NexGen Energy Ltd.

Rook I Project

Environmental Impact Statement

TSD VIII: Accidents and Malfunctions

wsp

ACCIDENTS AND MALFUNCTIONS FOR THE ROOK I PROJECT - TECHNICAL SUPPORT DOCUMENT

REPORT PREPARED FOR:

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ACCIDENTS AND MALFUNCTIONS FOR THE ROOK I PROJECT - TECHNICAL SUPPORT DOCUMENT

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EXECUTIVE SUMMARY

Ecometrix Incorporated (Ecometrix) was retained by NexGen Energy Ltd. (NexGen) to complete the accidents and malfunctions assessment for the NexGen Rook I Project (Project), a proposed uranium mining and milling operation in northwestern Saskatchewan. For reference, the assessment of accidents and malfunctions is intended to provide a clear identification of the potential Project-associated hazards that fall outside the range of “typical” day-to-day events.

This technical support document (TSD) provides the details of that assessment, which is included in the Environmental Impact Statement (EIS) Section 21, Accidents and Malfunctions.

Proposed Project

The Project is a proposed new uranium mining and milling operation that is 100% owned by NexGen. The Project would be located in northwestern Saskatchewan, approximately 40 km east of the Saskatchewan-Alberta border, 130 km north of the town of La Loche, and 640 km northwest of the city of Saskatoon. The Project would reside within Treaty 8 territory and within the Métis Homeland. At a regional scale, the Project would be situated within the southern Athabasca Basin adjacent to Patterson Lake and along the upper Clearwater River system. Access to the Project would be from an existing road off Highway 955.

Scope and Objective

The scope of this assessment includes all potential Project-related accidents and malfunctions that may occur during any phase of the Project and transportation-related accidents along the Project access road to Highway 955.

The objective of this assessment was to evaluate the potential effects on the human health and biophysical environment resulting from radiological and conventional accidents and malfunctions with consideration of proposed preventive and mitigative measures.

Assessment Methods

This assessment provides a framework for quantifying the risks associated with these hazards. The five basic steps in the process of risk assessment for the accidents and malfunctions assessment were as follows:

1. **Hazard identification**: the identification of physical situations with the potential for harming human health or the biophysical environment. Hazard scenarios were identified using a systematic approach with consideration of the existence of sources of hazards and initiating events for each project component and activity. Scenarios were identified for several potential events, such as releases of chemical and radiological constituents, fires, and explosions.

2. **Bounding scenarios**: the identified hazard scenarios were then screened qualitatively for the perceived effects and probability of occurrence as well as the potential risk using a risk matrix approach. Project information, experience from similar projects, particularly those located in Northern Saskatchewan, and professional judgment were used for this initial screening. Among the high or moderate-risk scenarios, bounding scenarios were selected. The bounding scenarios encompass the effects of other scenarios screened for each Project component and activity. The subsequent analysis focussed on these bounding scenarios.

3. **Probability analysis**: the estimation of the probability of occurrence of the selected bounding scenario occurring within a specific time period, or in specified circumstances.

4. **Effects analysis**: quantitative evaluation of the potential effects of a selected bounding scenario to the human health or biophysical environment.

5. **Risk estimation and ranking**: the estimation of the effect of a scenario and the probability with which it is likely to occur; that is, risk is the product of effect and probability (risk = consequence × probability of occurrence).

Hazard Identification and Screening

A total of 93 hazard scenarios were identified and screened. From these, six bounding scenarios were identified for further, quantitative analysis. These included three scenarios deemed to be high risk and three scenarios deemed to be moderate risk, based on the initial risk screening process. The six hazard scenarios that were selected as bounding scenarios for more detailed risk analysis are presented in Table ES-1.

Table ES-1: Bounding Scenarios Identified for Further Assessment by the Hazard Identification Process

No.	Accident or Malfunction Scenario	Location	Effect Pathway	Interactions with the Environment
1	Traffic accident (uranium concentrate)	Access road at bridge crossing	Aquatic release of uranium concentrate	Affects the water quality, sediment quality, terrestrial and aquatic biota, and members of the public
2	Traffic accident (chemical)	Access road at bridge crossing	Aquatic release of fuel, hazardous chemicals	Affects the water quality, sediment quality, terrestrial and aquatic biota, and members of the public
3	Solvent extraction fire or explosion	Solvent extraction building	Atmospheric release of uranium concentrate (chemical toxicity)	Affects the air quality, and members of the public
4	Tailings transfer pipe or pump failure	Tailings release to surface within secondary containment	Terrestrial release of radioactivity	Affects the soil and potentially groundwater, and terrestrial biota
5	Untreated effluent transfer pipe failure	Effluent treatment system	Terrestrial release of radioactivity	Affects the soil, groundwater, and terrestrial biota
6	Acid plant tail gas scrubber failure	Acid plant	Atmospheric release of sulphur dioxide	Affects air quality, and members of the public

Assessment of the Overall Risk Associated with the Bounding Scenarios

Detailed quantitative assessment of the six bounding scenarios was completed to reconsider the risks to the biophysical environment. The analysis considered both probability and potential effects to determine the overall level of risk. The results of the assessment are summarized below.

The detailed assessment (Table ES-2) found that the risks of the selected bounding scenarios are low to moderate, and they represent a tolerable level of risk in consideration of proposed safeguards and design features that reduce the risk level to as low as reasonably practical (ALARP).

Table ES-2: Summary of Assessment Results for Bounding Scenarios

No.	Accident or Malfunction Scenario	Location	Probability	Estimated Effects Consequence	Overall Risk Rating
1	Traffic accident (uranium concentrate)	Access road at bridge crossing	Highly unlikely	Moderate	Low risk
2	Traffic accident (chemical)	Access road at bridge crossing	Highly unlikely	Moderate	Low risk
3	Solvent extraction fire or explosion	Solvent extraction building	Unlikely	Minor to Moderate	Low risk
4	Tailings transfer pipe or pump failure	Tailings release to surface within secondary containment	Likely	Minor	Low risk
5	Untreated effluent transfer pipe failure	Effluent treatment system	Likely	Minor	Low risk
6	Acid plant tail gas scrubber failure	Acid plant	Likely	Minor to Moderate	Low to moderate risk

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Abbreviations

Acronym	Definition
AEGL	Acute Exposure Guideline Level
ALARP	as low as reasonably practicable
ALOHA	areal locations of hazardous atmospheres
ARF	airborne release fraction
ATSDR	Agency for Toxic Substances and Disease Registry
CNSC	Canadian Nuclear Safety Commission
DR	damage ratio
EIS	Environmental Impact Statement
ERPG	Emergency Response Planning Guideline
ETP	effluent treatment plant
HDPE	high density polyethylene
LPF	leak path factor
MAR	material at risk
NexGen	NexGen Energy Ltd.
NPAG WRSA	non-potentially acid generating waste rock storage area
PAG WRSA	potentially acid generating waste rock storage area
pH	potential of hydrogen
Project	Rook I Project
RBE	relative biological effectiveness
RF	respirable fraction
TSD	technical support document
U_3O_8	triuranium octoxide
UGTMF	underground tailings management facility
USDOE	United States Department of Energy
W1	worst-case weather conditions
W2	typical weather conditions

Units of Measure

Units	Definition
%	percent
µg/L	micrograms per litre
µL/L	microlitres per litre
µm	micron
Bq/g	becquerels per gram
Bq/L	becquerels per litre
cm	centimetre
cm/s	centimetres per second
g/cm^3	grams per cubic centimetre
g/m^3	grams per cubic metre
g/s	grams per second
gal	imperial gallon
GBq	giga-becquerels
GBq/h	giga-becquerels per hour
kg	kilogram
kg/d	kilograms per tonne
kg/m^3	kilograms per cubic metre
kg/t	kilograms per tonne
h	hour
km	kilometre
km^2	square kilometres
km/h	kilometres per hour
L	litre
$L/m^2/s$	litres per square metre per second
L/s	litres per second
m	metre
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/d	cubic metres per day
m^3/h	cubic metres per hour
m^3/s	cubic metres per second
m^3/yr	cubic metres per year
masl	metres above sea level
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre

Units	Definition
mGy/d	milligrays per day
MBq	mega-becquerels
MBq/h	mega-becquerels per hour
min	minute
mm	millimetre
mm/°C/d	millimetres per degrees Celsius day
mm/yr	millimetres per year
mph	miles per hour
ppm	parts per million
t	tonne
t/d	tonnes per day
t/h	tonnes per hour

1.0 INTRODUCTION

Ecometrix Incorporated (Ecometrix) was retained by NexGen Energy Ltd. (NexGen) to complete the accidents and malfunctions assessment for the NexGen Rook I Project (Project), a proposed uranium mining and milling operation in northwestern Saskatchewan. This technical support document (TSD) provides the details of that assessment, which is included in the EIS Section 21, Accidents and Malfunctions.

1.1 Overall Scope and Objective of the Assessment

The scope of this assessment includes all potential Project-related accidents and malfunctions that may occur during any phase of the Project and transportation-related accidents along the Project access road to Highway 955. The assessment of accidents and malfunctions is intended to provide a clear identification of the potential Project-associated hazards that fall outside the range of "typical" day-to-day events.

The objective of this assessment was to evaluate the potential effects on the human health and biophysical environment resulting from radiological and conventional accidents and malfunctions with consideration of proposed preventive and mitigative measures.

The effects on the occupational health and safety are not within the scope of this assessment. Consistent with CSA N288.6-22 (CSA Group 2022), nuclear energy workers would be classified and monitored in accordance with the requirements of NexGen's Radiation Protection Program and therefore did not require assessment. Non-nuclear energy workers at the Project site would be subject to occupational exposure and workplace monitoring outlined in NexGen's Health and Safety Program; therefore, these workers were also excluded.

1.2 Background Information

The Project is a proposed new uranium mining and milling operation that is 100% owned by NexGen. The Project would be located in northwestern Saskatchewan, approximately 40 km east of the Saskatchewan-Alberta border, 130 km north of the town of La Loche, and 640 km northwest of the city of Saskatoon. The Project would reside within Treaty 8 territory and within the Métis Homeland. At a regional scale, the Project would be situated within the southern Athabasca Basin adjacent to Patterson Lake and along the upper Clearwater River system. Access to the Project would be from an existing road off Highway 955.

Further Project-related information is provided in Section 2.0, Project Information.

1.3 Regulatory Context

For the purpose of this assessment, accidents and malfunctions refer to events or conditions that are not part of any activity or normal operation of the Project (i.e., typical day-to-day events) as proposed by NexGen. Despite rigorous planning and the implementation of best practices and preventative measures, the potential exists for accidents and malfunctions to occur during any

Project phase. If such unplanned events or conditions occur, adverse environmental effects could result if not addressed or responded to in an appropriate manner.

Federal guidance for the assessment of accidents and malfunctions is provided in Canadian Nuclear Safety Commission (CNSC) REGDOC-2.9.1: Environmental Protection: Environmental Principles, Assessments and Protection Measures (CNSC 2020). Specific considerations regarding the scope of such assessments are described in REGDOC-2.9.1, which indicates that the EIS should provide an assessment of potential health and environmental effects resulting from postulated radiological and conventional malfunctions and/or accidents. The EIS should also include any mitigation measures such as monitoring, contingency, clean up, or restoration work in the surrounding environment that would be required during or immediately following the postulated malfunction and accident scenarios (CNSC 2020).

Section 5.4 of the Transportation of Dangerous Goods Regulations (Government of Canada 2021) sets out the requirements for the loading and securing of dangerous goods to prevent damage to the container or to the means of transport that could lead to an accidental release. Section 8 of the Transportation of Dangerous Goods Regulations is relevant to accidental release and accidental release reporting requirements.

The provincial (i.e., Saskatchewan) mandate is less prescriptive than that provided within CNSC REGDOC-2.9.1. Both the technical proposal guidelines (Government of Saskatchewan 2014a) and the guidelines for the preparation of the terms of reference (Government of Saskatchewan 2014b) that have been prepared by the Environmental Assessment Branch of the Ministry of Environment under *The Environmental Assessment Act* (Government of Saskatchewan 1980) make reference to addressing effects associated with accidents and malfunctions that may occur during all Project phases within the EIS submission.

1.4 Report Format

Following this introductory subsection, the remainder of this TSD is organized follows:

- Section 2.0: provides Project-related information.
- Section 3.0: describes the methods for the accidents and malfunctions assessment.
- Section 4.0: presents general considerations and context for the accident and malfunctions assessment.
- Section 5.0: presents the environmental quality guidelines and toxicity benchmarks for the released contaminants.
- Section 6.0 through Section 11.0: present for each of the accident and malfunction bounding scenarios that have been identified: a description and characterization of the scenario, an assessment of probability of the scenario, and the potential effects associated with the scenario.
- Section 12.0: combines the results of probabilities and potential effects and presents the assessment of the risk of the bounding scenarios.

- Section 13.0: provides a list of references cited in this report.

The detailed hazard identification assessment completed in support of this assessment is provided Appendix A, Hazard Identification for the Accidents and Malfunctions Assessment.

2.0 PROJECT INFORMATION

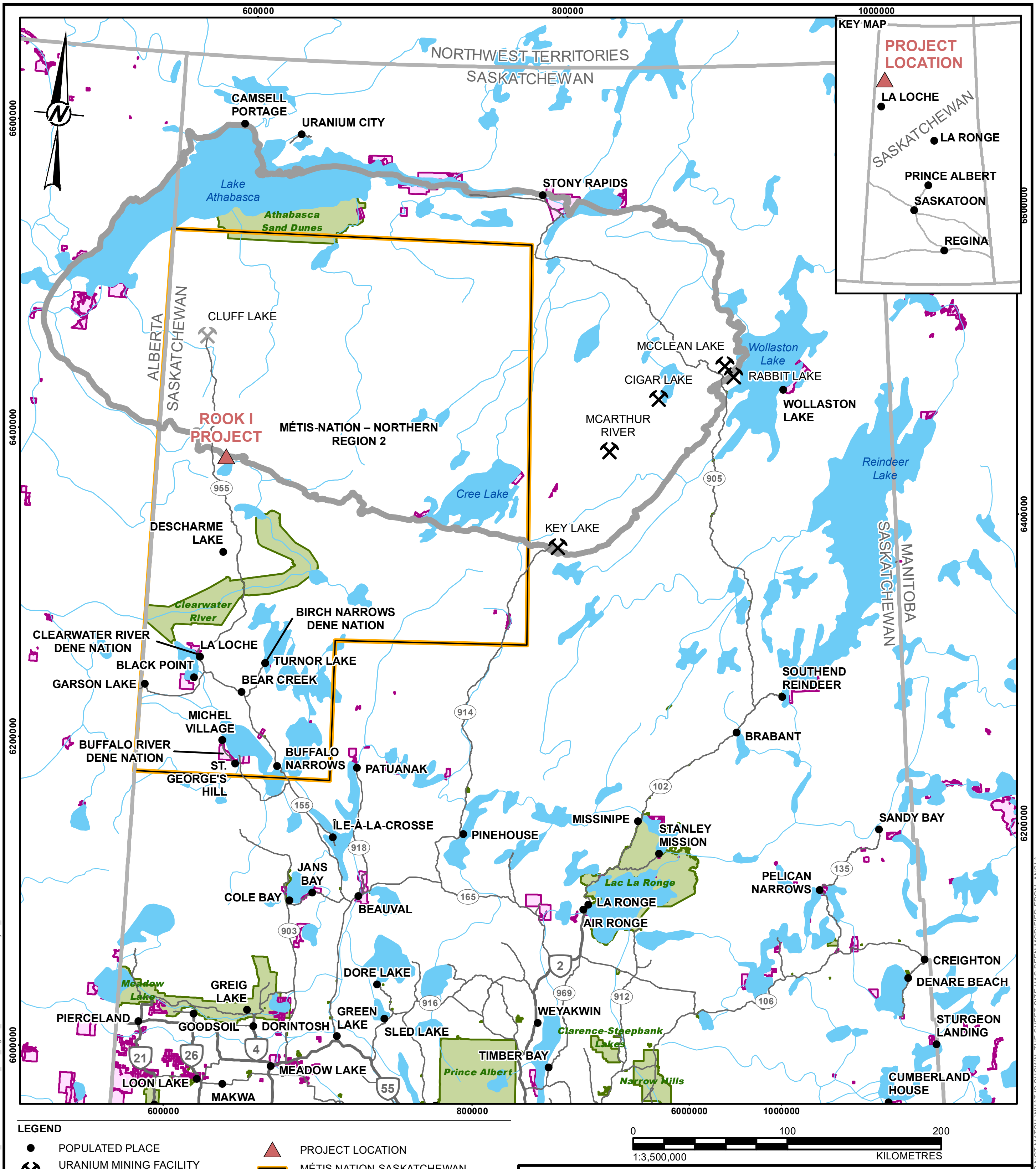
2.1 Project Location

The Project would be located approximately 40 km east of the Saskatchewan-Alberta border, 130 km north of the town of La Loche, and 640 km northwest of the city of Saskatoon (Figure 2-1). The Project would reside within Treaty 8 territory and the Métis Homeland. At a regional scale, the Project would be situated within the southern Athabasca Basin adjacent to Patterson Lake, along the upper Clearwater River system. Patterson Lake is at the interface of the Boreal Shield and Boreal Plain ecozones. Access to the Project would be from an existing road off Highway 955 (Figure 2-2), with on-site worker accommodation serviced by fly-in/fly-out access.

The Project would include the following key facilities to support the extraction and processing of uranium from the Arrow deposit for transportation off site (Figure 2-3):

- underground mine development;
- process plant buildings, including uranium concentrate packaging facilities;
- paste tailings distribution system;
- underground tailings management facility (UGTMF);
- potentially acid generating waste rock storage area (PAG WRSA);
- non-potentially acid generating waste rock storage area (NPAG WRSA);
- special waste rock[1] and ore storage stockpiles;
- surface and underground water management infrastructure, including water management ponds, effluent treatment plant (ETP), and sewage treatment plant;
- conventional waste management facilities and fuel storage facilities;
- ancillary infrastructure, including maintenance shop, warehouse, administration building, and camp;
- airstrip and associated infrastructure; and
- access road to Project and site roads.

[1] Special waste rock is mine rock that is mineralized with insufficient grade to be considered ore (i.e., greater than 0.03% of triuranium octoxide [U_3O_8] and less than 0.26% U_3O_8). All special waste would be temporarily stored in the special waste rock stockpile.



LEGEND

- POPULATED PLACE
- URANIUM MINING FACILITY (ACTIVE)
- URANIUM MINING FACILITY (DECOMMISSIONED)
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN BOUNDARY
- INDIAN RESERVE
- PROVINCIAL PARKS
- WATERBODY
- PROJECT LOCATION
- MÉTIS NATION-SASKATCHEWAN NORTHERN REGION 2

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. PARKS OBTAINED FROM IHS MARKIT CANADA ULC.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

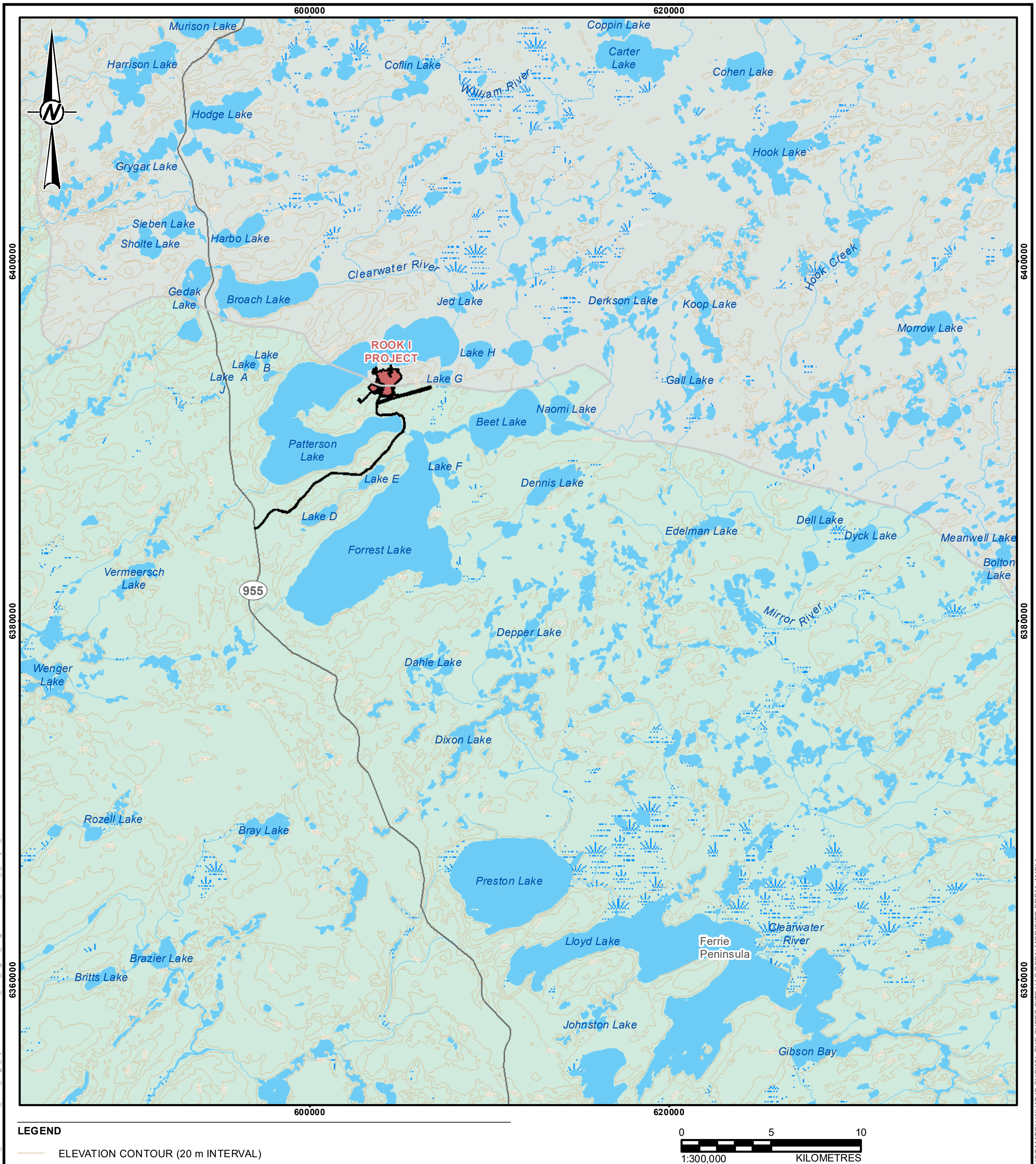
TITLE

LOCATION OF THE ROOK I PROJECT

CONSULTANT

[redacted]

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JMC	2022-02-28	SCALE AS SHOWN	REV. 0
GIS	NO	2022-02-28	**FIGURE 2-1**	
CHECK	JMC	2022-02-28		
REVIEW	MM	2022-02-28		



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021.
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

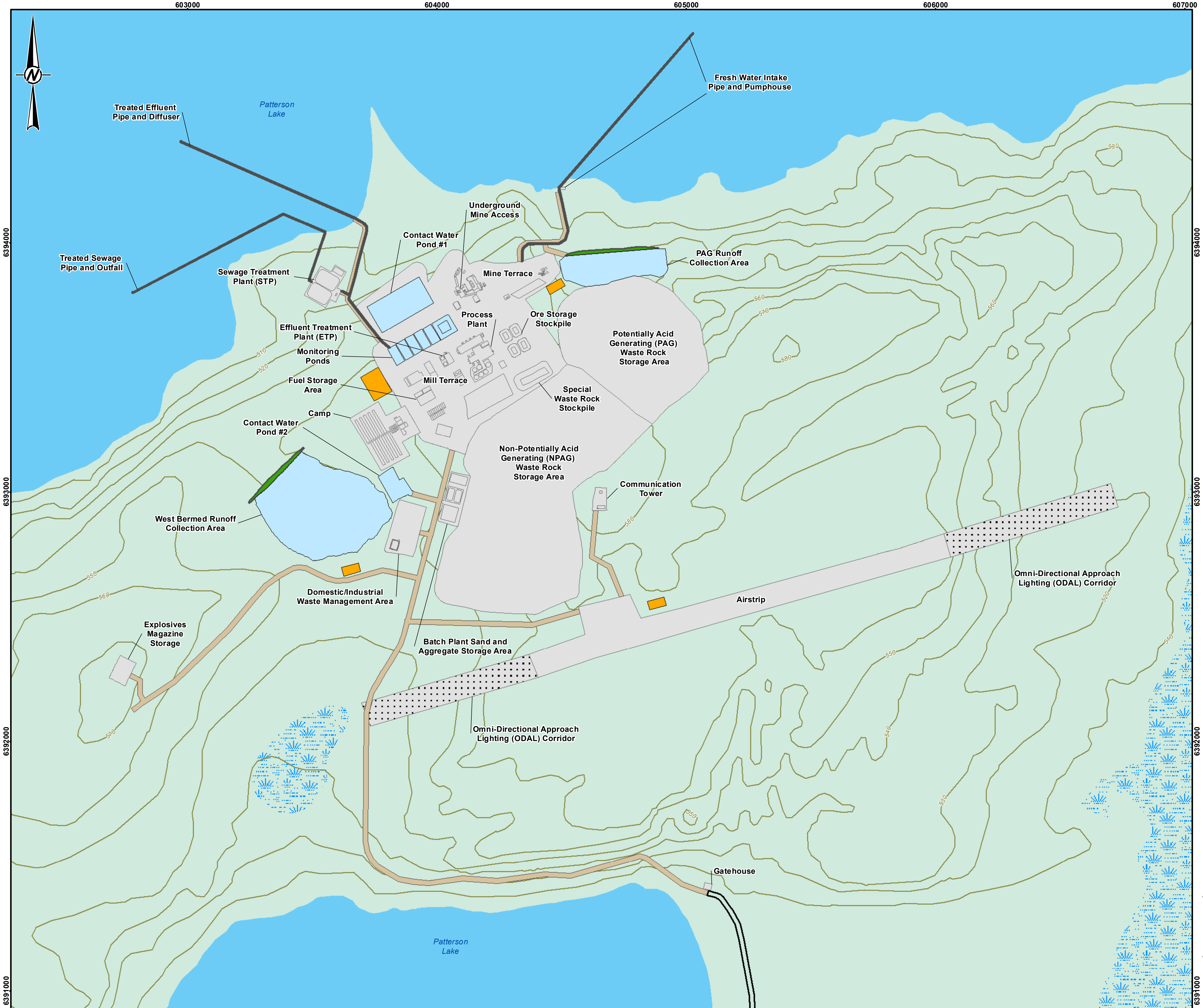
TITLE

REGIONAL AREA OF THE ROOK I PROJECT

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JMC	2023-10-25	SCALE AS SHOWN	REV. 0
GIS	NO	2023-10-25	**FIGURE 2-2**	
CHECK	JMC	2023-10-25		
REVIEW	MM	2023-10-25		



LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- WATERBODY
- WETLAND
- WOODED AREA
- INTAKE OR DISCHARGE PIPE
- ACCESS ROAD
- CONTACT WATER CONTAINMENT BERM
- OMNI-DIRECTIONAL APPROACH LIGHTING (ODAL) CORRIDOR
- PROJECT INFRASTRUCTURE
- SITE ROAD
- TOPSOIL STORAGE AREA
- WATER MANAGEMENT POND

0 0.5 1

1:15,500 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021 AND UPDATED JUNE 8, 2021 .
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

LAYOUT OF INFRASTRUCTURE AND FACILITIES FOR THE ROOK I PROJECT

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JV	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-10-25		
CHECK	JMC	2023-10-25	**FIGURE 2-3**	
REVIEW	MM	2023-10-25		

2.2 Project Details and Components

The Project would include the Construction, Operations, Decommissioning and Reclamation (i.e., Closure) of a uranium mine and process plant buildings, including associated infrastructure to support the extraction and processing of uranium ore. Key Project details are summarized in Table 2-1.

Table 2-1: Key Rook I Project Details

Terms	Details
Scope of the Project	• NexGen is proposing a new uranium mining and milling operation located adjacent to Patterson Lake in the southwestern Athabasca Basin in northern Saskatchewan • The proposed Project would include underground and surface facilities to support the mining and milling of uranium ore from the Arrow deposit • The Project would include an underground mine, a process plant, and additional infrastructure including a camp for personnel, an airstrip, an ETP, and supporting waste and water management facilities
Rook I Project	• The proposed Rook I Project is a new uranium mining and milling operation located on the Patterson Lake peninsula in the southwestern Athabasca Basin in northern Saskatchewan • The Rook I Project is 100% owned and managed by NexGen • The mineral resource basis for the proposed Project is the Arrow deposit, a land-based, 100% basement-hosted, high-grade uranium deposit
Arrow deposit	• A land-based, basement-hosted, high-grade uranium deposit that is 100% owned by NexGen
Underground mine development	• The Project would use long hole stoping mining methods to extract the ore, including primarily transverse stope mining and longitudinal retreat stope mining • The underground mine development would include a number of key activities, including shaft sinking, lateral development, vertical development, installation of mine services, and development of the UGTMF
Uranium concentrate	• The Project term for triuranium octoxide (U_3O_8) once the material has been processed and is ready for shipment
Process plant	• Process plant throughput is designed for 1,300 tonnes of ore per day • Total net uranium recovery from the milling process is estimated to be 97.6% based on the results of the metallurgical test programs completed in 2018 and 2019 • The process plant consists of the technologies and infrastructure used to transform uranium ore into uranium concentrate
UGTMF	• Purpose-built, underground facility with chambers dedicated to the storage and progressive decommissioning for tailings and other waste streams generated through mining and processing • Three UGTMF cavities are planned for initial development during Construction to provide adequate storage capacity to support the start of mining and milling operations
Mine rock	• Includes all material sourced from underground, including ore (equal or greater than 0.26% U_3O_8 and waste rock (less than 0.26% U_3O_8)

Terms	Details
Waste rock	• Includes non-potential acid generating mine rock, potentially acid generating mine rock, and special waste
NPAG	• The NPAG waste rock is clean mine rock with less than 0.03% U_3O_8 and less than 0.1% sulphur. All NPAG mine rock would either be stockpiled for use as construction material at site or become NPAG waste rock that is stored in the NPAG WRSA
PAG	• The PAG waste rock is mine rock with less than 0.03% U_3O_8 and greater than or equal to 0.1% sulphur. All PAG mine rock would become PAG waste rock that is stored in the PAG WRSA
Special waste	• Special waste is mine rock with insufficient grade to be considered ore (i.e., greater than 0.03% of U_3O_8 and less than 0.26% U_3O_8). All special waste would be temporarily stored in the special waste rock stockpile
NPAG WRSA	• The NPAG WRSA would permanently store clean mine rock at surface and would not be lined
PAG WRSA	• The PAG WRSA would permanently store PAG mine rock at surface and would be fully lined with HDPE and have self-contained water collection
Special waste rock stockpile	• The separate stockpile where special waste would be temporarily stored at surface and would be fully lined with HDPE and have self-contained water collection • Special waste would be processed throughout Operations and then transferred to the UGTMF for permanent storage
Ore storage stockpile	• The separate stockpile on surface where ore would be temporarily stored until transferred to the process plant. This stockpile includes four piles with differing grades and would be fully lined with HDPE and have self-contained water collection
ETP	• The Project facility that would treat contact water from the Project. The treated effluent would be pumped to the monitoring ponds, tested, and then discharged to the environment, after meeting discharge criteria
Sewage treatment plant	• The Project facility that would treat sewage from the Project. The treated sewage discharge would be released to the environment after meeting discharge criteria
Mine water	• Water that flows into the underground workings
Contact water	• Water that may have been physically or chemically altered by Project activities. This water may be diverted and require management (e.g., treatment) before release to the environment. This includes dewatering of mine water from underground mining activities as well as all runoff on surfaces disturbed by the Project
Non-contact water	• Water that has not been physically or chemically altered by Project activities. This water is typically diverted when practical and allowed to discharge directly to the receiving environment
Fresh water	• Water sourced from Patterson Lake for use by the Project
Release water	• Contact water that has been treated in the ETP and is discharged to the environment, after meeting discharge criteria
Waste water (or treated sewage discharge)	• Water that has been treated in the sewage treatment plant and is ready for discharge to the environment, after meeting discharge criteria

Terms	Details
Sewage	• Waste water from toilets, sinks, showers, laundry, kitchen, and other domestic sources and facilities at the Project, including but not limited to sanitary liquid waste of human origin
Supporting infrastructure	• Includes all Project surface facilities including but not limited to waste management infrastructure, water management and treatment infrastructure, administration and camp facilities, utilities, airstrip, and site roads

UGTMF = underground tailings management facility; PAG WRSA= potentially acid generating waste rock storage area; NPAG WRSA = non-potentially acid generating waste rock storage area; U_3O_8 = triuranium octoxide; ETP = effluent treatment plant; HDPE = high density polyethylene.

Based on the review of Project-related information, the following key Project components and activities were identified and form the basis of consideration of potential accident and malfunction scenarios:

- site preparation;
- shaft sinking;
- access road and land transportation;
- airstrip;
- mining;
- hoisting;
- mine dewatering system;
- processing plant;
- solvent extraction building;
- UGTMF and mining stopes;
- NPAG waste rock stockpile;
- ore, special, and PAG waste rock stockpiles;
- effluent treatment system;
- ponds and retention berms;
- gypsum precipitation, washing, and storage;
- acid plant;
- electrical system and power plant;
- fire protection system;
- low-level radioactive waste management system and incinerator;
- liquified natural gas power plant; and
- mine ventilation system.

2.3 Project Timeline

The timeline over which potential accident and malfunction scenarios has been considered includes the Project lifespan. The Project lifespan includes the period of time from the initiation of Construction to the completion of Closure (i.e., up to the subsequent transfer of the property to Institutional Control). The lifespan of the Project is anticipated to be 43 years, as summarized in Table 2-2.

Table 2-2: Rook I Project Timeline

<table>
<tr><th>Phase</th><th colspan="2">Description</th><th>Duration (Years)</th></tr>
<tr><td>Construction</td><td colspan="2">Construction includes site preparation; mine, process plant, and additional infrastructure development; transportation of people and materials to and from the Project; and all activities associated with commissioning the Project up until Operations commences.</td><td>4</td></tr>
<tr><td>Operations</td><td colspan="2">Operations includes all activities associated with mining and processing ore; tailings management; management of waste rock, domestic waste, and hazardous materials; water management; release of treated effluent; site maintenance; progressive reclamation; and transportation of staff and materials to and from the Project up until Decommissioning and Reclamation commences.</td><td>24</td></tr>
<tr><td rowspan="3">Decommissioning and Reclamation (i.e., Closure)</td><td colspan="2">Includes two stages:</td><td>15</td></tr>
<tr><td>Active Closure Stage</td><td>Active Closure Stage includes active decommissioning and reclamation activities that occur post-Operations such as backfilling mine workings, removal of physical infrastructure, recontouring and revegetating disturbed areas, waste disposal or removal, and any other activities required to achieve decommissioning objectives and return the site to a safe and stable condition prior to the Transitional Monitoring Stage.</td><td>5</td></tr>
<tr><td>Transitional Monitoring Stage</td><td>Transitional Monitoring Stage would continue until monitoring and reporting verifies that the performance criteria have been met. Once performance criteria have been fully demonstrated, an application to be released from the CNSC licence would be submitted to the CNSC for approval. Once that is achieved, and upon Provincial approval, the land would be transferred under Provincial management through the Institutional Control Program. Stage is nominally 10 years, however NexGen acknowledges this is dependent on the achievement of performance criteria.</td><td>10</td></tr>
</table>

CNSC = Canadian Nuclear Safety Commission.

3.0 ASSESSMENT METHODS

The methods by which the accident and malfunction assessment was carried out are described below.

For reference, the temporal and spatial extents of the assessment are as follows:

- The temporal extent of the evaluation includes all phases associated with the Project lifespan, including Construction, Operations, and Decommissioning and Reclamation (i.e., Closure).
- The spatial extent of the evaluation includes the Project site and the Project access road to its junction with Highway 955.

3.1 Overview

The assessment of accidents and malfunctions is designed to provide a clear definition of the potential Project-associated hazards that fall outside the range of typical day-to-day events and to provide a framework for quantifying the risks associated with these hazards.

The five basic steps in the process of risk assessment for the accidents and malfunctions assessment were as follows:

1. **Hazard identification**: the identification of physical situations with the potential for harming human health or the biophysical environment. Hazard scenarios were identified using a systematic approach with consideration of the existence of sources of hazards and initiating events for each project component and activity. Scenarios were identified for several potential events, such as releases of chemical and radiological constituents, fires, and explosions. The detailed methods and the complete list of identified scenarios are provided in the hazard identification report that is provided in Appendix A.

2. **Bounding scenarios:** The identified hazard scenarios were then screened qualitatively for the perceived effects and probability of occurrence as well as the potential risk using a risk matrix approach (Section 3.2.2). Project information, experience from similar projects, particularly those located in Northern Saskatchewan, and professional judgment were used for this initial screening. Among the high or moderate-risk scenarios, bounding scenarios were selected. The bounding scenarios encompass the effects of other scenarios screened for each Project component and activity. The subsequent analysis focussed on these bounding scenarios.

3. **Probability analysis**: the estimation of the probability of occurrence of the selected bounding scenario occurring within a specific time period, or in specified circumstances.

4. **Effects analysis:** quantitative evaluation of the potential effects of a selected bounding scenario to the human health or biophysical environment.

5. **Risk estimation and ranking**: the estimation of the effect of a scenario and the probability with which it is likely to occur; that is, risk is the product of effect and probability (risk = consequence × probability of occurrence). The risk was evaluated using the risk matrix presented in risk matrix approach (Section 3.2).

3.2 Hazard Identification

The hazard identification process is a systematic approach to identify possible hazards associated with all components (physical system) and activities in a work process. A hazard can be defined as a physical event or condition that has the potential for causing damage to people, property, or the environment (e.g., fire, explosion, release of chemicals, or radioactivity).

The full hazard identification report is provided in Appendix A. The hazard identification evaluation was used to identify a comprehensive list of potential Project-related accident and malfunction scenarios, screen these scenarios as to potential risks and, based on the initial screening results, select a number of high or moderate-risk scenarios as bounding scenarios. These bounding scenarios were carried forward for more detailed risk assessment. The hazard identification evaluation focussed on risks to the human health and biophysical environment.

The hazard identification involved the consideration of the following three elements that, in combination, present a risk to the human health and biophysical environment:

a) the sources of hazard (e.g., presence of hazardous materials),

b) hazardous situations (e.g., presence of ignition source), and

c) initiating events (e.g., natural causes, technical failure, or human error).

A screening evaluation was applied to all accident and malfunction scenarios by qualitatively evaluating the likelihood and consequence to determine a risk level.

The likelihood index is derived from the qualitative estimation of the probability of the scenarios. While there are standards and regulatory documents (e.g., REGDOC-2.4.2, Safety Analysis, Probabilistic Safety Assessment [PSA] for Reactor Facilities [CNSC 2014]) that govern the assessment of the probability of the hazard scenarios for nuclear reactors, no such documents exist for non-reactor facilities. The focus of these documents is design-basis and beyond design-basis accidents that affect the integrity of the reactor core. The annual probability of releases from these accidents can be $1x10^{-6}$ and lower, while the consequence of these accidents could be very severe (i.e., catastrophic). In contrast, the probability of accidents and malfunctions at non-reactor facilities such as mines and process plants can be higher, as derived from the operating experience of similar installations. The International Atomic Energy Agency’s TECDOC-1267 (IAEA 2002) states that while a plant-specific qualitative risk analysis should be conducted for a nuclear reactor facility, for non-nuclear facilities hazard identification and screening, evaluation of selected accident scenarios, and a combination of qualitative and quantitative analysis should be conducted. This document does not prescribe what probabilities should be considered.

Based on the operating experience of similar facilities considered in this assessment, a range of probabilities were considered. On a scale of increasing likelihood, scenarios were categorized as highly unlikely, unlikely, likely, very likely, and almost certain as shown in Table 3-1.

Table 3-1: Likelihood Index

Rating	Likelihood	Description
1	Highly unlikely	<1 occurrence in 1,000 years
2	Unlikely	≤1 occurrence in 100 years and >1 occurrence in 1,000 years
3	Likely	≤1 occurrence in 10 years and >1 occurrence in 100 years
4	Very likely	≤1 occurrence in 1 year and >1 occurrence in 10 years
5	Almost certain	>1 occurrence in 1 year

< = less than; ≤ = less than or equal to; > = greater than.

On a scale of increasing consequence, scenarios were categorized as negligible, minor, moderate, major, and catastrophic as shown in Table 3-2.

Table 3-2: Consequence Index

Rating	Consequence	Description
1	Negligible	No measurable biophysical environmental effects, or medical treatment not required
2	Minor	Short-term (less than one month in duration) minor effect on small area, or minor first aid injuries with no lost time
3	Moderate	Reversible or repairable (i.e., less than one year in duration) effect off site, or reversible injuries with lost time
4	Major	Extended-range, long-term (i.e., between 1 and 10 years in duration) effect off site, or severe injuries with long-lasting effects and/or disability
5	Catastrophic	Long-lasting (more than 10 years) or irreversible environmental effects, fatalities, or multiple disabilities

The resulting risk levels are defined according to the hazard analysis risk matrix shown in Figure 3-1.

For the purpose of the assessment, risks were identified as being low (i.e., coloured green in the matrix) where the screening evaluation considered the risk as generally being acceptable, as the likelihood of these scenarios can be effectively managed through application of planned controls and/or the consequence of the effect would be low. Low-risk scenarios have a consequence of negligible to moderate, with the likelihood ranging from highly unlikely to almost certain.

Risks are identified as being moderate (i.e., coloured yellow in the matrix) where the screening evaluation considers the risk as generally being tolerable. In some cases, a moderate-risk scenario can encompass the risk of several screened scenarios for each effect category (e.g., toxic release, fire). In these cases, a moderate-risk scenario can be carried forward as a bounding scenario for more detailed analysis. Moderate-risk scenarios have a consequence of minor to catastrophic, with a likelihood ranging from highly unlikely to almost certain. In many cases, risk-reduction activities would reduce the risk associated with these scenarios to as low as reasonably practicable (ALARP). Under this condition, the risk may be characterized as tolerable.

Risks were identified as being high (i.e., coloured red in the matrix) where the screening evaluation considered the risk as generally being unacceptable. High-risk scenarios have a consequence of major to catastrophic, with a likelihood ranging from unlikely to almost certain. As the evaluation of the risk at this hazard identification stage was qualitative and subject to some uncertainty, hazard scenarios identified as high risk that were not associated with the NexGen health and safety program best practices (i.e., risk is reduced to ALARP) were advanced for further detailed assessment so that a more detailed evaluation of risk and potential management activities could be considered.

Figure 3-1: Hazard Analysis Risk Matrix

Likelihood		**Consequence**				
		1	**2**	**3**	**4**	**5**
		Negligible	**Minor**	**Moderate**	**Major**	**Catastrophic**
5	**Almost certain**	Low	Moderate	Moderate	High	High
4	**Very likely**	Low	Low	Moderate	High	High
3	**Likely**	Low	Low	Moderate	Moderate	High
2	**Unlikely**	Low	Low	Low	Moderate	High
1	**Highly unlikely**	Low	Low	Low	Moderate	Moderate

3.2.1 Evaluation of Project Components and Activities

Sources of hazards, hazardous situations, and initiating events associated with Project components and activities were evaluated as described in the hazard identification report (Appendix A). A total of 93 hazard scenarios were identified and evaluated.

Following the screening evaluation outlined in Section 3.2, a total of nine of the hazard scenarios were characterized as high risk. Three of the high-risk scenarios were identified as requiring further detailed assessment for more accurate characterization of risk. Each of these three scenarios is associated with a release of contaminants to the environment where the potential effects may be more far-reaching than can be adequately assessed by the screening assessment. Therefore, additional, more quantitative evaluation is appropriate. The remaining six high-risk scenarios that were not recommended for further detailed assessment are associated with major injuries and/or occupational fatalities. These scenarios were not advanced in the accidents and malfunctions assessment as they are outside the scope of this assessment.

Thirty-three of the scenarios evaluated were characterized as moderate-risk scenarios. Generally, the moderate-risk scenarios were deemed to represent a tolerable level of risk in consideration of proposed safeguards and design features that reduce the risk level to ALARP. A total of nine moderate-risk scenarios were recommended for further detailed assessment - four for release of uranium from the mill building, three for release of sulphur dioxide from the acid plant, one for release of untreated effluent, and one for a surface release of tailings. The effects of four moderate-risk uranium release scenarios are expected to be much less than the loaded solvent fire scenario, which is a high-risk scenario due to the amount of uranium involved. Thus, the four moderate-risk uranium release scenarios are bounded by the uranium loaded fire scenario. The effects of two sulphur dioxide release scenarios are bounded by tail-gas scrubber failure scenario due to the amount of gas available for release upstream of the scrubber. Therefore, three moderate-risk scenarios were selected as bounding scenarios for further assessment.

The remaining 51 scenarios evaluated were characterized as low-risk scenarios based on their likelihood of occurrence and/or effect in consideration of the planned or existing safeguards and design features. Low-risk scenarios were not carried forward for more detailed analysis as they are adequately characterized by the screening process.

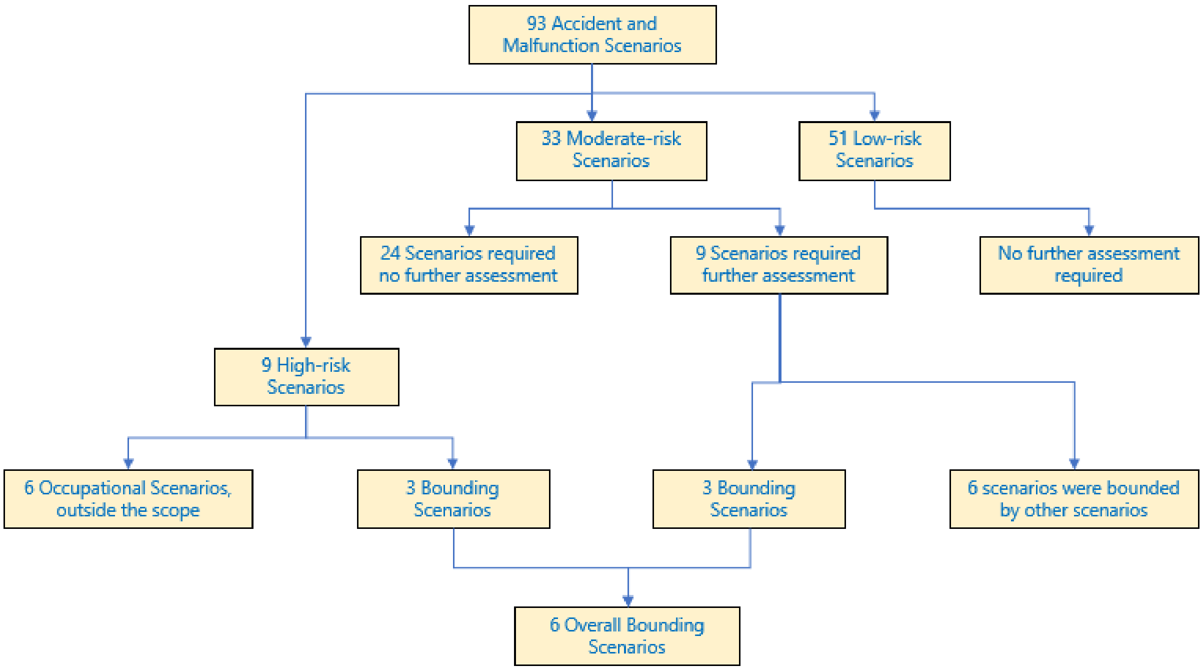
Figure 3-2 shows the process by which the bounding scenarios were selected.

The storage and transportation of explosives and detonators was not included in the list of Project components and activities used for this evaluation. The transport, storage, and use of explosives and detonators are heavily regulated to minimize risks. Use and handling of explosives for the Project would be managed as per the *Explosives Act*, as well as the following standards:

- CAN/BNQ 2910-500/2015 Explosives – Magazines for Industrial Explosives (SCC 2015a); and
- CAN/BNQ 2910-510/2015 Explosives – Quantity Distances (SCC 2015b).

Additionally, in accordance with The Mines Regulations, 2018, the location of the explosive or detonator facility would be a minimum of 60 m from any work area, fire hazard, or other vulnerable area, and would not be located on any main travel way (e.g., access ramp). Risks for transport, storage, and use of explosives would always be considered ALARP given the regulatory framework and the controls required (e.g., explosives management planning); therefore, these risks were not evaluated in the hazard assessment. For this reason, further assessment of potential effects to the environment, human health, and worker safety is not required.

Figure 3-2: Selection of Bounding Scenarios



3.2.2 Bounding Scenarios

From the initial screening process detailed in the hazard identification report (Appendix A), six hazard scenarios (i.e., three high risk and three moderate risk) were selected as bounding scenarios for more detailed risk analysis (Table 3-3). Herein, a bounding scenario is used to represent an event in which its potential effects are considered to represent those associated with other accident and malfunction scenarios; or, alternatively, the potential effects of scenarios that are bounded by another are expected to fit within the envelope of those associated with the bounding scenario. Utilizing the bounding scenario approach avoids duplication in the evaluation process while confirming the evaluation is completed in a conservative manner.

For six identified bounding scenarios, a general description of the hypothetical event, the release characterization (e.g., contaminants, quantities), the probabilities of the events, and their potential effects on the human health and biophysical environment are provided in Section 6.0 to Section 11.0.

Table 3-3: Bounding Scenarios Identified for Further Assessment by the Hazard Identification Process

No.	Accident or Malfunction Scenario	Location	Effect Pathway	Interactions with the Environment
1	Traffic accident (uranium concentrate)	Access road at bridge crossing	Aquatic release of uranium concentrate	Affects the water quality, sediment quality, terrestrial and aquatic biota, and members of the public
2	Traffic accident, (chemical)	Access road at bridge crossing	Aquatic release of fuel, hazardous chemicals	Affects the water quality, sediment quality, terrestrial and aquatic biota, and members of the public
3	Solvent extraction fire or explosion	Solvent extraction building	Atmospheric release of uranium concentrate (chemical toxicity)	Affects the air quality, and members of the public
4	Tailings transfer pipe or pump failure	Tailings release to surface within secondary containment	Terrestrial release of radioactivity	Affects the soil and potentially groundwater, and terrestrial biota
5	Untreated effluent transfer pipe failure	Effluent treatment system	Terrestrial release of radioactivity	Affects the soil and potentially groundwater, and terrestrial biota
6	Acid plant tail gas scrubber failure	Acid plant	Atmospheric release of sulphur dioxide	Affects air quality, and members of the public

high risk; moderate risk
Note: Effect Pathway describes nature of the event and exposure media, and therefore the nature of the assessment of effects.

3.3 Probability Analysis

The detailed assessment of the bounding scenarios requires the quantification of the probability of the effects of the bounding scenarios. The estimation of the probability requires the identification of the probability of the initiating events leading to the hazard scenario and the conditional probability of any of the associated events within the casual event chain.

Commonly, the probability estimation relies on the statistics collected by various government and non-government agencies for similar processes. These include:

- Transportation-related scenario probabilities estimated based on the transportation accident statistics available by various government agencies.
- Equipment and structural failures and incidents based on the industry experience and failure rates available from various organizations.

In some cases, there is not enough historical information to support a statistically meaningful evaluation of the probability. In these cases, the probabilities are reported as less than a specific value. For example, the probability of the mechanical failure of a structure is reported as less than 0.01 if the life span of the structure is 100 years and no historical information is available for mechanical failure of similar structures. In many cases, assessor’s experience and professional judgment are used in the probability evaluation.

The quantification of probabilities considered the prevention measures that would be implemented through NexGen's health, safety, environmental, and quality policies, practices, and procedures (Section 4.0).

3.4 Effects Analysis

The detailed assessment included the quantification of the potential effects of each of the bounding scenarios on the human health and biophysical environment. The quantification of the effects included the assessment of the fate and transport of a chemical or radiological release and associated exposures related to the scenario. It also included the characterization of the source terms when there is potential for the release of radioactivity and hazardous materials to the environment.

The fate and transport of the released materials and the exposure to the receptors were evaluated to quantify the effects of the scenario. Technical Support Document XXI, Environmental Risk Assessment, provides an understanding of how people interact with the environment within the vicinity of the Project and assesses the potential for human and ecological receptors to be exposed to Project-related media during one or more Project phases. Detailed rationale for human and ecological receptor selection is provided in the Environmental Risk Assessment.

The quantification of potential effects considered the risk prevention and mitigative measures that would be implemented through NexGen's health, safety, environmental, and quality policies, practices, and procedures (Section 4.0). This approach provided a more in-depth, quantitative and representative characterization of the risk of these scenarios, as the estimation of the risk in the hazard identification report (Appendix A) was preliminary, and completed at the screening level using primarily qualitative methods.

3.5 Risk Estimation and Ranking

The risk estimation for the bounding scenarios was performed through mapping the results of the quantification of the likelihood and consequence on the risk matrix presented in Section 3.2, Figure 3-1.

4.0 CONSIDERATIONS FOR THE ACCIDENT AND MALFUNCTIONS ASSESSMENT

Over the past four decades of global commercial nuclear facility operation, the frequency and severity of accidents has been markedly lower than those in related industrial operations (OECD 2010). This can be attributed to the rigorous regulatory framework and well-developed plans and procedures for safe operation of nuclear facilities, including uranium mining and milling operations, particularly in Northern Saskatchewan. The experience gained from the accidents that have occurred has resulted in improved engineered safety features and operating procedures. Therefore, assessing the probability that similar accidents might occur in the future based on historical data is conservative.

It is the intention of NexGen to develop and operate the Project in a manner that mitigates potential adverse effects on the human health and biophysical environment to the extent possible. NexGen would verify that all work to be completed during the Project would meet, or exceed, the regulatory requirements stipulated by the province of Saskatchewan, the CNSC, and other regulatory authorities. Through complying with all regulations and standards, engagement with Indigenous Groups, local communities, workers, and other stakeholders, and by embracing the application of technology and best practices, NexGen is focused on achieving high standards in all facets of the business and across the Project lifespan, which would serve to mitigate potential Project-related effects, including those that may be associated with postulated accident and malfunction scenarios. As part of this commitment, NexGen adopts a hierarchy of controls (i.e., elimination, substitution, engineering, administrative, personal protective equipment) as part of the Integrated Management System to prevent, eliminate, and reduce hazards and mitigate the risks associated with activities throughout the Project lifespan. In practice, these controls would be implemented and their effectiveness monitored via management system processes defined in topic-specific programs which include, but may not be limited to the following:

- Integrated Management System Manual;
- Health and Safety Program;
- Radiation Protection Program;
- Environmental Protection Program;
- Waste Management Program;
- Emergency Preparedness and Response Program;
- Fire Protection Program;
- Security Program;
- Training Program;
- Contractor Management Program;
- Indigenous and Public Engagement Program;
- Construction Management Program;
- Commissioning Management Program; and

- Asset Management Program.

The processes outlined in these programs would be described in more detailed topic-specific plans, procedures, and work instructions developed for the Project. This includes processes related to:

- process and operational controls;
- mine development and control;
- workplace inspections;
- training;
- radiation exposure monitoring and protection;
- spill response;
- security;
- environmental monitoring;
- emergency response; and
- transportation emergency response.

These plans, procedures, and work instructions would be implemented throughout the lifespan of the Project, and together would help to mitigate the likelihood of occurrence of accident and malfunction scenarios.

5.0 CHEMICAL, OCCUPATIONAL, AND RADIOLOGICAL BENCHMARKS

The following subsections define relevant benchmarks used to assess the potential effects of the postulated accident and malfunction scenarios. The benchmarks presented are specific to the bounding scenarios that have been considered, and are provided for atmospheric and aquatic environments. The benchmarks were specifically selected with consideration of the interactions of the bounding scenarios with the environment presented in Table 3-1 for the following:

- uranium (scenarios 1 and 3):
  - atmospheric environment; and
  - aquatic and terrestrial environment;
- radioactivity (scenarios 1, 4, and 5):
  - aquatic and terrestrial environment;
- sulphur dioxide (scenario 6):
  - atmospheric environment.

5.1 Uranium

<u>*Atmospheric Environment*</u>

The Agency for Toxic Substances and Disease Registry (ATSDR) provides evaluations of toxicity for numerous agents, including uranium. In its 2013 report *Toxicological Profile for Uranium* (USHHS 2013), the ATSDR reports that “natural and depleted uranium have the identical chemical effect on your body. The health effects of natural and depleted uranium are due to chemical effects and not to radiation.” The 2013 report by ATSDR further notes that “neither the National Toxicology Program, International Agency for Research on Cancer, nor the Environmental Protection Agency have classified natural uranium or depleted uranium with respect to carcinogenicity.”

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2017) indicates that the relative importance of chemical and radiological toxicity of uranium depends on a number of factors; notably, the degree of enrichment of uranium-234 and uranium-235. The chemical toxicity from uranium exposure is mainly exhibited as damage to the kidneys and is assumed not to occur below a threshold concentration. While uranium is a radioactive substance, for natural and depleted uranium, the risks from intake of uranium are related to its chemical toxicity, and the potential for such effects is the basis for the hazard and risk assessments described in this report.

Exposure limits for emergency scenarios are defined by a hierarchy of threshold concentrations for one-hour exposure. These include the Acute Exposure Guideline Level (AEGL), the Emergency Response Planning Guideline (ERPG), and the Temporary Emergency Exposure Limit (USDOE 2016). Temporary Emergency Exposure Limits are intended for use until AEGLs and ERPGs are adopted for chemicals and have similar definitions as the corresponding ERPG levels. The AEGL and ERPG are defined for three levels as follows (USDOE 2016):

AEGL-1 The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible on cessation of exposure.

AEGL-2 The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

AEGL-3 The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

The three AEGL levels have not been established for uranium oxide or uranium concentrate.

Emergency Response Planning Guidelines are intended to be a planning tool to help anticipate human adverse effects on the general public caused by toxic chemical exposure. These guidelines are only available for a one-hour exposure duration and are not designed for hypersensitive individuals.

ERPG-1 The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing effects other than mild transient adverse health effects, or perceiving a clearly defined, objectionable odour.

ERPG-2 The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.

ERPG-3 The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

The most commonly used benchmarks for emergency release scenarios are ERPG-2 and AEGL-2. Emergency Response Planning Guideline values developed by the American Industrial Hygiene Association are provided in Table 5-1. These values were taken from the Protective Action Criteria tables (USDOE 2016).

Table 5-1: Emergency Response Planning Guidelines for Uranium Oxide and Uranium Concentrate

Chemical	ERPG-2	ERPG-3
Uranium oxide	10 mg/m^3	30 mg/m^3
Uranium concentrate	10 mg/m^3	50 mg/m^3

Source: USDOE 2016.
ERPG = Emergency Response Planning Guideline.

Aquatic Environment

The maximum acceptable concentration is 20 µg/L for total uranium in drinking water (Health Canada 2019). The guideline is based on the chemical toxicity of naturally occurring uranium.

Canadian Water Quality Guidelines for uranium (total recoverable, unfiltered) for the protection of aquatic life are 15 µg/L and 33 µg/L for long-term exposure and short-term exposure, respectively (CCME 2011).

The water quality guidelines for drinking water and protection of aquatic life are not developed for emergency situations; however, they can be conservatively used during transient situations following an accident.

5.2 Radioactivity

Radiation Protection Regulations, SOR/2000-203, governs the annual effective dose equivalent limits for individual members of the public exposed to the radioactivity resulting from industrial activities such as uranium mining and process plant buildings. The effective dose limit for the general public is 1 mSv per calendar year (Government of Canada 2021).

The assessment of effects on ecological species from exposure to radioactive constituents involves estimation of the combined (total) dose that a receptor may receive from radionuclides taken into the body, as well as from exposure to radiation fields in the external environment. In addition, it is standard practice to take into account differences in the effects of alpha, beta, and gamma radiation. Radiation effects on biota depend not only on the absorbed dose, but also on the relative biological effectiveness (RBE) of the particular radiation (i.e., alpha, beta, or gamma radiation). For example, alpha particles can produce observable damage at lower absorbed doses than gamma radiation. Thus, in order to estimate the potential harm to non-human biota from a given absorbed dose, the absorbed dose is multiplied by an appropriate radiation weighting factor. This in turn is derived from an experimentally determined RBE.

There is uncertainty concerning the most appropriate RBE values for assessing risks to non-human biota. The RBE values depend on the radiation quality, the biota under consideration, the endpoint being considered and the reference photon energies. The RBE values selected to develop protection criteria should correspond to the endpoint being protected (e.g., health of a population). For this assessment, an RBE of 2 was used for “low beta” and an RBE of 10 was used for alpha components, to represent their greater relative effectiveness (CSA Group 2022).

The Canadian Standard N288.6, which addresses Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills (CSA Group 2022), recommends an RBE of 10 to be applied to the component of internal dose from alpha emitters. This assessment follows this recommendation. The standard also recommends that radiation dose benchmarks for quantitative effects assessment should follow UNSCEAR (2008); i.e., 100 µGy/h for terrestrial biota and 400 µGy/h for aquatic biota. Therefore, the benchmarks used in the assessment are 2.4 mGy/d for terrestrial biota and 9.6 mGy/d for aquatic biota.

5.3 Sulphur Dioxide

The AEGL values for sulphur dioxide are provided in Table 5-2 (USDOE 2016).

Table 5-2: Acute Exposure Guideline Levels for Sulphur Dioxide

Chemical	AEGL-2	AEGL-3
Sulphur dioxide	0.75 ppm	9.6 ppm

Source: USDOE 2016.
AEGL = Acute Exposure Guideline Level; ppm = parts per million.

6.0 BOUNDING SCENARIO 1: TRAFFIC ACCIDENT (URANIUM CONCENTRATE AND RADIOACTIVITY)

This bounding scenario consists of the release of uranium concentrate into the Clearwater River under the bridge along the Project access road. A general description of the hypothetical event, hypothetical contaminants release characterization (e.g., contaminants, quantities), the probability of the scenario, and its potential effects on the human health and biophysical environment is provided below.

6.1 Scenario Description

Vehicular access to the Project site would be via an existing road accessed from Provincial Highway 955 that leads to the current exploration camp. The access road would be used to transport equipment and supplies to and from the Project, as well as the trucking of the uranium concentrate product from site. Personnel would be flown to and from the site. The access road is roughly 13.7 km long and partially circumnavigates Patterson Lake until it reaches the Project site. The gravel access road has a posted speed limit of 40 km/h.

Figure 6-1 shows the mine footprint and the access road. There is one bridge across the Clearwater River with a posted weight limit of 50 t and speed limit of 10 km/h. The bridge is approximately 20 m long, 5.7 m wide, and has no guardrails. Small metal guards approximately 0.15 m high guide the driver across the bridge deck (NexGen 2019).

A traffic accident, collision, rollover, or run off near the Clearwater River crossing or on the bridge could potentially result in a release of uranium concentrate into the surface water under the bridge. The flow direction of the Clearwater River at the bridge is east towards Forrest, Beet, and Naomi lakes.

The flow rates for the waterbodies upstream and downstream of the postulated accident location are provided in the table below (Table 6-1).

Table 6-1: Flow Rates for Waterbodies Upstream and Downstream of the Site Access Road Bridge Crossing

Waterbody	Annual Average Outflow (m^3/s)
Patterson Lake South	1.3
Forrest Lake North	2.2
Beet Lake	2.4

The calcined (i.e., heated strongly to remove impurities) uranium concentrate would be packaged into standard 205 L (45 gal) steel drums for shipping. The gross weight of each drum is between 430 kg and 450 kg. It is projected that there would be 90 to 100 drums packaged per process plant operating day, requiring an average number of two trips per day, for 330 days per year.

LEGEND

- BRIDGE
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA

0 1.5 3

1:50,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021.
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. ECOZONES OBTAINED FROM AGRICULTURE AND AGRI-FOOD CANADA (AAFC).

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

LOCATION OF THE BRIDGE ACROSS THE CLEARWATER RIVER

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	LJ	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-28		
CHECK	JMC	2023-02-28	**FIGURE 6-1**	
REVIEW	LJ	2023-02-28		

In uranium concentrate, the short-lived decay products of uranium-238 (i.e., thorium-234; protactinium-234m; protactinium-234, which has a relative concentration of 0.16% of uranium-238; and uranium-234), and uranium-235 (i.e., thorium-231) are assumed to be in equilibrium with their respective parents as the analysis considers both uranium and its decay products. Radioactive equilibrium exists when a radionuclide decays at the same rate at which it is being produced by its parent decay. The activity concentration of these radionuclides in uranium concentrate can be derived using the uranium-238 concentration and branching ratios shown in Table 6-2. The branching ratio for decay is the percentage of particles that decay by an individual decay mode with respect to the total number of particles that decay.

Table 6-2: Radionuclides in Uranium Concentrate

Radionuclide	Half-Life	Branch Percentage
Uranium-238	$4.47 \times 10^{+09}$ years	n/a
Thorium-234	24.1 days	100% uranium-238
Protactinium-234m	1.16 minutes	100% uranium-238
Protactinium-234	6.7 hours	0.16% uranium-238
Uranium-234	$2.45 \times 10^{+05}$ years	100% uranium-238
Uranium-235 (4.6% of uranium-238)	$7.04 \times 10^{+08}$ years	n/a
Thorium-231	1.063 days	100% uranium-235

From other studies conducted for McClean Lake uranium mills in northern Saskatchewan, the particle size distribution for three calcined uranium concentrate samples were measured using a Beckman Coulter LS Particle Size Analyzer[2]. Table 6-3 provides a summary of particle size distribution for these studies.

Table 6-3: Uranium Concentrate Particle Size Distribution

Calcined Samples (Three Samples)		
Size Category (µm)	**Average Size (µm)**	**Percentage**
<5	2.5	4.0
5-15	8.6	14.7
15-25	19	46.1
25-35	30	32.8
35-55	44	2.5

Source: Obtained from Cameco Corporation during the assessment of accidents and malfunctions for Millennium Mine Project.
< = less than.

[2] This information was obtained from Cameco Corporation during the assessment of accidents and malfunctions for Millennium Mine Project.

The solubility of calcined samples from the McClean Lake Operation located in northern Saskatchewan were analyzed over 24, 48, and 72 hours. The Organisation for Economic Cooperation and Development (OECD) Guideline for Testing of Chemicals; Water Solubility (adopted 27.07.95; OECD 1995), flask method, was followed for these tests. The results are shown in Table 6-4. For these tests, bulk and particle densities of uranium concentrate were 2.1 g/cm^3 and 9.6 g/cm^3, respectively. Based on the solubility data from the McClean Lake Operation samples, on average, a solution of about 0.125 g of uranium concentrate in 250 mL of water in 24 hours would lead to a uranium concentration of 4,800 µg/L. This value was assumed to apply to the release of uranium concentrate into the surface water under the scenario being assessed.

Table 6-4: Solubility of Calcined Uranium Concentrate

Sample Source	Sample No.	Estimated Solubility (g/L) by Test Duration		
		24 h	48 h	72 h
McClean Lake (calcined)	1	0.0035	0.0045	0.0046
	2	0.0060	0.0071	0.0067
	3	0.0053	0.0062	0.0090
	4	0.0038	0.0036	0.0039
	5	0.0070	0.0068	0.0064
	16 to 20 (average)	0.003 to 0.008 (0.005)	n/a	n/a

n/a – values not determined for these tests.
Source: Obtained from Cameco Corporation during the assessment accidents and malfunctions for Millennium Mine project.

6.2 Release Characterization

The performance of drums similar to those proposed to be used for uranium concentrate shipment during transportation accident scenarios was determined by McSweeney et al. (2004). The authors concluded that, based on drum deformations performed in a previous analysis, if a drum experienced a crush force of 100,000 lbs, then the deformation of the drum would cause the lid to detach from the drum. Using this drum failure mechanism, and assuming the drums weigh 450 kg and are arranged in the truck four rows across in a single layer with no stacking, at a speed of 48 km/h, the front 25% of the drums would fail, at 60 km/h to 97 km/h, 55% would fail, at 145 km/h, 75% would fail, and at ≥193 km/h, all would fail.

Given that the speed of the truck would be less than 40 km/h, it was concluded that less than 25% of the drums would fail upon a traffic accident scenario. Assuming 100 drums in two shipments per day, each shipment would have 22,500 kg (49,560 lb) of uranium concentrate based on the following calculation:

- 100 drums in two shipments / 2 = 50 drums per shipment.
- 50 drums x 450 kg/drum = 22,500 kg uranium concentrate = 49,560 lb.

If 25% of this amount is released, the total release weight would be approximately 5,625 kg of uranium concentrate. It is also assumed that 95% of the released uranium concentrate can be recovered from the released location after the accident. This assumption is based on the expectation that most of the uranium concentrate released would remain in relatively close proximity to the release location, given the high particle density of uranium concentrate (8.3 g/cm^3) that results in a high settling velocity (USDOE 2001) and the low water velocity and depth at the release location (Table 6-1).

The short-term dissolved release rate was estimated using solubility data. Solubility of calcined uranium ore concentrate was considered at an average value of 4,800 µg/L (or 4.8 g/m^3) over the first 72 hours, which is the average solubility of McClean Lake uranium ore concentrate samples. It was assumed that such concentrations applied to a cross section of water defined by the lateral footprint of the spill (i.e., the total 6 m of the Clearwater River crossing) and a water column depth of 10 cm. The water velocity was assumed to be 1 m/s. At an average depth of 0.3 m, the total flow rate is 1.8 m^3/s:

- 6 m × 0.3 m × 1 m/s = 1.8 m^3/s.

The dissolution rate is calculated as 2.9 g/s.

- 6 m × 0.1 m × 1 m/s × 4.8 g/m^3 = 2.9 g/s.

Long-term concentrations were also estimated to account for transfer of the settled uranium from sediment to water. The long-term release rate is based on the concentration estimated for pore-water quality. It was assumed that such concentrations applied to a cross section of water defined by the lateral footprint of the spill and a water column depth of 10 cm.

6.3 Assessment of Probability

Traffic risk mitigation measures include:

- traffic control measures, such as the speed limit at the bridge of 10 km/h;
- a travel management plan;
- a spill and emergency response plan; and
- driver training.

Despite the risk control measures, there is always a residual probability of accidents occurring. The probability of occurrence of a transportation accident and sequence of events resulting in a release of hazardous materials is the key factor for quantifying the transportation risk. Statistical data for transportation accidents are available for general transportation, as well as the transportation of hazardous materials. General transportation accident statistics are commonly presented as the number of accidents per million kilometres or million miles of transport vehicle travelled, and specific hazardous materials transportation accident statistics are commonly presented as the number of accidents per million tonne-miles or million tonne-kilometres of materials transported.

Using hazardous material transportation accident statistics would be more relevant for risk assessment studies; however, the statistical datasets for hazardous material transportation are less available and were therefore not used for this assessment. The data regarding the total volume and mass transported by various modes of transportation are maintained by shipping companies, and in most cases, are only available to regulatory agencies such as Transport Canada. The publicly available information is reported on a lump sum basis (i.e., the information does not include the breakdown for specific chemical or transportation route). In addition, the statistical breakdown for transportation routes is not readily available and the route data, particularly for road transportation, are maintained by road transport companies and are not publicly available. Therefore, in many cases, general transportation accidents statistics for trucks, trains, and marine vessels are used to conduct the risk assessment.

In Canada, the statistics related to the transportation and road accidents are primarily collected and maintained by federal and provincial government agencies including Transport Canada (2019) and its branches (such as the Canada Transportation Safety Board), the Saskatchewan Ministry of Highways and Infrastructure, and Saskatchewan Government Insurance (SGI 2019). The statistics indicate that average accident rates for Canada and Saskatchewan were 1.2 and 0.89 per one million kilometres travelled, respectively. The local statistics indicate that these rates were 2.68 and 0.8 per one million kilometres travelled for Highway 915 and Highway 955, respectively. These highways are part of the transportation route and are the closest to the proposed Project site.

It was also assumed that a traffic accident on the bridge or within 40 m from either side of the bridge would have the potential to release uranium concentrate to the Clearwater River. Using the transportation route lengths and the transportation accident rates estimated above, and assuming two trips per day for 330 days per year, the frequency of traffic accidents involving uranium concentrate in the vicinity of the Clearwater River crossing (i.e., considering a 40 m buffer at each side of the bridge) are estimated as follows:

for release to water: 5.3×10^{-05} to 1.7×10^{-04} per year.

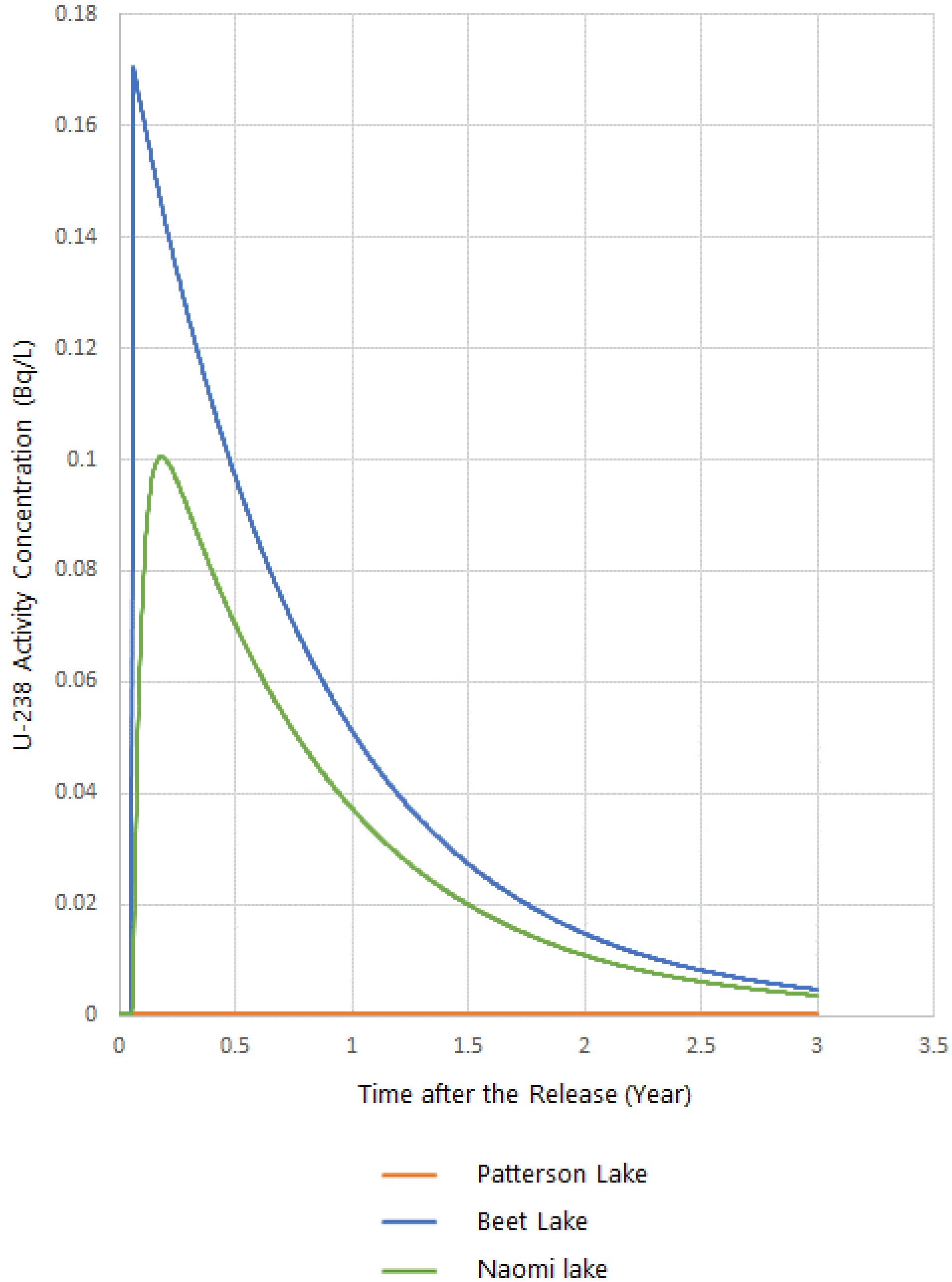
The above probabilities were calculated as a range using both Transport Canada and Saskatchewan Government Insurance statistics.

According to the probability ratings described in Section 3.2, Table 3-1, the probability that this accident and malfunction scenario would occur is highly unlikely.

6.4 Assessment of Potential Effects

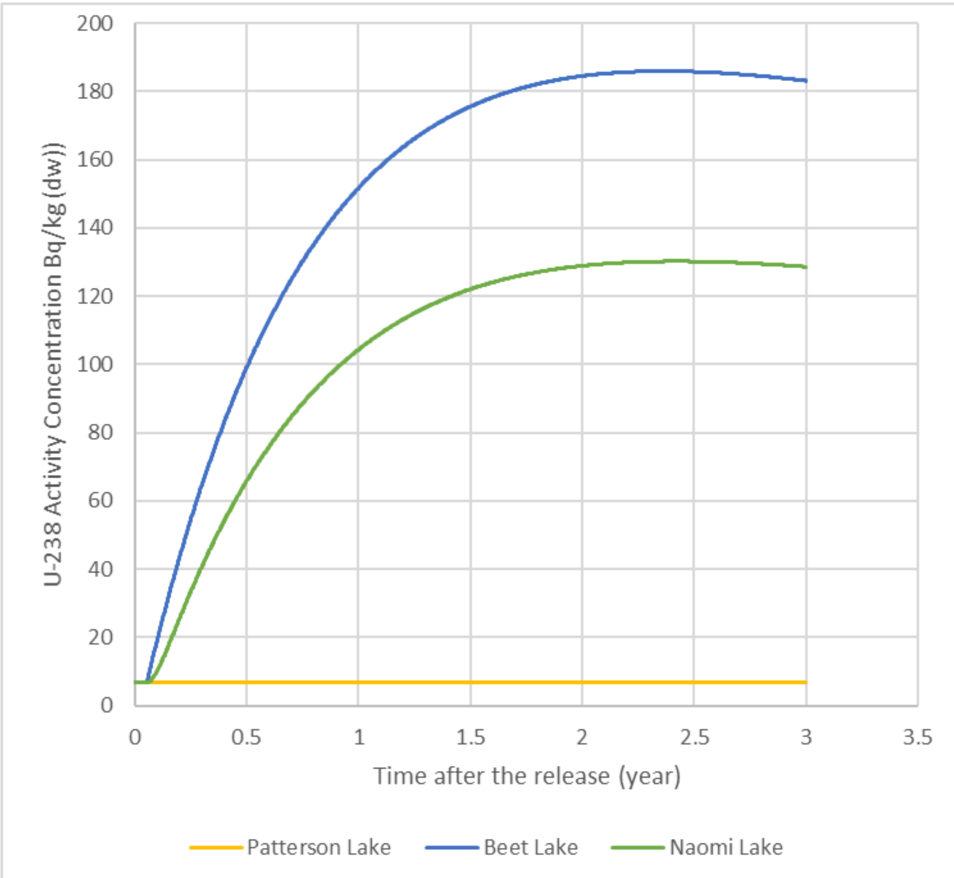
Using the release rate of uranium concentrate calculated in Section 6.2, the long-term surface water and sediment activity concentrations of uranium were calculated. Figure 6-2 and Figure 6-3 show the concentrations in Patterson Lake, Beet Lake, and Naomi Lake. The surface water and sediment concentrations would be much higher in a small area immediately downstream of the release location.

Figure 6-2: Long-Term Surface Water Activity Concentrations of Uranium Following an Aquatic Release of Uranium Concentrate



U-238 = uranium-238; Bq/L = becquerels per litre.

Figure 6-3: Long-Term Sediment Activity Concentrations of Uranium Following an Aquatic Release of Uranium Concentrate



U-238 = uranium-238; Bq/kg (dw) = becquerels per kilogram, dry weight.

The maximum calculated surface water concentration in Beet Lake is 0.17 Bq/L or 13.7 µg/L (based on uranium-238 specific activity of 12,445 Bq/g). This concentration is less than both the 20 µg/L guideline for total natural uranium in drinking water and the 15 µg/L guideline for the protection of aquatic life for long-term exposure. In the immediate vicinity of the release (Forrest Lake North), the maximum uranium concentration is calculated to be 29.2 Bq/L or 2,345 µg/L, which constitutes an exceedance of the water quality objectives presented above. However, this maximum concentration would occur for a short period of time (i.e., less than an hour) in a localized area, and would quickly dissipate to concentrations below both the guidelines for drinking water and protection of aquatic life.

The calculated surface water and sediment concentrations were used to estimate the radioactive dose to a number of human, terrestrial, riparian, and aquatic receptors. For reference, receptors identified are the same as those used in the Project Environmental Risk Assessment (TSD XXI).

The closest receptor considered is the subsistence harvester at Beet Lake. The maximum total doses due to all exposure pathways to human receptors present in the area are shown in Table 6-5. Although the short-term exposure to a human receptor following a release in close proximity to the release area could be high, this exposure is unlikely because emergency response would isolate this area and prevent direct access to it. The calculated long-term doses to all human receptors are lower than the CNSC effective dose limits for the public of 1 mSv in one year.

Table 6-5: Estimated Maximum Total Radiation Dose to Human Receptors Following an Aquatic Release of Uranium Concentrate (Reference Location Representative of Baseline Exposure)

Receptor	Receptor Location	Total Dose[(a)] (mSv/yr)
Subsistence harvester	Reference location	2.66×10^{-03}
Subsistence harvester one-year-old	Reference location	3.17×10^{-03}
Subsistence harvester	Beet Lake	3.05×10^{-03}
Subsistence harvester one-year-old	Beet Lake	3.39×10^{-03}

a) The Subsistence Harvester in this scenario is conservatively assumed to consume the entirety of their Traditional Food from the Beet Lake location.
mSv/yr = millisieverts per year.

The maximum total dose rates due to all exposure pathways to terrestrial and riparian ecological receptors are shown in Table 6-6. Although the short-term exposure of these receptors following a release at the close vicinity of the release area could be high, this exposure is short-term (within a few hours because of the dilution of dissolved portion of the released uranium concentrate) and limited to a small geographic area (less than few hundred metres from the release location). The calculated maximum dose rates at Beet Lake to all terrestrial and riparian receptors are lower than the benchmark of 2.4 mGy/d.

Table 6-6: Estimated Maximum Total Radiation Dose to Terrestrial and Semi-Aquatic Receptors at Beet Lake Following an Aquatic Release of Uranium Concentrate

Receptor	Total Dose (mGy/d)
Beaver *(Castor canadensis)*	2.50×10^{-05}
Black bear *(Ursus americanus)*	1.74×10^{-05}
Canada goose *(Branta canadensis)*	7.05×10^{-05}
Grey wolf *(Canis lupus)*	1.42×10^{-06}
Grouse *(Falcipennis canadensis)*	5.01×10^{-04}
Little brown myotis *(Myotis lucifugus)*	7.33×10^{-06}
Common loon *(Gavia immer)*	4.79×10^{-05}
Mallard *(Anas platyrhynchos)*	7.32×10^{-04}
Mink *(Neovison vison)*	4.11×10^{-06}
Moose *(Alces americanus)*	2.08×10^{-05}
Muskrat *(Ondatra zibethicus)*	2.90×10^{-05}
Red fox *(Vulpes vulpes)*	1.30×10^{-06}
Rusty blackbird *(Euphagus carolinus)*	8.45×10^{-04}
Snowshoe hare *(Lepus americanus)*	2.11×10^{-05}
Southern red-backed vole *(Myodes gapperi)*	7.67×10^{-06}
Woodland caribou *(Rangifer tarandus caribou)*	1.60×10^{-05}

mGy/d = milligrays per day.

The maximum total dose rates due to all exposure pathways to aquatic receptors are shown in Table 6-7 and Table 6-8 in Patterson Lake (reference location upstream of the release, provided for comparison) and Beet Lake, respectively. Although the short-term exposure of these receptors following a release at the close vicinity of the release area could be high, this exposure is short-term (within a few hours because of the dilution of dissolved portion of the released uranium concentrate) and limited to a small geographic area (less than few hundred metres from the release location). The calculated maximum dose rates at Beet Lake to all aquatic receptors are lower than the benchmark of 9.6 mGy/d.

Table 6-7: Estimated Maximum Total Radiation Dose to Aquatic Receptors in Patterson Lake Upstream of the Release of Uranium Concentrate

Receptor	Total Dose (mGy/d)
Benthic invertebrate	1.09×10^{-08}
Zooplankton	4.44×10^{-05}
Northern pike *(Esox lucius)*	8.83×10^{-06}
Whitefish *(Coregonus clupeaformis)*	1.67×10^{-06}
Macrophytes	2.22×10^{-05}
Phytoplankton	2.22×10^{-05}

mGy/d = milligrays per day.

Table 6-8: Estimated Long-Term Total Radiation Dose to Aquatic Receptors in Beet Lake Following an Aquatic Release of Uranium Concentrate

Receptor	Total Dose (mGy/d)
Benthic invertebrate	2.92×10^{-07}
Zooplankton	5.98×10^{-04}
Northern pike	1.19×10^{-04}
Whitefish	2.24×10^{-05}
Macrophytes	2.99×10^{-04}
Phytoplankton	2.99×10^{-04}

mGy/d = milligrays per day.

Based on the potential for short-term and localized exposure, and calculated long-term exposure and dose to ecological receptors as well as the calculated long-term dose to human receptors, and in consideration of the effect scale described in Section 3.2, Table 3-2, the consequence of this bounding scenario is judged to be moderate.

7.0 BOUNDING SCENARIO 2: TRAFFIC ACCIDENT (CHEMICAL)

This bounding scenario consists of the release of fuel and hazardous chemicals into the Clearwater River under the bridge along the Project access road. A general description of the hypothetical event, hypothetical contaminants release characterization (e.g., contaminants, quantities), the probability of the scenario and its potential effects on the human health and biophysical environment is provided below.

7.1 Scenario Description

This scenario is similar to Bounding Scenario 1, except that it potentially results in the release of chemicals or fuel such as diesel, gasoline, or liquified natural gas at the site access bridge over the Clearwater River. The information related to the fuel and chemicals transported to the site is summarized in Table 7-1.

Table 7-1: Chemicals Transported to the Project Site

Chemical	Variable	Value
Diesel and gasoline	Fuel tanker truck capacity	30 m^3
	Fuel tanker truck trips per day	10 each for diesel and gasoline
Organic solvents	Daily volume of organic solvent consumption	Negligible. The solvent consumption is minimum due to regeneration
	Organic solvent tanker truck capacity	40 t
	Organic solvent tanker truck trips per month	1 (assumed). The solvent consumption is minimum due to regeneration)
Liquified natural gas	Liquified natural gas tanker truck capacity	48 m^3
	Liquified natural gas tanker truck trips per day	3
Hydrogen peroxide	Daily volume of hydrogen peroxide consumption	18,289 L
	Hydrogen peroxide tanker truck capacity	11,350 L to 18,900 L
	Hydrogen peroxide tanker truck trips per day	0.97 to 1.61
Molten sulphur	Daily volume of molten sulphur consumption	50,280 L
	Molten sulphur tanker truck capacity	25 t
	Molten sulphur tanker truck trips per day	3.5

Source: NexGen 2021.

7.2 Release Characterization

It was conservatively assumed that the entire cargo would be released during an event. Based on information provided by NexGen (2021), the following is assumed:

- Diesel fuel (30 cubic metre [m^3] release): The released diesel forms a sheen on top of water with a thickness of approximately 1 μm. While as much as 15% of the diesel would dissolve in the water column (NOAA 2023), up to 30% would evaporate from the surface of water

(Silver and Mackay 1984). The rest of the fuel, which is predominantly heavier components, would stay afloat or be adsorbed into the soil or shallow sediments along the river and downstream lake banks.

- Gasoline (30 m^3 release): The released gasoline forms a sheen on top of water with a thickness of approximately 1 µm. While as much as 25% of the gasoline would dissolve in the water column, up to 70% would evaporate from the surface of water (Silver and Mackay 1984). The rest of the fuel, which is predominantly heavier components, would stay afloat or be adsorbed into the soil or shallow sediments along the river and downstream lake banks.
- Organic solvents (40 t release): The released solvent behaves similarly to diesel fuel, as discussed above.
- Liquified natural gas (30 m^3 release): The release would most likely undergo a phenomenon called cold explosion. The released liquified natural gas would evaporate quickly and be released to the atmosphere (Melhem and Ozog 2006).
- Hydrogen peroxide (approximately18 m^3 release): Hydrogen peroxide and water are miscible liquids. Thus, upon release, the entire volume of hydrogen peroxide would mix with water. Hydrogen peroxide is a reactive oxygen species and decomposes slowly when exposed to light in natural environment, and rapidly in the presence of organic compounds. Decomposition releases hydroxyl radicals that react rapidly with organic compounds in the environment. The typical products of hydrogen peroxide decomposition (i.e., water and oxygen) do not harm organisms in fresh water. Organisms in small, confined waterbodies could be affected by hydrogen peroxide itself, or by reactive hydroxyl radicals formed when it reacts with metal catalysts in the water such as iron (II) sulphate (Schmidt et al., 2006). This would need to occur before hydrogen peroxide decomposes or dilutes to background levels in the environment. In a study conducted by Rach et al. (1997), fish were exposed to hydrogen peroxide concentrations ranging from 100 µL/L to 5,000 µL/L parts per million (ppm) for 15-min or 45-min treatments every other day for four consecutive treatments to determine the sensitivity of various species and life stages of fish. It was found that most species of fish tolerated hydrogen peroxide of greater than 1,000 ppm with no adverse effects. The concertation of 1,000 ppm requires a dilution of less than 1 to 1,000. It means 18 m^3 should be diluted to 18,000 m^3. This would occur in a stretch of less than 200 m of Clearwater River before it reaches the Forest Lake. Therefore, acute effects on a large fish population are not expected. The effects are expected to be transient, and chronic effects are not expected.
- Molten sulphur (25 t release): When molten sulphur is released into cold surface water, brownish amorphous or plastic sulphur is produced by the rapid cooling process. The amorphous form has long coiled polymeric molecules that make it elastic. The solubility of this substance is extremely low and can be considered to not be released into the water column through the dissolution process.

Based on the release characterization, the effects of releases of liquified natural gas, hydrogen peroxide, and molten sulphur were not analyzed further.

7.3 Assessment of Probability

Traffic risk mitigation measures for this scenario are the same as those presented for Bounding Scenario 1. The frequency of traffic accidents involving fuel or chemicals in the vicinity of the Clearwater River crossing (i.e., considering 40 m buffer at each side of the bridge), assuming 12 trips per day for 330 days per year, are estimated as:

for release to water: 3.1×10^{-04} to 1.0×10^{-03} per year.

The above probabilities were calculated as a range using both Transport Canada and Saskatchewan Government Insurance statistics.

According to the probability ratings described in Section 3.2, Table 3-1, the probability that this accident and malfunction scenario would occur is highly unlikely.

7.4 Assessment of Potential Effects

Among the chemicals considered for this scenario, the effects of the release of gasoline and solvents are bounded by the effects associated with the release of diesel fuel. Both gasoline and solvents are lighter with higher vapour pressure; therefore, they have a shorter residence time in the aquatic environment and have a lesser tendency for adsorption to sediments and suspended solids in the water column. To that end, the assessment of effects from a potential spill of fuel and hazardous materials due to a traffic accident at the access road bridge crossing of the Clearwater River focused on the release of diesel. The release of diesel into the Clearwater River was deemed by the preliminary hazard assessment to have the greatest likelihood and consequence in terms of potential adverse effects on aquatic and semi-aquatic biota among the fuel and chemical types that would be transported to or from the Project site. This assumption is based on the expected behaviour of diesel fuel in water and its potential for toxicity.

Diesel fuel is considered a non-persistent oil. It will lose 45% of its volume due to evaporation and dissolution within 48 hours of an accidental release, even in cold weather. Small diesel spills (i.e., 2 m^3 to 20 m^3) will usually evaporate and disperse within a day or less in the aquatic environment; thus, seldom is there any oil on the surface for responders to recover (NOAA 2023). With a specific gravity between 0.82 and 0.88, diesel fuel is lighter than water, so it is not possible for diesel to sink and accumulate on the sediment bed as pooled or free oil unless adsorption occurs with sediment. Diesel dispersed in the water column can adhere to fine-grained suspended sediments that can then settle out and deposit at the bottom. This process is more likely to occur where there is a presence of fine-grained sediment, which is not the case in the Clearwater River as it is fed by large lakes that effectively remove sediment from the water column. This process is not likely to result in measurable sediment contamination for small spills (NOAA 2023). The residual diesel would likely be completely degraded within one to two months; therefore, a complete surface water cleanup for small-scale diesel spills is not feasible.

Nevertheless, the unplanned release of diesel still poses a threat to aquatic organisms and particularly aquatic birds if they are exposed. Fish, aquatic invertebrates, and aquatic vegetation that come in direct contact with a diesel spill may be killed. However, small spills in open water are so rapidly diluted that fish kills are unlikely, unless the spill is in confined, shallow water.

The theoretical maximum size of 1 μm thick diesel fuel sheen that can be created by a 30 m^3 spill is 3 × 10^{+07} square metres (m^2); however, due to evaporation and dissolution of 45% of the spilled diesel, the size the slick is much smaller, particularly in a slow-moving surface waterbody. This is the case at the Project site, where the elevations of Patterson Lake (498.59 metres above sea level [masl]), Forrest Lake (498.34 masl), and Beet Lake (498.29 masl) are similar. The water flow rate in the Clearwater River between Forrest Lake and Beet Lake is approximately 2.3 m^3/s, and when considering the width of the connecting channel between the two lakes (i.e., 100 m to 400 m) and the depth of less than 2 m, the average water velocity is less than 1 cm/s. At this velocity, a spill would travel less than 1 km in a day. Considering the lifetime of diesel fuel, the diesel sheen would likely not travel beyond 2 km from the bridge on the access road. Thus, the affected areas would be limited to the northern end of Forrest Lake and Beet Lake Channel.

Emissions associated with evaporated diesel fuel would be transient in nature, localized, and likely dispersed rapidly by prevailing winds. Given this, wildlife and avian risks related to exposure to diesel components emitted to the atmosphere through volatilization are expected to be highly unlikely, with avoidance being the most likely outcome, though toxicity through the inhalation pathway is still possible (King et al. 2021). Exposure of workers and crews dispatched to respond to the accidental release could also be at risk of exposure via inhalation. Such risks would be mitigated through the use of risk management measures, such as personal protective equipment and adherence to appropriate safety protocols. These risk management measures would be described in the risk management processes and applicable documentation within NexGen's Integrated Management System, including spill response planning and procedures. These measures would be developed and implemented prior to the initiation of licensed Project activities.

Overall, the effects of a diesel spill under this scenario are transient, and some adverse effects to aquatic biota and potentially birds may occur within the affected area. Due to short-term exposure, irreversible population-level residual effects are not expected. Additionally, risks to accident responders are assumed to be mitigated through the use of risk management measures that would be described in emergency response planning documentation.

Based on the above, and in consideration of the effect scale described in Section 3.2, Table 3-2 the consequence of this accident and malfunction scenario is judged to be moderate, per the matrix shown in Figure 3-1.

8.0 BOUNDING SCENARIO 3: SOLVENT EXTRACTION FIRE OR EXPLOSION

This bounding scenario involves damage to equipment or vessels containing uranium-bearing solutions resulting in fire and release of uranium concentrate to the environment. A general description of the hypothetical event, hypothetical contaminants release characterization (e.g., contaminants, quantities), the probability of the scenario, and its potential effects on the human health and biophysical environment is provided below.

8.1 Scenario Description

This bounding scenario involves damage to the equipment or vessels containing uranium-bearing solutions due to human error or equipment failure, resulting in release to the environment, fire, and exposure of workers or members of the public to airborne uranium.

The Olympic Dam Mill (BHP Billiton) in Australia had three fires in the solvent extraction circuit in 1999, 2001, and 2002. These fires indicated flaws in design and operation of solvent extraction facilities erected prior to 2002 in relation to fire prevention and protection. For plants designed since 2002, fire safety issues have been closely examined and incorporated into appropriate low-risk designs. In light of the lessons learned from these fires, fire prevention and fire protection measures have been implemented in the new designs of the solvent extraction circuits. The BHP Billiton's 2003 Environment, Health and Safety Annual Report states:

> The hazard of an internal fire was not identified at any time during the design, construction and operation prior to the fire incidents. In rebuilding the solvent extraction plants, we incorporated new standards for fire prevention and fire protection as identified in the investigation of the 2001 fire. (BHP Billiton 2003)

Despite major improvements in the design and operation of the solvent extraction circuits, the history of fire indicates that a fire in the solvent extraction area is possible and is a plausible scenario. NexGen's design and operational procedures for the solvent extraction area at the Project site would include provisions for fire safety, specifically those related to the release of flammable materials, static electricity, and other sources of ignition as well as fire-fighting capabilities.

A fire that originates in the solvent extraction process area and involves loaded solvent could potentially release a large amount of uranium to the atmosphere. The fire that would follow a spill and exposure of spilled solvent to an ignition source could spread to other process plant areas if not extinguished rapidly. The accumulated organic vapour could also form an explosive vapour cloud.

The selected fire scenario was assessed through two separate scenarios:

1. Indoor fire in the solvent extraction building; and
2. Unconfined fire.

8.2 Release Characterization

The quantification of release followed the widely accepted methods proposed by the United States Department of Energy (USDOE) to estimate source terms (USDOE 1994). According to the USDOE, the airborne source term is typically estimated by the following five-component linear equation:

source term (kg/lb or kg/lb/s) = MAR (kg/lb or kg/lb/s) × DR × ARF × RF × LPF

where:

MAR = Material at risk is the amount of chemical or radionuclide available to be acted on by a given physical stress. For facilities, processes, and activities, the MAR is a value representing some maximum quantity of chemical present or reasonably anticipated for the process or structure being analyzed.

DR = Damage ratio is the fraction of the MAR affected by the initiating event(s) (i.e., accident-generated conditions). The DR is estimated based on engineering analysis of the response of structural materials, and materials of construction for containment to the type and level of stress or force generated by the event. These estimates often include a degree of conservatism due to simplification of phenomena to obtain a useable model.

ARF = Airborne release fraction, or airborne release rate for continuous release, is the coefficient used to estimate the amount of a chemical released or suspended in air as an aerosol or gas and thus available for transport due to physical stresses from a specific accident.

RF = Respirable fraction is the fraction of airborne chemical particles that can be transported through air and inhaled into the human respiratory system. The RF is commonly assumed to include particles of 10 µm aerodynamic equivalent diameter or less. Other definitions of "respirable particles" have been presented by various groups at different times, but for the present purposes, 10 µm and smaller particles were considered respirable. For gaseous chemicals, the RF is 1.

LPF = Leak path factor is the fraction of the chemical or radionuclide transported through some confinement deposition or filtration mechanism. There can be many LPFs for some accident conditions (e.g., the fraction transported from the package, such as a shipping container, to the enclosure; the fraction leaked from the enclosure to the operating area around the enclosure or room; the fraction leaked from the room to the building–atmosphere interface).

Background information on source term parameters for the solvent fire scenario is summarized in Table 8-1, and estimates for each parameter are developed below, as well as the estimated airborne source term value.

<u>MAR:</u>

The total volume of the uranium-rich solvent is 100 m^3, which will burn during a fire. The fire is assumed to be unmitigated (not extinguished). The US Nuclear Regulatory Commission (USNRC 2004) Fire Dynamics Tools were used to calculate the Fire Duration, T_{FD}, for a liquid pool fire:

$$T_{FD} = 4V/\pi D^2 v$$

where:

V = volume of solvent available for burning: 100,000 L

D = solvent spill or exposure area diameter; in the worst-case scenario, the entire ground floor area could be involved in a fire (i.e., 20 m by 20 m)

v = regression rate (i.e., liquid pool burning rate) based on solvent properties (USNRC 2004) of 0.05 $L/m^2/s$ for the solvent

The theoretical burning rate will be 400 × 0.05 = 20 L/s and the fire duration was calculated as 83 min. The maximum uranium concentration in the loaded solvent is 8 g/L (8 kg/m^3) and the density of this solution is approximately 1,500 kg/m^3. Therefore, MAR will be calculated as:

$$MAR = 20 \text{ L} \times 8 \text{ g/L} = 160 \text{ g/L} = 0.16 \text{ kg/s}$$

<u>DR:</u>

A constant burn rate was assumed with no credit for initial fire build-up time. In practice, the fire duration may be less because the fire would be extinguished as part of the fire response. If it is assumed that the fire would last one hour, the DR would be 0.45. Conservatively, the fire duration limit of one hour was not considered and the DR was assumed to be 1. Also, the effects of oxygen availability on the burning rate were not considered, which is a conservative assumption because oxygen limitation is often a factor that governs compartment fire behaviour. If oxygen starvation becomes a limiting factor in burning rate (e.g., fire in enclosed or congested areas), the burning rate could be less.

ARF:

From the information presented in Table 8-1, the ARF is assumed to be 0.1 based on the ARF data published by USDOE (USDOE 1994).

RF:

It was assumed that all the aerosols produced in the fire are respirable; therefore, the RF = 1 (Table 8-1).

LPF for confined fire in the building:

During a fire, natural or mechanical ventilation would be enhanced by the chimney effect of the fire. The building ventilation rate during a fire can be estimated based on the volume of air drawn into the building to support the fire. The volume of air needed to support a burning rate of 20 L/s kerosene is approximately 220 m^3/s. Assuming 14 air changes per hour (typical of a closed building during fire), maximum air flow through the building is about 27 m^3/s. This volume of air can only support a burning rate of 2.5 L/s of solvent. The limiting factor in the rate of fire is the availability of oxygen. Thus, the LPF would be 2.5/20 = 0.125.

The airborne source term is calculated as:

> 0.16 kg/s × 1 × 0.1 × 1 × 0.125 = 0.002 kg/s uranium = 0.0024 kg/s (0.005 lb/s) U_3O_8 (uranium concentrate)

LPF for unconfined fire:

If the building envelope is breached, then the calculations for the previous scenario are still valid; however, the LPF would be 1. Therefore, the source term for this scenario would be 0.016 kg/s uranium or 0.0189 kg/s U_3O_8 (uranium concentrate).

Since the atmospheric benchmarks (Protective Action Criteria) are defined for 1-hour exposure and the fire can potentially burn for more than an hour, it was conservatively assumed for the source term that the above amount is released in one hour.

Table 8-1: Airborne Release Fraction and Respirable Fraction Values for Various Fire Scenarios

Liquid Fire Parameter Values – Summary Values									
Type of Stress	***Material***	**Conditions**			**Median ARF**	**Bounding ARF**	**Median RF**	**Bounding RF**	**Comments**
Fire	Organic combustible liquids	Quiescent burning	Small surface area or Small solvent layer over large pool that burns to self-extinguishment	n/a	6×10^{-03}	1×10^{-02}	1	1	n/a
Fire	Organic combustible liquids	Vigorous boil-off	Large surface area or pool or Solvent layer burning over limited aqueous layer with sufficient turbulence to disrupt the bulk of the aqueous layer	Does not burn to complete dryness	n/a	3×10^{-02}	n/a	1	Does not involve burning to complete dryness
Fire	Organic combustible liquids	Vigorous boil-off	Large surface area	Burns to complete dryness or burning solvent over aqueous phase burning to complete dryness for both phases	1×10^{-02}	1×10^{-01}	1	1	Typically an external outside heat source
Fire	Organic combustible liquids	Aqueous solution or air-dried salts	Porous absorbing surface (e.g., cracks, pits, soil, sand)	n/a	n/a	5×10^{-03}	n/a	0.4	Based on gasoline fire
Fire	Organic combustible liquids	Aqueous Solution or air-dried salts	Heat conducting surface (e.g., metal)	n/a	n/a	2×10^{-01}	n/a	0.3	Based on gasoline fire

Source: USDOE 1994.
Note: Quiescent burning = relatively undisturbed liquid surface (opposite of vigorous boil-off), while vigorous boil-off = strongly disturbed liquid surface (opposite of quiescent burning).
ARF = airborne release fraction; RF = respirable fraction.
n/a = data not provided in original source material.

8.3 Assessment of Probability

The following mitigating measures would be in place to reduce the probability of a release and potential for fire:

- concrete mixer-settler to facilitate visual leak inspection;
- emergency organic dump tanks and fast-acting valves to transfer solvent extraction mixer-settlers in case of fire;
- fire detection systems;
- fire safety plan and firefighting systems;
- regular and preventive inspections, testing, and maintenance programs;
- emergency response plan;
- full containment of process plant building or mixer-settler area; and
- ambient air monitoring.

Uranium bearing solution would be stored or processed in mixer-settler or storage tanks and transported through piping systems. A spill of these solutions could occur as a result of the following events:

- overflow of storage or process vessels;
- leaks or rupture in storage tanks and process vessels;
- failure of valves or other piping system components;
- failure of the pumps; and
- failure of other process components such as screens and filters.

Average probabilities of failures for different components in the solvent extraction building were based on the information provided by the Center for Chemical Process Safety of the American Institute of Chemical Engineers (AIChE-CCPS 1989) and are shown in Table 8-2.

Table 8-2: Average Failure Probability for Solvent Extraction Process Equipment

Equipment with Potential for a Major Spill or Fire	Failure Rate (All Modes; Per Year)
Vessels (i.e., atmospheric and metallic; assuming 2 major vessels containing uranium reach solvents)	10^{-3}
Piping (i.e., metal; straight section and connection; assuming 100 sections)	10^{-4} per item
Pumps (e.g., motor driver and pressure-centrifugal; assuming 5 pumps)	10^{-2}

Source: Center for Chemical Process Safety (AIChE-CCPS 1989).

If it is assumed that the plant is in service 350 days per year for eight hours per day (i.e., 2,800 hours per year), this would result in a failure frequency of 6×10^{-02} per year under this scenario.

$$10^{-3} \times 2 + 10^{-4} \times 100 + 10^{-2} \times 5 = 6 \times 10^{-02} \text{ per year}$$

Less than 10% of the releases would result in a fire (AIChE-CCPS1989); therefore, the probability of fire would be 6×10^{-02} x 0.1 = 6×10^{-03} per year.

The US Nuclear Regulatory Commission reported that the frequency of a major solvent extraction fire occurring at a uranium process plant was in the range of 4×10^{-04} to 1×10^{-02} per year (USNRC 1980). The above calculated value is within the range provided by the USNRC.

According to the probability ratings described in Section 3.2, Table 3-1, the probability that this accident and malfunction scenario would occur is unlikely.

8.4 Assessment of Potential Effects

To estimate the consequence of the potential effects associated with Bounding Scenario 3, the Areal Locations of Hazardous Atmospheres (ALOHA) model was used. ALOHA is a standalone software application developed and supported by the Emergency Response Division, a division within the National Oceanic and Atmospheric Administration (NOAA) in collaboration with the Office of Emergency Management of the Environmental Protection Agency. The primary purpose of ALOHA is to provide estimates of the spatial extent of some common hazards associated with chemical spills or releases to emergency response personnel (NOAA 2013).

As mentioned in Section 8.2, Release Characterization, a fire that originates in the solvent extraction building and involves loaded solvent could release uranium to the atmosphere. This fire event was assessed through two separate scenarios:

1. a contained, indoor fire in the solvent extraction building; and
2. an unconfined fire.

As noted in Section 5.1, although uranium is a radioactive substance, for natural and depleted uranium, the risks from intake of uranium are related to its chemical toxicity, and the potential for such effects is the basis of the assessment for this scenario.

8.4.1 Confined Indoor Fire

This scenario assumes that the fire is confined inside the building and that the building envelope remains intact. The fire could involve the loaded solvent directly, such as a fire in the loaded solvent vessels or from spilled loaded solvent.

The design of the process and the operational procedures minimize the probability of ignition leading to a fire. For example, all switches and motor controls would be explosion proof and designed not to create a source of ignition, and welding would not be permitted in the area except under extremely controlled conditions, including the use of a fire watch during and after the job in accordance with the required work permit. To the extent that the building envelope remains intact after the unlikely initiating event, it may act as containment for the release scenario.

The source term calculated in Section 8.2 was 2.0 g/s uranium or 2.4 g/s uranium concentrate. The air concentration versus distance was calculated and compared with the benchmarks provided in Section 5.0, Chemical, Occupational, and Radiological Benchmarks, for the following two weather conditions:

- W1: worst-case weather conditions: 95th percentile wind speed and Pasquill stability class F. Stability class F is a stable atmospheric condition that occurs during nighttime, overcast conditions, with a wind speed of less than 2 m/s, typically 1.5 m/s. Thus, wind speed of 1.5 m/s and stability class F were selected as the worst-case condition for dispersion of released materials (NOAA 2019).
- W2: typical weather conditions: average wind speed and Pasquill stability class D. Stability class D is a neutral atmospheric condition that occurs during slight to moderate daytime solar intensity and thin nighttime overcast conditions, with a wind speed of around 5.0 m/s or slightly higher. This represents the average condition for dispersion of released materials (NOAA 2019). The wind rose in the area of the Project indicates that the most frequent wind speed is approximately 5 m/s. Thus, 5 m/s was selected as the typical wind speed.

The probability of W1 weather condition is less than 5% of the probability of weather condition W2.

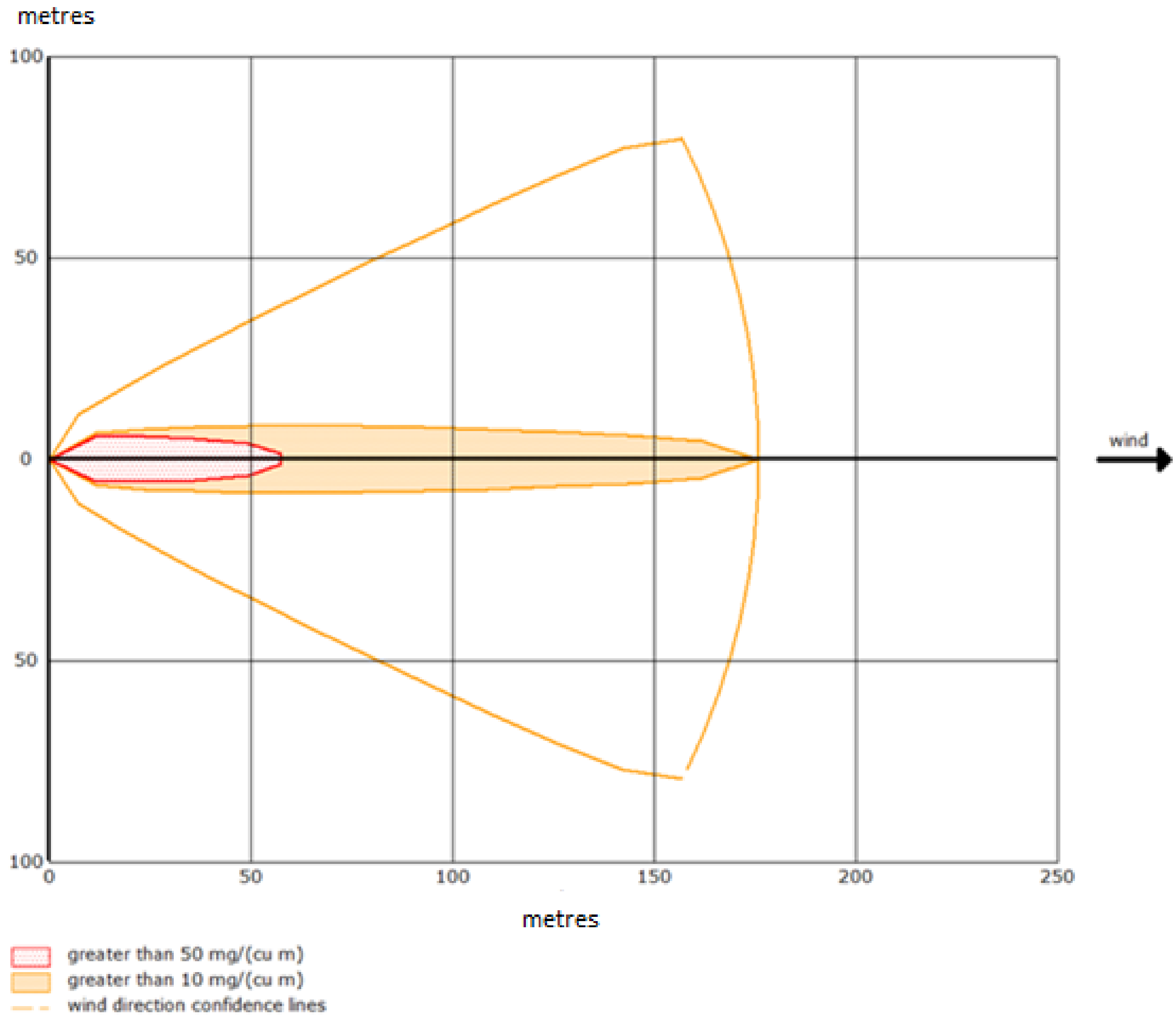
The results of the modelling of uranium concentration in air down-wind or the fire are summarized in Table 8-3. Figure 8-1 shows the results for W1 weather condition, and Figure 8-2 shows the results for W2 weather condition.

Table 8-3: Results of Uranium Fire Release Modelling for the Contained, Indoor Fire

Weather Condition	Distance to ERPG-3 (m)	Distance to ERPG-2 (m)
W1	58	176
W2	30	68

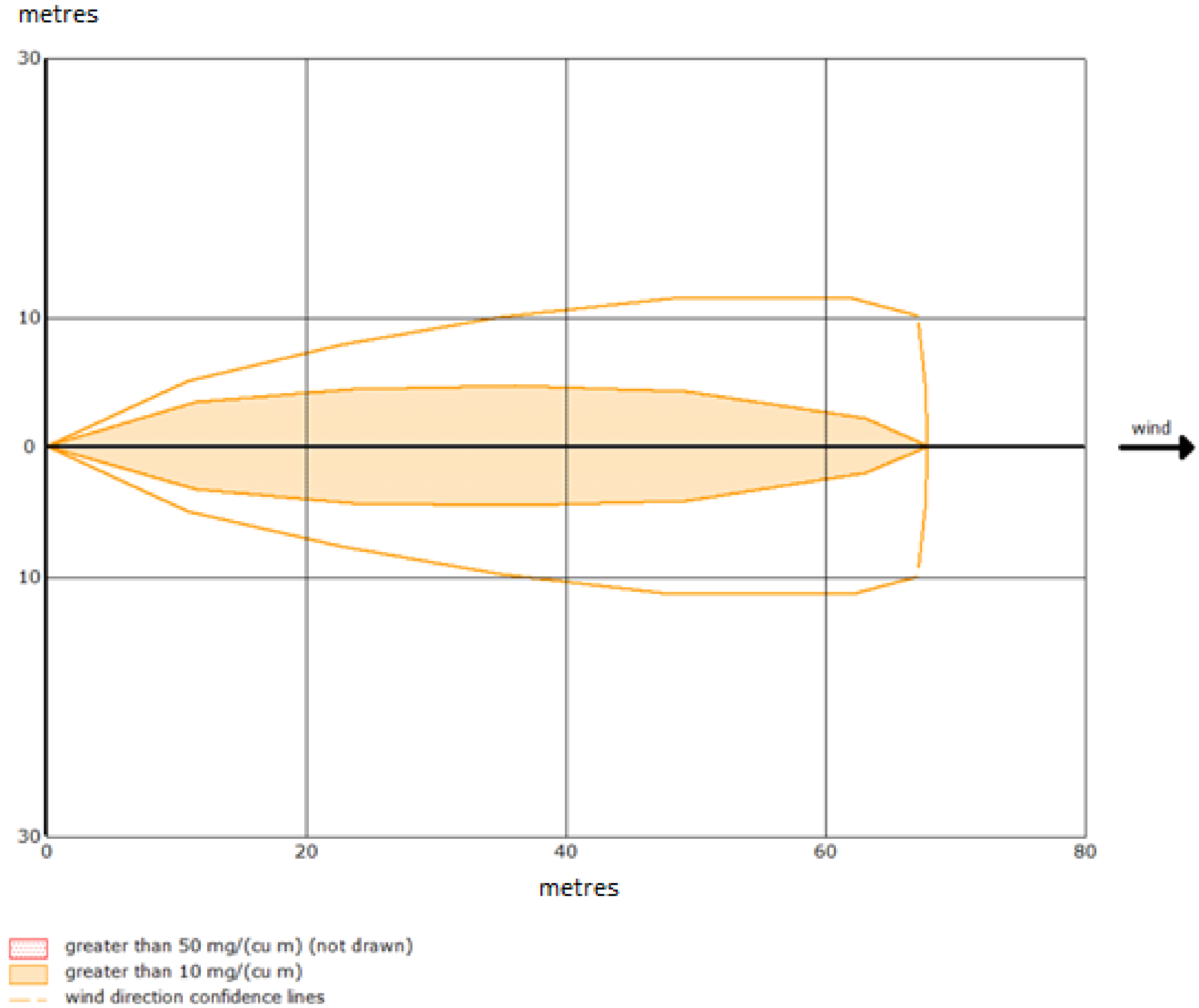
ERPG = Emergency Response Planning Guideline; W1 = worst-case weather conditions; W2 = typical weather conditions.

Figure 8-1: Concentration of Uranium in Air for a Confined Indoor Fire for Worst-Case Weather Conditions



Note: The ERPG-2 for uranium concentrate is 10 mg/m^3; ERPG-3 for uranium concentrate is 50 mg/m^3.
cu m = cubic metre; ERPG = Emergency Response Planning Guideline.

Figure 8-2: Concentration of Uranium in Air for a Confined Indoor Fire for Typical Weather Conditions



Note: The ERPG-2 for uranium concentrate is 10 mg/m³; ERPG-3 for uranium concentrate is 50 mg/m³.
Cu m = cubic metre; ERPG = Emergency Response Planning Guideline.

As highlighted in Section 5.0, the most frequently used benchmark for emergency release scenarios is ERPG-2. The results indicate that the ERPG-2 benchmark of 10 mg/m³ would be reached (i.e., the uranium levels would be below the threshold beyond this distance) at 176 m from the assumed source of the release (i.e., the solvent extraction building) for weather condition W1, and at 68 m for weather condition W2 representing the more likely weather condition.

It should be noted that the release during a fire is short-term (i.e., less than a few hours in duration); therefore, surface accumulation, and extended exposure to vegetation and wildlife, is not expected.

Based on the above, and in consideration of the consequence scale described in Section 3.2, Table 3-2, the consequence of the potential effects of this scenario are rated minor to moderate within a relatively short distance from the release.

8.4.2 Unconfined Fire

For an unconfined fire, where it is assumed the building envelope has been breached, the calculations described for the contained, indoor file remain valid; however, the LPF would be 1 and the release rate, as calculated in Section 8.2, would be 16 g/s uranium or 18.9 g/s uranium concentrate. The air concentrations versus distance were modelled using these release rates for the W1 and W2 weather conditions and compared with the benchmarks provided.

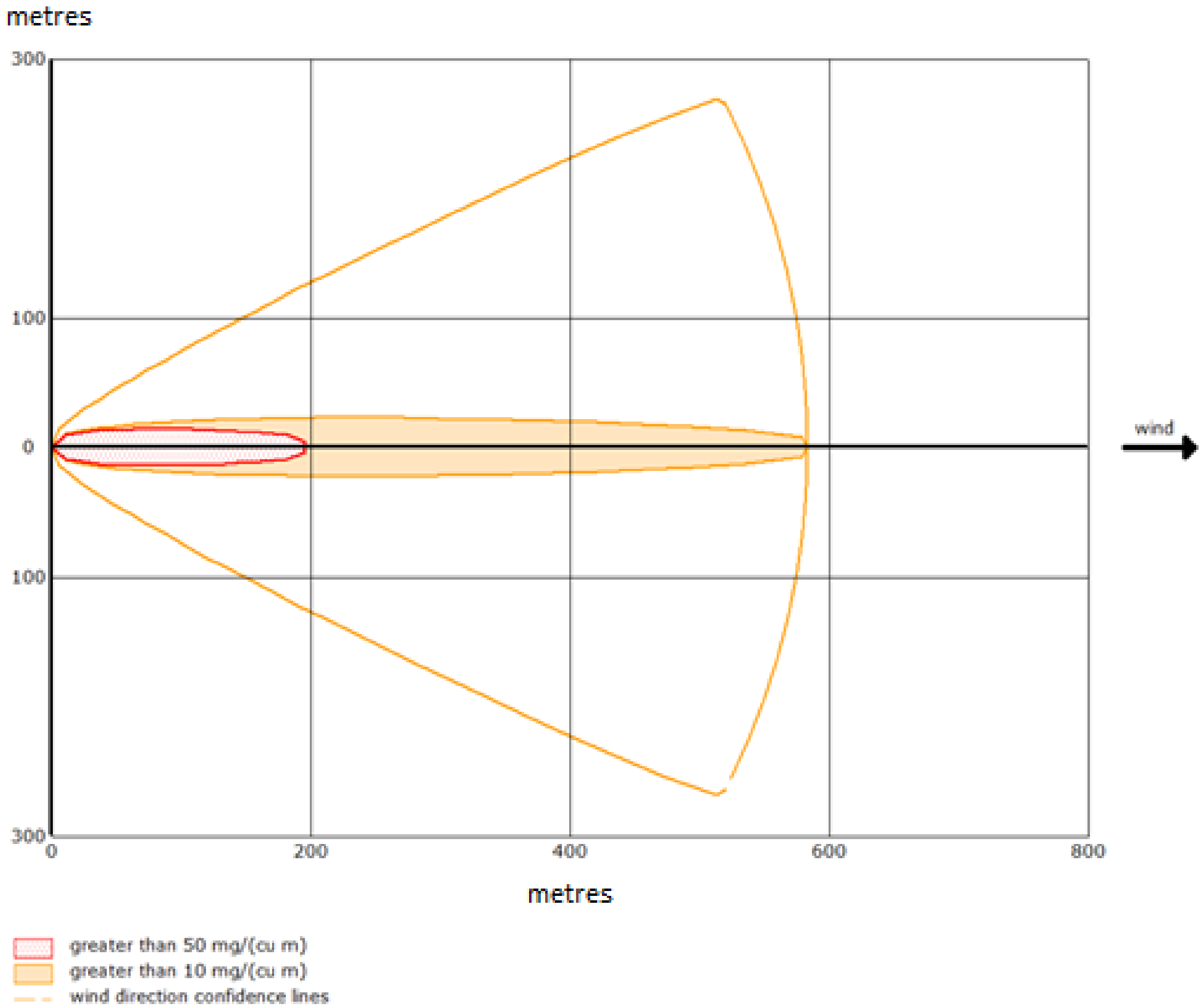
The results of the modelling of uranium concentration in air down-wind of the fire are summarized in Table 8-4. Figure 8-3 shows the results for W1 weather condition, and Figure 8-4 shows the results for W2 weather condition.

Table 8-4: Results of Uranium Fire Release Modelling for Unconfined Fire

Weather Condition	Distance to ERPG-3 (m)	Distance to ERPG-2 (m)
W1	196	584
W2	91	214

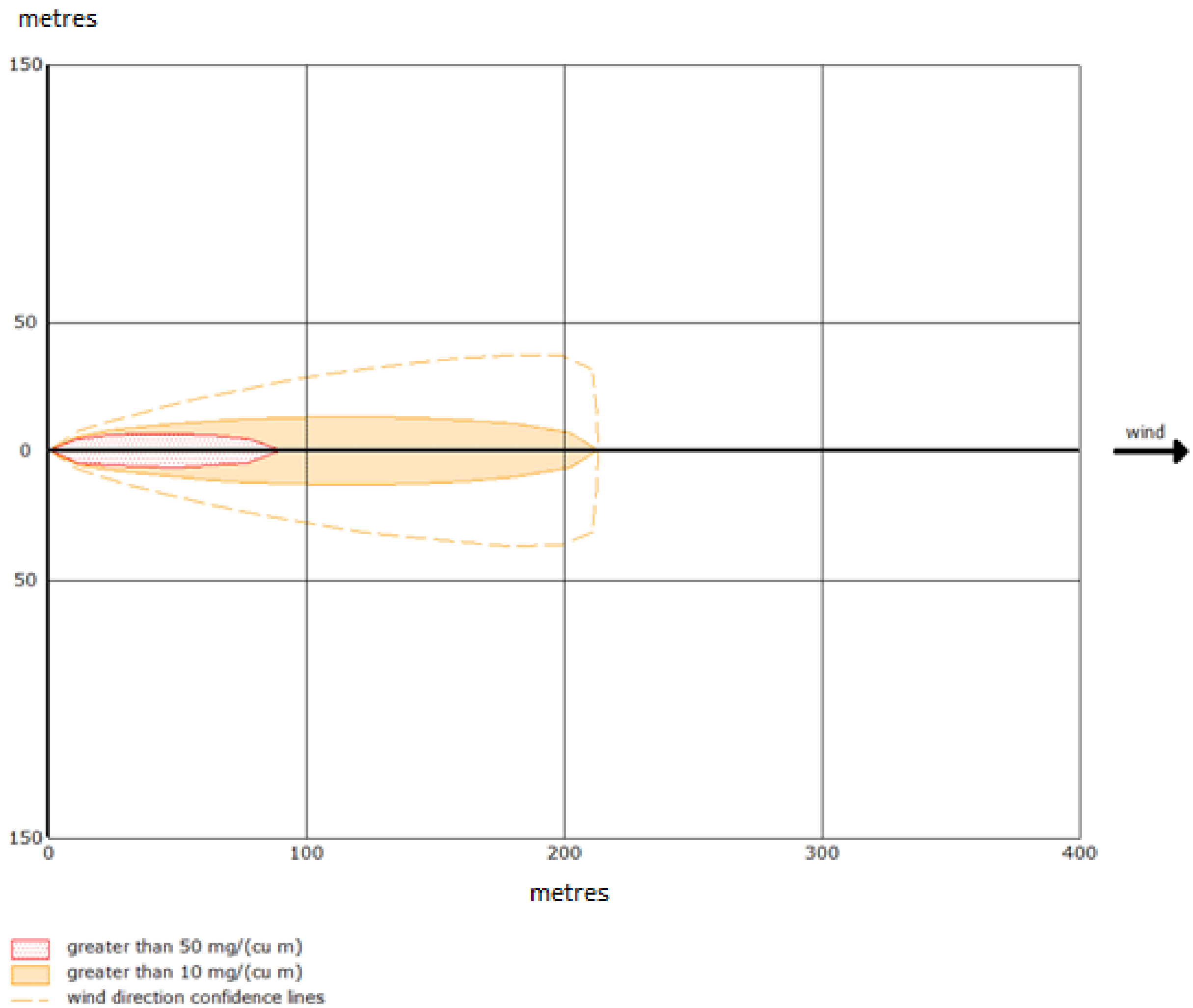
ERPG = Emergency Response Planning Guideline; W1 = worst-case weather conditions; W2 = typical weather conditions.

Figure 8-3: Concentration of Uranium in Air for Unconfined Fire for Worst-Case Weather Conditions



Note: The ERPG-2 for uranium concentrate is 10 mg/m[3]; ERPG-3 for uranium concentrate is 50 Mg/m[3].
cu m = cubic metre; ERPG = Emergency Response Planning Guideline.

Figure 8-4: Concentration of Uranium in Air for Unconfined Fire for Typical Weather Conditions



Note: The ERPG-2 for uranium concentrate is 10 mg/m^3; ERPG-3 for uranium concentrate is 50 Mg/m^3.
cu m = cubic metre; ERPG = Emergency Response Planning Guideline.

As per Section 5.1, the most frequently used benchmark for emergency release scenarios is ERPG-2. The results indicate that the ERPG-2 benchmark would be reached (i.e., the uranium levels would be below the threshold beyond this distance) at 584 m from the source of the release (i.e., the solvent extraction building) for weather condition W1, and at 214 m for weather condition W2 representing the more likely weather condition.

Based on the above, and in consideration of the effect scale described in Section 3.2, Table 3-2, the consequence of the potential effects of this scenario is rated minor to moderate within a relatively short distance from the release.

9.0 BOUNDING SCENARIO 4: TAILINGS TRANSFER PIPE OR PUMP FAILURE

This bounding scenario involves the release of tailings from pump and pipes at the surface. A general description of the hypothetical event, hypothetical contaminants release characterization (e.g., contaminants, quantities), the probability of the scenario, and its potential effects on the human health and biophysical environment is provided below.

9.1 Scenario Description

In the process plant, ore would be leached with sulphuric acid and hydrogen peroxide through series of leach tanks in the leaching circuit. The leached slurry would be transferred to the counter current decantation circuit where the uranium bearing solution is separated from the leached residue. Uranium is concentrated in solution as it flows through the series of thickener tanks in the opposite direction of the solids residue. The tailings slurry from the counter current decantation circuit that contains the solids residue would be transferred to the tailings neutralization area where it would be neutralized using lime followed by a dewatering step using a belt filter. The dewatered tailings would be transported to the paste plant and blended with a binder. This product would primarily used for making cemented paste backfill for placement in mined stopes. Another portion of the neutralized tailings, along with gypsum and effluent precipitates, would be pumped to and mixed in the paste backfill plant. This combined paste product would then be transferred underground through a piping system and placed into the UGTMF.

A breach in the piping down the mine shaft and underground workings would result in the release of paste tailings in the mine. This may result in occupational exposure; however, environmental exposures, including those via the groundwater pathways, are highly unlikely. Thus, only the release of tailings from pump and pipes near the paste plant is considered in this assessment. The catastrophic failure of the tailings transfer pipe near the paste plant presents the bounding effect for this scenario. If the tailings are released outside the paste plant, the release may cause soil and groundwater contamination. There is a potential for surface water contamination if the released materials reach the lake.

The tailings pipe transport information is summarized in Table 9-1.

Table 9-1: Tailings Transport Information

Parameter	Value
Transfer rate of tailings	To mine stopes: 59.7 m^3/h (max) To UGTMF: 73.5 m^3/h (max)
Tailings density	To mine stopes: 1,690 kg/m^3 (max) To UGTMF: 1,537 kg/m^3 (max)

Parameter	Value
Tailings transfer pipe length	Surface borehole casing = 1,444 m Inter-level borehole casing = 478 m Level piping - high pressure = 850 m Level piping - mid pressure = 6,840 m Level piping - low pressure = 5,288 m Stope piping = 9,059 m
Activity concentration of the main radionuclide (e.g., radium-226) in tailings	Radium-226 (s) = 390 Bq/g in backfill stopes Radium-226 (s) = 185 Bq/g in UGTMF tailings

Source: NexGen 2021.
UGTMF = underground tailings management facility; s = soluble; Bq/g = becquerels per gram.

The area in the vicinity of the solvent extraction and process plant buildings is considered the most probable location for surface release of tailings under this scenario. In the worst-case situation, the released tailings would flow north, away from the developed footprint of the site. For the assessment, it was conservatively assumed that the surface water management system would not collect any portion of the released tailings, and therefore, the volume of mixed tailings solids and untreated tailings supernatant would flow unmitigated to the north. The distance between the edge of the facility and Patterson Lake shoreline is more than 300 m with a slope ranging between 2% and 5%.

9.2 Release Characterization

The transport of radioactivity (radium-226) within the pipes is calculated as follows:

To mine stopes: 59.7 m^3/h x 1,690 kg/m^3 × 390,000 Bq/kg = 39.3 GBq/h; and

To UGTMF: 73.5 m^3/h × 1,537 kg/m^3 × 185,000 Bq/kg = 20.9 GBq/h.

The larger value of 39.3 GBq/h was considered for this assessment.

A major release from the piping system would result in the sudden drop in flow and pressure within the pipe that would be detected by the automated control system. The process control allows for the isolation of the failed portion of the piping system. With this in mind, it is expected that the contents of the isolated section of piping would be released within a few minutes and therefore a 15-minute release scenario is reasonable and conservative. Assuming a 15-minute release period, the amount of release would be 15/60 h × 59.7 m^3/h = 14.93 m^3, which would contain 9.83 GBq of radium-226. Based on the residual uranium content, the amount of uranium concentrate released under this scenario would be 3.8 kg. The potential exposure to alpha radiation from radon progeny and long-lived radioactive dust is limited to workers, which is outside the scope of this assessment. The dust release associated with contaminated soil is only a concern when the soil is dry. In this condition, the entrained soil particles can be mobilized due to wind erosion resulting in dust, and possibly exposure. Public exposure due to contaminated dust is only possible if the material remains in place after it has dried. Emergency response to a tailings release would be swift, so such conditions would not likely prevail, and therefore public exposure is highly unlikely and was not addressed in this assessment.

9.3 Assessment of Probability

The piping system would be designed and constructed in compliance with process piping code ASME B31.3. The entire system would be regularly inspected and tested for defects. A maintenance program would be in place to confirm the mechanical integrity of the process components.

According to the Center for Chemical Process Safety of the American Institute of Chemical Engineers (AIChE CCPS 1989), the probability of a failure of a piping system similar to that of the Project is approximately 2×10^{-02} per year.

According to the probability ratings described in Section 3.2, Table 3-1, the probability that this accident and malfunction scenario would occur is likely.

9.4 Assessment of Potential Effects

The transport of the liquid materials released to the surface is affected by several factors including:

- the slope of the ground;
- permeability of the ground and rate of penetration into the ground; and
- the volume of the release.

Landforms such as drumlins, lakes, wetlands, rivers, and muskegs are common in the area of the proposed Project. Elevations in the region range from 583 masl at the crest of major drumlins to 480 masl (i.e., surface elevation) for some of the lowland lakes. The surface elevation of Patterson Lake is approximately 499 masl.

The proposed Project location is dominated by sandstone; bedrock outcroppings are rare but are known to exist in areas to the eastern half of the exploration lease. The organic topsoil layer at the surface is very thin. The sandy surficial material hydraulic conductivity ranges from 1×10^{-06} m/s to 7×10^{-05} m/s (NexGen 2021). For similar soil characteristics, Simmons and Keller (2005) conducted a series of experiments contracted by the USDOE and showed that the penetration rate of spilled liquid into soil depends on slope, soil permeability, soil wettability, surface roughness, and initial moisture content of soil. In this study, experimental results were fitted into the Green-Ampt equation (Simmons and Keller, 2005). This equation relates the vertical infiltration rate with soil permeability, pressure head, and capillary suction. The results show that the penetration rates ranged from 0.07 cm/s to 0.1 cm/s for silt loam and sandy soils (i.e., with air porosity of 30% to 45%) with slopes of 2.4% and 4.8%. This experimental condition is similar to the surface conditions around the Project site. In most experiments, the final moisture content of 60% was reached after the front head of the spills disappeared.

Assuming the water content of the soil increases from 20% to 60% for a maximum tailings release of 14.93 m^3 in this scenario (i.e., 9.83 GBq of radium-226), approximately 37.3 m^3 of the soil could be contaminated, as calculated below:

0.6 - 0.2 = 0.4 (40% of additional water)

14.93/0.4 = 37.3 m^3 of soil

If the soil was completely saturated following the spill, the maximum slurry release of 14.93 m^3 would result in 18.7 m^3 of contaminated–soil:

1 - 0.2 = 0.8 (80% of additional water)

14.93/0.8 = 18.7 m^3 of soil

If the penetration lasted 15 min, the maximum depth of contamination would be 90 cm, assuming a penetration rate of 0.1 cm/s:

depth = 900 s × 0.1 cm/s = 90 cm = 0.9 m

For a penetration rate of 0.07 cm/s, the depth of contamination would be 63 cm:

depth = 900 s × 0.07 cm/s = 63 cm = 0.63 m

The surface area potentially affected by the spill based on the different saturation conditions and penetration rates is estimated to range from 20.8 m^2 to 59.2 m^2, as calculated below:

area = 37.3/0.9 = 41.4 m^2 (i.e., 60% saturation and depth of 0.9 m)

area = 18.7/0.63 = 29.7 m^2 (i.e., 100% saturation and depth of 0.63 m)

area = 37.3/0.63 = 59.2 m^2 (i.e., 60% saturation and depth of 0.63 m)

area = 18.7/0.9 = 20.8 m^2 (i.e., 100% saturation and depth of 0.9 m)

For any of these combinations, a relatively small area would be expected to be affected in comparison to the distance to the Patterson Lake. Thus, the possibility of the release reaching Patterson Lake is improbable, and therefore, no effects on the lake from the accidental release of tailings to surface water would be expected. The maximum area of 59.2 m^2 is equivalent to an oval (since the release is on a slope) with a major axis of 12.2 m and minor axis of 6.1 m. For context, the distance from the hypothetical accident location to Patterson Lake is on the order of 300 m. Although enhanced runoff that may be associated with wet weather events could influence this evaluation, any potential effects on Patterson Lake are likely to be minimal, given the small size of the affected area.

Shallow groundwater flow is generally affected by local-scale topography, which is representative of conditions at the site. Shallow groundwater flow movement is from the topographic high located south of the proposed mine and process plant development in a northerly direction towards Patterson Lake. There is potential for groundwater contamination within the predicted area of soil contamination under this scenario, and therefore, there is the potential for groundwater-associated transport to Patterson Lake.

The velocity of groundwater at this location can be calculated as follows:

$$V = K \times I/n$$

where:

V = groundwater velocity

K = horizontal hydraulic conductivity

I = horizontal hydraulic gradient

n = effective porosity

As described above, k = 1×10^{-06} m/s, and the hydraulic gradient was assumed to be the maximum of the surface slope = 0.058. The effective porosity was assumed at 0.45.

In this case:

$$V = 1 \times 10^{-06}\ \text{m/s} \times 0.058/(0.45) = 1.1 \times 10^{-07}\ \text{m/s.}$$

Assuming the above velocity, it is estimated that it would take the groundwater approximately 85 years to reach Patterson Lake. Implementation of the spill response plan and associated cleanup would be expected to occur over a time period of days, or at maximum weeks, following the incident and therefore no material migration of contaminated groundwater outside the immediately affected area would be expected. Thus, the contamination of soil and shallow groundwater is expected to be contained within a small area near the release location, and no contamination would be expected to reach Patterson Lake along the groundwater pathway, because the contaminated soil would be removed during spill clean-up.

During the winter months, when the soil is frozen, no penetration of spilled tailings supernatant into the soil is expected. Therefore, no soil or groundwater contamination is expected; however, it is conceivable that the materials could spread over a larger surface area, and therefore from a practical perspective, the cleanup may be more extensive and take longer.

Based on the above, and in consideration of the effect scale described in Section 3.2, Table 3-2, the consequence of the potential effects of this scenario is rated minor.

10.0 BOUNDING SCENARIO 5: UNTREATED EFFLUENT TRANSFER PIPE FAILURE

This bounding scenario involves the release of untreated effluent from the piping system connecting the first stage reactor tanks, first stage clarifier, second stage reactor tanks, and the effluent treatment system. The distance between the piping and the Patterson Lake shoreline is variable, but is on the order of a few hundred meters with a slope between 1% and 5%. A general description of the hypothetical event, hypothetical contaminants release characterization (e.g., contaminants, quantities), the probability of the scenario, and its potential effects on the human health and biophysical environment are provided in the following subsections.

10.1 Scenario Description

Site contact water (e.g., process plant waste water, mine water, mineralized site runoff) would be treated and tested as required prior to release to the environment. As part of this process, contact water requiring treatment would be collected and stored in a settling pond prior to treatment. The settling pond would be double-lined with 80 mm high density polyethylene (HDPE) liner for primary and secondary containment.

The current design for the ETP includes a two-stage chemical (lime neutralization) treatment process to remove metals followed by a pH adjustment process prior to pumping to the treated effluent water tank. The treatment process would consist of first and second stages of treatments, with all stages containing two reactor tanks and a clarifier and a pH adjustment tank. Further details of the treatment technology are provided in EIS Section 4.0, Project Alternatives. As noted in that subsection, the ETP design is subject to further refinement as part of licensing for the Project.

Treated effluent from the effluent water tank would report to one of four monitoring ponds which would allow composite sample to be collected while the pond is filled. When the pond is full, the composite sample would be analyzed, and assay results would be examined based on effluent release limits. Once the quality of the water is within specification of the limits, it can be released to Patterson Lake. Any off-specification treated effluent water would return to settling for re-processing.

Table 10-1 summarizes the characteristic of the ETP and includes treatment capacity, piping size to and from the plant, estimated radium loading entering the plant, and fluid density assumption.

A breach in the untreated effluent piping at the surface is considered in this scenario. The catastrophic failure of the transfer pipe at the surface represents the bounding effect for this scenario. Failure of the piping between the process plant and the ETP would result in a release inside the mill building or outside the mill building within the mill terrace. The specific scenario considers a release of untreated effluent to surface outside the mill building.

Table 10-1: Untreated Effluent Transfer Information

Item	Value
Effluent treatment capacity (feed)	275 m^3/h to 600 m^3/h
Effluent pipe size (diameter) to and from the ETP	12" from settling pond to ETP
Maximum activity concentration of the main radionuclide (e.g., radium-226) in untreated effluent	Radium-226 (aq) = 600 Bq/L based on the untreated effluent pumped to ETP
Assumed density of effluent	1,000 kg/m^3

Source: NexGen 2021.
aq = aqueous; Bq/L = becquerels per litre; ETP = effluent treatment plant.

10.2 Release Characterization

The transport of radioactivity (radium-226) within the pipe is calculated as follows:

$$600 \text{ m}^3/\text{h} \times 1{,}000 \text{ kg/m}^3 \times 600 \text{ Bq/L} = 360 \text{ mega-becquerels per hour (MBq/h)}$$

As discussed in Section 9.2, it is expected the content of the isolated section releases within a few minutes and therefore a 15-minute release scenario is reasonable and conservative. Assuming a 15-minute release, the amount of release would be 15/60 h × 600 m^3/h = 150 m^3, which would contain 90 MBq of radium-226. Based on the residual uranium content, the amount of uranium concentrate released would be 7.6 kg.

10.3 Assessment of Probability

The piping systems would be designed and constructed in compliance with process piping code ASME B31.3. The entire system would be regularly inspected and tested for defects. A maintenance program would be in place to confirm the mechanical integrity of the process components.

According to the Center for Chemical Process Safety (AIChE-CCPS 1989), the failure of a piping system similar to that of the Project is approximately 2×10^{-02} per year.

According to the probability ratings described in Section 3.2, Table 3-1, the probability that this accident and malfunction scenario would occur is likely.

10.4 Assessment of Potential Effects

The assessment of this scenario is similar to that of Bounding Scenario 4.

Assuming the water content of the soil increases from 20% to 60% in the affected area during this event, for the maximum untreated effluent release of 150 m^3, approximately 375 m^3 of soil would be contaminated along the release pathway under this scenario, as calculated below:

0.6 - 0.2 = 0.4 (40% of additional water added to the soil)

150 m^3/0.4 = 375 m^3 of soil

It is conservatively assumed that no untreated effluent would be contained within the site surface water management system in this event.

If the soil is completely saturated following the spill, for the maximum untreated effluent release of 150 m^3, 187.5 m^3 of soil would potentially be contaminated along the release pathway, as calculated below:

1 – 0.2 = 0.8 (80% of additional water added to the soil)

150 m^3/0.8 = 187.5 m^3 of soil

If the penetration lasts 15 minutes, the maximum depth of contamination would be 90 cm, assuming a penetration rate of 0.1 cm/s:

depth = 900 s × 0.1 cm/s = 90 cm = 0.9 m

For a penetration rate of 0.07 cm/s, the depth of contamination would be 63 cm:

depth = 900 s × 0.07 cm/s = 63 cm = 0.63 m

The surface area affected by the spill based on the different saturation conditions and penetration rates is estimated to range from 208 m^2 to 595 m^2, as calculated below:

area = 375 m^3/0.9 m = 417 m^2 (i.e., 60% saturation and penetration depth of 0.9 m)

area = 187.5 m^3/0.63 m = 298 m^2 (i.e., 100% saturation and penetration depth of 0.63 m)

area = 375 m^3/0.63 m = 595 m^2 (i.e., 60% saturation and penetration depth of 0.63 m)

area = 187.5 m^3/0.9 m = 208 m^2 (i.e., 100% saturation and depth of 0.9 m)

For any of these combinations, a relatively small area is expected to be affected in comparison to the distance to the Patterson Lake. Thus, the possibility of the accidental release reaching Patterson Lake is improbable; and therefore, no effects on the lake from the surface water pathways would be expected.

There is potential for groundwater contamination within the area of soil contamination. Shallow groundwater flow is generally affected by local-scale topography, which is representative of conditions at the Project site. Shallow groundwater flow movement is from the topographic high located south of the proposed mine and process plant development in a northerly direction towards Patterson Lake. There is potential for groundwater contamination within the area of soil contamination and therefore there is a potential for groundwater-associated transport to Patterson Lake.

As discussed in Section 9.0, Bounding Scenario 4: Tailings Transfer Pipe or Pump Failure and Release of Radioactivity, implementation of the spill response plan and associated cleanup would be expected to occur over a time period of days (or at maximum, weeks) following the incident, whereas groundwater transport would be measured in years. No meaningful migration of contaminated groundwater outside the immediately-affected area would be expected. Thus, the contamination of soil and shallow groundwater is expected to be contained within a small area near the release location, and no contamination would be expected to reach Patterson Lake along the groundwater pathway.

Based on the above, and in consideration of the effect scale described in Section 3.2, Table 3-2, the consequence of the potential effects of this scenario are rated as minor.

11.0 BOUNDING SCENARIO 6: ACID PLANT TAIL GAS SCRUBBER FAILURE

This bounding scenario involves an uncontrolled release of sulphur dioxide from the tail gas scrubbers. A general description of the hypothetical event, hypothetical contaminants release characterization (e.g., contaminants, quantities), the probability of the scenario and its potential effects on the human health and biophysical environment is provided below.

11.1 Scenario Description

Molten sulphur would be fed to the acid plant where it would be burned in the presence of dry air to produce a sulphur dioxide gas stream. The sulphur dioxide gas stream would be cooled and then fed to a converter system where it would be converted into sulphur trioxide gas via a catalytic oxidation process. The sulphur trioxide gas would be scrubbed with water to produce sulphuric acid at a production grade between 94% and 98% for use in the milling process. The tail gas from the process would be scrubbed in a wet scrubber system to remove the sulphur dioxide before releasing residual gases into the atmosphere.

The acid plant would be in a standalone building separate from the process plant. The plant is designed to produce 300 t/d of sulphuric acid, requiring 90 t/d of sulphur feed.

Any process upset, or failure of equipment, instrumentation, or piping in the burner and converter, absorber, or tail gas scrubbers could potentially result in the release of sulphur dioxide. If the vessels, exchangers, and/or piping system handling sulphur dioxide fail, then a release of sulphur dioxide into the atmosphere could result.

The catastrophic failure of the piping system in the acid plant is highly unlikely. A more likely event is the failure of the tail gas scrubber. This event would result in the release of tail gas containing sulphur dioxide to the atmosphere before scrubbing.

11.2 Release Characterization

The throughput of sulphur dioxide in the acid plant is 180 t/d, or 7.5 t/h or 2,880 m^3/h. The total volume of the pipes and vessels containing sulphur dioxide upstream of the tail pipe scrubber is estimated at about 200 m^3 or 0.5 t.

The sulphur dioxide content of the tail gas in a typical acid plant is approximately 15 kg/t of acid produced. This would be 15 kg/t × 300 t = 4,500 kg/d. Under this scenario, the total amount released during a 15-minute event would be 47 kg, or approximately 0.05 t. This released amount is 10% of the entire capacity upstream of the tail gas scrubber.

11.3 Assessment of Probability

The following mitigating measures would be in place to reduce the probability of a release and potential for tailings release:

- sulphur dioxide monitoring;
- routine and preventive inspection, testing, and maintenance program; and
- ambient air monitoring.

A release of sulphur dioxide could occur as a result of the following events:

- failure of the sulphur furnace, heat exchanger, economizer, waste heat boilers, absorption tower; and tail gas scrubber.
- failure of valves or other piping system components.

As described above, the failure of the tail gas scrubber is the most likely cause of the sulphur dioxide release. According to the Center for Chemical Process Safety (AIChE-CCPS 1989), the probability of a failure of a wet scrubber is less than 3×10^{-02} per year.

According to the probability ratings described in Section 3.2, Table 3-1, the probability that this accident and malfunction scenario would occur is likely.

11.4 Assessment of Potential Effects

The source term calculated in Section 11.2 for the release of sulphur dioxide from the acid plant was 47 kg of sulphur dioxide based on a 15-minute response time, or 52 g/s of sulphur dioxide. The air concentration versus distance was calculated using the ALOHA model and compared with the benchmarks provided in Section 5.3 for the W1 and W2 weather conditions (AEGL-2). As indicated previously, the probability of the W1 weather condition is less than 5% of the probability of weather condition W2.

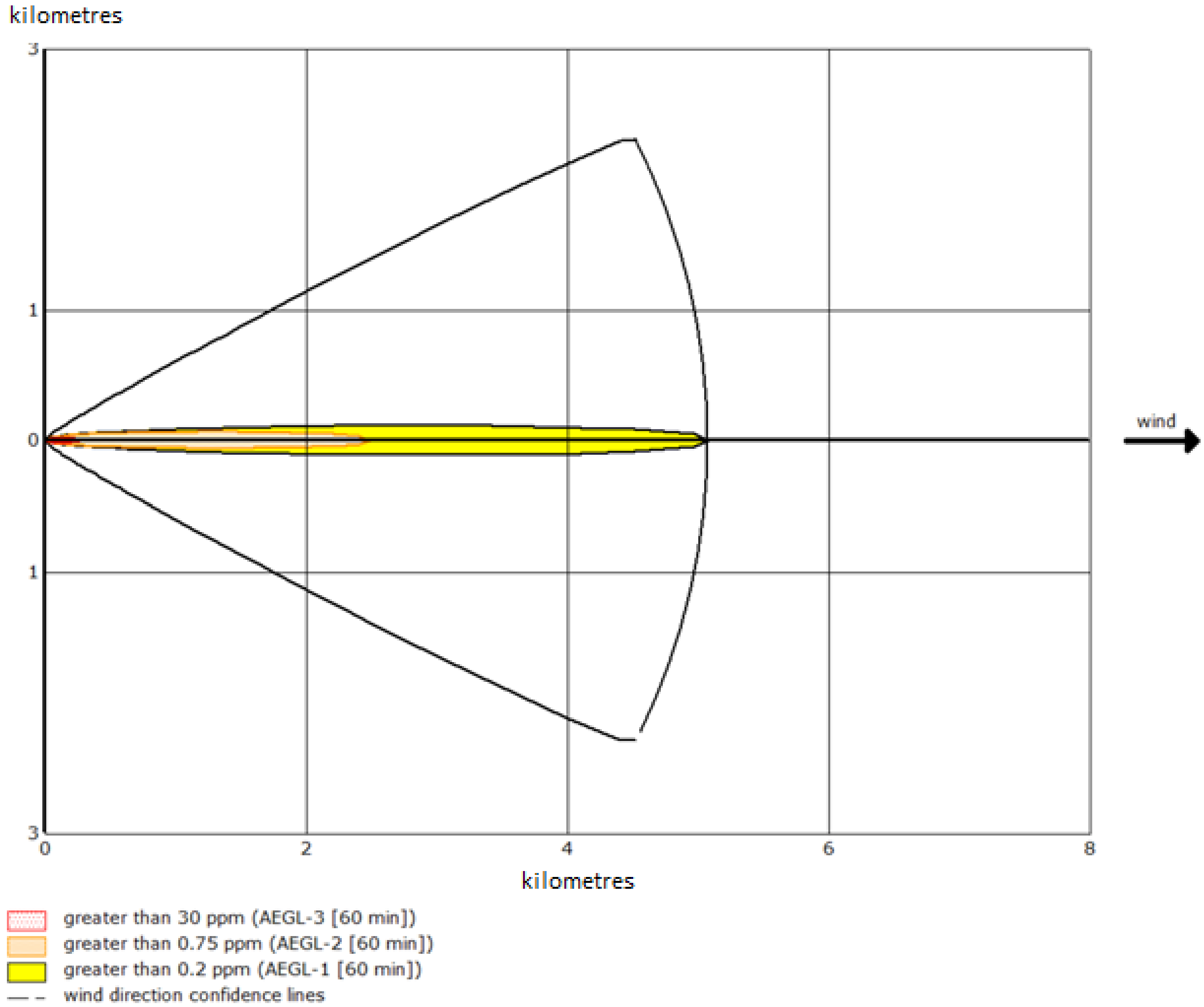
The results of the modelling are summarized in Table 11-1. Figure 11-1 shows the results for the W1 weather condition and Figure 11-2 shows the results for the W2 weather condition.

Table 11-1: Results of Sulphur Dioxide Release Modelling

Weather Condition	Distance to AEGL-3 (m)	Distance to AEGL-2 (m)	Distance to AEGL-1 (m)
W1	261	2,500	5,100
W2	122	849	1,700

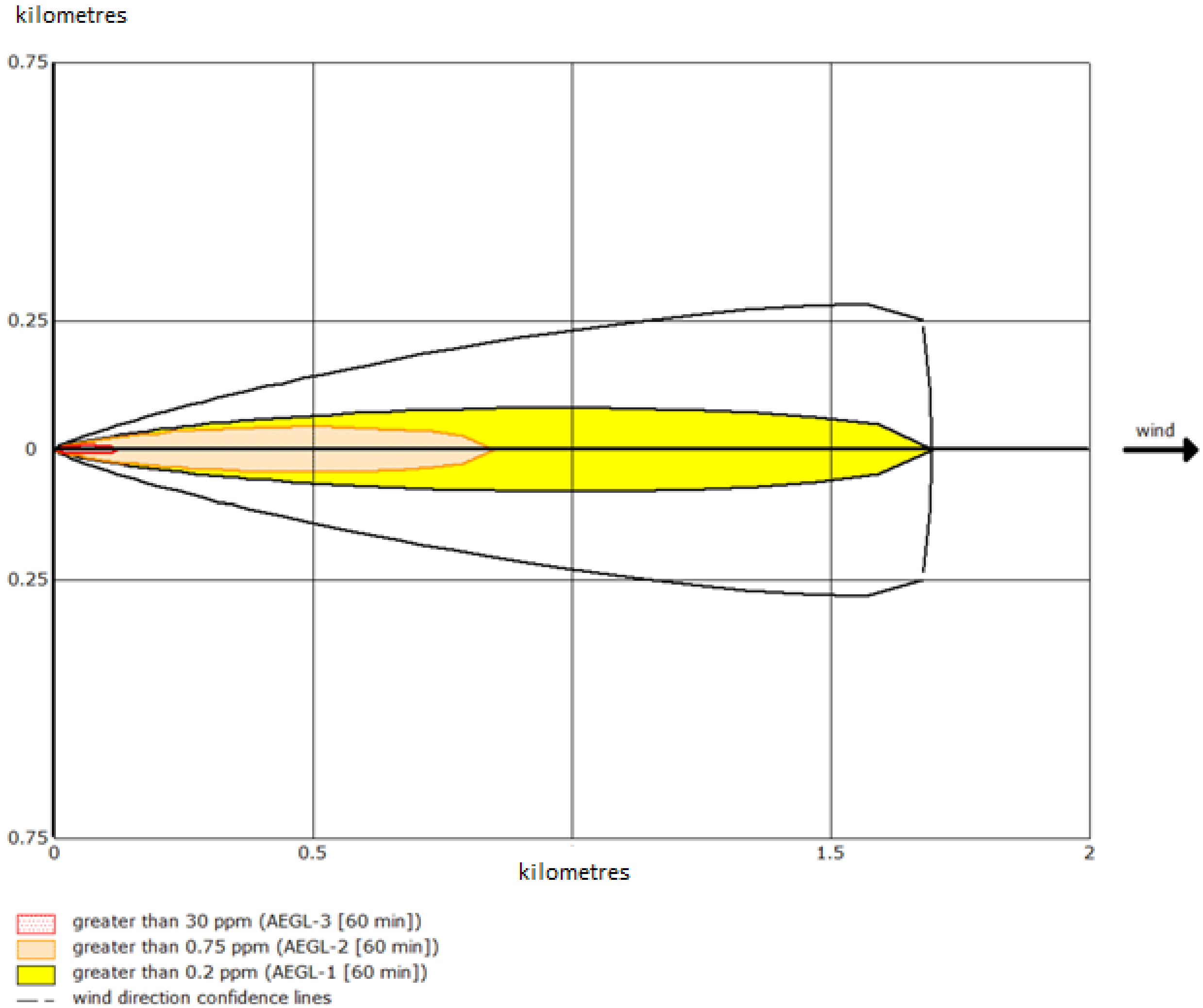
AEGL = Acute Exposure Guideline Level; W1 = worst-case weather conditions; W2 = typical weather conditions.

Figure 11-1: Sulphur Dioxide Dispersion for Worst-Case Weather Conditions



Note: Concentration of sulphur dioxide in air is shown.
AEGL = Acute Exposure Guideline Level; ppm = parts per million.

Figure 11-2: Sulphur Dioxide Dispersion for Typical Weather Conditions



Note: Concentration of sulphur dioxide in air is shown.
AEGL = Acute Exposure Guideline Level; ppm = parts per million.

As highlighted in Section 5.2, the most frequently used benchmark for emergency scenarios is AEGL-2. The results indicate that the AEGL-2 benchmark would be reached (i.e., sulphur dioxide levels would be below the threshold beyond this distance) at 2,500 m from the source of the release (i.e., the acid plant) for weather condition W1, and at 849 m for weather condition W2 representing the more likely weather condition.

As mentioned in Section 11.3, this weather scenario occurs with a probability of 3×10^{-02} per year (i.e., approximately once in 33 years) with a duration of about one hour. The conditional probability of a rain event occurring at the same time makes surface deposition less probable. In addition, due to short duration of this event, surface accumulation of any deposition was considered to be negligible and the effects on the wildlife or vegetation were therefore judged to be minor.

Based on the above, and in consideration of the effect scale described in Section 3.2, Table 3-2, the consequence of the potential effects of this scenario was rated minor to moderate within a short distance from the release.

12.0 ASSESSMENT OF RISK OF BOUNDING SCENARIOS

The results of the risk assessment of the bounding accident scenarios are summarized in Table 12-1.

The results combine the analysis of both likelihood and consequence of effect for each bounding scenario (Section 6.0 through Section 11.0) to identify and overall risk rating according to the risk ranking framework presented in Section 3.0. The difference between the risk ranking presented below and the original risk screening process (Section 3.0) is that the risk ratings below were assigned based on the quantitative assessment of these accident and malfunction scenarios.

The overall risk ratings indicate that the traffic accident scenarios releasing uranium concentrate (Scenario 1) and chemicals (Scenario 2), failure of pipes and pumps for tailings (Scenario 3), effluent transfer pipe failure (Scenario 4), and the untreated effluent transfer pipe failure (Scenario 5) have a low risk. The overall risk associated with tail gas scrubber failure (Scenario 6) has been determined to be low to moderate. Low to moderate risk scenarios were deemed to represent a tolerable level of risk in consideration of proposed safeguards and design features that reduce the risk level to ALARP.

Table 12-1: Summary of Assessment Results for Bounding Scenarios

No.	Accident or Malfunction Scenario	Location	Likelihood	Estimated Effects Consequence	Overall Risk Rating[(a)]
1	Traffic accident (uranium concentrate)	Access road at bridge crossing	Highly unlikely	Moderate	Low risk
2	Traffic accident (chemical)	Access road at bridge crossing	Highly unlikely	Moderate	Low risk
3	Solvent extraction fire or explosion	Solvent extraction building	Unlikely	Minor to moderate	Low risk
4	Tailings transfer pipe or pump failure	Tailings release to surface within secondary containment	Likely	Minor	Low risk
5	Untreated effluent transfer pipe failure	Effluent treatment system	Likely	Minor	Low risk
6	Acid plant tail gas scrubber failure	Acid plant	Likely	Minor to moderate	Low to moderate risk

a) Based on Figure 3-1.

13.0 REFERENCES

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Appendix A HAZARD IDENTIFICATION FOR THE ACCIDENTS AND MALFUNCTIONS ASSESSMENT - NEXGEN ROOK I PROJECT

HAZARD IDENTIFICATION FOR THE ACCIDENTS AND MALFUNCTIONS ASSESSMENT – APPENDIX A - NEXGEN ROOK I PROJECT

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Ecometrix | Environmental INTELLIGENCE

HAZARD IDENTIFICATION FOR THE ACCIDENTS AND MALFUNCTIONS ASSESSMENT – APPENDIX A - NEXGEN ROOK I PROJECT

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EXECUTIVE SUMMARY

Ecometrix Incorporated (Ecometrix) was retained by NexGen Energy Ltd. (NexGen) to complete the accidents and malfunctions assessment for the NexGen Rook I Project (Project), a proposed uranium mining and milling operation in northwestern Saskatchewan. For reference, the assessment of accidents and malfunctions is intended to provide a clear identification of the potential Project-associated hazards that fall outside the range of "typical" day-to-day events. This report details the Hazard Identification (HI) that has been completed to support the Environmental Assessment in the EIS. The HI is used to identify potential hazard scenarios, screen these scenarios as to potential environmental risks and, based on this screening, recommend scenarios that would be carried forward for more detailed consideration in the completion of the Accidents and Malfunctions Assessment.

Scope and Applicability

The scope of the HI included consideration across the following Project phases: Construction, Operations, and Decommissioning and Reclamation (i.e., Closure).

The spatial extent of the evaluation included the Project site and associated access road to its junction with Highway 955.

The evaluation focused on potential environmental risks associated with identified hazard scenarios. Although some hazards related to worker safety were identified, worker safety (risks and consequences) is out of the scope of this assessment.

Methods

The hazard identification process is a systematic approach to identify possible hazards associated with all components (physical system) and activities in a work process. A hazard can be defined as a physical event or condition that has the potential for causing damage to people, property, or the environment (e.g., fire, explosion, release of chemicals, or radioactivity). The components and activities for hazard identification were selected through the review of Project-related components. The hazard scenarios were identified by investigating the components and activities individually. The evaluation considered the sources of the hazard (e.g., presence of hazardous materials), hazardous situations (e.g., height or extreme heat), and initiating events (e.g., natural causes, technical failure, human error), that in combination, present a risk to the biophysical environment. A screening evaluation was applied to each scenario by qualitatively evaluating consequence and likelihood to determine a risk level (low, moderate, or high).

The following nodes were considered in the HI:

- site preparation;
- shaft sinking;

- access road / land transportation;
- airstrip;
- mining;
- hoisting;
- mine dewatering system;
- processing plant;
- solvent extraction building;
- tailings transfer pipe and underground tailings management facility (UGTMF) and mining stopes;
- non-potentially acid generating (NPAG) waste rock stockpile;
- ore, special waste, and potentially acid generating (PAG) waste rock stockpiles;
- effluent treatment system;
- ponds and retention berms;
- gypsum precipitation, washing, and storage;
- acid plant;
- electrical system and power plant;
- fire protection system;
- low-level radioactive waste management system / incinerator;
- liquified natural gas (LNG) power plant; and
- mine ventilation system.

Recommended Scenarios for Further Consideration

Based on the HI process, the hazard scenarios that were selected for more detailed risk analysis are listed below.

Node	Accident or Malfunction Scenario	Location	Effect pathway
3.1	Traffic accident (uranium concentrate)	Access road at bridge crossing	Aquatic release of uranium concentrate
3.3	Traffic accident (chemical)	Access road at bridge crossing	Aquatic release of fuel, hazardous chemicals
9.3	Solvent extraction fire or explosion	Solvent extraction building	Atmospheric release of uranium concentrate (chemical toxicity)
10.2	Tailings transfer pipe or pump failure	Tailings release to surface within secondary containment	Terrestrial release of radioactivity
13.3	Untreated effluent transfer pipe failure	Effluent treatment system	Terrestrial release of radioactivity
16.3	Acid plant tail gas scrubber failure	Acid plant	Atmospheric release of sulphur dioxide

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ABBREVIATIONS AND UNITS OF MEASURE

Abbreviations

Acronym	Definition
ALARP	As Low as Reasonably Practicable
EIS	Environmental Impact Statement
HI	Hazard Identification
ID	identification
LNG	liquified natural gas
NexGen	NexGen Energy Ltd.
NPAG	non-potentially acid generating
PAG	potentially acid generating
Project	Rook I Project
UGTMF	underground tailings management facility

Units of Measure

Units	Definition
%	percent
>	greater than
km	kilometres
t	tonne

1.0 INTRODUCTION

The NexGen Energy Ltd. (NexGen) Rook I Project (Project) is a proposed new uranium mining and milling operation that is 100% owned by NexGen. The Project would be located in northwestern Saskatchewan, approximately 40 km east of the Saskatchewan-Alberta border, 130 km north of the town of La Loche, and 640 km northwest of the city of Saskatoon. The Project would reside within Treaty 8 territory and within the Métis Homeland. At a regional scale, the Project would be situated within the southern Athabasca Basin adjacent to Patterson Lake and along the upper Clearwater River system. Access to the Project would be from an existing road off Highway 955.

Ecometrix Incorporated (Ecometrix) was retained by NexGen to complete the accidents and malfunctions assessment for the Project, a proposed uranium mining and milling operation in northwestern Saskatchewan. For reference, the assessment of accidents and malfunctions is intended to provide a clear identification of the potential Project-associated hazards that fall outside the range of "typical" day-to-day events. This report details the Hazard Identification (HI) that has been completed to support the Environmental Assessment in the EIS. The HI is used to identify potential hazard scenarios, screen these scenarios as to potential environmental risks and, based on this screening, recommend scenarios that would be carried forward for more detailed consideration in the completion of the Accidents and Malfunctions Assessment.

1.1 Project Information

The Project includes the Construction, Operations, Decommissioning and Reclamation (i.e., Closure) of a uranium mine and processing plant, including associated infrastructure to support the extraction and processing of uranium ore. Key Project details are summarized in **Table** 1-1. The timeline for the Project from the initiation of Construction to the completion of Closure (and subsequent transfer of the property to Institutional Control) is anticipated to be 43 years.

Table 1-1: Key Rook I Project Details

Terms	Details
Scope of the Project	• NexGen is proposing a new uranium mining and milling operation located adjacent to Patterson Lake in the southwestern Athabasca Basin in northern Saskatchewan • The proposed Project would include underground and surface facilities to support the mining and milling of uranium ore from the Arrow deposit • The Project would include an underground mine, a process plant, and additional infrastructure including a camp for personnel, an airstrip, an ETP, and supporting waste and water management facilities
Rook I Project	• The Rook I Project is a new uranium mining and milling operation located on the Patterson Lake peninsula in the southwestern Athabasca Basin in northern Saskatchewan • The Rook I Project is 100% owned and managed by NexGen • The mineral resource basis for the proposed Project is the Arrow deposit, a land-based, 100% basement-hosted, high-grade uranium deposit
Arrow deposit	• A land-based, basement-hosted, high-grade uranium deposit that is 100% owned by NexGen

Table 1-1: Key Rook I Project Details

Terms	Details
Underground mine development	• The Project would use long hole stoping mining methods to extract the ore, including primarily transverse stope mining and longitudinal retreat stope mining. • The underground mine development would include a number of key activities, including shaft sinking, lateral development, vertical development, installation of mine services, and development of the UGTMF
Uranium concentrate	• The Project term for triuranium octoxide (U_3O_8) once the material has been processed and is ready for shipment
Process plant	• Process plant throughput is designed for 1,300 tonnes of ore per day • Total net uranium recovery from the milling process is estimated to be 97.6% based on the results of the metallurgical test programs completed in 2018 and 2019 • The process plant consists of the technologies and infrastructure used to transform uranium ore into uranium concentrate
UGTMF	• Purpose-built, underground facility with chambers dedicated to the storage and progressive decommissioning for tailings and other waste streams generated through mining and processing • Three UGTMF cavities are planned for initial development during Construction to provide adequate storage capacity to support the start of mining and milling operations
Mine rock	• Includes all material sourced from underground, including ore (equal or greater than 0.26% U_3O_8 and waste rock (less than 0.26% U_3O_8)
Waste rock	• Includes non-potential acid generating mine rock, potentially acid generating mine rock, and special waste
NPAG	• The NPAG waste rock is clean mine rock with less than 0.03% U_3O_8 and less than 0.1% sulphur. All NPAG mine rock would either be stockpiled for use as construction material at site or become NPAG waste rock that is stored in the NPAG WRSA
PAG	• The PAG waste rock is mine rock with less than 0.03% U_3O_8 and greater than or equal to 0.1% sulphur. All PAG mine rock would become PAG waste rock that is stored in the PAG WRSA
Special waste	• Special waste is mine rock with insufficient grade to be considered ore (i.e., greater than 0.03% of U_3O_8 and less than 0.26% U_3O_8). All special waste would be temporarily stored in the special waste rock stockpile
NPAG WRSA	• The NPAG WRSA permanently stores clean mine rock at surface and would not be lined
PAG WRSA	• The PAG WRSA permanently stores PAG mine rock at surface and would be fully lined with HDPE and have self-contained water collection
Special waste rock stockpile	• The separate stockpile where special waste would be temporarily stored at surface and would be fully lined with HDPE and have self-contained water collection • Special waste would be processed throughout Operations and then transferred to the UGTMF for permanent storage
Ore storage stockpile	• The separate stockpile on surface where ore would be temporarily stored until transferred to the process plant. This stockpile includes four piles with differing grades and would be fully lined with HDPE and have self-contained water collection
ETP	• The Project facility that treats contact water from the Project. The treated effluent is pumped to the monitoring ponds, tested, and then discharged to the environment, after meeting discharge criteria

Table 1-1: Key Rook I Project Details

Terms	Details
Sewage treatment plant	• The Project facility that treats sewage from the Project. The treated sewage discharge is released to the environment, after meeting discharge criteria
Mine water	• Water that flows into the underground workings
Contact water	• Water that may have been physically or chemically altered by Project activities. This water may be diverted and require management (e.g., treatment) before release to the environment. This includes dewatering of mine water from underground mining activities as well as all runoff on surfaces disturbed by the Project
Non-contact water	• Water that has not been physically or chemically altered by Project activities. This water is typically diverted when practical and allowed to discharge directly to the receiving environment
Fresh water	• Water sourced from Patterson Lake for use by the Project
Release water	• Contact water that has been treated in the ETP and is discharged to the environment, after meeting discharge criteria
Waste water (or treated sewage discharge)	• Water that has been treated in the sewage treatment plant and is ready for discharge to the environment, after meeting discharge criteria
Sewage	• Waste water from toilets, sinks, showers, laundry, kitchen, and other domestic sources and facilities at the Project, including but not limited to sanitary liquid waste of human origin
Supporting infrastructure	• Includes all Project surface facilities including but not limited to waste management infrastructure, water management and treatment infrastructure, administration and camp facilities, utilities, airstrip, and site roads

UGTMF = underground tailings management facility; PAG WRSA= potentially acid generating waste rock storage area; NPAG WRSA= non-potentially acid generating waste rock storage area; U_3O_8 = triuranium octoxide; ETP = effluent treatment plant; HDPE = high density polyethylene.

1.2 Scope and Applicability of the Hazard Identification Process

The regulations governing the EIS requires that the effects of Accidents and Malfunctions related to the Project components be assessed. As a step towards the Accidents and Malfunctions assessment, an HI evaluation needs to be completed. The objective of HI is to identify all scenarios that have a potential to present a risk to the biophysical environment. The HI includes a screening assessment of the scenarios to identify those that require more detailed assessment of the probabilities and the severity of their consequences. The screening evaluation is applied to a given scenario by qualitatively evaluating consequence and likelihood to determine an overall risk ranking (Section 2.0, Hazard Identification Methodology). The evaluations of the probabilities and severity of the consequences, as well as the characterization of the risk of the selected scenarios, are included in the Accidents and Malfunctions assessment.

The scope of the HI included consideration of the following Project phases: Construction, Operations, and Decommissioning and Closure. The spatial extent of the evaluation included the Project site and associated access road to its junction with Highway 955.

The evaluation focused on potential environmental risks associated with identified hazard scenarios. Although some hazards related to worker safety were identified, worker safety (risks and consequences) is out of the scope of this assessment.

1.3 Information Sources

Information used to complete this evaluation has been provided by NexGen. Key information has been drawn from the Project's Feasibility Report, as well as reports that have been generated by NexGen's risk review and management process. The list of information sources is provided in the reference section of this report.

2.0 HAZARD IDENTIFICATION METHODOLOGY

The HI evaluation was performed to identify hazard scenarios associated with the Project that may result in consequences to the biophysical environment. The hazard scenarios were subsequently assessed at a screening level as to potential risks to the biophysical environment, and to identify scenarios that should be carried forward for more detailed evaluation.

2.1 Process Hazards Analysis

The hazard identification process is a systematic approach to identify possible hazards associated with all components (physical system) and activities in a work process. A hazard can be defined as a physical event or condition that has the potential for causing damage to people, property, or the environment (e.g., fire, explosion, release of chemicals, or radioactivity).

The hazard identification evaluation was used to identify a comprehensive list of potential Project-related accident and malfunction scenarios, screen these scenarios as to potential risks, and, based on the initial screening results, select a number of high or moderate-risk scenarios as bounding scenarios. These bounding scenarios were carried forward for more detailed risk assessment. The hazard identification evaluation focussed on risks to the human health and biophysical environment.

The hazard identification involved the consideration of the following three elements that, in combination, present a risk to the human health and biophysical environment:

a) the sources of hazard (e.g., presence of hazardous materials),

b) hazardous situations (e.g., presence of ignition source), and

c) initiating events (e.g., natural causes, technical failure, or human error).

A screening evaluation was applied to all accident and malfunction scenarios by qualitatively evaluating the likelihood and consequence to determine a risk level.

The likelihood index is derived from the qualitative estimation of the probability of the scenarios. While there are standards and regulatory documents (e.g., REGDOC-2.4.2, Safety Analysis, Probabilistic Safety Assessment [PSA] for Reactor Facilities (CNSC n.d.[1]) that govern the assessment of the probability of the hazard scenarios for nuclear reactors, no such documents exist for non-reactor facilities. The focus of these documents is design-basis and beyond design-basis accidents that affect the integrity of the reactor core. The annual probability of releases from these accidents can be $1x10^{-6}$ and lower, while the consequence of these accidents

[1] CNSC (Canadian Nuclear regulatory Commission). n.d. REGDOC-2.4.2, Safety Analysis Probabilistic Safety Assessment (PSA) for Reactor Facilities, Version 2. Available at **https://www.nuclearsafety.gc.ca/eng/pdfs/regulatory-documents/regdoc2-4-2/REGDOC-2_4_2_Probabilistic_Safety_Assessment_(PSA)_for_Reactor_Facilities_Version_2.pdf.**

could be very severe. In contrast, the probability of accidents and malfunctions at non-reactor facilities such as mines and process plants can be higher, as derived from the operating experience of similar installations. The International Atomic Energy Agency's TECDOC-1267 (IAEA 2002[2]) states that while a plant-specific qualitative risk analysis should be conducted for a nuclear reactor facility, for non-nuclear facilities hazard identification and screening, evaluation of selected accident scenarios, and a combination of qualitative and quantitative analysis should be conducted. This document does not prescribe what probabilities should be considered.

Based on the operating experience of similar facilities considered in this assessment, a range of probabilities were considered. On a scale of increasing likelihood, scenarios were categorized as highly unlikely, unlikely, likely, very likely, and almost certain as shown in Table 2-1.

Table 2-1: Likelihood Index

Rating	Likelihood	Description
1	Highly unlikely	<1 occurrence in 1,000 years
2	Unlikely	≤1 occurrence in 100 years and >1 occurrence in 1,000 years
3	Likely	≤1 occurrence in 10 years and >1 occurrence in 100 years
4	Very likely	≤1 occurrence in 1 year and >1 occurrence in 10 years
5	Almost certain	>1 occurrence in 1 year

< = less than; ≤ = less than or equal to; > = greater than.

On a scale of increasing consequence, scenarios were categorized as negligible, minor, moderate, major, and catastrophic as shown in Table 2-2.

Table 2-2: Consequence Index

Rating	Consequence	Description
1	Negligible	No measurable biophysical environmental effects, or medical treatment not required
2	Minor	Short-term (less than one month in duration) minor effect on small area, or minor first aid injuries with no lost time
3	Moderate	Reversible or repairable (i.e., less than one year in duration) effect off site, or reversible injuries with lost time
4	Major	Extended-range, long-term (i.e., between 1 and 10 years in duration) effect off site, or severe injuries with long-lasting effects and/or disability
5	Catastrophic	Long-lasting (more than 10 years) or irreversible environmental effects, fatalities, or multiple disabilities

[2] IAEA (International Atomic Energy Agency). 2002. Procedures for conducting probabilistic safety assessment for non-reactor nuclear facilities, IAEA-TECDOC-1267, January 2002, ISSN 1011–4289. Available at **https://www-pub.iaea.org/MTCD/Publications/PDF/te_1267_prn.pdf.**

The resulting risk levels are defined according to the hazard analysis risk matrix shown in Figure **2-1**.

For the purpose of the assessment, risks were identified as being low (i.e., coloured green in the matrix) where the screening evaluation considered the risk as generally being acceptable, as the likelihood of these scenarios can be effectively managed through application of planned controls and/or the consequence of the effect would be low. Low-risk scenarios have a consequence of negligible to moderate, with the likelihood ranging from highly unlikely to almost certain.

Risks are identified as being moderate (i.e., coloured yellow in the matrix) where the screening evaluation considers the risk as generally being tolerable. In some cases, a moderate-risk scenario can encompass the risk of several screened scenarios for each effect category (e.g., toxic release, fire). In these cases, a moderate-risk scenario can be carried forward as a bounding scenario for more detailed analysis. Moderate-risk scenarios have a consequence of minor to catastrophic, with the likelihood ranging from highly unlikely to almost certain. In many cases, risk-reduction activities would reduce the risk associated with these scenarios to as low as reasonably practicable (ALARP). Under this condition, the risk may be characterized as tolerable.

Risks were identified as being high (i.e., coloured red in the matrix) where the screening evaluation considered the risk as generally being unacceptable. High-risk scenarios have a consequence of major to catastrophic, with the likelihood ranging from unlikely to almost certain. As the evaluation of the risk at this hazard identification stage was qualitative and subject to some uncertainty, the hazard scenarios identified as high risk were advanced for further detailed assessment so that a more detailed evaluation of risk and potential management activities could be considered.

Figure 2-1: Hazard Analysis Risk Matrix

Likelihood		**Consequence**				
		1	**2**	**3**	**4**	**5**
		Negligible	**Minor**	**Moderate**	**Major**	**Catastrophic**
5	**Almost Certain**	Low	Moderate	Moderate	High	High
4	**Very Likely**	Low	Low	Moderate	High	High
3	**Likely**	Low	Low	Moderate	Moderate	High
2	**Unlikely**	Low	Low	Low	Moderate	High
1	**Highly Unlikely**	Low	Low	Low	Moderate	Moderate

2.2 Definition of Project Components and Activities

Based on the review of key Project components and activities, the following nodes were considered in the HI evaluation:

- site preparation;
- shaft sinking;
- access road / land transportation;
- airstrip;
- mining;
- hoisting;
- mine dewatering system;
- process plant;
- solvent extraction building;
- tailings transfer pipe and underground tailings management facility (UGTMF);
- non-potentially acid generating (NPAG) waste rock stockpile;
- ore, special waste, and potentially acid generating (PAG) waste rock stockpiles;
- effluent treatment system;
- ponds and retention berms;
- gypsum precipitation, washing, and storage;
- acid plant;
- electrical system and power plant;
- fire protection system;
- low-level radioactive waste management system / incinerator;
- liquified natural gas (LNG) power plant; and
- mine ventilation system.

3.0 EVALUATION OF NODES

For each of the nodes, HI evaluations are shown in Table 3-1 through Table 3-21. In each case, the evaluation considers consequence(s), existing safeguards and design features, and the qualitative evaluation of likelihood and severity of consequences.

The following notations are provided in support of the HI tables:

- "CO" is Construction;
- "OP" is Operations;
- "ADR" is Active Decommissioning and Reclamation Stage;
- "TM" is Transitional Monitoring Stage;
- "L" is likelihood;
- "S" is severity of the consequences; and
- "RR" is risk ranking.

With consideration of sources of hazard and initiating events, a total of 93 hazard scenarios were identified and evaluated.

Six of the hazard scenarios characterized as high-risk (3) or ALARP-moderate (3) scenarios require further detailed assessment for more accurate characterization of the risk.

Six high-risk scenarios that were not recommended for further detailed assessment are associated with major injuries and/or occupational fatalities. These scenarios have not been advanced since it is assumed that the NexGen health and safety program will be best practice and therefore in these cases the risk is ALARP.

Thirty-three of the scenarios evaluated were characterized as moderate-risk scenarios. Generally, the moderate-risk scenarios were deemed to represent a tolerable level of risk in consideration of proposed safeguards and design features that reduce the risk level to ALARP. As noted above, three moderate-risk scenarios are recommended for further detailed assessment. Each of these is associated with a contaminant release to the environment. A further six moderate-risk scenarios were also considered for further detailed assessment; however, they were deemed to be bounded by other scenarios and therefore no further analyses were completed.

The balance of the scenarios evaluated (51) were characterized as low-risk scenarios, based on low likelihood of occurrence and/or consequence in consideration of planned existing safeguards and design features.

Site preparation: For site preparation, nine hazard scenarios were identified, and each have the potential to occur during all phases and stages of the Project. All hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-1: Hazard Identification Evaluation – Site Preparation

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
1.1	Fall/slip	CO / OP / ADR / TM	Occupational major injuries	Occupational health and safety program Personnel training and orientation Personal protection equipment	5	4	ALARP, High	Best practice in worker health and safety program resulting in ALARP, no further assessment
1.2	Fall/slip	CO / OP / ADR / TM	Occupational fatalities	Occupational health and safety program Personnel training and orientation Personal protection equipment	2	5	ALARP, High	Best practice in worker health and safety program resulting in high but ALARP, no further assessment
1.3	Vehicle and construction equipment accident	CO / OP / ADR / TM	Occupational major injuries	Occupational health and safety program Personnel training and orientation Preventive and routine maintenance	4	4	ALARP, High	Best practice in worker health and safety program resulting in ALARP, no further assessment
1.4	Vehicle and construction equipment accident	CO / OP / ADR / TM	Occupational fatalities	Occupational health and safety program Personnel training and orientation Preventive and routine maintenance	2	5	ALARP, High	Best practice in worker health and safety program resulting in high but ALARP, no further assessment
1.5	Vehicle accident	CO / OP / ADR / TM	Hazardous materials spill	Site traffic control, speed limit, signage Personnel training and orientation Spill and emergency response plan	4	2	Low	Risk level is low, minor consequences, no further assessment
1.6	Fuel storage failure	CO / OP / ADR / TM	Hydrocarbon release	Storage inspection, maintenance Double-walled fuel storage and or secondary containment Spill and emergency response plan	1	3	Low	Risk level is low, highly unlikely event, no further assessment
1.7	Refuelling accident	CO / OP / ADR / TM	Hydrocarbon release	Personnel training Containment Spill and emergency response plan	4	2	Low	Risk level is low, low consequence event, no further assessment
1.8	Fuel storage and transfer fire and explosion	CO / OP / ADR / TM	Occupational major injuries	Fire safety plan and firefighting system Personal protection equipment Personnel training and orientation	2	4	ALARP, Moderate	Best practice in worker health and safety program resulting in ALARP, no further assessment
1.9	Fuel storage and transfer fire and explosion	CO / OP / ADR / TM	Occupational fatalities	Fire safety plan and firefighting system Buried pipes Personal protection equipment Personnel training and orientation	1	5	ALARP, Moderate	Best practice in worker health and safety program resulting in ALARP, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; TM = Transitional Monitoring; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Shaft sinking: For shaft sinking, four hazard scenarios were identified, which have the potential to occur during the Construction of the Project. All hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-2: Hazard Identification Evaluation – Shaft Sinking

ID#	Accident/Malfunction	Phase	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
2.1	Shaft wall failure	CO	Occupational major injuries	Occupational health and safety program Personnel training and orientation Personal protection equipment	5	4	ALARP, High	Best practice in worker health and safety program resulting in ALARP, no further assessment
2.2	Shaft wall failure	CO	Occupational fatalities	Occupational health and safety program Personnel training and orientation Personal protection equipment	1	5	ALARP, Moderate	Best practice in worker health and safety program resulting in ALARP, no further assessment
2.3	Groundwater ingress	CO	Underground flooding and potential for groundwater contamination	Temporary ground freeze Mine construction procedure based on geotechnical analysis Engineered shaft liner design where required Emergency response procedure Groundwater monitoring	3	2	Low	Risk level is low, low consequence event, no further assessment
2.4	Surface flood	CO	Underground flooding and potential for groundwater contamination	Surface water and flood management, shaft opening protection and structure Emergency response procedure Groundwater monitoring	2	2	Low	Risk level is low, low consequence event, no further assessment

CO = Construction; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Access road / land transportation: For access road / land transportation, eight hazard scenarios were identified, which have the potential to occur during the Construction, Operations, and Closure of the Project. The screening assessment shows that two hazard scenarios may be high risk and further assessment is required to characterize the risk in more detail. Other hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-3: Hazard Identification Evaluation – Access Road / Land Transportation

ID#	Accident/Malfunction	Phase or Stage	Consequences	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
3.1	Traffic accident at bridge crossing (uranium concentrate)	CO / OP / ADR	Aquatic release of radioactivity	Traffic control measures Travel management plan Spill and emergency response plan Personnel training	3	5	High	Further assessment recommended
3.2	Vehicle accident including rollover, collision, run off road	CO / OP / ADR	Terrestrial release of radioactivity	Traffic control measures Travel management plan Spill and emergency response plan Personnel training	3	4	ALARP, Moderate	Best practice in terrestrial spill containment and cleanup resulting in ALARP, no further assessment
3.3	Traffic accident at bridge crossing (chemical)	CO / OP / ADR	Aquatic release of fuel, hazardous, chemicals and reagents	Traffic control measures Travel management plan Spill and emergency response plan Personnel training	3	5	High	Further assessment recommended
3.4	Vehicle accident including rollover, collision, run off road	CO / OP / ADR	Terrestrial release of fuel, hazardous, chemicals and reagents	Traffic control measures Travel management plan Spill and emergency response plan Personnel training	3	4	ALARP, Moderate	Best practice in terrestrial spill containment and cleanup resulting in ALARP, no further assessment
3.5	Vehicle fire	CO / OP / ADR	Release of hydrocarbons and fuel	Travel management plan Spill and emergency response plan Fire safety plan and firefighting systems Personnel training	1	4	ALARP, Moderate	Best practice in terrestrial spill containment and cleanup resulting in ALARP, no further assessment
3.6	Vehicle fire	CO / OP / ADR	Atmospheric release of particulate and combustion by-products	Travel management plan Spill and emergency response plan Fire safety plan and firefighting systems Personnel training Ambient air monitoring	1	3	Low	Low risk, low probability event. Reversible and transient effect. No further assessment
3.7	Vehicle fire	CO / OP / ADR	Uncontrolled explosion of explosives	Explosives management plan Fire safety plan and firefighting systems Personnel training	1	5	ALARP, Moderate	Best practice in explosive management resulting in ALARP, no further assessment
3.8	Vehicle – wildlife collision	CO / OP / ADR	Wildlife injury/fatality	Traffic control measures Travel management plan	4	2	Low	Individual level effect, reversible and nonsignificant effect, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Airstrip: For the airstrip, four hazard scenarios were identified, which have the potential to occur during the Construction, Operations, and Closure of the Project. The hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-4: Hazard Identification Evaluation – Airstrip

ID#	Accident/Malfunction	Phase of Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
4.1	Fuel storage failure	CO / OP / ADR	Hydrocarbon release	Storage inspection and maintenance Secondary containment Spill and emergency response plan	1	3	Low	Risk level is low, highly unlikely event, no further assessment
4.2	Refuelling accident	CO / OP / ADR	Hydrocarbon release	Personnel training Containment Spill and emergency response plan	4	2	Low	Risk level is low, low consequence event, no further assessment
4.3	Airplane crash	CO / OP / ADR	Occupational major injuries / fatality Atmospheric release of particulate and combustion by-products Release of hydrocarbons and fuel Damage to mine infrastructure structure	Travel management plan Spill and emergency response plan Fire safety plan and firefighting systems Personnel training	1	5	ALARP, Moderate	Highly unlikely event, ALARP, no further assessment
4.4	Plane de-icing chemical release	CO / OP / ADR	Terrestrial release of reagent; possible aquatic release of reagent	Personnel training Containment Spill and emergency response plan	3	2	Low	Risk level is low, low consequence event, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Mining: For mining, ten hazard scenarios were identified, which have the potential to occur during the Operations of the Project. The screening assessment shows that one hazard scenario requires further assessment to characterize the risk in more detail. All other hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-5: Hazard Identification Evaluation – Mining

ID#	Accident/Malfunction	Phase	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
5.1	Mine back or wall failure	OP	Release of hazardous materials (corrosive, toxic, and flammable materials including chemicals and reagents) and potential for groundwater contamination	Mine water management and containment Monitoring Spill and emergency response plan	1	3	Low	Low risk, highly unlikely event, no further assessment
5.2	Mine back or wall failure	OP	Occupational major injuries	Occupational health and safety program Personnel training and orientation Refuge stations	1	4	ALARP, Moderate	Best practice in worker health and safety program resulting in ALARP, no further assessment
5.3	Mine back or wall failure	OP	Occupational fatalities	Occupational health and safety program Personnel training and orientation Mining procedure Geotechnical investigation and analysis Refuge stations	1	5	ALARP, Moderate	Best practice in worker health and safety program resulting in ALARP, no further assessment

ID#	Accident/Malfunction	Phase	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
5.4	Personnel falls into open ore/waste pass	OP	Occupational major injuries/fatality	Adequate lighting and signage and indicator lights Wheel stop barriers Vent plug on empty passes Occupational health and safety program Personnel training and orientation Mining procedures	1	5	ALARP, Moderate	Best practice in worker health and safety program resulting in ALARP, no further assessment
5.5	Uncontrolled explosion	OP	Damage to mine structure due to blast over pressure and potential for release of hazardous materials Occupational injuries/fatality	Best practice in mine development Explosives management Engineered blast designs	1	5	ALARP, Moderate	Best practice in mine development and highly unlikely event resulting in ALARP, no further assessment
5.6	Vehicle accident	OP	Release of fuel and groundwater contamination	Mine water management and containment Monitoring Spill and emergency response plan	2	2	Low	Low risk, low consequence event, no further assessment
5.7	Mine fire by any cause	OP	Atmospheric release of radioactive materials Occupational injuries/fatalities	Emergency response plan Fire safety plan and firefighting systems Fire fighting system Self rescuer units carried by personnel Ambient air monitoring Air monitoring in underground mine Remote ventilation control Underground refuge stations	2	5	ALARP, High	Best practice in worker health and safety program, the environmental consequences are limited, no further assessment
5.8	Fuel storage failure	OP	Hydrocarbon release underground and potential groundwater contamination	Storage inspection and maintenance Secondary containment Spill and emergency response plan	1	3	Low	Risk level is low, highly unlikely event, no further assessment
5.9	Refuelling accident	OP	Hydrocarbon release underground and potential groundwater contamination	Personnel training Containment Spill and emergency response plan	4	2	Low	Risk level is low, low consequence event, no further assessment
5.10	Failure of pipes and pumps for tailings transfer	OP	Release of radioactivity to the environment	Mine water management Groundwater monitoring Routine inspection and maintenance Emergency response plan	2	4	ALARP, Moderate	Best practice in tailings management and moderate consequence event resulting in ALARP; however, due to unknown consequence at the screening level this scenario is recommended for further assessment and is considered in Scenario 10.2

OP = Operations; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Hoisting: For hoisting, one hazard scenario was identified, which has the potential to occur during the Construction, Operations, and Closure of the Project. The hazard scenario has appropriate safeguards and design features to minimize the risk such that no further assessment is required for this hazard.

Table 3-6: Hazard Identification Evaluation – Hoisting

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
6.1	Hoist failure	CO / OP / ADR	Release of hazardous materials (chemicals and reagents) and potential for groundwater contamination	Hoist Safety Systems Mine water management and containment Monitoring Spill and emergency response plan	1	3	Low	Low risk, highly unlikely event, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking.

Mine dewatering system: For the mine dewatering system, two hazard scenarios were identified, which have the potential to occur during the Construction, Operations, and Closure of the Project. The hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-7: Hazard Identification Evaluation – Mine Dewatering System

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
7.1	Main Underground Dewatering System failure	CO / OP / ADR	Mine flooding and potential for groundwater contamination	Redundancy Preventive and routine maintenance System monitoring Mine water management Emergency response plan	3	2	Low	Risk level is low, low consequence event, no further assessment
7.2	High flow – groundwater ingress, surface flooding	CO / OP / ADR	Mine flooding and potential for groundwater contamination	Appropriate design and pump capacity Mine water management Emergency response plan	2	2	Low	Risk level is low, low consequence event, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking.

Processing plant: For the processing plant (excluding the solvent extraction circuit), eleven hazard scenarios were identified, which have the potential to occur in the Operations of the Project. The screening assessment shows that three hazard scenarios involving release of uranium are moderate risk. All these scenarios were bounded by a large solvent fire scenario. All other hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-8: Hazard Identification Evaluation – Process Plant

ID#	Accident/Malfunction	Phase	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
8.1	Ore spill	OP	Release of radioactivity	Ambient monitoring Spill and emergency response plan	2	2	Low	Low risk, low consequence event, no further assessment
8.2	Process vessel and piping system failure	OP	Release of sulphuric acid	Ambient monitoring Secondary containment Process sumps Mill building is contained Redundant temperature/reagent controls on leach tanks to protect liners from high temperature Spill and emergency response plan	3	2	Low	Low risk, low consequence event, no further assessment
8.3	Process vessel and piping system failure, clarifier overflow	OP	Release of pregnant aqueous solution	Ambient monitoring Secondary containment Process sumps Mill building is contained Redundant temperature/reagent controls on leach tanks to protect liners from high temperature Spill and emergency response plan	3	2	Low	Low risk, low consequence event, no further assessment
8.4	Process vessel and piping system failure	OP	Release of acidic fume and radon in leaching building	Ambient monitoring Building ventilation Redundant temperature/reagent controls on leach tanks to protect liners from high temperature	3	2	Low	Low risk, low consequence event, no further assessment

ID#	Accident/Malfunction	Phase	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
				Spill and emergency response plan				
8.5	Belt filter air exhaust to atmosphere	OP	Not expecting particulate in this exhaust stream. Could be radon, sulphuric acid	Filter bed exhaust to be scrubbed before atmospheric release	3	2	Low	Low risk, low consequence event, no further assessment
8.6	Hydrogen peroxide spill	OP	Potential for fire	Separate and contained hydrogen peroxide system (separation from organics) Spill and emergency response plan	2	3	Low	Low risk, low consequence event, no further assessment
8.7	Facility fire	OP	Release of uranium concentrate powder to atmosphere	Ambient air monitoring Fire safety plan and firefighting systems Emergency response plan	2	4	ALARP, Moderate	The consequence is bounded by Scenario 9.3
8.8	Process containment and gas cleaning and filtration system failure	OP	Release of uranium concentrate powder to atmosphere	Regular and preventive inspection, testing, and maintenance program Ambient air monitoring	3	4	ALARP, Moderate	The consequence is bounded by Scenario 9.3
8.9	Calciner wet scrubber failure	OP	Release of uranium dust and residual fluorine gas to atmosphere	Regular and preventive inspection, testing, and maintenance program Ambient air monitoring The release is short-term as the operation will stop upon failure of the scrubber	3	3	ALARP, Moderate	The consequence is bounded by Scenario 9.3
8.10	Hydrogen buildup in the in the leach tanks	OP	Hydrogen evolution may result in formation of explosive atmosphere in the leach tanks. It may explode upon presence of ignition source	The results of hydrogen evolution quantification tests performed on samples with different grades showed no hydrogen gas was detected during the leaching of a different grade ore; as a precaution, the installation of hydrogen detectors may be investigated	2	3	Low	The energy content of hydrogen gas mixture (within explosive limits) inside the tanks are low. The explosion energy is therefore low and may result in localized damage. Low risk, low consequence event, no further assessment
8.11	Paste plant mixing error	OP	Low moisture content paste may set prematurely inside the underground pipe causing the blockage of the piping system	Operator training Quality control Operating procedures Maintenance program for the control systems	3	2	Low	Low risk, low consequence event, no further assessment

OP = Operations; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Solvent extraction building: For the solvent extraction circuit, four hazard scenarios were identified, which have the potential to occur in the Operations of the Project. The screening assessment shows that one hazard scenario, involving a solvent extraction fire and/or explosion (Scenario 9.3), may require further assessment to characterize the risk in more detail. A second scenario involving a solvent extraction fire and/or explosion, Scenario 9.2, is bounded by this former scenario. The additional two scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-9: Hazard Identification Evaluation – Solvent Extraction Building

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
9.1	Process vessel and piping system failure	OP	Release of organic solvent	Concrete mixer-settler to facilitate visual leak inspection Regular and preventive inspection, testing, and maintenance program Secondary containment Mill building is contained Ambient monitoring Spill and emergency response plans	3	2	Low	Low risk, low consequence event, no further assessment
9.2	Solvent fire and/or explosion	OP	Atmospheric release of radioactivity	Dump tanks and fast-acting valves to transfer SX mixer/settlers in case of fire. Fire detection Regular and preventive inspection, testing, and maintenance program Fire safety plan and firefighting systems Ambient air monitoring Emergency response plan	2	4	ALARP, Moderate	The consequence is bounded by Scenario 9.3
9.3	Solvent extraction fire and/or explosion	OP	Domino effect and process plant fire resulting in release of radioactivity	Dump tanks and fast-acting valves to transfer SX mixer/settlers in case of fire. Fire detection Regular and preventive inspection, testing, and maintenance program Fire safety plan and firefighting systems Ambient air monitoring Emergency response plan	1	5	High	Further assessment recommended
9.4	Dump tank leak	OP	Leakage from the dump tank following a fire scenario and groundwater contamination	The dump tank is a concrete underground tank that is normally empty; the tank will be inspected regularly for any visual sign of structural defects	2	3	Low	Low risk, low consequence event, no further assessment

OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Tailings transfer pipe and UGTMF: For the UGTMF, as well as the mining stopes, two hazard scenarios were identified, which have the potential to occur during the Operations and Closure of the Project. The screening assessment shows that one hazard scenario requires further assessment to characterize the risk in more detail. For the second hazard scenario, appropriate safeguards and design features would be in place to minimize the risk such that no further assessment is required.

Table 3-10: Hazard Identification Evaluation – Tailings Transfer Pipe and UGTMF

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
10.1	Failure of tailings cell containment	OP / ADR	Potential for groundwater contamination	Engineered Design Groundwater monitoring	1	5	ALARP, Moderate	Best practice in tailings management and highly unlikely event resulting in ALARP, Inherent Safety, no further assessment
10.2	Tailings transfer pipe or pump failure	OP / ADR	Potential for soil / groundwater contamination	The pipe is in a secondary containment Groundwater monitoring Routine inspection and maintenance Emergency response plan	3	3	ALARP, Moderate	Further assessment recommended

OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

NPAG waste rock stockpile: For the NPAG Waste Rock Stockpile, four hazard scenarios were identified, which have the potential to occur during the Construction, Operations, and Closure of the Project. All hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-11: Hazard Identification Evaluation – Non-Potentially Acid Generating Waste Rock Stockpile

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
11.1	Stockpile slope failure	CO / OP / ADR	Release of material into surrounding environment	Regular inspection	2	2	Low	Low risk, unlikely event, no further assessment
11.2	Stockpile erosion	CO / OP / ADR	Blockage or diversion of ditches or surface water and discharge of materials into the environment	Containment being designed to accommodate a 24-hour, 1 in 100 year event Regular inspection	1	3	Low	Low risk, unlikely event, no further assessment
11.3	Uncontrolled leachate / seepage release through runoff	CO / OP / ADR	Discharge of materials into the environment	NPAG stockpile containment being designed to accommodate a 24-hour, 1 in 100 year event Regular inspection Ambient monitoring Surface water management Spill response plan	1	2	Low	Low risk, unlikely event, no further assessment
11.4	Uncontrolled leachate / seepage release	CO / OP / ADR	Discharge of materials into the environment	NPAG stockpile containment being designed to accommodate a 24-hour, 1 in 100 year event Regular inspection and maintenance of facility Groundwater monitoring Spill response plan	2	3	Low	Low risk, unlikely event, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; NPAG = non-potentially acid generating.

Ore, special waste, and PAG waste rock stockpiles: For ore, special waste, and PAG waste rock stockpiles, four hazard scenarios were identified, which have the potential to occur during the Construction, Operations, and Closure of the Project. All hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-12: Hazard Identification Evaluation – Ore, Special, and Potentially Acid Generating Waste Rock Stockpiles

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
12.1	Stockpile slope failure	CO / OP / ADR	Release of contaminants into surrounding environment	Containment being designed to accommodate a 24-hour, 1 in 100 year event Single-lined pad with leak detection system Regular inspection The slope of the stockpile is designed to provide stability	1	4	ALARP, Moderate	Best management practice results in ALARP, highly unlikely event, no further assessment
12.2	Stockpile erosion	CO / OP / ADR	Blockage or diversion of ditches or surface water and discharge of materials into the environment	Containment being designed to accommodate a 24-hour probable maximum precipitation event Single-lined pad with leak detection system Regular inspection	1	3	Low	Low risk, unlikely event, no further assessment
12.3	Uncontrolled leachate / seepage release through runoff	CO / OP / ADR	Discharge of contaminants into the environment	Regular inspection Ambient monitoring Surface water management Spill response plan	1	3	Low	Low risk, unlikely event, no further assessment
12.4	Uncontrolled leachate / seepage release through lining failure	CO / OP / ADR	Discharge of contaminants into the environment	Regular inspection and maintenance of lining Groundwater monitoring Spill response plan	1	4	ALARP, Moderate	Best management practice results in ALARP, highly unlikely event, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Effluent treatment system: For the effluent treatment system, three hazard scenarios were identified, which have the potential to occur during the Operations and Closure of the Project. The screening assessment shows that one hazard scenario requires further assessment to characterize the risk in more detail. Other hazard scenario would have appropriate safeguards and design features in place to minimize the risk such that no further assessment is required.

Table 3-13: Hazard Identification Evaluation – Effluent Treatment System

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
13.1	Equipment/piping failure	OP / ADR	Contaminant and radioactivity release	Routine and preventive testing, inspection, and maintenance program Piping design pressure higher than pumps shutoff pressure Process monitoring Secondary containment for clarifier Spill response plan	2	3	Low	Low Risk, no further assessment
13.2	Effluent clarifier overflow	OP / ADR	Contaminant and radioactivity release	Secondary containment Spill response plan	2	3	Low	Low Risk, no further assessment
13.3	Untreated effluent transfer pipe failure	OP / ADR	Release of reagents, occupational exposure, and environmental contamination	Routine and preventive testing, inspection, and maintenance program Process monitoring Controls to maintain barium chloride below its maximum solubility Spill response plan	3	3	ALARP, Moderate	Further assessment recommended

OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Ponds and retention berms: For ponds and retention berms, four hazard scenarios were identified, which have the potential to occur during the Operations and Closure of the Project. All hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-14: Hazard Identification Evaluation – Ponds and Retention Berms

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
14.1	Pond overtopping	OP / ADR	Contaminant and radioactivity release	Ponds to have capacity for a 24-hour probable maximum precipitation or 1 in 100 year event Process control Surface water management Ambient monitoring Spill and emergency response plan	2	3	Low	Low risk, low probability event, no further assessment
14.2	Pond containment or embankment failure	OP / ADR	Contaminant and radioactivity release	Regular inspection and maintenance program Surface water management Ambient monitoring Spill and emergency response plan	1	5	ALARP, Moderate	Best engineering practice in maintenance and inspection of the containment systems and berms, no further assessment
14.3	Pond lining failure and leakage	OP / ADR	Contaminant and radioactivity release	Groundwater monitoring Hydraulic containment with a separate well	3	4	ALARP, Moderate	Best engineering practice in maintenance, no further assessment
14.4	Surface flooding	OP / ADR	Contaminant and radioactivity release	Ponds to have capacity for a 24-hour probable maximum precipitation event Process control Surface water management Ambient monitoring Spill and emergency response plan	1	3	Low	Low risk, low probability event, no further assessment

OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Gypsum precipitation, washing, and storage: For gypsum precipitation, washing, and storage, two hazard scenarios were identified, which have the potential to occur in the Operations of the Project. These hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-15: Hazard Identification Evaluation – Gypsum Precipitation, Washing, and Storage

ID#	Accident/Malfunction	Phase	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
15.1	Loaded strip piping leakage	OP	Contaminant release	Secondary containment for piping between buildings	2	2	Low	Low risk, low consequence event, no further assessment
15.2	Gypsum reactor failure	OP	Contaminant release	Secondary containment Spill and emergency response plan	2	3	Low	Low risk, low probability event, no further assessment

OP = Operation; L = likelihood; S = severity; RR = risk ranking.

Acid plant: For the acid plant, five hazard scenarios were identified that have the potential to occur in the Operations of the Project. The screening assessment shows that one hazard scenario requires further assessment to characterize the risk in more detail. Two of the scenarios were bounded by an acid plant tail gas scrubber failure scenario. Two other hazard scenarios would have appropriate safeguards and design features in place to minimize the risk such that no further assessment is required.

Table 3-16: Hazard Identification Evaluation – Acid Plant

ID#	Accident/Malfunction	Phase	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
16.1	Truck, tanks, reactor, and storage vessels failure, sulphur spill during offloading (this is very common)	OP	Release of sulphur and acid	Housekeeping procedure Secondary containment Routine and preventive inspection, testing, and maintenance program Acid plant building is contained Spill and emergency response plans	3	2	Low	Low risk, low consequence event, no further assessment
16.2	Piping and piping component failure	OP	Release of acid	Acid resistant lined secondary containment with leak detection Sumps Routine and preventive inspection, testing, and maintenance program Acid plant building is contained Spill and emergency response plans	2	2	Low	Low risk, low consequence event, no further assessment
16.3	Acid plant tail gas scrubber failure	OP	Release of acid gas to the atmosphere, worker exposure, environmental damage	Sulphur dioxide and hydrogen sulphide monitors Routine and preventive inspection, testing, and maintenance program Ambient air monitoring	2	4	ALARP, Moderate	Further assessment recommended
16.4	Scrubber, absorber failure	OP	Release of acid gas to the atmosphere, worker exposure, environmental damage	Sulphur dioxide and hydrogen sulphide monitors Routine and preventive inspection, testing, and maintenance program Ambient air monitoring	2	4	ALARP, Moderate	This scenario is bounded by Scenario 16.3
16.5	Sulphur dioxide gas emission during plant start-up that spreads to other process plant area	OP	Release of acid gas to the atmosphere Worker inhalation of sulphur dioxide fume causing respiratory acid burn, Environmental damage	Sulphur dioxide and hydrogen sulphide monitors Routine and preventive inspection, testing, and maintenance program Ambient air monitoring	2	4	ALARP, Moderate	Relatively low likelihood event. Scenario is bounded from a biophysical environment perspective by Scenario 16.3

OP = Operation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Electrical system and power plant: For the electrical system and power plant, three hazard scenarios were identified, which have the potential to occur during Construction, Operations, and Closure of the Project. All hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-17: Hazard Identification Evaluation – Electrical System and Power Plant

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
17.1	Substation transformer leak	CO / OP / ADR	Release of mineral oil and potential for groundwater contamination	Spill and emergency response plan Secondary containment and gravel pit	3	2	Low	Low risk, low consequence event, no further assessment
17.2	Transformer, turbine, generator fire/explosion	CO / OP / ADR	Occupational major injuries	Fire safety plan and firefighting systems Occupational health and safety program Personnel training and orientation Personal protection equipment Fire detection and alarm Emergency response plan	2	4	ALARP, Moderate	Best practice in worker health and safety program resulting in ALARP, no further assessment
17.3	Transformer, turbine, generator fire/explosion	CO / OP / ADR	Occupational fatalities	Fire safety plan and firefighting systems Occupational health and safety program Personnel training and orientation Personal protection equipment Emergency response plan	1	5	ALARP, Moderate	Best practice in worker health and safety program resulting in ALARP, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

Fire protection system: For the fire protection system, two hazard scenarios were identified, which have the potential to occur during Construction, Operations, and Closure of the Project. These hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-18: Hazard Identification Evaluation – Fire Protection System

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
18.1	Failure of fire pump or foam system	CO / OP / ADR	Loss of firefighting capacity	Redundancy Regular and preventive testing, maintenance, and inspection Fire safety plan and firefighting systems Emergency response plan	1	3	Low	Low risk, highly unlikely event, no further assessment
18.2	Loss or lack of fire water	CO / OP / ADR	Loss of firefighting capacity	Fire safety plan and firefighting systems	1	3	Low	Low risk, highly unlikely event, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking.

Low-level radioactive waste management system / incinerator: For the low-level radioactive waste management system / incinerator, two hazard scenarios were identified, which have the potential to occur during Construction, Operations, and Closure of the Project. These hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-19: Hazard Identification Evaluation – Low-Level Radioactive Waste Management System / Incinerator

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
19.1	Hazardous waste spill	CO / OP / ADR	Potential for surface water and soil contamination	Waste management plan On-site monitoring Emergency response plan	3	2	Low	Low risk, low consequence event, no further assessment
19.2	Incinerator fire	CO / OP / ADR	Uncontrolled release of hazardous material	Fire safety plan and firefighting systems Operate incinerator within design parameters Ambient air monitoring Radiation Protection personal protective equipment, such as powered air purifying respirator or self-contained breathing apparatus Emergency response plan	2	3	Low	Low risk, low consequence event, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking.

LNG power plant: For the LNG power plant, six hazard scenarios were identified that have the potential to occur during Construction, Operations, and Closure of the Project. All hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-20: Hazard Identification Evaluation – Liquified Natural Gas Power Plant

ID#	Accident/Malfunction	Phase or Stage	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
20.1	LNG transportation accident	CO / OP / ADR	Fire or explosion resulting major injuries	Regular truck inspection and maintenance Travel management plan Fire safety plan and firefighting systems Emergency response plan	3	4	ALARP, Moderate	Regular truck inspection and maintenance resulting in ALARP, no further assessment
20.2	LNG transportation accident	CO / OP / ADR	Fire or explosion resulting fatalities	Regular truck inspection and maintenance Travel management plan Fire safety plan and firefighting systems Emergency response plan	1	5	ALARP, Moderate	Regular truck inspection and maintenance resulting in ALARP, no further assessment
20.3	LNG storage failure and release of gas	CO / OP / ADR	Fire or explosion	Regular storage facility inspection and maintenance Fire safety plan and firefighting systems Emergency response plan	1	5	ALARP, Moderate	Regular storage facility inspection and maintenance resulting in ALARP, no further assessment
20.4	Piping and piping component failure and release for gas	CO / OP / ADR	Fire or explosion	Regular storage facility inspection and maintenance Fire safety plan and firefighting systems Emergency response plan	3	2	Low	Low risk, low consequence event, no further assessment
20.5	Vaporization unit failure and release of gas	CO / OP / ADR	Fire or explosion	Regular piping inspection and maintenance Fire safety plan and firefighting systems Emergency response plan	3	2	Low	Low risk, low consequence event, no further assessment
20.6	Pump failure and release of gas	CO / OP / ADR	Fire or explosion	Regular pumps inspection and maintenance Fire safety plan and firefighting systems Emergency response plan	3	2	Low	Low risk, low consequence event, no further assessment

CO = Construction; OP = Operation; ADR = Active Decommissioning and Reclamation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable; LNG = liquified natural gas.

Mine ventilation system: For the mine ventilation system, three hazard scenarios were identified, which have the potential to occur during Construction and Operations of the Project. All hazard scenarios have appropriate safeguards and design features to minimize the risk such that no further assessment is required for any of these hazards.

Table 3-21: Hazard Identification Evaluation – Mine Ventilation System

ID#	Accident/Malfunction	Phase	Consequence	Existing Safeguards / Design Features	L	S	RR / Significance	Screening Decision / Rationale
21.1	Power outage	CO / OP	Loss of ventilation and accumulation of radon, toxic fumes	Radiation protection plan Occupational health and safety program Refuge stations Equipment monitoring and alarms Second egress from Exhaust Shaft Emergency response plan	2	3	Low	Risk level is low, highly unlikely event, no further assessment
21.2	Ventilation fans failure	CO / OP	Loss of ventilation and accumulation of radon, toxic fumes	Radiation protection plan Occupational health and safety program Equipment monitoring and alarms Refuge stations Emergency response plan	2	3	Low	Risk level is low, highly unlikely event, no further assessment
21.3	Mine air heater fire	CO / OP	Smoke release into the mine	Preventive maintenance of the heating equipment Fire safety plan and firefighting systems and firefighting systems Equipment monitoring and alarms Engineered safety systems Air monitoring in underground mine Refuge stations Emergency response plan	3	4	ALARP, Moderate	Regular and preventive inspection and maintenance resulting in ALARP, no further assessment

CO = Construction; OP = Operation; L = likelihood; S = severity; RR = risk ranking; ALARP = As Low as Reasonably Practicable.

4.0 SELECTION OF ACCIDENT SCENARIOS FOR FURTHER ASSESSMENT

Based on the HI process presented in the previous section, six hazard scenarios have been selected for more detailed risk analysis (Table 4-1). This further assessment will include the calculation of the likelihood and consequences of each of these selected scenarios. This will result in more in-depth and representative characterization of the risk of these scenarios, as the estimation of the risk in this current report was preliminary and at the screening level.

Table 4-1: Hazard Scenarios Identified for Further Assessment by the Hazard Identification Process

Node	Accident or Malfunction Scenario	Location	Effect Pathway
3.1	Traffic accident (uranium concentrate)	Access road at bridge crossing	Aquatic release of uranium concentrate
3.3	Traffic accident (chemical)	Access road at bridge crossing	Aquatic release of fuel, hazardous chemicals
9.3	Solvent extraction fire or explosion	Solvent extraction building	Atmospheric release of uranium concentrate (chemical toxicity)
10.2	Tailings transfer pipe or pump failure	Tailings release to surface within secondary containment	Terrestrial release of radioactivity
13.3	Untreated effluent transfer pipe failure	Effluent treatment system	Terrestrial release of radioactivity
16.3	Acid Plant tail gas scrubber failure	Acid plant	Atmospheric release of sulphur dioxide

5.0 REFERENCES

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