like how the site has responded to climate events, sources of failure, and mitigation efforts are beneficial to identify risk that might not be otherwise reported. Having operations staff involved in the risk assessment process is extremely valuable, particularly where documentation is not available.
5. **Incident Reports.** For example, the March 2012 dam breach provided details on the development of a failure scenario.
6. **Ongoing Monitoring Reporting.** Where ongoing monitoring is or has occurred on site, like for water quality, vegetation and system performance, summary reports can identify possible early warning signs that remedial work is not functioning adequately or that climate is influencing performance. Wherever possible, monitoring and reporting is more valuable when weather conditions are recorded alongside observations.
7. **Codes and Standards.** Can be used as a starting point for understanding the performance of the designs.
8. **Site Visits.** A site visit was not conducted for Kam Kotia, however, could provide more opportunity to observe the site and identify areas where issues may arise.

There are numerous risk management frameworks that can be used to monitor and prescribe management actions, including TARP (Trigger, Action, Response Plans). NOAMI (2016) provides additional guidance on the long-term management, including monitoring and maintenance. The core elements for an effective management framework include information management, site monitoring and maintenance, responding to unforeseen events, and application and enforcement of legal or other mechanisms to restrict future use.

Likelihood and consequences scoring used in this assessment were adapted to Kam Kotia but would benefit from further definition refinement to align with other risk management approaches within ENDM. For example, assigning more specific financial consequence values (e.g. a "high" financial consequence is equal to greater than $X amount) could allow for a more tailored approach.

The site is not currently meeting Provincial water quality objectives; however, water quality is expected to improve over time. When discussing risks in future climate scenarios, it can be difficult to assess multiple factors like improvements to water quality but climate change negatively impacting other components without more detailed modelling. It is therefore important to document conditions that may change over time, despite uncertainty.

When considering the temporal scope of a mining risk assessment, there are benefits to consider longer duration (e.g., to 2100), however these need to be weighed against the ability to effectively plan in an increasingly long time-period and with reduced certainty from climate models. Where possible, considering multiple time horizons (e.g., 2050s and 2080s) allows for assessment of components that have a shorter intended design life, like the water treatment plant, and components that are designed to perform in perpetuity, like impoundment dams.

Permafrost degradation was not considered for this assessment, since permafrost does not exist at the site. However, permafrost is a critical component for many abandoned mine sites that rely on it as part of their containment structure design. The role of increasing temperatures on permafrost cannot be ignored for sites that contain permafrost. Acid rock drainage (ARD) and mine tailings have historically also been stored frozen and can have significant risk associated with warming temperatures which have not been a significant consideration in this assessment.

The construction phase of remediation was not discussed in detail in this report, however if extreme weather events impacted the budget and/or timeline of implementation that could be relevant for planning new remediation activities. For example, work that requires tailings are frozen may benefit from considering current climate conditions at the site rather than relying on historic best practices.

For many sites, particularly those that require ongoing institutional care, one of the greatest risks to their long-term performance is associated with sufficient oversight to ensure remedial works are performing as intended. For example, in the absence of monitoring, emerging concerns may be missed. Similarly, insufficient care and maintenance can result in the gradual degradation of critical infrastructure until a preventable acute failure occurs. These issues may be linked to the availability of funding and therefore represents an important consideration to consider for other mining-related assessments and projects.

8 Concluding Remarks

There are numerous opportunities in incorporating climate change considerations and building upon this risk assessment for abandoned/orphaned mining sites across Ontario and Canada. Risk assessment and adaptation processes are designed to be iterative.

Engineers and site managers should expect the need to revisit research and assessment results on a regular basis to ensure they are updated as new information and new climate science emerges. There are also opportunities to dive "deeper" on risk assessments, such as this process that has been undertaken for Kam Kotia (e.g., undertaking modeling, engineering analysis to determine thresholds of failure, further customizing climate hazards of concern, etc.).

Likewise, it is important to recognize that adapting to climate change takes time, resources and sometimes involves difficult decisions (e.g., trade-offs). A "silver bullet" approach to achieve resilience is unrealistic, and thus as risk and adaptation processes proceed, it helps to create a team of trusted colleagues and to seek external input where needed.

Finally, as climate change is increasingly integrated into remediation plans and activities, it is important to set yourself for success. This includes 1) beginning with the end in mind: identifying ideal outputs, what resources are available, and what level of detail is required before diving deep; and 2) enabling the implementation of results: avoiding unclear conclusions, considering what it will take to implement and identifying lead and support roles for implementation activities.

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Appendix A

Background Information

- Table A-1: Components removed from scope and rationale
- Table A-2: List of Resources Provided to complete CCRA
- Table A-3: Adapted from Mining Association of Canada Outlining Potential Climate Change Risks in the Mining Sector

Table A-1: Components removed from scope and rationale

Site Component	Description	Rationale for Removing from Risk Assessment
Aggregate Extraction	Clay and sand site pits used to extract material for construction. Flooding could further reduce access to pits if needed in the future, which would be required for routine maintenance and operation.	Limited information was available for the components and the site is still active. Any future planning for closure should consider climate change.
Wildlife in adjacent Ecosystems	Species (e.g., beaver) range expansion due to warming. Beavers may dam rivers causing impacts onsite.	Lack of data on the existing wildlife to compare for future scenarios.
Site-wide	Increased wind may cause blowing dust due to exposed soils and site infrastructure, which could impact neighbouring communities through worse air quality.	No projected wind data, no known reports or monitoring of on the impact of wind on site.
Underground Mine - Crown Pillar	The crown pillar is fenced off to reduce hazards. Previous hazard assessments have been completed (Trow 1994, Golder 2011).	The ENDM project team identified this component as having limited climate related impacts during preliminary scoping. A more detailed hazard assessment that included field investigation and modelling has been completed for the area and identified crown pillars recommended for remediation. Recommendations included maintaining fencing, backfilling, and monitoring. It was therefore determined that incorporating climate change into the assessment was out of scope due to the existing information and gaps in the impact of climate change.

Open Pit rim, slope and wall	The open pit is currently undergoing additional remediation and has been backfilled with waste rock and tailings.	The ENDM project team identified this component as having limited climate related impacts during preliminary scoping. No reports or data was available to the project team for review of the ongoing remediation of the open pit. An assessment of the previous conditions was therefore not considered valuable.
Gates, chain link fence	Gates and fencing are present on site and are used to prevent access from hazardous areas of the site.	The ENDM project team identified this component as having limited climate related impacts during preliminary scoping.
Roads and Access Points	There are roads and access points throughout the site that are at risk of damage, particularly in large storm events.	Site access was identified as a low priority by ENDM as there are multiple access points to the site and localized washout/road damage would not prevent access.
Non-Hazardous Waste Material	Some non-hazardous wase materials are present at numerous locations across the site, including within the former open pit.	The ENDM project team identified this component as having limited climate related impacts during preliminary scoping.
Building foundations	Some building foundations and structures are present on site and have not been decommissioned during remediation.	The ENDM project team identified this component as having limited climate related impacts during preliminary scoping.

Table A-2: List of Resources Provided to complete CCRA

Resource	Type	File type	Date	Organization/Author	Notes
Pollutional Characteristics of Kam-Kotia Mines Ltd.	Report	PDF	1976	Ontario Ministry of the Environment, Gibson, C.R. and W. Finch; Gibson, C.R. and W. Finch	The report focuses on the Kamiskotia lake, however, does mention "mining or waste rock drainage that can have chronic or acute toxic effects on plant and animal life". Low levels of heavy metals were found, at or below the detection limits.
The Recreational Water Quality of Kamiskotia Lake	Report	PDF	1976	Ontario Ministry of the Environment	The report notes that the Kam Kotia mine site has impaired the local area, including changes to the aquatic chemistry and a change in water colour. The study shows an increase in metal ion concentrations, exceptionally high levels of dissolved solids, particularly sulphates, and pH depression.
Kam Kotia Tailings Reclamation Project	Report	PDF	1983	Prepared by Ontario Ministry of Environment by Kilborn Limited	The report consists of an executive summary and three technical volumes to present possible reclamation processes.
Surface Hazard Location at the Kam Kotia Mine	Report	PDF	1986	Ministry of Natural Resources; prepared by Kian A. Jensen Exploration and Consulting Services and William E. McRae Geological Services.	The report is based on the surface hazards at the 100 level stopes and raises.
Kam Kotia Mine Rehabilitation Program - Final Design document	Report	PDF	1987	Comrie Consulting Ltd; D.C. Comrie, J.H. Paterson	Comrie Consulting was hired by MNR in 1987 to prepare recommendations and develop the final design for rehabilitation of the Kam Kotia mine site and associated effected areas. The report is very detailed (390 pages including appendices) and discusses site components like the open pit, tailings, waste rock storage, SUT, NUT, NIT. The project objective was to develop a biologically productive, natural, self-sustaining area capable of producing commercial timber and waterfowl habitat.
Technical Memorandum on the Results of the 1987 Kamiskotia Survey (Baseline Impact Assessment)	Report	PDF	1988	Ontario Ministry of the Environment, Northeastern Region	The report provides background data to support reclamation activities.
Kamkotia Consolidation Report	Report	PDF	1991	MNR	The report includes a history of site, studies and rehabilitation up until 1991.
Abandoned Mines Hazards Abatement Program - Kam Kotia Rating	Report	PDF	1993	Unknown, presumed ENDM	The document provides risk scores for numerous components on site, however there is no supporting data or report to discuss the findings.
A Biological Survey of the Kamiskotia and Little Kamiskotia Rivers	Report	PDF	1993	NAR Environmental Consultants Inc., A.B. Bowman; A.B. Bowman	The study included a water quality and benthic survey of the Little Kamiskotia and Kamiskotia Rivers. Provincial water and sediment quality guidelines were exceeded. Metal concentrations at two of four stations exceeded the Severe Effect Level, indicating levels that affect the health of benthic macroinvertebrates. Sediments were heavily contaminated with copper, zinc, and iron.
Crown Pillar Study	Report	PDF	1994	Trow Consulting Engineers Ltd, prepared for MNR.	This study investigated the feasibility of backfilling the crown pillar area.
Stream and Weir Flow Datasets	Data	Excel	1995	N/A	single year (1995) datasets
Terrestrial Effects Studies Near Mine Tailings at Kam Kotia Mines Ltd.	Report	PDF	1995	Ontario Ministry of Environment and Energy, Technical Support Section, D.J Racette and Griffin H.D.; D.J Racette and Griffin H.D.	A study on the tailings in 1994 with three consecutive moss bag exposure surveys, vegetation, soil and tailings sampling and vegetation injury assessment.
Reclamation of Mine Tailings with Recycled Paper Waste and	Report	PDF	1997	MicroTek, Wayne Smith; Wayne Smith	Summary report on the use of paper mill biosolids for reclamation of poor soils by using pulp mill waste (sludge and biosolids) on mine tailings as an organic layer. Three plots were planted to compare the performance of seedlings with primary biosolids, secondary biosolids and no organic cover. The trees that

Tree Seedlings in Northern Ontario.					were planted into tailings without biosolids died due to the harsh soil conditions. Growth was significantly better for plants in secondary biosolids compared to primary. The results demonstrate how organic soil additions can provide a better medium for plant growth.
Kam Kotia Environmental Summary Report	Report	PDF	1997	Klohn-Crippen	A review of surface and groundwater quality data collected between 1992 and 1996 to identify existing environmental impacts and deterioration to the surface or groundwater quality as a result of Falconbridge Exploration and other parties active. The report is detailed with a 103-page summary report and numerous site drawings.
Kam Kotia Rehabilitation Project Phase I	Report	PDF	2000	SENES Consulting Ltd, Lakefield Research Limited, ESG International, Denison Environmental Services	The final report is the detailed description of rehabilitation prepared for the site. The report included a summary of existing site information, site visits and literature review that resulted in a costed rehabilitation plan. The report outlines the phased (A-E) approach taken. Detailed information is available for each site subcomponent and phase.
Identification of Beneficial Mycorrhizal Fungi for the Remediation of the Kam Kotia Mine Site	Report	PDF	2003	Queens University, Department of Biology, Dr. Sharon Regan; Dr. Sharon Regan	Study on Arbuscular Mycorrhizal Fungi (AMF), beneficial microorganisms that can enhance plant growth and, in some cases, participate in the bioremediation of heavy metal contaminated sites. 10 AMF species were identified at the Kam Kotia site from samples collected at the NUT.
The Continuing Rehabilitation of the Kam Kotia Mine Site	Report	PDF	2007	ENDM, Chris Hamblin.	The report is a high-level overview of the phased approach to rehabilitation for the site, including challenges faced during rehabilitation.
The Rehabilitation of Ontario's Kam Kotia Mine: An Abandoned Acid Generating Tailings Site	Presentation	PDF	2008	ENDM, Chris Hamblin.	A presentation prepared by Chris Hamblin that includes site photo, background information a summary of rehabilitation work including phasing, cost, and challenges experienced.
A study to determine the stability and design the most appropriate rehabilitation measures for the Crown Pillars and Open Pit at Kam Kotia Mine Site, Timmins, Ontario	Report	PDF	2011	Golder Associates	Geotechnical report of the near-surface mine workings (stopes and open pit). Remediation options have previously been prepared in 1994 by Trow Ontario Ltd, including backfilling via two drop raises and the crown would then be blasted down. None of the remediation options were implemented. Additional mining hazards were identified in this report, including stopes and adjacent crown pillars, northwest of the 101 stope from the 100 and 200 mining levels, five raises and stope and the interaction between the open pit and the underground workings. A field investigation was conducted in May 2009 to assess changes in crown pillar conditions, followed by modelling and additional stability assessments. Crowns classified as 'very high to high concern for instability' were recommended for remediation. Wall failures were not likely to generate sufficient energy to generate waves to displace sludge and tailings, and it is more likely that higher water levels will be generated in the pit from the spring run-off than from wall instability. Recommendations included constructing fences beyond the maximum practical stand back distance, however fencing is not a permanent solution for rehabilitation and therefore long term monitoring is recommended.
Snow Course Readings	Data	Excel	2012	ENDM	snow depth and water content for various mine sites; not Kamkotia; records beginning in 1950s; extending into 2012; sites include Mattagami, Mountjoy, Shillington, Shining Tree, Porcupine, Imperial,
Kam Kotia Borehole records summary	Data	PDF	2012	ENDMF	
Study for Sludge Handling and Waste Rock Clean up at Kam Kotia Mine Site	Report	PDF	2012	Conestoga-Rovers and Associates , N/A; N/A	This report describes possible improvements to the Sludge Management and waste rock clean up, including options for long-term management of effluent sludge from the Wastewater Treatment Plant, methods for rehabilitation of waste rock piles, and a water treatment optimization analysis. The report found: 1) the WWTP was functioning adequately but not optimally, and modifications including the lime slurry

					makeup and dosing systems could improve lime utilization and better pH control. 2) Sludge from the WWTP is being released into the former Open Pit, which functions as a large sludge settling/storage pond. Recommendations include continue using open pit for dewatering and disposal, sludge settling ponds outside of open pits, mechanical dewatering. 3) Waste rock was identified around the site (south of WWTP, northeast of WWTP, east of open pit and a road berm pile southeast of open pit), the waste rock sampled are considered "ARD Generators". waste rock management options include consolidate and cover and placing the waste rock in the open pit and capping with an engineered cover. The alternative recommended is to construct sludge settling ponds outside the Open Pit to stabilize/solidify sludge. The report further outlines recommendations for additional design activities, like topographic surveys, sludge charactizeration and hydrogeologic investigation.
Site plan with Select Contours	Drawing	PDF (Drawing)	2012	Unknown, presumed ENDM	Site plan with contours created from a LiDAR survey completed in June 2012, after completion of phased rehabilitation (e.g. the NUT has been impounded, WTP in place).
Dam Breach 2012	Photos	Photos	2012	ENDM	A series of photos that show the dam breach in March 2012.
As-Built Summary Report: NUT Impoundment Dam Raise and Spillway Construction	Report	PDF	2015	AMEC Environment & Infrastructure	Construction as the result of the dam failure in March 2012. The report includes a detailed summary of the events that led to the dam being breached. The report also found that the dam was 0.3m-0.4m lower than the design elevation (301 masl) and the volume to be impounded was larger, raising the tailings elevation by 0.5m. The water level within the impoundment will eventually be raised by 0.5m above the tailings surface to 300.75 masl, exceeding the current elevation of the Dam's clay core. **Work completed:** 1) Raise the NUT Impoundment Dam (NUT Dam); 2) Construct a spillway and concrete flow control structure (weir) for the NUT Dam; 3) Construct a spillway at the North Impounded Tailings(NIT) Dam; and,4) Reinstate the former spillway breach area at the NUT Dam. **Recommendations:** 1) Completion of a hydraulic analysis of the NUT Spillway.2) Regular inspections, with specific attention to seepage rate and clarity , downstream toe area of emergency breach repair and spillway breach reinstatement. 3) Implementation of an initial and annually scheduled Dam Safety Inspections (as per regulatory guidelines). 4) Repair and maintenance of any erosion gullies that may develop at hydro-seeded areas 6) Installation of groundwater monitoring wells and slope stability instrumentation (i.e.inclinometers)at strategic locations of the NUT Dam. 6) Installation of telemetry instrumentation to record and transmit water levels at the NUT pond, and, discharge water from the NUT Spillway weir
Detailed Engineering Repair Design for the Acid Water Collection Pond: AWCP Embankment Raise - Technical Specification	Report	PDF	2015	WSP	Technical specifications provided to the contractor outlining the scope of work for the AWCP Embankment Raise.
Detailed Engineering Repair Design for the Acid Water Collection Pond	Drawing	PDF (Drawing)	2015	WSP	10 drawings prepared for the Acid Water Collection Pond. These are not final stamped drawings and include comments from ENDM.
Kam Kotia Erosion Monitoring	Photos	Photos	2016	ENDM	Photos taken in April and May 2016 at various locations across the site, including culverts to the AWCP, the NUT spillway and other components, vegetation loss and water collection. The photos of the vegetative die off are of particular relevance for drought scenarios.

Memorandum (#1-5): Metals Leaching and Kinetic Testing – Open Pit Closure	Report	PDF	2019	GHD	The purpose of the sampling program was to evaluate whether the material proposed to be left in place in the SUT area below the visually observed layer of tailings and above the clay layer could leach metals and is acid generating. HCT-1, -3, and -4 results of the HCT indicate that soil could potentially be acid generating. However, the generally positive trend of pH and negative trend of sulphate production, acidity production, and sulphide percent depletion, indicate the soil is trending away from being potentially acid generating overtime. The recent lime application in Winter 2019 has put the soil within a pH range suitable for plant growth. Due to the possibility that the pH of the soil could decrease over the long term, it would be recommended that plant species have a greater tolerance for lower acidity soil and a wetland environment be implemented if feasible.
Revised SUT Remediation and Closure of Open Pit	Drawing	PDF (Drawing)	2020	GHD	Design drawings details for SUT remediation, including detailed drawings of BGM liner, riprap swale, open pit cover consisting of BGM liner over contaminated soil and waste rock, 600mm of fill, 100mm of topsoil and vegetative cover.
OMA Report on NUT Dam Revegetation	Report	PDF	unspecified (2000s)	OMA-MNDM Mines Rehabilitation Partnership	One-page document showing the results of the dam repair and vegetation on the NUT. This demonstrates the benefit of the vegetation that was added to the NUT dam, with photos.
Miscellaneous Photos	Photos	Photos	Various	ENDM, unknown	Numerous site photos, including aerial footage (2003, 2004, 2012), footage of the SUT, open pit and waste dump, little kamiskotia discharge location, NUT impoundment construction.
Misc. Surface and Groundwater Data and Reporting	Data	Various (PDF, Excel, Word)	Various	Various	Includes: Raw data from 2014, 2015, 2016 metal and mineral test results and toxicity test results pH data from 2016-2017 Surface water quality and flow data 2003-2017 across site; flows at culvert(s), in stream 2003-2008 Surface Water and Groundwater Data 2017 Ni Contamination Report to Kilborn Limited on geotechnical investigation (1983) Hydrogeological investigation (1983-1984) GEOTEM data from mine site (1993) Monitoring Well Installation Report (1996) one report on the conductive plume (1993)

Table A-3: Adapted from Mining Association of Canada Outlining Potential Climate Change Risks in the Mining Sector (2020)

Increasing Temperatures	• Changes in temperature may affect successful growth of flora/vegetation species for closure activities. • Higher temperatures may damage infrastructure remaining on sites after closure. • May increase dust generation and impact dust mitigation activities.
Extreme Heat	• Extreme heat may damage infrastructure remaining on sites after closure. • Extreme heat may result in vegetation die-back. • Extreme heat may impact the effectiveness of closure strategies for mine waste (e.g., performance of cover systems). • May increase dust generation and impact dust mitigation activities.
Drought	• Long-term effectiveness of tailings covers may decrease in areas under water stress. • Increased frequency of drought events may lead to vegetation die-back. • May impact the effectiveness of mine waste management strategies (e.g., need to maintain saturated conditions to prevent acidic drainage), which may in turn impact water management and treatment needs.
Changing Wind	• Potential for long-term infrastructure to be damaged as a result of increased winds. • Increasing winds may lead to erosion of tailings structures and dams.
Changing Precipitation	• Changes in seasonal precipitation may affect rehabilitation of flora/vegetation for closed sites. • Changes in seasonal precipitation will affect hydrology and soil moisture which may impact the ability of waste containment structures to prevent contamination of surrounding land and groundwater. • Increased precipitation and high temperatures may accelerate the weathering of acid-generating waste rock and causing earlier onset and increased volume of acid mine drainage. • Changes to the flow of water through mine sites as a result of changes in precipitation may cause failures with slope stability, potentially damaging tailings and dams.

	• Changes to the flow of water through the site may impact water management including site drainage.
High Intensity Precipitation	• Final water management structures may overflow, and downstream structures may be overwhelmed as a result of extreme rain events. • May result in localized or downstream flooding (see Flooding section). • Intense precipitation events may cause road washouts, limiting access to mine sites and interrupting supplies and services. • Tailings facilities may overflow, and downstream structures may be overwhelmed as a result of extreme rain events. • May have impacts on site drainage. • May cause contamination downstream from waste rock and tailings.
Changes in Snowfall	• Potential for long-term infrastructure to be damaged as a result of increased snow loads. • Changes to the flow of water through mine sites as a result of changes in snowfall may cause failures with slope stability, tailings and dams. • Decreases in snowfall may lead to increased erosion of tailings structures and dams. • Changes in snowfall patterns and increased frequency of winter thaws and “rain-on-snow” events by increase the risk of avalanches and may also increase the risk associated with high flows and excessive run-off during the winter.
Rapid Snowmelt	• Tailing ponds may overflow, and other structures may be overwhelmed as a result of greater intensity freshet. • Final water management structures may overflow, and downstream structures may be overwhelmed as a result of excessive snowmelt (see High Intensity Precipitation Events section).
Glacial Retreat	• May impact water management on site for remaining infrastructure.
Changing Growing Seasons	• The length of growing season may impact the species selection and rehabilitation of flora/vegetation.
Permafrost Degradation	• Potential for long-term infrastructure, particularly tailings facilities and water management infrastructure, to be damaged as a result of permafrost degradation. • May cause failures with slope stability, potentially damaging tailings facilities and dams.

	• May impact the effectiveness of mine waste management strategies (e.g., need to maintain frozen conditions to prevent acidic drainage), which may in turn impact water management and treatment needs.
Sea Level Rise	• May damage infrastructure if close to sea level.
Storm Events	• Potential for long-term infrastructure to be damaged as a result of storm events post closure. • May increase dust generation and impact dust mitigation activities.
Coastal Erosion	• May impact long-term infrastructure if the stability of slopes is compromised.
Flooding	• Final water management structures may overflow, and downstream structures may be overwhelmed as a result of flooding.
Wildfires	• May cause damage to long-term infrastructure post closure. • Wildfires may lead to temporary interruptions of power supply, site access, and other resources which may have implications for water management (e.g., power for pumps and other equipment) and may result in disruptions to maintenance and surveillance activities (e.g., disruption of tailings facility surveillance).
Humidity / Evapotranspiration	• May impact the effectiveness of closure strategies for mine waste (e.g., performance of cover systems). • May impact dust generation and impact dust mitigation activities • May impact revegetation.
Biological Communities	• May cause a shift or loss of available habitat for species, change community composition, shift the assimilative capacity of receiving environment, and drive effluent criteria.

Appendix B

Risk Assessment Detailed Results

- Table B-1: Complete Risk Registry
- Workshop notes

Table B-1: Summarized Risk Registry

Scenario Number	Site component	Simplified Risk Statement	Climate Event	Indicator Thresholds	Current (Baseline)	Future (2050s)	Future (2080s)	Sensitivity Factors	Financial Losses	Environmental Damage	Service Disruption	Human Health & Public Safety	Current Risk (Qualitative)	2050s Risk (Qualitative)	2080s Risk (Qualitative)
1	Northern Unenclosed Tailings (NUT) Impoundment Area - Wet Cover	Dry conditions can result in loss of moisture in the wet cover, resulting in increased oxygenation of tailings and ultimately lead to **degraded water quality** and release of metals into the surrounding environment.	Dry Conditions / Drought	Average water deficit in Summer - Fall (mm)	Unlikely	Possible	Likely	The performance of the wet cover is not meeting design criteria, modeling likely didn't adequately account for hydrology. The wet cover is currently flooded/too wet.	High	Medium	Very Low	Medium	**Class III**	**Class IV**	**Class IV**
2	Northern Unenclosed Tailings (NUT) Impoundment Area - Wet Cover	Dry conditions can result in loss of moisture in the wet cover, resulting in exposure of tailings to **environment** and **wildlife**.	Dry Conditions / Drought	Average water deficit in Summer - Fall	Unlikely	Possible	Likely	The performance of the wet cover is not meeting design criteria, modeling likely didn't adequately account for hydrology. The wet cover is currently flooded/too wet.	High	Medium	Very Low	Medium	**Class III**	**Class IV**	**Class IV**
3	Northern Unenclosed Tailings (NUT) Dam - Vegetation and Rip Rap	Dry conditions can result in degradation of vegetation and rip rap, resulting in erosion and slope destabilization of NUT impoundment dam, increasing the risk of **dam failure/breach** and the release of tailings into surrounding environment.	Dry Conditions / Drought	Average water deficit in Summer - Fall	Unlikely	Possible	Likely	Vegetation on the dam has had numerous issues with erosion already and was highlighted for future work in 2014. Reduced sensitivity of scenario: vegetation and rip rap are not engineered structures and are not critical for dam performance. Limited vegetation species can be used. For example, cannot propose 'drought resistant plants' if they are not suitable for soil acidity and dam requirements, which would take priority.	Low	Very Low	Very Low	Low	**Class I**	**Class II**	**Class III**

Scenario Number	Site component	Simplified Risk Statement	Climate Event	Indicator Thresholds	Current (Baseline)	Future (2050s)	Future (2080s)	Sensitivity Factors	Financial Losses	Environmental Damage	Service Disruption	Human Health & Public Safety	Current Risk (Qualitative)	2050s Risk (Qualitative)	2080s Risk (Qualitative)
4	Northern Unenclosed Tailings (NUT) Impoundment Area - Impoundment structure (spillway)	Rain-on-snow can result in exceeded capacity at NUT, if spillways are blocked/cannot discharge quickly enough, leading to breach(es) of dam, resulting in discharge to surrounding environment and/or river and repair to damaged infrastructure.	Rain-on-snow	Days Min Temp >0C in Winter AND Total Precipitation Winter	Possible	Likely	Almost Certain	The performance of the wet cover is not meeting design criteria, modeling likely didn't adequately account for hydrology. The wet cover is currently flooded/too wet. NUT Dam and spillway were redesigned and reconstructed in 2014 after the breach.	High	Medium	Low	Medium	**Class IV**	**Class IV**	**Class IV**
5	Northern Unenclosed Tailings (NUT) Impoundment Area - Impoundment structure (spillway)	Rain-on-snow can result in exceeded capacity at NUT, if spillways are blocked/cannot discharge quickly enough, leading to overtopping of dam, resulting in discharge to surrounding environment and/or river.	Rain-on-snow	Days Min Temp >0C in Winter AND Total Precipitation Winter	Possible	Likely	Almost Certain	The performance of the wet cover is not meeting design criteria, modeling likely didn't adequately account for hydrology. The wet cover is currently flooded/too wet. NUT Dam and spillway were redesigned and reconstructed in 2014 after the breach.	Medium	Low	Very Low	Very Low	**Class III**	**Class III**	**Class IV**

Scenario Number	Site component	Simplified Risk Statement	Climate Event	Indicator Thresholds	Current (Baseline)	Future (2050s)	Future (2080s)	Sensitivity Factors	Financial Losses	Environmental Damage	Service Disruption	Human Health & Public Safety	Current Risk (Qualitative)	2050s Risk (Qualitative)	2080s Risk (Qualitative)
6	Northern Unenclosed Tailings (NUT) Impoundment Area - Impoundment structure (spillway)	**Extreme precipitation** can result in upstream components **exceeding capacity** and **breach(es)** of dam if spillways are blocked or cannot discharge quickly enough, resulting in discharge to surrounding environment and/or river and repair to damaged infrastructure.	Extreme precipitation	Maximum 1-Day Precipitation Annually AND Days precip >20mm	Likely	Almost Certain	Almost Certain	Lack of information on all of the interconnected components on site. Blockage of spillway could result in multiple breaches. Wet cover not functioning as designed. Dam Safety Inspections required to be completed annually as per regulatory guidelines.	High	Medium	Low	High	**Class IV**	**Class IV**	**Class IV**
7	Northern Unenclosed Tailings (NUT) Impoundment Area - Impoundment structure (spillway)	**Extreme precipitation** can result in upstream components **exceeding capacity** and **overtopping** of dam if spillways are blocked or cannot discharge quickly enough, resulting in discharge to surrounding environment and/or river.	Extreme precipitation	Maximum 1-Day Precipitation Annually AND Days precip >20mm	Likely	Almost Certain	Almost Certain	Lack of information on all of the interconnected components on site. Wet cover not functioning as designed. Dam Safety Inspections required to be completed annually as per regulatory guidelines.	Medium	Low	Very Low	Low	**Class III**	**Class IV**	**Class IV**
8	Northern Unenclosed Tailings (NUT) Impoundment Area - NUT Impoundment Dam	**Storm** (high precipitation and wind) can **overwhelm system** and lead to a **breach** of dam resulting in discharge to river and costly repairs for damaged infrastructure.	Combined events	Maximum 1-Day Precipitation Annually AND Maximum wind gust speed	Possible	Possible	Likely	From design standard: dam was raised in 2014. EXP did the hydrologic work based on 24-hour storm. Timmins storm: is about ~200-year storm. The dam should have been sized with 1:1000 event or PFM event.	High	Medium	Low	Medium	**Class IV**	**Class IV**	**Class IV**

Scenario Number	Site component	Simplified Risk Statement	Climate Event	Indicator Thresholds	Current (Baseline)	Future (2050s)	Future (2080s)	Sensitivity Factors	Financial Losses	Environmental Damage	Service Disruption	Human Health & Public Safety	Current Risk (Qualitative)	2050s Risk (Qualitative)	2080s Risk (Qualitative)
9	Northern Unenclosed Tailings (NUT) Impoundment Area - NUT Impoundment Dam	Storm (high precipitation and wind) can overwhelm system and lead to overtopping of the dam or discharge from spillways, resulting in discharge to surrounding environment and/or river.	Combined events	Maximum 1-Day Precipitation Annually AND Maximum wind gust speed	Possible	Possible	Likely	From design standard: dam was raised in 2014. EXP did the hydrologic work based on 24-hour storm. Timmins storm: is about ~200-year storm. The dam should have been sized with 1:1000 event or PFM event.	Medium	Low	Very Low	Low	**Class III**	**Class III**	**Class III**
10	Northern Impounded Tailings (NIT) Impoundment Area - Vegetation	Dry conditions can result in degradation of vegetation, resulting in erosion and damage to NIT cover and fill material, exposing tailings to surrounding environment.	Dry Conditions / Drought	Average water deficit in Summer - Fall (mm)	Unlikely	Possible	Likely	Vegetation has specific growing conditions. limited to native plants without deep roots that can impact the liner.	Low	Low	Very Low	Low	**Class I**	**Class II**	**Class III**
11	Northern Impounded Tailings (NIT) Impoundment Area - Dry Cover	Freeze-thaw conditions can damage the GCL, resulting in failure of capillary break and exposure of acidic water.	Freeze-thaw cycles	Freeze-Thaw Cycles - Winter Season	Likely	Likely	Likely	GCL requires an additional cover (approximately 1m of clay and sand).	Low	Low	Very Low	Very Low	**Class III**	**Class III**	**Class III**

Scenario Number	Site component	Simplified Risk Statement	Climate Event	Indicator Thresholds	Current (Baseline)	Future (2050s)	Future (2080s)	Sensitivity Factors	Financial Losses	Environmental Damage	Service Disruption	Human Health & Public Safety	Current Risk (Qualitative)	2050s Risk (Qualitative)	2080s Risk (Qualitative)
12	Northern Impounded Tailings (NIT) Impoundment Area - Impoundment structure (spillway)	**Extreme precipitation** can exceed capacity of NIT, **discharging to the NUT and AWCP**, damaging **downstream infrastructure** and/or **releasing contaminants** into the environment.	Extreme precipitation	Maximum 1-Day Precipitation Annually AND Days precip >20mm	Likely	Almost Certain	Almost Certain	Lack of information on all of the interconnected components on site. NIT is designed to drain access water into the AWCP, the AWCP has a spillway.	High	Medium	Very Low	Medium	**Class IV**	**Class IV**	**Class IV**
13	Northern Impounded Tailings (NIT) Impoundment Area - NIT East-West Dam	**Extreme precipitation** can **damage NIT East-West Dam**, including vegetation, rip rap and **downstream infrastructure** and/or releasing contaminants into the environment.	Extreme precipitation	Maximum 1-Day Precipitation Annually AND Days precip >20mm	Likely	Almost Certain	Almost Certain	Lack of information on all of the interconnected components on site.	Medium	Medium	Low	Medium	**Class III**	**Class IV**	**Class IV**
14	Northern Impounded Tailings (NIT) Impoundment Area - Vegetation	**Rain-on-snow** can result in **reduced or no infiltration** by the NIT vegetation, resulting in higher peak flows and runoff to the surrounding area and AWCP, damaging **downstream infrastructure** and/or **releasing contaminants** into the environment (SUT).	Rain-on-snow	Days Min Temp >0C in Winter AND Total Precipitation Winter	Possible	Likely	Almost Certain	Vegetation has specific growing conditions. limited to native plants without deep roots that can impact the liner. Lack of information on all of the interconnected components on site. NIT is designed to drain access water into the AWCP, the AWCP has a spillway.	Low	Very Low	Very Low	Medium	**Class III**	**Class III**	**Class IV**

Scenario Number	Site component	Simplified Risk Statement	Climate Event	Indicator Thresholds	Current (Baseline)	Future (2050s)	Future (2080s)	Sensitivity Factors	Financial Losses	Environmental Damage	Service Disruption	Human Health & Public Safety	Current Risk (Qualitative)	2050s Risk (Qualitative)	2080s Risk (Qualitative)
15	Underground Mine and Open Pit - Open shafts and raise collars	**Shifting hydrology** can increase groundwater fluctuations, resulting in **surface subsidence** for backfilled areas and increase hazards for **access** and **collapse.**	Shifting hydrology / groundwater conditions	Average water surplus in Winter (mm)	Unlikely	Possible	Possible		Low	Low	Medium	Low	**Class II**	**Class III**	**Class III**
16	Underground Mine and Open Pit - Bituminous Geosynthetic Membrane (BGM) over Pit	**Dry conditions** can **erode overlying cover** of open pit, and if exposed the **degradation of the BGM** and exposure of waste rock and debris.	Dry Conditions / Drought	Average water deficit in Summer - Fall (mm)	Unlikely	Possible	Likely	The existing cover requires continuous maintenance. A cover of over 1m would be more effective.	Medium	Low	Very Low	Low	**Class II**	**Class III**	**Class III**
17	Water Treatment Plant - Acid Water Collection Pond and emergency spillway	**Extreme precipitation** can increase **discharge to the AWCP**, if capacity is exceeded, **contaminants released** into the environment in the SUT area.	Short duration, high intensity rainfall	Maximum 1-Day Precipitation Annually	Likely	Almost Certain	Almost Certain	Frequent maintenance and operations required. AWCP embankment and spillways were improved in 2015 construction.	High	Medium	Very Low	Medium	**Class IV**	**Class IV**	**Class IV**
18	Water Treatment Plant - Treatment infrastructure and components	**High winds** can result in power loss, resulting in a **shutdown of pumps** and **release of untreated water** from the treatment plant.	Winds	Days with average windspeed >= 63 km/hr AND Max Wind Gust Speed	Likely	Likely	Likely	Frequent maintenance and operations required. Shorter intended life span (designed to approx. 2050).	Medium	Low	Very Low	Low	**Class III**	**Class III**	**Class III**
19	Water Treatment Plant - Acid Water Collection Pond and emergency spillway	**Storm (high winds + precipitation)** can result in power loss, resulting in a **shutdown of pumps.** If system is over capacity due to increased flow, can **release untreated water** from the treatment plant and the AWCP.	Combined events	Maximum 1-Day Precipitation Annually AND Maximum wind gust speed	Possible	Possible	Likely	AWCP embankment and spillways were improved in 2015 construction. Combination of high winds with excess water (spring freshet, storm etc) means AWCP is more likely to be over capacity and spill. Frequent maintenance and operations required. Shorter intended life span (designed to approx. 2050).	High	Medium	Very Low	Medium	**Class IV**	**Class IV**	**Class IV**

Scenario Number	Site component	Simplified Risk Statement	Climate Event	Indicator Thresholds	Current (Baseline)	Future (2050s)	Future (2080s)	Sensitivity Factors	Financial Losses	Environmental Damage	Service Disruption	Human Health & Public Safety	Current Risk (Qualitative)	2050s Risk (Qualitative)	2080s Risk (Qualitative)
20	Adjacent Lands and Ecosystem - Kamiskotia Lake, Kamiskotia River	**Dry conditions** can reduce flow in the Little Kamiskotia River, resulting in **higher contaminant load** that may require a **new permit** or **discharge location** to not exceed water quality objectives.	Drought conditions	Average water deficit in Summer - Fall (mm)	Unlikely	Possible	Likely	Multiple discharges to the river are not monitored. Not meeting existing water quality targets.	Low	Low	Very Low	Low	**Class I**	**Class II**	**Class III**

Workshop 1 Notes

Project	AP720 Mining
Date and Time:	October 15, 2020 (1:00pm – 4:30pm EDT)
Meeting Type:	Kam Kotia Climate Change Risk Assessment – Workshop #1 – Scoping and Information Gathering
Meeting Location:	Virtual (teams)
Next Meeting:	Virtual Workshop #2 – November 2nd
Meetings Recorded By:	Kirsten MacMillan

ATTENDEES

PRESENT	REGRETS
CRI: • Jackie Richard • Erik Sparling • Glenn Milner • Kirsten MacMillan ENDM: • Juan Gimon • Tom Sulatycky • Julie McFarling • Kim McAlpine	ENDM: • Jennifer Paetz

MINUTES NOTES

DESCRIPTION
Note: meeting notes focus on questions, discussions, and conversation of workshop rather than repeating contents from presentation. Refer to Workshop #1 PowerPoint for additional details.
Part 1: Project Objectives – presentation and discussion • Identify, assess and prioritized management risks and opportunities specific to Kam Kotia
Part 2: Climate science overview – presentation and discussion • Temperature, precipitation has increased and will continue to increase. Extreme weather events are also changing in frequency and intensity. Wildfire also a large focus in Ontario. Climate projections are important to discuss based on different scenarios and understanding risk. • Understanding the full picture of changes will assist with selecting scenarios (i.e., combination of temperature increase with snow coverage, multiple days without freezing…). • Tom: lived in Timmins at the time of dam failure (2012) and has a first-hand account of how quickly the snow melted and all of the subsequent issues that arose. Timmins stopped recording snow data in approximately 2008 so there is data gap, however his team was still record snow cores to try to keep track of information. There was significant snow coverage that winter. Tom

also noted that it was extremely cold again in April, demonstrating the extreme nature of events. In this case, rapid melt but also dealing with temperatures plummeting again afterwards, what are the effects of these variabilities?

- *Note for further discussion*: there may be recent remediation measures, cascading impacts need to be considered with how climate change may affect remediation plans.

Questions and discussion:

- *Vegetation and drought* – will discuss later in workshop

<u>Part 3: Proposed risk assessment approach, focus, scope – presentation and brief working session</u>

- Feasibility of this risk assessment compared to other scales. Kam Kotia is a site level risk assessment, with a more general or average assessment instead of a very in-depth analysis that may include modelling, engineering calculations etc.

<u>Part 4: Kam Kotia site and its climate sensitivities – discussion and working session</u>

- Geographic boundaries, temporal boundaries, Kam Kotia management efforts
- <u>Boundaries</u>
  - Geographic: what areas on site are most important to look at?
  - Themes: infrastructure, water quality, ecological, human health?
  - Temporal boundaries: historical + 2030s, 2050s, 2080s?
    - Need to consider uncertainty in level of planning
    - Infrastructure on site: what is the average design life? How do we plan for these assets in the future to design life or beyond?
- <u>Discussion on Boundaries:</u>
  - ‘Design life’ or ‘service life’ implies there is a decommissioning. Mining dams do not get ‘decommissioned’ in the same way as infrastructure like hydroelectric. **As sites contain waste that is not going away, need to consider it will work in perpetuity**. Treatment plant has a design life, however there are risks of contaminants leaching for centuries. **Generally, water quality needs to forecast hundreds of years into the future.**
    - Using “end of century” scenario has more uncertainty, however benefits to considering the longer life span of assets.
    - Canadian dam association: design criteria is based on factors like inflow design flow, risk of earthquake etc. These are all designed for a minimum of 1:100 storm event, however in some cases are designed for 1:1000 or PMF.
  - Example from previous designs in Northern Canada. The conditions always change, need to decide if the risk assessment needs to be revisited in 20 years and reassessed. In some instances, climate change and other factors are combined (i.e., increasing precipitation but also less output) can make risk assessment more complex. **Closure risk assessment can be projected to a certain number of years, but ultimately needs to be reassessed.**
  - Are there any events we might miss if we only project to 2080s? For example, are we concerned about a rise in freeze thaw in the coming decades and then a decline in 2080s as there are generally warmer temperatures?
    - water quality at the mine is expected to change or get better over time, this might reduce the risk. The risk is high right now because water quality is bad, an

unexpected event will have higher risk now than in several years because water quality has improved.
    - Can document things like water quality improving as part of management strategy and how these shifts over time.
- Important to understand the dam safety review process.
    - This depends on hazard potential and safety inspection. A dam safety review 10 years from now may ask "what was the criteria used to design the components of the dam at that time" (i.e., peak flows, peak floods).
    - Geotechnical perspective will review the dam design; however, it was designed to have a wet cover that was supposed to improve the water quality. At this point, it has not worked. If the inspection is set up based on what was supposed to happen and what actually happened was different, there are challenges in the review process. The design has not met expectations.
    - Would climate change exacerbate if water quality is better or worse? If there is a drier period: water cover is even less than what it is now, this will make water quality issues worse.
    - Mid-century provides more certainty and provides more opportunity to update risk assessment in 10 years and compare how water quality has performed.
- Are there timelines for implementing improvements or upgrades on key components on the site? Do these fall within 50-year time horizon?
    - Water treatment plant is a key component that is due to be demolished soon. In general, we are still dealing with conservative factors of safety. For example, **peak flow rates today may be slightly lower than in ten years, however because there is conservatism built into the process there may not be a need to raise an alarm.**
    - Conditions now on site are changing (open pit is not an open pit any longer, there is an interaction between runoff water from open pit stock pile and the NUT and NIT).
    - Because reclamation, stabilization and other work has already taken place it makes sense to look at shorter term. **It will be harder to immediately revise infrastructure due to smaller changes (i.e., if flow rate increases by 5%, harder to complete redo the flow path). 2080s may be more appropriate for sites where no work has been done and are planning for 100s of years.**
- **Summary:** need to select one-time horizon for ease of the risk assessment scope and budget. Because uncertainty is much greater for 2080s, 2050s provides a 'middle ground' and is beneficial for an iterative process if we revisit these topics in the future. Will also continue to think about this and can revisit in the future. There is also an option to do some additional climate work for 2080s without going through the full risk assessment process, to provide discussion on future things to consider.

<u>Identifying Climate Sensitive Components</u>

General discussion on layout of site components:

- Acid water collection pond: that prevents runoff from leaving the site and treats before discharge.

- Underground mine and Open Pit. Open pit was largely filled with tailings, sludge, contaminated soil, leaching waste rock etc., was replaced in what remained of the open pit. It is now 40m above ground, not an open pit.
- Ditches and drainage: spillways and ditches that water from the upper surface of the tailings dam are a higher priority as this is a stability risk compared to site ditches and drainage that could wash out roads.
- Electrical: Hydro one powerline services the site. There are no generators, no backup generator for the water treatment plant.
- Aggregates: clay pit could be a risk if accessing this area is needed in the future as its currently flooded.
- Bituminous geomembrane: goes on top of consolidated waste in the pit. There is a sand cover and a vegetative cover. It is very resilient, generally need to consider degradation of the material for geomembrane. There is a protective cover. If it is exposed to sunlight it will degrade. Geosynthetic clay liner: if there is less vegetative growth will require less maintenance.

Adjacent Lands and Ecosystems:

- Little Kamiskotia River. When applying for environmental compliance for discharge, look at receiver and ability to handle a specific chemical load.
- Example: drought conditions or low flow conditions could result in the chemical load being much higher and impact downstream ecology substantially. If only permitted for one discharge point, may need to consider discharge to another receiver.
- Possible to look at this with relation to site, will depend on flow level data available, there is a rating curve available. GHD also has updated the rating curve this year. Level data also available. Instead of full-scale flood modelling, can look at the variability and changes over time. At a minimum, can be considered in cascading impacts.

Treatment Plant:

- Needs to be considered, or the sludge management facility or acid water collection pond. The treatment plant has a design rate that it treats at, becomes a storage capacity issue at the acid water collection pond.
- Acid water collection pond has an emergency spillway (helps manage it).
- Two cells (1.5m capacity, 1ha size) operate like an earth and dam perimeter. Gravity drain back into NUT. Potential extreme storm events hitting when it is at capacity will potentially result in loss of infrastructure.

Power:

- The area of Kam Kotia Road loses power frequently due to wind storms. May not be overly important or is out of scope.
- Possibility to use generators for pumps.

Moist Cover:

- Modelling likely didn't account for hydrogeology. The cover has never functioned as it was supposed to.
- Flushing solubles back into water 'post drought'. This response would happen quickly. Look into if this is a multi-day or multi-week drought event.
- Needs water to flush, likely more of a summer drought consequences.

- Example from another site with exposed tailings: from -5 to 5C the upper layer of tailings can create a very dry condition.

Impoundment:
- Wind can lead to overtopping, erosion. Very fast, intense storm can overwhelm the system. Need adequate freeboard.
- Rain-on-snow event is usually not the governing event, generally an intense event that can overwhelm capacity.
- Possible to look at the detailed sections for design specifications here. From design standard: dam was raised in 2014. EXP did the hydrologic work based on 24-hour storm. Tom will look into.

Tailings:
- Timmins storm: is about ~200-year storm. Need to look at these thresholds. The dam should have been sized with 1:1000 event or PFM event.
- Climate unlikely to affect the contained tailings, more likely to be a concern related to the spillway.

General Site Connectivity:
- NIT flows into the NUT so there is a cascading nature. A rapid, rain-on-snow event is of significant because the upstream watershed (NIT) can flood. NIT has a vegetative cover, need to rely on some uptake of water and infiltration there. Peak flows may not be as bad, but with a rapid snow melt there is no infiltration, and everything will run off.

NIT:
- Vegetation can only be grasses, not trees as the trees can break through the liner. The soil needs to be good enough to support native plants.
- Tailings are a subsequent impact of the cover or vegetation.
- 150 ha area and does not have internal drainage. From a surface runoff perspective, the flow paths that water takes is 100s of meters. Likely to result in sheet flow, gullying etc. No internal mechanism to route water off of the cover.
- Vegetation on the SUT is more related to the tailings, the harsh chemistry is a larger impact than climate.

Drainage (general):
- There is no drainage design for the site. Juan has typically worked on a drainage plan to route everything naturally through the site and this needs to be developed for Kam Kotia to manage more effectively. Wants this to be tied up into the CCRA.

Dams:
- Too much water, overtopping, flooding.
- Drought issues on vegetation also an issue.
- There may be some modelling to see what event governs. Generally, for spillways it is a rapid event where you are impounding water and there are capacity issues, and the volume is too high instead of the peak flow.
- Winter: if there is an increase in warmer temperatures and shorter winter seasons you would have less snowpack. Does may mean that rain-on-snow period would not be as significant? When looking at rainfall changes, need to also look at the impacts of other things to find the balancing effect of multiple conditions. Need to discuss this in the report.

- There may be some natural vegetation on the NUT impoundment dam, can look back into the detailed. Is this critical for dam function or capacity?
- Dams: have separated for this exercise to discuss climate change but in the report will talk about how they interact together.

Underground Mine and Open Pit:

- From a mine stability view: the only mechanism at risk is if climate change results in increased groundwater fluctuation. These are stabilized with a sand backfill.
- Degradation due to sunlight to BGM, however will have sand cover and vegetation that will limit impact of sunlight. Only an issue of the overlying cover fails (loss of vegetation and erosion). BGM is generally very resilient.

Kamiskotia:

- Low flow is the concern. Load from the site/treatment plant has a maximum amount that river can receive.
- High flow is less of a concern. There are some backwater effects in the river/lake that could flood but this is unrelated to the mine.
- Is level of dilution dependent on temperature or biological interactions? This is non-mining related, this is consistent across any creek or river in the area. Not sure if temperature dependent. If you had higher temperatures in receive, there is an ammonium issue however this does not apply as it is not really treating site runoff. That is the only one that is temperature dependent.

Access:

- Example: emergency repair. Under current conditions this is not really an issue, access roads are all well maintained and have access to the site. This is a low risk/not a priority. The site has many different access point so one washout would not prevent all access for emergency.

Wildlife

- Wildlife (birds etc) can drink/interact the tailings, impact on water quality. is this something that can be captured for a climate risk?
- Can look at scenarios or themes, like environmental implications and capture the severity (e.g. if water quality deteriorates, the implication for wildlife surrounding the site could be high).
- Could a change in climate encourage certain species to be introduced into the area that could become a problem to infrastructure? E.g. beaver dams can result in infrastructure issues, is it possible that species expansion will impact?

Wrap up

- Survey to confirm scope and risk

Workshop 2 Notes

Project	AP720 Mining
Date and Time:	November 5th, 2020 (2:00pm – 4:30pm EDT)
Meeting Type:	Kam Kotia Climate Change Risk Assessment – Workshop #2 – Characterizing Vulnerabilities
Meeting Location:	Virtual (teams)
Next Meeting:	Virtual Workshop #3 & 4
Meetings Recorded By:	Jackie Richard & Kirsten MacMillan

ATTENDEES

PRESENT	REGRETS
CRI: • Jackie Richard • Erik Sparling • Glenn Milner • Kirsten MacMillan ENDM: • Juan Gimon • Julie McFarling • Kim McAlpine NRCan: • John Sommerville	CRI: • Erik Sparling ENDM: • Tom Sulatycky • Jennifer Paetz

MINUTES NOTES

DESCRIPTION
Note: meeting notes focus on questions, discussions, and conversation of workshop rather than repeating contents from presentation. Refer to Workshop #2 PowerPoint for additional details.
<u>Part 1: Recap on Workshop #1 and Climate Data</u> • Glenn provided a review of what we covered on the last workshop. No questions or comments. • Glenn presented an overview of new climate information since the last workshop. This is draft format and sets the stage of site characterization, however further refinement is needed.
<u>Part 2: Draft Vulnerability Scenarios</u> • What is a vulnerability scenario? **NUT Impoundment Area**: no comments on the scenarios. • Juan can provide the as built of the NUT from after 2012 and more details. • The surface was intended to be saturated and not flooded.

- Plans to do a survey of the bathymetry of the NUT to determine the depth of water and better understand what is needed and how much water they have to deal with.
- Spillways are 100% accessible, they can be accessed by the roadway. They are made out of Rip Rap. They do have a potential for overtopping. Juan can provide additional information on this. Juan is not aware of if the spillway could be blocked by ice but can discuss with others on the project. Blockages are important for understanding ice jams in the spring.

SUT: not presented as a separate scenario, however questions outstanding about what was relocated.

- Part of the SUT area was partially relocated on the open pit design was relocating from the SUT. Need to do more work because of the acidity of the area to make remediation successful.

General question / comment about scenarios: is the risk assessment looking at the ideal scenario or current conditions? We will look at the current conditions but also consider adaptive capacity, like if there is ongoing work to assess or remediate that will reduce the level of risk. This can be captured in part 3 as “Risk Management/Mitigation Measures”.

NIT Impoundment Area:

- NIT has two different paths:
    - Spillway connecting NIT to NUT (north west).
    - Surface water seepage is collected by the Acid water collection pond which was built before the SUT and drains by gravity.
- Closed loop:
    - Juan noted the question in the survey describing a ‘closed loop’. In his previous experience, you would normally see tailings with perimeter ditches that collect overflow/seepage to a polishing pond to be treated. This does not happen in Kam Kotia, the AWCP is not capturing the water from the NUT. There is a new structure in the open pit, and some part of the water is draining into the SUT and the NUT and this hasn’t been captured.
    - We can document this as a possible solution. We want to think about over what time frame and to what extent is that realistic in this risk assessment or in 5 years from now. Want to be accurate on risk.
    - Juan ranks this risk as very high.

Water Treatment:

- Juan was on site last week and there was a loss of power. The lack of generator on site was surprising and is a priority to modify.
- Can provide detail on the Acid Water Collection Pond.
- Baseline conditions indicate that Provincial Water Quality Objectives are not being met (e.g., a deficit)
- Asked if there is a loss of power with a large precipitation event – with systems at or near capacity – is there a tipping point for the plant being out? Juan answered that as there are no back up ponds, extreme events would require pumping out water and there is no contingency plan to manage these events. Water would go into the spillways and be released. The difference between the power being out for an hour versus a day is a similar impact, just more water (no “tipping point”).

Surrounding Areas:

- Asked how long the site could function without discharging to the river.
- Groundwater and surface water around the NUT are the biggest concern for the water quality and are not meeting the current provincial guidelines.
- Glenn described anecdotal evidence from other areas with the water balance graph. The worst potential case in a lack of dilution is in late summer (August more sensitive than June). This impacts aquatic species in central Ontario, may not be applicable to site.
- Juan noted that there is some available data that he can provide. Have the locations and the trends in discharge, groundwater and water levels.

Open Pit & Underground Mine

- The cover of the Open Pit is similar in design to the NIT, but the liner (BGM) is a better quality than the GCL on the NIT.
- The design cover that is there now is not deep enough, so there are limitations to only grasses instead of vegetation with deep roots. Having just the grass instead of deep vegetation has an increased risk of erosion. Juan would typically want to design with 1.5m cover instead of 600mm, so there is more capacity for vegetative cover and reduced the risk of erosion.
- This is a matter of cost (as need to cover almost 45ha with greater depth) but this is an issue that can reoccur, including after precipitation event. This is a perpetual exercise.
- Open pit has a slurry wall that is intercepting some of the contaminants, but that is the issue on top of the area. Managing drainage. Cover is going to last 50 years but may require additional work in the future.
- Bottom of open pit (stockpile) was a collection channel that took water into the NUT from the north side of open pit and discharge into the NUT).
- Report from Golder has identified “no go” zones in the future. Put up fence to avoid access for those areas. There is a long-term stability nature, but this is hard to manage in the short term.
- Water treatment plant is outside of that hazard zone. Water treatment plant was constructed on top of the waste rock, that area is potentially adding some metals that have not been managed to date. Big unknown.
- Aquifer: there is a sand aquitard in the area. Shallower groundwater aquifers tend to be more exposed or have a quicker in response to surficial climate conditions and events, whereas deeper will have a longer lag. There is not enough data right now to understand the contamination and how the groundwater is flowing on the site. This will be identified as a gap for future study/research in the risk assessment report.

Clay and Sand Pits

- Aggregate pits of the Kam Kotia has permits with MNR. These remain active. Access water in those pits needs to be managed and drained. There is a rehabilitation plan there, need to determine if the clay borrow will continue to be used. That is done as per the closing requirements (spillway, drains, revegetation).

Overall questions and discussion: Did we miss anything?

- John – great this much climate information available!

Part 3: Refining Scoring Methods to Inform our Risk Assessment

Comments? We will send this to Jenn to get input/feedback from ENDM folks

- Juan – financial/socio-economic/public health – put a dollar value on that – to make judgement better
    - Yes, if those numbers are available – we can definitely add them but need to know what those numbers are… Glenn will give Juan/Jenn that homework. Dollar values or more specifics based on experience (it will be appended in report so we can explain how we reached the framework).

No other questions or comments on the risk matrix or ranking.

Wrap up

- We are proposing combining workshop #3 and #4 and will send a poll.

Workshop 3 Notes

Project	AP720 Mining
Date and Time:	November 30th, 2020 (1:30pm – 4:00pm EST)
Meeting Type:	Kam Kotia Climate Change Risk Assessment – Workshop #3 – Risk Scoring and Evaluation
Meeting Location:	Virtual (teams)
Next Meeting:	TBD
Meetings Recorded By:	Jackie Richard & Kirsten MacMillan

ATTENDEES

PRESENT	REGRETS
<u>CRI:</u> • Jackie Richard • Glenn Milner • Kirsten MacMillan <u>ENDM:</u> • Juan Gimon • Julie McFarling • Kim McAlpine	<u>CRI:</u> • Erik Sparling <u>ENDM</u>: • Tom Sulatycky • Jennifer Paetz • <u>Envision Strategic Environmental Consulting:</u> • Tony Brown <u>NRCan:</u> • John Sommerville

MINUTES NOTES

DESCRIPTION
Note: meeting notes focus on questions, discussions, and conversation of workshop rather than repeating contents from presentation. Refer to Workshop #3 PowerPoint for additional details.
<u>Part 1: Recap on Work Completed since Workshop #2</u> • Glenn provided a recap of work completed since Workshop #2 o Incorporated additional research and material into risk scenarios, finalized 19 scenarios for risk ranking, refined climate events and indicators, assigned climate event likelihoods for baseline, 2050s, and 2080s o Reminder - Risk Scenario: sequence of events that provide a representation of how climate events may impact site components, and how vulnerabilities, likelihood and consequences interact to estimate risk o Have assigned likelihoods, however reminder that Climate model projections for some climate conditions are more uncertain than others. o Recall we have used the “high emission scenario” RCP8.5. Uncertainty also increases as we march through time.

- Provided a summary of historic and future changes, how climate can influence the likelihood. Seeing a lot of changes to winter season, which has been a focus for some of the scenarios.
- **When estimating likelihood, we assume that the likelihood of the climate event occurring is representative of the scenario – based on project scope and available data for Kam Kotia.**
- Extreme precipitation: days where minimum temperatures are >0C in the winter. Historically, this has only occurred 0.03 times… but this expected to dramatically rise. This is similar to conditions that have caused rapid snowmelt, precipitation in the winter. Likelihood columns are our interpretations.

Comments on likelihoods:

- Juan: normally have a column of 'unwanted events', is this included? Yes, this is what we will be rating.

<u>Part 2: Risk Scoring Approach</u>

- Glenn provided a recap of the risk scoring approach
  - Risk: "The chance of injury or loss as defined as a measure of the likelihood and severity of an adverse effect to health, property, the environment or other things of value"
  - Reminder of NOAMI Risk Matrix approach
- No comments on the approach.

Part 3: Risk Rating and Evaluation Activity

General Comments

- All rankings for **Public Health** assumes that the site remains closed to the public, it is not defined in the future as "walk out closure" condition, it cannot be opened to the public (e.g. ATV trails, accessible site) and the public cannot come in contact with the contaminated water and tailings.
- The definition of 'Very High' **financial consequence** is "unable to accommodate within reserve funds. Permanent loss in socio-economic activity." The assumption (based on previous incidents and knowledge of budgeting) is that as the owner, the government can provide emergency funding in all instances and therefore 'very high' has not been used in the assessment. This could benefit from additional comments and review from ENDM.

<u>Scenario Walk Through</u>

Scenario 1: Dry conditions can result in loss of moisture in the wet cover, resulting in increased oxygenation of tailings and ultimately lead to degraded water quality and release of metals into the surrounding environment.

- **Question**: Change in temperature can cause more evaporation, but there could be more precipitation as well, how are these incorporated? **Answer**: Scenario is based on the water balance, potential moisture in the summer season. This is why we have used the water deficit scenario instead of simply temperature.
- **Comments on Scoring:** Financial high or very high (selected high) due to the consequences of the lost cover and requiring repairs. Environment: would have an impact on aquatic species. Note that we have another scenario that speaks to the wildlife specifically.

Scenario 2: Dry conditions can result in degradation of vegetation & rip rap, resulting in erosion/slope destabilization of NUT impoundment dam, increasing the risk of dam failure/breach and release of tailings into environment.

- **Comments:** Need to consider vegetation and biodiversity on site. Do not have the luxury to introduce any species we want, there are limitations on vegetation already as there can essentially only be grass introduced due to the dam and the existing soil acidity. The natural variability is limited. If we introduced a species that was more drought resistant, this might not be applicable for the dam.
- **Scoring:** lower financial considerations, it was not an engineering design for the purpose. The engineering design and stability is not heavily influenced by the vegetation and rip rap.

Scenario 3: Storm (high precipitation and wind) can overwhelm system and lead to overtopping, erosion or breach of dam resulting in discharge to river and potential repairs for damaged infrastructure.

- **Comments:** This is really two different events here, there is a spillway for emergencies so are only looking at if this is blocked and the dam is subsequently breached. The consequence of breach is higher than overflow from the spillway. There is limited difference between overtopping and discharge from spillway. Have split the scenario in two in excel.
- **Scoring:** Financial – already have evidence of a breach of the dam being a high cost (March 2012 event).

Scenario 4: Extreme precipitation can result in upstream components exceeding capacity and overtopping/breach of dam if spillways are blocked or cannot discharge quickly enough, potential repairs for damaged infrastructure.

- **Comments:** has been split to demonstrate difference between breach of dam and overtopping of dam. If the spillway is blocked, there could be multiple breaches. Financial cost could be very high, but the government should always have the capacity to repair. Looking at the upstream components, the biggest consequences are still going to be downstream but could also have spilling to the AWCP and the SUT. Does not change the consequences.

Scenario 5: High winds can result in power loss, resulting in a shutdown of pumps and release of untreated water from the AWCP to the SUT area and east of the treatment plant.

- **Comments:** will be cautious to include caveats in the report to explain the climate results, even if the models are not showing increases for wind because we do not have data, we can assume that it will get worse over time. This event happened very recently and happens frequently on site. The power risk can be managed by adding a backup generator. The problem is the plant capacity and whether it can keep up with excess water. It’s not just one component of the site, it’s the entire system. Question: is there a certain duration of power loss that matters more? Juan: depends on the system, the water was low in the winter time and there is a greater risk in the spring after the freshet… Lower consequence in winter.
- **Scoring:** Significant, localized loss of property.

Scenario 6: Rain-on-snow can result in reduced or no infiltration by the NIT vegetation, resulting in higher peak flows and runoff to NUT and AWCP, damaging downstream infrastructure and/or releasing contaminants into the environment.

- **Comments:** runoff is designed to flow to the AWCP and the AWCP goes to the spillway.
- **Scoring:** Biggest impacts here are on the environmental components.

Remaining scenarios were ranked directly in Excel and not presented/numbered in PowerPoint

- Dry conditions can result in loss of moisture in the wet cover, resulting in exposure of tailings to environment and wildlife.
  - Same consequences as other dry conditions

- Shifting hydrology can increase groundwater fluctuations, resulting in surface subsidence for backfilled areas and increase hazards for access and collapse.
  - Depends on so many components, infiltration, water balance etc. that are difficult to assess. The level of uncertainty is much higher. Seeing surplus water availability and shifting seasonality.
  - Underground infrastructure is likely to subside but it isn't impacting the property. It is just an access hazard.

- Dry conditions can erode overlying cover of open pit, and if exposed the degradation of the BGM and exposure of waste rock and debris.
  - Dry conditions if the vegetation is not established. Moderate to high impact of having to repair the BGM. Limited physical damage. The liner is protected, so lower consequences.

- AWCP and Treatment Plant
  - If the treatment plant is over capacity, it is going to be discharging. The pumping capacity is inadequate, but there is still an emergency spillway that will prevent some damage. The power outage that occurred last month resulted in some damage to equipment.

- Dry conditions can reduce flow in the Little Kamiskotia River, resulting in higher contaminant load that may require a new permit or discharge location to not exceed water quality objectives.
  - Discharge locations are far enough to minimize this impact. Would need to have a week of uncontrolled discharge. Normally within days this situation can be fixed.

- Dry conditions can result in degradation of vegetation, resulting in erosion and damage to NIT cover and fill material, potentially exposing tailings to surrounding environment.
  - Consequences of the dam slopes are a higher consequence than the NIT Cover.

- Extreme precipitation can damage NIT East-West Dam, including vegetation, rip rap and downstream infrastructure and/or releasing contaminants into the environment.

- NIT East / West Dam: shared with the sludge management facility. Consequences downstream.

Part 4: Adaptation and Capacity to Cope

- Discussion on coping versus adaption
  - Trying to move towards adaptation that is more continuous, proactive, not motivated by crisis or impacts.
  - What are the opportunities to adapt or plan for the impacts and scenarios we've discussed.

High Level Adaptation Actions Identified

- Monitoring Programs
  - Erosion Monitoring: identify risks for vegetation and rip rap and opportunity to repair. Was completed in 2016. There is no set up monitoring program. This is typical for other mines (1 year, 3 year, 10 year monitoring program) for erosion, vegetation, geotechnical, surface water and groundwater. Generally happens with a warranty for ongoing construction. Need to make sure the vegetation is established.
  -
  - Surface water and groundwater: ongoing.
- Vegetation Plan
  - New recommendations for climate change resilient vegetation
- Drainage Plan
  - Opportunity to identify higher risk scenarios and solutions
- Upgrades and Construction
  - "Reactive" – 2014 NUT Dam and Spillway, Diesel Generator
  - "Proactive"– Sludge Management

Need for more redundancy

- There is no Plan B for the site
- From the environmental side, we need to look at water quality. Adaptation: need to consider water quality in the future.

Effective adaptation:

- The only thing in place right now is a more aggressive vegetation plan for the uncovered areas in the SUT and NUT. This may be offering as a buffer to mitigate impacts going into the surface water.
- There are plans: for example overtopping of the NUT, should build ditches from these areas and run water into the AWCP to avoid and further impacts to manage water more effectively.
- Open pit will discharge into the NUT, need to monitor.
- These plans need to happen

Test to switch from Wet Cover to Dry Cover in the NUT

- This is a financial assessment.

Ranking of Existing Adaptation Actions

- Always effective, highly effective, moderately effective, minimally effective, not effective
- Did not identify any current adaptation, but a lot for the future

Adaptation:

- Human resources, financial resources
- A higher degree of people on the site, thinking about the site etc. can be an adaptation measure. Is there a need to bolster the human resources?
- This is not a "one man show", not that short on resources. Consultants provide some effective work as well, particularly when signing off. No issues with having contractors available.
- On the planning side, what is lacking is a more defined closure objective and a final goal. Juan is working on a gap analysis that will be distributed across the Ministry to participate. Can be executed by consultants and contractors in the future.

Wrap up

Questions and Discussion:

- Do you have any general questions around the risk analysis process?
- Are there any clarifications around the consequence or likelihood ratings?
    - The classes have ranges, how can we tell the difference between Class IV 16 points versus Class IV 20 points... There is a predefined logic

Timeline:

1. Populate Risk Scoring for Remaining Scenarios – Dec. 7th
    - Now that we have the risk scoring, we will clean up and circulate tomorrow or Wednesday for review by ENDM.
2. Draft Risk Assessment Report – estimated: Dec. 18th
    - Synthesising information in a report in the next two weeks.
3. ENDM Review - comments due by Jan. 8th
    - No comments on the timelines from Juan.
4. Final Risk Assessment Report – estimated: End of January

Appendix C

Climate Model Parameters Summary

Table C-1: Detailed climate modelling results

Climate Indicator	Condition	Units	Baseline	Projected Condition		Change Relative to Baseline	
			Historical (1981-2010)	2050s (2041-2070)	2080s (2071-2100)	2050s (2041-2070)	2080s (2071-2100)
Air Temperatures							
Mean Temperature	Annual	°C	1.8	5.3	7.7	3.5	5.8
Mean Temperature	Winter	°C	-14.2	-9.9	-7.2	4.3	7.1
Mean Temperature	Spring	°C	1.3	4.5	6.7	3.2	5.3
Mean Temperature	Summer	°C	16.1	19.3	21.6	3.2	5.5
Mean Temperature	Fall	°C	4.0	7.2	9.5	3.2	5.4
Mean Temperature	January	°C	-16.8	-12.3	-9.3	4.5	7.5
Mean Temperature	February	°C	-14	-10.1	-7.2	3.9	6.8
Mean Temperature	March	°C	-7.4	-4	-1.7	3.4	5.7
Mean Temperature	April	°C	1.8	5.1	7.2	3.3	5.4
Mean Temperature	May	°C	9.6	12.5	14.5	2.9	4.9
Mean Temperature	June	°C	14.9	17.9	20	3.0	5.1
Mean Temperature	July	°C	17.5	20.8	23.1	3.3	5.6
Mean Temperature	August	°C	16	19.3	21.8	3.3	5.8
Mean Temperature	September	°C	11.1	14.3	16.7	3.2	5.6
Mean Temperature	October	°C	4.4	7.5	9.6	3.1	5.2
Mean Temperature	November	°C	-3.4	-0.1	2.1	3.3	5.5
Mean Temperature	December	°C	-11.9	-7.4	-5	4.5	6.9
Max Temperature	Annual	°C	7.9	11.2	13.4	3.3	5.6
Max Temperature	Winter	°C	-8.2	-4.7	-2.5	3.5	5.7
Max Temperature	Spring	°C	8.0	11.2	13.3	3.2	5.3
Max Temperature	Summer	°C	22.9	26.1	28.6	3.3	5.7
Max Temperature	Fall	°C	8.9	12.1	14.4	3.2	5.5
Max Temperature	January	°C	-10.6	-7	-4.6	3.6	6.0
Max Temperature	February	°C	-7.2	-4	-1.7	3.2	5.5
Max Temperature	March	°C	-0.6	2.6	4.8	3.2	5.4
Max Temperature	April	°C	8	11.4	13.5	3.4	5.5
Max Temperature	May	°C	16.6	19.5	21.5	2.9	4.9
Max Temperature	June	°C	21.9	24.9	27	3.0	5.1
Max Temperature	July	°C	24.2	27.6	30.1	3.4	5.9
Max Temperature	August	°C	22.5	25.9	28.6	3.4	6.1
Max Temperature	September	°C	17	20.3	22.8	3.3	5.8
Max Temperature	October	°C	9	12.2	14.4	3.2	5.4
Max Temperature	November	°C	0.6	3.7	5.9	3.1	5.3
Max Temperature	December	°C	-6.9	-3.2	-1.2	3.7	5.7

Min Temperature	Annual	°C	-4.3	-0.6	1.9	3.7	6.2
Min Temperature	Winter	°C	-20.2	-15.2	-11.9	5.0	8.4
Min Temperature	Spring	°C	-5.4	-2.0	0.3	3.4	5.7
Min Temperature	Summer	°C	9.3	12.4	14.6	3.1	5.3
Min Temperature	Fall	°C	-0.8	2.4	4.7	3.2	5.5
Min Temperature	January	°C	-23	-17.8	-14.2	5.2	8.8
Min Temperature	February	°C	-20.7	-16.1	-12.5	4.6	8.2
Min Temperature	March	°C	-14.2	-10.3	-7.5	3.9	6.7
Min Temperature	April	°C	-4.5	-1.1	1.1	3.4	5.6
Min Temperature	May	°C	2.5	5.3	7.4	2.8	4.9
Min Temperature	June	°C	7.8	10.7	12.7	2.9	4.9
Min Temperature	July	°C	10.7	13.8	16.1	3.1	5.4
Min Temperature	August	°C	9.4	12.6	14.9	3.2	5.5
Min Temperature	September	°C	5.2	8.2	10.6	3.0	5.4
Min Temperature	October	°C	-0.3	2.7	4.8	3.0	5.1
Min Temperature	November	°C	-7.4	-3.8	-1.4	3.6	6.0
Min Temperature	December	°C	-17	-11.8	-8.9	5.2	8.1
Days Min Temp >0C	Winter	# days	1.95	6.00	11.10	208%	469%
Total Precipitation							
Total Precipitation	Annual	mm	838.6	907.4	936.2	8%	12%
Total Precipitation	Winter	mm	157.2	182.9	198.1	16%	26%
Total Precipitation	Spring	mm	178.1	205.7	220.5	15%	24%
Total Precipitation	Summer	mm	258.5	255.4	248.1	-1%	-4%
Total Precipitation	Fall	mm	244.8	263.4	269.5	8%	10%
Extreme Precipitation							
Maximum 1-day Precipitation	Annual	mm	37.1	40.2	44.0	8%	18%
Maximum 1-day Rainfall	Annual	mm	37.1	-	-	-	-
Maximum 1-day Snowfall	Annual	mm	19.1	-	-	-	-
Max 3-Day Precipitation	Annual	mm	49.4	-	-	-	-
Max 5-Day Precipitation	Annual	mm	58.1	-	-	-	-
Max 7-Day Precipitation	Annual	mm	64.3	-	-	-	-
Days Precipitation >20mm	Annual	# days	6.3	7.4	7.9	17%	25%
Dry Conditions / Drought							
Number of Dry Days	Annual	# days	179.8	179.8	179.8	0%	0%
Number of Dry Days	Winter	# days	37.5	37.5	37.5	0%	0%
Number of Dry Days	Spring	# days	54.8	54.8	54.8	0%	0%
Number of Dry Days	Summer	# days	48.2	48.2	48.2	0%	0%
Number of Dry Days	Fall	# days	39.3	39.3	39.3	0%	0%

Average water surplus	Annual	mm	435.3	412.5	410.4	-5%	-6%
Average water surplus	Winter	mm	23.5	72.5	112.1	209%	377%
Average water surplus	Spring	mm	106.2	81.2	73.0	-24%	-31%
Average water surplus	Summer	mm	4.4	2.5	1.6	-44%	-64%
Average water surplus	Fall	mm	26.7	29.7	24.8	11%	-7%
Average water surplus	January	mm	6.4	18.1	31.5	183%	392%
Average water surplus	February	mm	2.4	14.9	25.2	521%	950%
Average water surplus	March	mm	25.6	56	87.2	119%	241%
Average water surplus	April	mm	205.6	175.8	121.5	-14%	-41%
Average water surplus	May	mm	87.5	11.8	10.4	-87%	-88%
Average water surplus	June	mm	6.8	6.1	4.1	-10%	-40%
Average water surplus	July	mm	3.5	1.3	0.6	-63%	-83%
Average water surplus	August	mm	2.8	0	0	-100%	-100%
Average water surplus	September	mm	7.5	2.7	0	-64%	-100%
Average water surplus	October	mm	19.5	23.5	15	21%	-23%
Average water surplus	November	mm	53	62.8	59.5	18%	12%
Average water surplus	December	mm	14.7	39.5	55.4	169%	277%
Average water deficit	Annual	mm	39.2	73.6	109.2	88%	179%
Average water deficit	Winter	mm	0.0	0.0	0.0	0%	0%
Average water deficit	Spring	mm	0.5	0.8	1.1	44%	100%
Average water deficit	Summer - Fall	mm	6.3	11.9	17.7	90%	182%
Average water deficit	Summer	mm	12.2	22.6	32.8	86%	170%
Average water deficit	Fall	mm	0.4	1.2	2.5	218%	591%
Average water deficit	January	mm	0	0	0	0%	0%
Average water deficit	February	mm	0	0	0	0%	0%
Average water deficit	March	mm	0	0	0	0%	0%
Average water deficit	April	mm	0	0	0.1	0%	0%
Average water deficit	May	mm	1.6	2.3	3.1	44%	94%
Average water deficit	June	mm	7.8	13.2	18.7	69%	140%
Average water deficit	July	mm	15.4	26.2	38.5	70%	150%
Average water deficit	August	mm	13.3	28.4	41.2	114%	210%
Average water deficit	September	mm	0.9	3.5	7.6	289%	744%
Average water deficit	October	mm	0.2	0	0	-100%	-100%
Average water deficit	November	mm	0	0	0	0%	0%
Average water deficit	December	mm	0	0	0	0%	0%
Freeze-Thaw Conditions							
Freeze-Thaw Cycles	Annual	days	88.5	74.5	66.7	-16%	-25%
Freeze-Thaw Cycles	Winter	days	10.2	20.4	25.3	100%	148%
Freeze-Thaw Cycles	Spring	days	14.8	11.5	9.3	-22%	-37%

Freeze-Thaw Cycles	Summer	days	0.5	0.0	0.0	-93%	-100%
Freeze-Thaw Cycles	Fall	days	10.8	6.5	4.5	-40%	-58%
Freeze-Thaw Cycles	January	days	2.2	5.5	7.0	150%	218%
Freeze-Thaw Cycles	February	days	3.5	6.5	8.9	86%	154%
Freeze-Thaw Cycles	March	days	13.0	15.7	16.0	21%	23%
Freeze-Thaw Cycles	April	days	20.5	15.2	10.8	-26%	-47%
Freeze-Thaw Cycles	May	days	10.8	3.6	1.1	-67%	-90%
Freeze-Thaw Cycles	June	days	1.3	0.1	0.0	-92%	-100%
Freeze-Thaw Cycles	July	days	0.0	0.0	0.0	0%	0%
Freeze-Thaw Cycles	August	days	0.2	0.0	0.0	-100%	-100%
Freeze-Thaw Cycles	September	days	4.7	0.5	0.1	-89%	-98%
Freeze-Thaw Cycles	October	days	15.5	7.3	3.3	-53%	-79%
Freeze-Thaw Cycles	November	days	12.3	11.7	10.1	-5%	-18%
Freeze-Thaw Cycles	December	days	4.5	8.4	9.4	87%	109%
Winds							
Average windspeed	Annual	km/hr	11.8	-	-	-	-
Average windspeed	Winter	km/hr	12.1	-	-	-	-
Average windspeed	Spring	km/hr	12.9	-	-	-	-
Average windspeed	Summer	km/hr	11.2	-	-	-	-
Average windspeed	Fall	km/hr	11.8	-	-	-	-
Maximum wind gust speed	Annual	km/hr	158	-	-	-	-
Maximum wind gust speed	Winter	km/hr	105	-	-	-	-
Maximum wind gust speed	Spring	km/hr	108	-	-	-	-
Maximum wind gust speed	Summer	km/hr	158	-	-	-	-
Maximum wind gust speed	Fall	km/hr	105	-	-	-	-
Days with average windspeed >= 52 km/hr	Annual	days	2.3	-	-	-	-
Days with average windspeed >= 63 km/hr	Annual	days	0.3	-	-	-	-