CMD 25-H12.1-Ref5

Date: 2025-10-15

Reference from NexGen Energy Ltd.

Référence de NexGen Energy Ltd.

In the matter of

À l'égard de

NexGen Energy Ltd.

NexGen Energy Ltd.

Licence application to prepare a site for and construct its Rook 1 uranium mine and mill project

Demande de permis concernant la préparation de l'emplacement et la construction de son projet de mine et d'usine de concentration d'uranium Rook I

Commission Public Hearing Part 1

Audience publique de la Commission Partie 1

November 19, 2025

Le 19 novembre 2025

Document ID: DAMZHJW66V33-166150894-8320

Canada

Volume 2: Rook I Project Environmental Impact Statement

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Rook I Project

Environmental Impact Statement

Section 7 Air Quality, Noise, and Climate Change

Submitted to:
Canadian Nuclear Safety Commission
Saskatchewan Ministry of Environment

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November 2024

Executive Summary

Section Purpose

Section 7 of the Environmental Impact Statement (EIS) provides a comprehensive assessment of potential effects of the Rook I Project (Project) on the atmospheric environment. The assessment of the atmospheric environment encompassed the following three discipline components:

- air quality (Section 7.2);
- noise (Section 7.3); and
- climate change (Section 7.4).

This atmospheric assessment included consideration of both potential effects from the Project and cumulative effects from the Project and other reasonably foreseeable developments (RFDs). The assessment for Section 7 used widely accepted scientific practices and incorporated Indigenous and Local Knowledge.

At a regional scale, the Project would be located within the southern Athabasca Basin adjacent to Patterson Lake, approximately 40 km east of the Saskatchewan-Alberta border and 640 km northwest of the city of Saskatoon. Given the differences in spatial extents of potential effects, each of the three discipline components used different study areas as described below.

Air Quality

Air quality represented an intermediate component in the Environmental Assessment (EA); the selection was based on the connection of air quality to soil and water and the health of vegetation, wildlife, and people. The air quality assessment provided information that was used to support valued component (VC) assessments such as human health, as well as the assessments of other intermediate components such as surface water quality, sediment quality, and terrain and soils. Intermediate components, such as air quality, were not assessed for significance.

Setting

The local study area (LSA) for the air quality assessment was defined as a 90,000 ha (900 km^2) area centred on the Project. The LSA is the area within which air quality effects due to the Project may be highest and can be predicted or measured with reasonable certainty. The LSA encompasses the local lakes surrounding the Project (e.g., Patterson Lake, Broach Lake, Jed Lake, Forrest Lake, Beet Lake, Naomi Lake) that are important to the assessments of other disciplines.

The regional study area (RSA) is defined as a 640,000 ha (6,400 km^2) area centred on the Project. The RSA encompasses large waterbodies (e.g., Preston Lake and Lloyd Lake) and areas that are more than 20 km from the proposed Project site. The RSA was designed to provide broader context for the assessment of Project effects on air quality and was the appropriate scale for the assessment of cumulative effects.

The air dispersion modelling domain is defined as a 1,000,000 ha (10,000 km^2) area centred on the Project and included the entire LSA and RSA. This area was designed to be large enough so that the predictions made within the RSA either reach background levels or are less than 10% of the air quality criteria.

Existing Conditions (Section 7.2.3)

A baseline field study and desktop study were undertaken to characterize air quality within the LSA and RSA. The passive sampling data collected in the LSA for nitrogen dioxide and sulphur dioxide indicated that concentrations remained below the annual Saskatchewan Ambient Air Quality Standards (SAAQS).

The measured sulphur dioxide data indicated that local activities (e.g., traffic, fuel combustion) may be contributing to ambient sulphur dioxide levels above the Saskatchewan Air Quality Model Guideline (SAQMG) annual background concentration for sulphur dioxide, although levels remain low.

Measured particulate matter with a nominal diameter of 2.5 microns or less ($PM_{2.5}$) was generally below the 24-hour and annual air quality standards in the most recent five years of monitoring, with occasional exceedances of 24-hour SAAQS from wildfire smoke.

Particulate matter with a nominal diameter of 10 microns or less (PM_{10}) was not monitored in the LSA; instead, background measurement data were established using monitoring data from an existing station, Buffalo Narrows Station in 2019 and 2020. Exceedances of the 24-hour SAAQS were recorded at this existing station in 2019 whereas there were no exceedances of SAAQS in 2020.

Background concentrations of $PM_{2.5}$, PM_{10}, total suspended particulates (TSP), carbon dioxide, nitrogen dioxide, sulphur dioxide were modelled as required by Saskatchewan Ministry of Environment guidance. The background concentrations are representative of a rural setting, being relatively unaffected by outside influences on air quality. Based on the monitoring results, existing air quality conditions were close to or lower than the prescribed background concentrations.

Potential Effects and Proposed Mitigations (Section 7.2.4)

An analysis was completed to evaluate Project components and activities and associated effects pathways that could potentially affect air quality. The evaluation also considered similar combined effects from the Fission Patterson Lake South Property, the identified RFD for the air quality assessment.

Project activities that would have the potential to affect air quality during the Project lifespan include:

- combustion of fossil fuels in stationary, mobile, and heavy equipment;
- handling and stockpiling of waste rock, special waste rock, and ore;
- underground drilling and blasting; and
- waste incineration.

Similar activities that could affect air quality would be expected to occur for the Fission Patterson Lake South Property.

As part of the pathway analysis, proposed environmental design features and mitigation measures were considered to determine whether effects to the environment could be avoided or reduced to negligible levels, thereby removing the pathway. Project environmental design features and mitigation to limit air quality effects included reducing fuel combustion requirements of infrastructure and equipment during detailed design; use of pollution control technology on process plant exhaust stacks; application of water and/or chemical suppressants to site roads, access road, and airstrip to mitigate dust emissions; and implementation of the Effluent and Emissions Plan. These mitigations have been used extensively within the mining sector and have been proven effective. Similar mitigation and adaptive management practices would also be expected to be implemented by the Fission Patterson Lake South Property.

After mitigation measures were considered, the pathways screening analysis determined that some of the potential pathways from the Project to the environment could be removed from the assessment. However, it was identified that the Project could still adversely affect air quality from the following pathways:

- emissions of criteria air contaminants (CACs) from Project activities during Construction and Operations; and
- emissions of CACs from mobile and stationary combustion sources during Closure.

Therefore, these pathways were carried forward into the residual effects analysis.

Residual Effects Analysis (Section 7.2.5)

A residual effects analysis was conducted to determine the potential effects on air quality under two assessment cases: effects of the Project (i.e., Application Case), and combined effects of the Project and the Fission Patterson Lake South Property (i.e., the RFD Case). The residual effects analysis considered seven measurement indicators:

- nitrogen oxides reported as nitrogen dioxide;
- sulphur dioxide;
- sulphuric acid;
- carbon monoxide;
- $PM_{2.5}$;
- PM_{10}; and
- TSP.

A dispersion modelling approach was used to predict concentrations of CACs from the Project and the Fission Patterson Lake South Property. Model results were then compared to baseline conditions and the relevant air quality criteria. Air quality is predicted to change from existing conditions due to both the Project and the Fission Patterson Lake South Property. However, most of the CACs (i.e., nitrogen dioxide, sulphur dioxide, sulphuric acid, carbon monoxide, and $PM_{2.5}$) are predicted to remain compliant with the SAAQS or below the applicable ambient criteria for all Project phases within the RSA. Short-term concentrations of 24-hour PM_{10} and 24-hour TSP are predicted to be above the SAAQS but the exceedance frequencies remain low, and the exceedance areas are localized to within a few hundred metres of the maximum disturbance area for the Project.

Because the effects of CACs on air quality cease as soon as the emissions stop, the duration of the effect is limited to the duration when emissions would be released. In the case of Construction, this period is four years; in Operations, the duration of the predicted effect is 24 years; in Active Closure, the duration of the predicted effect is five years.

Prediction Confidence and Uncertainty (Section 7.2.7)

Overall, there is a high degree of confidence in predictions related to the air quality assessment. Uncertainty was primarily and appropriately addressed by making assumptions that conservatively overestimated rather than underestimated potential effects (i.e., a precautionary assessment). The air dispersion model was also configured conservatively to predict maximum concentrations of measurement indicators for this assessment.

Monitoring and Follow-Up (Section 7.2.8)

Monitoring and follow-up programs would be used to verify the predictions through monitoring of air quality during Construction, Operations, and Closure. Monitoring would also be used to evaluate the effectiveness of mitigation actions and modify or enhance mitigation measures as necessary. The current baseline monitoring program that measures meteorological parameters, nitrogen dioxide, sulphur dioxide, TSP, and $PM_{2.5}$ would be continued through all Project phases, and the program would consider modifications identified through the licensing and permitting processes. The Environmental Protection Program would be implemented, which would include the Environmental Monitoring Plan and Effluent and Emissions Plan as components.

Noise

Noise represented an intermediate component in the EA; the selection was based on the potential for increased noise emissions from the Project to influence wildlife and land users. The noise assessment provided information that was used to support VC assessments such as wildlife and wildlife habitat, Indigenous land and resource use, and other land and resource use. Intermediate components, such as noise, were not assessed for significance.

Setting

A maximum disturbance area was delineated around the anticipated Project footprint, and an LSA (6,629 ha) and RSA (61,544 ha) were then defined for the noise assessment.

The LSA and RSA are generally composed of forested landscape intermixed with water and wetland features. Given the remote setting of the area, existing noise from anthropogenic (i.e., human-related) features and activities is mainly from Highway 955, mineral exploration, recreation (e.g., hunting, fishing), and Indigenous land and resource use.

Existing Conditions (Section 7.3.3)

A baseline field study was undertaken at three locations within the LSA and RSA to measure existing noise levels that may be experienced by wildlife, Indigenous Peoples, and recreational users. Three locations were selected to be representative of different settings within the LSA and RSA: swampy areas near Forrest Lake, rocky areas near Patterson Lake, and general forest environments.

Contributing sources to baseline noise measurements included:

- wind in the vegetation;
- birds and other wildlife;
- waves at locations near the lakes; and
- recreational users at the Forrest Lake location.

Existing noise levels in the LSA and RSA vary based on time of day and local conditions. Noise levels are generally greater during daytime than during nighttime and are generally greater near exposed waterbodies than in forested areas.

Existing noise level measurements at all locations in the LSA and RSA are less than noise thresholds outlined in *Environmental Code of Practice for Metal Mines* (Environment Canada 2009), *Guidance for Evaluating Human Health Impacts in Environmental Assessment – Noise* (Health Canada 2017), and Directive 038: Noise Control (AER 2007).

The measured baseline noise levels were used to determine existing daytime and nighttime noise levels at key receptor locations within the LSA and RSA. Sixteen noise receptor locations were identified through engagement and Joint Working Group meetings with Indigenous Groups; these locations included:

- active and historical cabins;
- lodges and campgrounds; and
- known locations used for fishing.

Potential Effects and Proposed Mitigations (Section 7.3.4)

An analysis was completed to evaluate Project components and activities and associated effects pathways that could potentially affect noise. The evaluation also considered similar combined effects from the Fission Patterson Lake South Property, the identified RFD for the noise assessment.

Noise emissions from equipment and mining-related activities that would have the potential to increase noise levels during the Project lifespan include:

- land clearing;
- site preparation;
- construction of facilities and infrastructure;
- underground mine development;
- power plant operation;
- airstrip traffic;
- milling and underground operations; and
- decommissioning and reclamation (i.e., closure) activities.

Similar activities that could increase noise levels would be expected to occur for the Fission Patterson Lake South Property.

As part of the pathways analysis, proposed environmental design features and mitigation measures were considered to determine whether effects to the environment could be avoided or reduced to negligible levels, thereby removing the pathway. Project environmental design features and mitigation to limit noise effects included designs to attenuate (i.e., reduce or dampen) noise from certain structures and equipment, proper maintenance of Project roads, and the implementation of health and safety programs. These mitigations have been used extensively within the mining sector and have been proven effective. Similar mitigation and adaptive management practices would also be expected to be implemented by the Fission Patterson Lake South Property.

After mitigation measures were considered, noise emissions from Project equipment and activities that would increase noise levels during all phases were determined to be pathways and were carried forward into the residual effects analysis.

Residual Effects Analysis (Section 7.3.5)

A residual effects analysis was conducted to determine the potential effects on noise under two assessment cases: effects of the Project (i.e., Application Case), and combined effects of the Project and the Fission Patterson Lake South Property (i.e., RFD Case). The residual effects analysis considered four measurement indicators:

- energy-equivalent sound levels for the daytime period;
- energy-equivalent sound levels for the nighttime period;
- a combined day-night sound level; and
- the maximum sound level.

Computer models were used to predict noise levels at the receptors from the Project and the Fission Patterson Lake South Property. The models were developed for one temporal snapshot during Construction and another during Operations. Details of the models are as follows:

- Temporal snapshots were selected to conservatively capture maximum noise effects.
- Noise effects were assessed using guidance and thresholds from Environment and Climate Change Canada (ECCC; Environment Canada 2009), Health Canada (2017), and the Alberta Energy Regulator (AER 2007).
- For each noise receptor, predictions were compared to the ECCC recommended thresholds. Those predictions indicate that noise levels from all project activities would not exceed 55 A-weighted decibels (dBA) at off-site receptors during the daytime period, and 45 dBA during the nighttime period (Environment Canada 2009).
- Predicted noise levels were used to calculate the percentage of a typical population that would be highly annoyed by combined day-night sound levels from the various activities and equipment, and by the maximum noise levels from the Project and Fission Patterson Lake South Property airstrips (Health Canada 2017).
- The potential low-frequency noise component measurements were compared to the model predictions (AER 2007).

The analysis indicated that noise from the Project and the Fission Patterson Lake South Property is predicted to result in detectable changes from existing conditions. However, cumulative noise levels are predicted to be of low magnitude, and noise at all receptors considered in this assessment would remain below the ECCC, Health Canada, and Alberta Energy Regulator thresholds.

Similarly, maximum noise levels associated with the Fission Patterson Lake South Property airstrip and the Project airstrip are predicted to be below Health Canada guidance thresholds.

Changes in the noise environment of the LSA and RSA were assumed to be continuous through the life of both projects but reversible at the end of the individual closure phases for the Project and Fission Patterson Lake South Property.

Prediction Confidence and Uncertainty (Section 7.3.7)

Overall, there was a moderate to high degree of confidence in the predictions related to the noise assessment. Uncertainty was primarily and appropriately addressed by making assumptions that conservatively overestimated rather than underestimated potential effects (i.e., a precautionary assessment), and by using model inputs that were based on accurate and precise estimates. The assessment also applied a precautionary and conservative approach by basing conclusions on the greatest magnitude, duration, and geographic extent of potential adverse effects when a range of potential outcomes was possible.

Monitoring and Follow-Up (Section 7.3.8)

Discipline specific follow-up studies would be implemented to verify effects predictions, mitigate noise effects, identify unanticipated effects, and apply adaptive management, if required.

Monitoring would verify compliance with regulatory noise requirements considered in the EIS (Environment Canada 2009; Health Canada 2017; AER 2007). In doing so, monitoring would be used to verify the model predictions and to address residual uncertainty.

Climate Change

For the purposes of the EA, climate change represents the change in global or regional climate patterns primarily attributed to increased atmospheric concentrations of greenhouse gases (GHGs) (Government of Canada 2021b). Assessing GHGs is the most effective method for estimating a project’s effect on climate change, as GHGs contribute to the greenhouse effect by absorbing infrared radiation in the atmosphere, increasing temperature, and changing weather patterns (Government of Canada 2015). The climate change assessment considered effects from the Project in the context of provincial and federal GHG emission levels.

Climate change was selected as a VC for the EA based on the following factors:

- the socio-economic and cultural importance of climate change;
- federal and provincial commitments to decrease GHG emissions; and
- the potential for Project GHG emissions to contribute to climate change.

Setting

The climate change assessment for the Project considered both provincial and federal emission levels, which correspond to administrative boundaries that are currently applied to GHG emissions under federal GHG policy, regulations, and legislation.

Existing Conditions (Section 7.4.3)

Existing conditions for GHG emissions were characterized using the provincial and federal GHG emissions levels prescribed by the ECCC *National Inventory Report 1990–2019: Greenhouse Gas Sources and Sinks in Canada* (ECCC 2021). Existing GHG emission levels were used as a basis to evaluate potential changes resulting from the Project.

In 2017, Canada produced 1.5% of the total global GHG emissions. Greenhouse gas emissions vary across provinces and territories, depending on each province or territory's (ECCC 2021):

- population size;
- energy sources; and
- types of industries.

The baseline GHG emissions at the provincial level, national sector, and federal level are provided below in megatonnes (one million tonnes) of carbon dioxide equivalent (Mt CO_2e). These emissions levels include the cumulative effects of existing projects and activities in Saskatchewan and Canada:

- Saskatchewan (all sectors), 75 Mt CO_2e; and
- Canada (all sectors), 730 Mt CO_2e.

Potential Effects and Proposed Mitigations (Section 7.4.4)

An analysis was completed to evaluate Project components and activities and associated effects pathways that could potentially contribute to climate change. A specific assessment of other RFDs was not completed as the Application Case provided all required information for the federal government to consider the Project relative to the cumulative effects of historical, existing, and future projects.

As part of the pathways analysis, proposed mitigation measures, policies, and actions were considered to determine whether the Project's GHG emissions and effects to the environment could be avoided or reduced to negligible levels, thereby removing the pathway. Proposed mitigation measures included:

- the use of liquid natural gas for power generation;
- heat recovery systems for heating certain Project processes and buildings; and
- the efficient management of energy and equipment at the Project.

While mitigation measures would reduce potential GHG emissions, the Project is expected to emit GHGs throughout Construction, Operations, and Closure through different sources that produce carbon dioxide, methane, and nitrous oxide.

Project components and activities that would contribute to GHG emissions include:

- the burning of fossil fuels in mobile and stationary equipment;
- non-hazardous and hazardous waste incineration;
- industrial processes; and
- explosives detonation.

Also, given the socio-economic and cultural importance of climate change, and international, federal, and provincial commitments to reduce GHGs, the Project GHG emissions and contributions to climate change were identified as a pathway and carried forward into the residual effects analysis.

Residual Effects Analysis (Section 7.4.5 and Section 7.4.6)

A residual effects analysis was conducted to determine the potential effects of the Project on climate change. The residual effects analysis considered three measurement indicators:

- Project emissions of carbon dioxide;
- Project emissions of methane; and
- Project emissions of nitrous oxide.

The estimated annual direct GHG emissions of the Project were calculated for each GHG compound as well as the total carbon dioxide equivalent emissions. The residual effects analysis identified the annual direct emission sources for all phases of the Project, which included:

- electricity generation;
- on-site mobile equipment;
- heating;
- land use change emissions; and
- stationary combustion.

The residual effects of the estimated maximum annual Project GHG emissions from each Project phase on provincial, national sector, and federal levels were assessed through the comparison to the most recent available emission totals for Saskatchewan and Canada. Years with the greatest emissions during each Project phase were selected for the comparison, which provided a conservative assessment of the Project's annual emissions. From this comparison, Project GHG emissions are predicted to have an adverse effect on climate change due to the global and permanent nature of GHG emissions; however, total Project emissions are expected to be low in magnitude, with the Project contributing less than 0.5% of the provincial annual total emissions and less than 0.1% of the federal annual total emissions.

Significance Determination (Section 7.4.6)

Effects to the climate change VC as a result of the Project were assessed to be **not significant**. The assessment determined that the Project GHG emissions would be of low magnitude and would not meaningfully affect Saskatchewan's and Canada's ability to reach climate change commitments within the current regulatory framework.

The potential effects of the Project's emissions in the overall context of the downstream nuclear power generation were also considered. Due to the low GHG emissions associated with nuclear power generation compared to coal and natural gas power generation, the downstream effects of the Project are predicted to increase Canada's ability to meet the national emission reduction targets (CNSC 2017). Additionally, the Project may support Canada's transition to a low carbon economy by providing the country with the fuel needed from cleaner energy sources (i.e., nuclear power).

Prediction Confidence and Uncertainty (Section 7.4.7)

Overall, there was a high degree of confidence in predictions related to the assessment of Project effects on climate change. Potential uncertainty was addressed by verifying the quality of emission calculation inputs and making assumptions that conservatively overestimated rather than underestimated potential effects (i.e., a precautionary assessment). It is anticipated that the Project GHG emissions would likely be lower than the calculated maximum annual emissions used in this assessment.

Monitoring and Follow-Up (Section 7.4.8)

The federal GHG reporting program requires reporting of facilities that produce GHG emissions over the 10 kt threshold; the Project would undertake this reporting, should this threshold be exceeded. Specifically, reporting of GHGs would involve quantifying the Project GHG emissions and reporting the Project GHG emissions annually to the applicable regulatory reporting program, which is Canada's Greenhouse Gas Reporting Program (ECCC 2019). Additional follow-up actions are listed in the Climate Change Road Map for the Project (Appendix 6A).

Abbreviations and Units of Measure

Abbreviation	Definition
%HA	percent highly annoyed
AAAQO	Alberta Ambient Air Quality Objective
AER	Alberta Energy Regulator
AERMOD	American Meteorological Society / Environmental Protection Agency Regulatory Model
ATV	all-terrain vehicle
BNDN	Birch Narrows Dene Nation
BRDN	Buffalo River Dene Nation
CAAQS	Canadian Ambient Air Quality Standards
CAC	criteria air contaminant
CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CNSC	Canadian Nuclear Safety Commission
CRDN	Clearwater River Dene Nation
EA	Environmental Assessment
ECAC	European Civil Aviation Conference
ECCC	Environment and Climate Change Canada
EIS	Environmental Impact Statement
ENV	Saskatchewan Ministry of Environment
ERA	environmental risk assessment
GHG	greenhouse gas
IKTLU	Indigenous Knowledge and Traditional Land Use
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JWG	Joint Working Group
L_{dn}	combined day-night sound level
$L_{eq,day}$	energy equivalent sound level for the daytime period
$L_{eq,night}$	energy equivalent sound level for the nighttime period
L_{max}	maximum sound level
LFN	low frequency noise
LNG	liquified natural gas
LPA	local priority area
LSA	local study area
MN-S	Métis Nation – Saskatchewan
N_2O	nitrous oxide
NexGen	NexGen Energy Ltd.
PM	particulate matter
$PM_{2.5}$	particulate matter with a nominal diameter of 2.5 microns or less
PM_{10}	particulate matter with a nominal diameter of 10 microns or less
Project	Rook I Project
RFD	reasonably foreseeable development
RSA	regional study area
SAAQS	Saskatchewan Ambient Air Quality Standards
SAQMG	Saskatchewan Air Quality Model Guideline
TSD	technical support document

Abbreviation	Definition
TSP	total suspended particulates
U_3O_8	triuranium octoxide
USEPA	United States Environmental Protection Agency
VC	valued component

Unit	Definition
%	percent
°C	degrees Celsius
$\mu g/m^3$	micrograms per cubic metre
µm	micron
dBA	A-weighted decibel
dBC	C-weighted decibel
GJ	gigajoule
h	hour
ha	hectare
Hz	hertz
kHz	kilohertz
km	kilometre
km^2	square kilometre
km/h	kilometres per hour
kt	kilotonne
kt CO_2e/yr	kilotonnes of carbon dioxide equivalent per year
L/h	litres per hour
mm	millimetre
m/s	metres per second
MJ/m^2	megajoules per square metre
Mt CO_2e/yr	megatonnes of carbon dioxide equivalent per year
t	tonne
t CO_2e/yr	tonnes of carbon dioxide equivalent per year
t/yr	tonnes per year

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Appendix 7C Greenhouse Gas Emissions Estimation Methodology Report

7 AIR QUALITY, NOISE, AND CLIMATE CHANGE

7.1 Introduction

NexGen Energy Ltd. (NexGen) is proposing to develop a new uranium mining and milling operation in northwestern Saskatchewan, called the Rook I Project (Project). The Project would be located approximately 40 km east of the Saskatchewan-Alberta border, 130 km north of the Northern Village of La Loche, and 640 km northwest of the city of Saskatoon (Figure 7.1-1). 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 7.1-2), with on-site worker accommodation serviced by fly-in/fly-out access.

This section of the Environmental Impact Statement (EIS) characterizes the potential residual effects of the Project on air quality, noise, and climate change, which are attributes or components of the atmospheric environment. Air quality and noise represent intermediate components and climate change is a valued component (VC) for the Environmental Assessment (EA).

Project-related activities could alter air quality through the emission and deposition of gases and particulates from fossil fuels and fugitive dust. As changes in air quality could influence biophysical VCs and intermediate components and socio-economic VCs, the results of the air quality assessment were considered within the assessments of surface water and sediment quality (Section 10, Surface Water Quality and Sediment Quality), fish and fish habitat (Section 11, Fish and Fish Habitat), terrain and soils (Section 12, Terrain and Soils), vegetation (Section 13, Vegetation), wildlife and wildlife habitat (Section 14, Wildlife and Wildlife Habitat), human health (Section 15, Human Health), Indigenous land and resource use (Section 16, Cultural and Heritage Resources and Indigenous Land and Resource Use), and other land and resource use (Section 17, Other Land and Resource Use).

Increased noise levels from the Project could affect wildlife, Indigenous land and resource use, and other land and resource use; therefore, potential effects from noise were considered in Section 14, Section 16, and Section 17, respectively.

The climate change VC considers the influence of Project greenhouse gas (GHG) emissions on climate change. Climate change is defined as change in global or regional climate patterns, primarily attributed to increased atmospheric concentrations of GHGs. Greenhouse gases are defined as gases that trap radiation, essentially heating the atmosphere. The most common GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone, perfluorocarbons, hydrofluorocarbons, and sulphur hexafluoride.

The climate change VC estimates the GHG emissions from the Project to assess the Project's influence on provincial and national GHG emissions levels. The climate change VC also estimates the GHG emissions intensity, which is defined the mass of emissions divided by mass of triuranium octoxide (U_3O_8) produced annually.

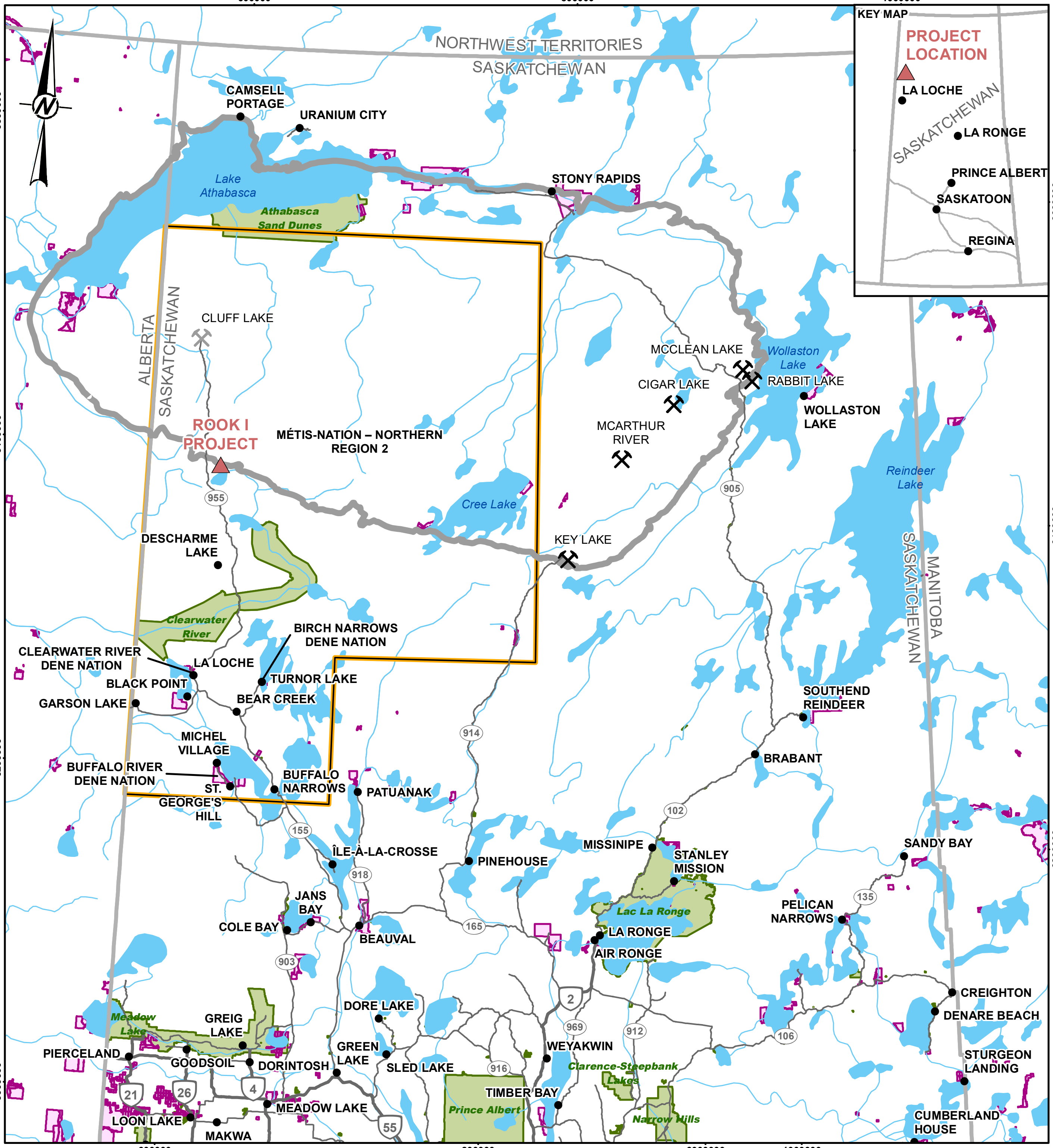
Climate change is also considered in the context of other intermediate components and VCs, as well as potential effects of the environment on the Project. Other ways that climate change was considered in the EIS are described in the Climate Change Road Map (Appendix 6A).

7.1.1 Project Summary

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 7.1-3):

- underground mine development;
- process plant buildings, including uranium concentrate packaging facilities;
- paste tailings distribution system;
- underground tailings management facility;
- potentially acid generating (PAG) waste rock storage area (WRSA);
- non-potentially acid generating (NPAG) WRSA;
- special waste rock[1] and ore storage stockpiles;
- surface and underground water management infrastructure, including water management ponds, effluent treatment plant, 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

0 100 200
1:3,500,000 KILOMETRES

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
wsp

PROJECT	20144150	SCALE AS SHOWN	REV. 0

FIGURE 7.1-1

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\07_Air_Quality_Noise_and_Climate\8_5x11\20144150_Fig7_1-1_Location-of-the-RookI-Project_NoTitleblock_Rev0.mxd PRINTED ON: 2023-02-07 AT: 1:07:20 PM

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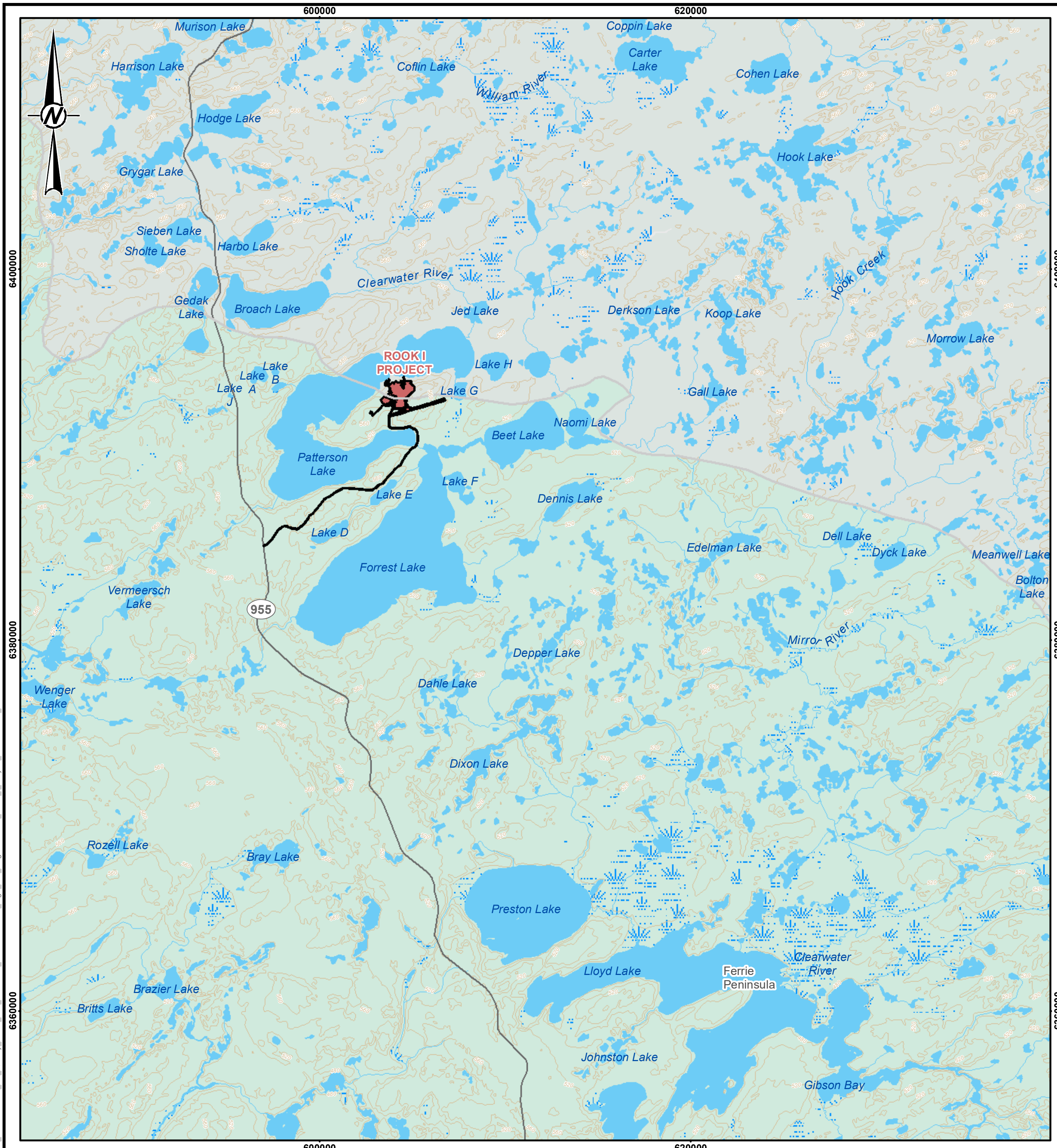

0 5 10

1:300,000 KILOMETRES

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	PROJECT 20144150	SCALE AS SHOWN	REV. 0
wsp	**FIGURE 7.1-2**		

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\07_Air_Quality_Noise_and_Climate\8_5x11\20144150_Fig7_1-2_Regional-Area_Rook_I_Project_NoTitleblock_Rev0.mxd PRINTED ON: 2023-02-07 AT: 1:07:45 PM

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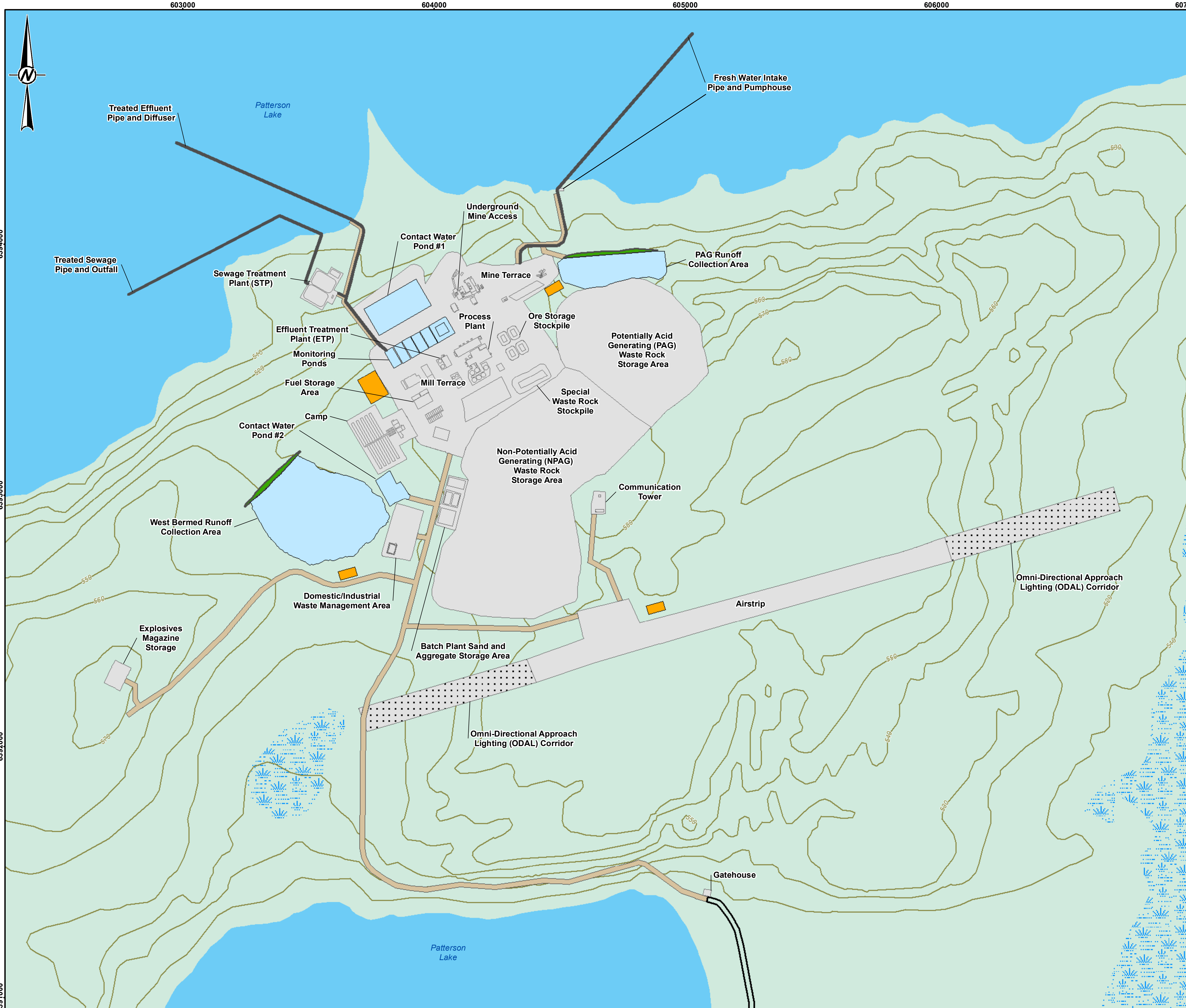

LEGEND

- 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	SCALE AS SHOWN	REV. 0

FIGURE 7.1-3

25mm

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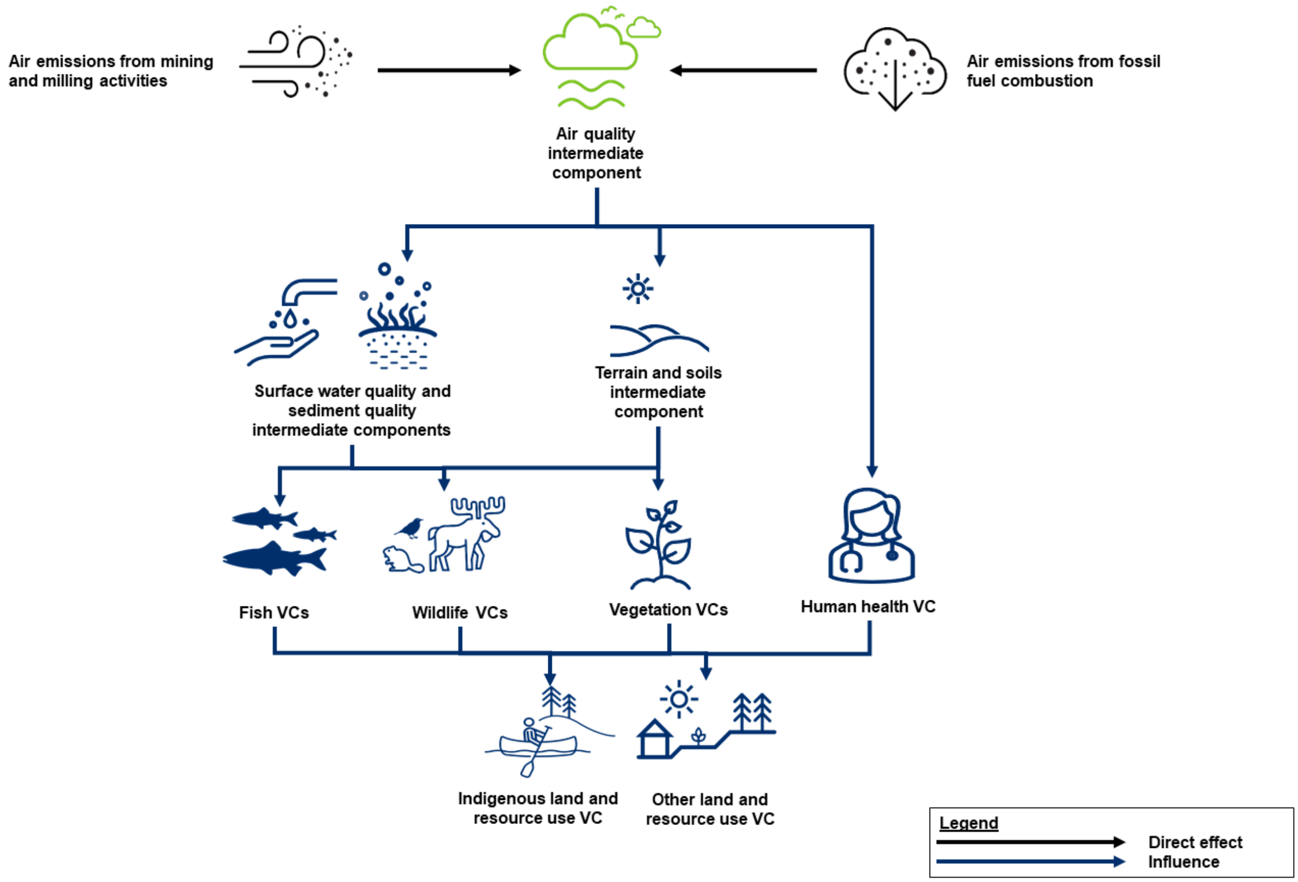
7.2 Air Quality

7.2.1 Introduction

Section 7.2, Air Quality, of the EIS characterizes the potential residual effects of the Project on air quality, which is an attribute of the atmospheric environment. Air quality represents an intermediate component for the EA. The term air quality refers generally to how well the air that makes up the atmosphere that people, plants, and animals rely upon meets objective measures of cleanliness. Those measures are defined by regulatory agencies provincially, and in some cases federally, as measured concentrations of target contaminants. Air that is free of contaminants is preferred but is not practical as all developments contribute some level of air contaminants and even remote locations can be influenced from distant developments. For this reason, regulatory agencies have established values of cleanliness (i.e., air quality standards) that consider the environment, health, economics, and practicality. It is against these measures that changes to air quality conditions arising from the Project were evaluated.

Project-related activities can alter air quality through the emissions from fossil fuel combustion and mining and milling activities. Changes in air quality could influence biophysical VCs and intermediate components (i.e., surface water and sediment quality, fish and fish habitat, terrain and soils, vegetation, and wildlife and wildlife habitat) and socio-economic VCs (i.e., human health, Indigenous land and resource use, and other land and resource use). The air quality assessment provides information that is used to support the assessments of other biophysical, cultural, and socio-economic VCs and intermediate components. A simplified linkage diagram, Figure 7.2-1, illustrates how proposed Project activities could result in a direct or indirect effect on air quality and the VCs that could be influenced through changes to air quality.

Figure 7.2-1: Linkage Diagram of Project Effects on Air Quality and Influenced Valued Components



VC = valued component.

7.2.1.1 Purpose and Approach to the Assessment

The purpose of Section 7.2 is to provide a detailed and comprehensive assessment of all potential Project-specific effects and cumulative effects from the Project and other previous, existing, and reasonably foreseeable developments (RFDs), if applicable, on-air quality. This subsection meets the Terms of Reference for the Project submitted to the Saskatchewan Ministry of Environment (ENV) and the Canadian Nuclear Safety Commission (CNSC) *Generic Guidelines for the Preparation of an Environmental Impact Statement – Pursuant to the Canadian Environmental Assessment Act, 2012* (Appendix 1A, Concordance Tables). The assessment of air quality followed the overall EA approach and methods (Section 6, Environmental Assessment Approach and Methods) and includes the following primary steps:

Step 1 – Define component-specific methods (Section 7.2.2): presents the specific approaches and methods used to measure and assess the effects of the Project on air quality as well as cumulative effects from the Project and those from previous, existing, and approved projects/activities and RFDs, if applicable.

Step 2 – Characterize existing conditions (Section 7.2.3): describes and characterizes existing conditions to provide context and a basis for evaluating potential changes to air quality caused by the Project.

Step 3 – Evaluate Project interactions and mitigations (Section 7.2.4): identifies Project components and/or activities with the potential to affect air quality and provides environmental design features and mitigation policies and actions committed to by the proponent to avoid or minimize potential adverse effects. A pathways analysis was used to focus further assessment on key interactions between the Project and air quality by evaluating the different effects pathways to determine if, after incorporation of mitigation, there is still potential to cause residual adverse effects. Primary pathways anticipated to result in residual adverse effects after incorporation of mitigation are carried forward to Step 4 for further analysis. Where potential adverse effects are adequately mitigated and thus not forwarded for further analysis (i.e., where mitigation results in negligible effects or avoids the pathway altogether), the reasons for concluding the assessment at this stage are provided.

Step 4 – Analyze and classify residual effects (Section 7.2.5 and Section 7.2.6): evaluates and describes the potential Project effects on air quality that are anticipated to occur through the primary pathways through a comparison of assessment predictions to applicable federal or provincial guidelines or standards. The residual effects analysis is presented as an integrated narrative that describes the effects of the Project over time and highlights predicted effects at the point when adverse effects of the Project are expected to be greatest. This step also includes an analysis of residual cumulative effects from the Project, other previous and existing projects and activities, and RFDs. Residual effects for air quality are classified and tabulated using the criteria direction, magnitude, geographic extent, duration, reversibility, and frequency to provide structure and comparability across all VCs and intermediate components in the EA.

Step 5 – Describe uncertainty and define prediction confidence (Section 7.2.7): identifies key uncertainties and explains how these uncertainties have been addressed to achieve a conservative, precautionary assessment. The implications of the approaches used to address uncertainties and the level of confidence in the residual effects analysis are discussed.

Step 6 – Identify monitoring and follow-up (Section 7.2.8): outlines the proposed actions to verify predicted residual effects. The purpose of these actions is to evaluate effectiveness of planned mitigation designs, policies, and practices, and address key sources of uncertainty.

7.2.2 Component Methods

7.2.2.1 Incorporation of Indigenous and Local Knowledge

Indigenous and Local Knowledge included in the assessment of air quality was shared by potentially affected First Nations and Métis Groups (collectively referred to as Indigenous Groups) and local priority area (LPA)[2] community members through the Project engagement process. The overall approach and methods for the incorporation of Indigenous and Local Knowledge into the EA is discussed in detail in Section 3, Indigenous and Local Knowledge. Issues and concerns related to air quality raised by Indigenous Groups and LPA community members, and how these comments were addressed, are summarized in Appendix 2B, Summary of Issues and Concerns Identified by Indigenous Groups, and identified and addressed in this assessment, where applicable.

A key source of Indigenous and Local Knowledge is the Project-specific studies completed by Indigenous Groups, including Traditional Land Use and Occupancy studies, Traditional Knowledge and Use studies, and Indigenous Rights and Knowledge studies (henceforth referred to collectively as Indigenous Knowledge and

[2] The LPA consists of the local communities closest to the Project that would experience most of the Project effects and for which NexGen would prioritize local training, employment, and business opportunities for the Project. These communities are located along, or accessed via, Highways 155 and 955 north of the intersection of Highways 155 and 925.

Traditional Land Use [IKTLU] Studies). The IKTLU Studies that were reviewed and referenced in the EIS as technical support documents (TSDs) are listed below:

- TSD II (BNDN), Birch Narrows Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD III (BRDN), Buffalo River Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD IV (MN-S), Métis Nation – Saskatchewan Northern Region 2 Traditional Land Use & Diet Study for the NexGen Rook I Project;
- TSD V.1 (CRDN), Preliminary Identification of Issues and Concerns Related to the Proposed NexGen Energy Ltd. Rook I Project in the Patterson Lake Area; A Review; Clearwater River Dene Nation; Traditional Land Use and Occupancy Mapping Interviews; 2010 – 2016;
- TSD V.2 (CRDN), Clearwater River Dene Nation Indigenous Rights and Knowledge Survey related to the proposed NexGen Energy Ltd. Rook I Project in the Patterson Lake Area;
- TSD V.3 (CRDN), Socio-economic and Harvest Study; Clearwater River Dene Nation; NexGen Rook 1 Project; and
- TSD VI (YNLR), Provision of Athabasca Denesųłiné Traditional Knowledge, Land Use and Occupancy Information for the NexGen Rook I Project Environmental Assessment.

Another key source of Indigenous and Local Knowledge was information shared by Indigenous Group representatives during Joint Working Group (JWG) meetings. The JWGs represent an agreed-upon primary engagement mechanism as outlined in the Study Agreements signed by each Indigenous Group and NexGen. More details regarding the JWGs can be found in Section 2, Indigenous, Regulatory, and Public Engagement and Section 3, Indigenous and Local Knowledge. There are four JWGs with the Project's primary Indigenous Groups (Section 2.4.1, Identification of Indigenous Groups for Engagement):

- Clearwater River Dene Nation (CRDN) JWG;
- Métis Nation – Saskatchewan (MN-S) JWG representing MN-S Northern Region 2 (NR2);
- Birch Narrows Dene Nation (BNDN) JWG; and
- Buffalo River Dene Nation (BRDN) JWG.

The leadership of each Indigenous Group selected their JWG participants with consideration of group diversity; where possible, members included Elders, youth, different genders, a range of ages, and land users around Patterson Lake.

In addition to the IKTLU Studies and JWGs, Indigenous and Local Knowledge shared during specific engagement activities undertaken through the EA development process was incorporated into the assessment, where appropriate. These engagement activities included, but were not limited to:

- community information sessions held in four locations in 2019 (NexGen 2019);
- site tours;
- comments from the CRDN (2019a) on the Cluff Lake Mine licence renewal;
- other formal and informal meetings;
- workshops with specific groups (e.g., Fur Block N-19 trapper's workshop); and

- environmental and socio-economic baseline data collection.

Comments submitted by Indigenous Groups on the Project Description (CRDN 2019b; MN-S 2019; YNLRO 2019; ACFN 2019; CNSC 2019) were also reviewed for applicable Indigenous and Local Knowledge.

Indigenous and Local Knowledge related to air quality was incorporated into the assessment by viewing the information as complementary and influential alongside scientific information. Where possible, knowledge from each potentially affected Indigenous Group or LPA community member was described separately and cited accordingly. Where information is described for multiple potentially affected Indigenous Groups they are collectively referred to as "Indigenous Groups" throughout the assessment.

Indigenous and Local Knowledge was included in the air quality assessment in the following ways:

- **Component methods – Valued components and intermediate components:** Indigenous and Local Knowledge was considered in the selection of the air quality intermediate component and reflects the importance of having access to "clean fresh air" while practising traditional activities and contributing to community well-being. The importance of air quality was also reflected by comments made by Indigenous Groups about the interrelationships between different environmental components and the critical role it plays in aquatic and terrestrial environmental health (Section 7.2.2.2.1).
- **Existing conditions:** Indigenous and Local Knowledge was shared about observations related to existing air quality.
- **Project interactions and mitigation:** Indigenous and Local Knowledge helped to inform the scoping of Project interactions and pathway analysis and consideration of mitigation measures (Section 7.2.4). This included observations and experiences of land users related to the cumulative effects of industry on air quality and the subsequent effects on human, aquatic, and terrestrial environmental health.
- **Monitoring, follow-up, and management:** Feedback provided by Indigenous Groups during engagement, including recommendations, was considered in the development of monitoring and follow-up activities (Section 7.2.8). In addition, NexGen plans to consider ongoing feedback from Indigenous Groups on the effectiveness of mitigations when updating monitoring and management plans. Independent Indigenous monitors chosen by each primary Indigenous Group would also have opportunities to participate in environmental monitoring programs for the Project.

Specific references to Indigenous and Local Knowledge, and Project comments and concerns related to air quality raised by Indigenous Groups and LPA community members, are included in the applicable sections of this assessment.

7.2.2.2 Valued Components, Intermediate Components, and Measurement Indicators

7.2.2.2.1 Valued Components and Intermediate Components

Valued components are aspects of the biophysical, cultural, and socio-economic environments that are considered to have scientific, social, cultural, economic, historical, archaeological, or aesthetic importance (Beanlands and Duinker 1983; CNSC 2021). Intermediate components include physical attributes of the biophysical environment or media upon which VCs rely, such as air quality, terrain and soils, hydrogeology, and hydrology (Section 6.3.3, Intermediate Components). Valued components and intermediate components are assessed using the same steps; however, unlike VCs, intermediate components do not have assessment endpoints or significance criteria. Instead, the significance of changes in intermediate components is evaluated in the context of related influences to VCs, which are the ultimate receptors.

Air quality was selected as an intermediate component based on the connection to soil and water and the health of vegetation, wildlife, and people. Air quality is critical to the assessment of VCs for the EA; however, the importance or significance of changes in air quality can only be evaluated in context of the related influences on VCs such as moose, traditional use plants, or human health. Therefore, the assessment of air quality is fundamental to understanding the total effects of the proposed Project on the biophysical environment (Section 6.3.3) and supports the Environmental Risk Assessment (ERA; TSD XXI) and the assessment of the following intermediate components and VCs:

- surface water quality and sediment quality (Section 10);
- fish and fish habitat VCs (Section 11);
- terrain and soils (Section 12);
- vegetation VCs (Section 13);
- wildlife and wildlife habitat VCs (Section 14);
- human health (Section 15);
- Indigenous land and resource use (Section 16); and
- other land and resource use (Section 17).

Indigenous Groups have reported that having access to a healthy environment and clean natural resources is critical for harvesting activities, including hunting, trapping and plant gathering, and for community well-being. For example, members of the MN-S, BNDN, and BRDN commented that “clean fresh air” is one of the things they appreciate the most about where they live and is important for community well-being (BNDN-JWG 2020a; BRDN-JWG 2020b; MN-S-JWG 2020). The CRDN stated that living and harvesting activities “are predicated on clean air and clean water” (TSD V.2: CRDN). Members of the MN-S highlighted the importance of respecting the air and keeping it clean for human health and also for future generations (MN-S-JWG 2019a). In community information sessions, LPA community members noted that air quality was a key interest and concern and important component of the environment (NexGen 2019).

Indigenous Groups described the importance of air quality in terms of the interrelationships between different components of the biophysical environment and the vital role air quality plays in aquatic and terrestrial environmental health (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). For example, some Indigenous Group members have noted that air pollution, including dust and odours from existing industrial developments, has affected water quality and fish, vegetation, and wildlife populations. The CRDN has stated that “unclean air and water conditions from a Denesųłiné perspective ultimately and fundamentally affect all forms of life” (TSD V.2: CRDN). The air quality intermediate component addresses issues such as effects on air quality and the maintenance of clean fresh air by comparing predicted air quality to regulatory standards that are protective of human health and the environment. Air quality was analyzed using a science-based approach with a regulatory-approved dispersion model to determine the Project-specific and cumulative changes, if applicable, in measurement indicators. The rationale for selecting air quality as an intermediate component is summarized in Table 7.2-1.

7.2.2.2.2 Measurement Indicators

Measurement indicators are used to characterize changes to attributes of the environment from the Project, other human developments, and natural factors. The changes in measurement indicators are used to predict overall effects on VCs and intermediate components (Section 6.3.2, Assessment Endpoints and Measurement Indicators). Seven measurement indicators were identified and used for the air quality assessment (Table 7.2-1). The effects assessment focused on evaluating the air quality measurement indicators that have been defined as ambient air concentrations of selected air contaminants to be emitted from the Project that also have applicable Saskatchewan and/or federal ambient air quality criteria:

- **Nitrogen dioxide:** Nitrogen dioxide belongs to the "oxides of nitrogen" group of compounds that are formed primarily through the burning of fossil fuels, composed mainly of nitric oxide and nitrogen dioxide. Nitrogen oxides are emitted as a mix of nitric oxide and nitrogen dioxide, but the nitric oxide can be quickly converted in the atmosphere to nitrogen dioxide. Nitrogen dioxide would be emitted from the combustion of fossil fuel at the Project. Both nitrogen dioxide in its untransformed state, and the acid and nitrate transformation products of nitrogen dioxide, can have adverse effects on human health or the environment. At higher concentrations, nitrogen dioxide has a strong, harsh odour and can typically be seen over large cities as a brownish haze. Once formed, nitrogen dioxide can combine with water molecules in the air to form compounds such as nitric acid and nitrous acid. Ultimately, these compounds fall to earth through precipitation (e.g., rain, snow, fog), where they contribute to the acidification and eutrophication of ecosystems (CCME 2021).
- **Sulphur dioxide:** Sulphur dioxide is a colourless gas that smells like burnt matches. It belongs to a group of sulphur-containing gases called sulphur oxides. Sulphur dioxide is emitted when fossil fuels or raw materials containing sulphur are burned or used in an industrial process. Sulphur dioxide itself can cause adverse effects on respiratory systems of humans and animals, and damage to vegetation. Sulphur dioxide contributes to the formation of $PM_{2.5}$ (i.e., particulate matter with a nominal diameter of 2.5 microns or less) and smog, and when combined with water molecules in the air, it can form compounds such as sulphuric acid, which eventually fall to earth as acid rain, snow, and fog (CCME 2021).
- **Sulphuric acid:** Sulphuric acid is a brownish, odourless, oily mineral acid. Sulphuric acid would be produced at the acid plant at the proposed Project as part of the process to break down and extract uranium from the ore. When emitted to the atmosphere, sulphuric acid can contribute to haze and smog and affect public health. When falling to the surface as acid rain, sulphuric acid can cause damage to lakes and rivers, forests, soils, fish and wildlife populations, and buildings.
- **Carbon monoxide:** Carbon monoxide is a colourless, odourless, and tasteless gas. It is a product of incomplete combustion of fossil fuels (Government of Canada 2021a). Carbon monoxide was modelled for assessment of potential effects on human health.
- **Particulate matter with a nominal diameter of 2.5 µm or less ($PM_{2.5}$):** Particulate matter (PM) is a major component of smog, consisting of airborne particles in solid or liquid form. Particulate matter may be classified as primary or secondary, depending on the process that led to its formation. Primary PM is emitted directly into the atmosphere from a source, such as a smokestack or exhaust pipe, or from wind-blown soils or vehicle traffic on a dirt road. Secondary PM is formed in the atmosphere through a series of chemical and physical reactions involving gases such as sulphur oxides and nitrogen oxides. Particulate matter exists in various sizes, and the main particle size of concern for human health is $PM_{2.5}$, also referred to as fine PM (CCME 2021).

- **Particulate matter with a nominal diameter of 10 µm or less (PM_{10}):** Another subgroup of PM, PM_{10} can also be inhaled into human respiratory systems. Both $PM_{2.5}$ and PM_{10} can be inhaled, with some depositing throughout the airways, though the locations of particle deposition in the lung depend on particle size. The $PM_{2.5}$ is more likely to travel into and deposit on the surface of the deeper parts of the lung, while PM_{10} is more likely to deposit on the surfaces of the larger airways of the upper region of the lung (CARB 2021).
- **Total suspended particulates (TSP):** Refers to airborne particles having a nominal diameter between 0.1 µm and 30 µm. Improved understanding of PM and its effects on human health and the environment has led to a belief that the smaller particle fractions (i.e., $PM_{2.5}$) are primarily responsible for adverse human health and environmental effects (Environment Canada 1998).

These measurement indicator compounds (i.e., nitrogen dioxide, sulphur dioxide, sulphuric acid, carbon monoxide, $PM_{2.5}$, PM_{10}, and TSP) are hereafter referred to as criteria air contaminants (CACs) as they would all be directly emitted by the Project and they all have either federal or provincial ambient air quality criteria. Similarly, the term "criteria" is used generically to refer to any set of regulated air concentrations, whereas "standards" refer to specific sets of standards set by provincial or federal governments (Section 7.2.2.8.2, Comparison to Canadian Ambient Air Quality Standards).

Table 7.2-1: Rationale and Measurement Indicators for the Air Quality Intermediate Component

Intermediate Component	Rationale	Measurement Indicators
Air quality	▪ Sensitivity of the environment (e.g., soils, plants, animals) to air quality ▪ Link to human health	Ambient air concentrations of CACs that have applicable provincial or federal ambient air quality criteria and would be emitted directly from the Project: ▪ nitrogen oxides reported as nitrogen dioxide ▪ sulphur dioxide ▪ sulphuric acid ▪ carbon monoxide ▪ $PM_{2.5}$ ▪ PM_{10} ▪ TSP

$PM_{2.5}$ = particulate matter with a nominal diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal diameter of 10 µm or less; TSP = total suspended particulates; CAC = criteria air contaminant.

The air quality assessment used a dispersion model to predict the transportation and maximum ground-level concentrations of these CACs and compare them to the applicable regulatory criteria. The evaluation of the effects of changes to air quality on the receiving environment is provided in the residual effects analysis of the other VCs or intermediate components.

In addition to the CACs / air quality measurement indicators described above, other air contaminants are expected to be emitted from the Project, dispersed in the air, and affect the receiving environment. The following non-CACs were not considered to be measurement indicators for the air quality assessment, but were included as inputs in the air quality model to support related sections of the EIS:

- Dust is a term that is used throughout the EIS. Dust commonly refers to the largest of the generated particles that tend to settle out of suspension in the air by gravity within a short distance (i.e., usually within a few hundred metres) from their source. Dry deposition of dust refers to the gravitational settling of particles larger than the size of $PM_{2.5}$. Gases and particles smaller than $PM_{2.5}$ are not subject to appreciable gravitational settling, and are primarily removed from the air, along with dust, by rainfall or snowfall. Aerial deposition of dust can alter soil chemistry or affect vegetation growth by altering the photosynthesis, respiration, and transpiration processes. The amount of aerial deposition of dust due to the proposed Project is predicted in the EIS (Appendix 7A, Air Dispersion Modelling Report) and provided to the ERA (TSD XXI), aquatic (Section 10 and Section 11) and terrestrial (Section 12, Section 13, and Section 14) disciplines for their assessments.
- Dioxins and furans are the short names for compounds in a family of toxic substances that all share a similar chemical structure. Burning of municipal waste is a source of dioxin and furans. The health effects associated with human exposure to dioxins and furans include skin disorders, liver problems, impairment of the immune system, and certain types of cancers. The ambient concentrations of dioxins and furans expected to result from Project emissions are predicted in the EIS (Appendix 7A) and are provided for the ERA and human health assessment (Section 15).
- Radon released to the environment from mining and processing uranium ore is important when considering potential radiation exposures to workers and the public population near a facility. Radon emissions from the proposed Project are considered in the EIS (Appendix 7A) and are provided for the ERA and human health assessment (Section 15).
- Metals such as arsenic, molybdenum, selenium, uranium, and 22 additional metals (Appendix 7A) are emitted as a component of PM from fugitive sources of mineral dust and PM associated with combustion emissions. The metals adhered to the surface of suspended particles when inhaled can cause adverse effects on human health. The aerial deposition of metals to surface may contaminate soil and water. Metals concentrations and deposition are considered in the EIS. The results were used in ERA and the residual effects analysis of water quality (Section 10) and terrain and soils (Section 12) to assess the effects of metals on the aquatic and terrestrial environments, respectively.
- Radionuclides, including radon, would be emitted from the mining and processing of uranium ore. Long-term inhalation exposure to radionuclides could have adverse effects on human and environmental health. Radionuclide concentrations and deposition rates resulting from the mining and processing of uranium ore are included in the EIS (Appendix 7A). The results are provided for ERA (TSD XXI) and residual effects analysis of water quality (Section 10), terrain and soils (Section 12), and human health (Section 15).

7.2.2.3 Spatial Boundaries

The emission, transport, and deposition of CACs were simulated using an air dispersion model, as described in Appendix 7A. The model used is able to reliably predict concentrations of contaminants within a certain distance from the source of emissions. However, the quality and confidence of the model predictions deteriorates when predictions extend far from the source emissions. Therefore, the spatial boundaries for the air quality assessment consisted of an air dispersion modelling domain, a regional study area (RSA), and a local study area (LSA) for the effects assessment (Table 7.2-2). The LSA, RSA, air dispersion modelling domain, and the maximum disturbance area are shown in Figure 7.2-2.

The LSA provides local context for assessing Project effects. The LSA for air quality is defined as a 90,000 ha (900 km^2) area centred on the Project. The LSA is the area within which air quality effects may be greater and can be predicted or measured with reasonable certainty. The LSA also encompasses the local lakes surrounding the Project (e.g., Patterson Lake, Broach Lake, Jed Lake, Forrest Lake, Beet Lake, Naomi Lake) that are important to the assessments of other disciplines. For example, air quality predictions were made for each of these lakes because they represent specific areas of focus for water quality.

The RSA was designed to provide broader context for the assessment of Project effects on air quality, and was the appropriate scale for the assessment of cumulative effects. The RSA is defined as a 640,000 ha (6,400 km^2) area centred on the Project. The RSA encompasses large waterbodies (e.g., Preston Lake, Lloyd Lake) and areas that are more than 20 km from the Project site. At the RSA boundary, air concentrations are predicted to either be at background levels or less than 10% of the applicable criteria.

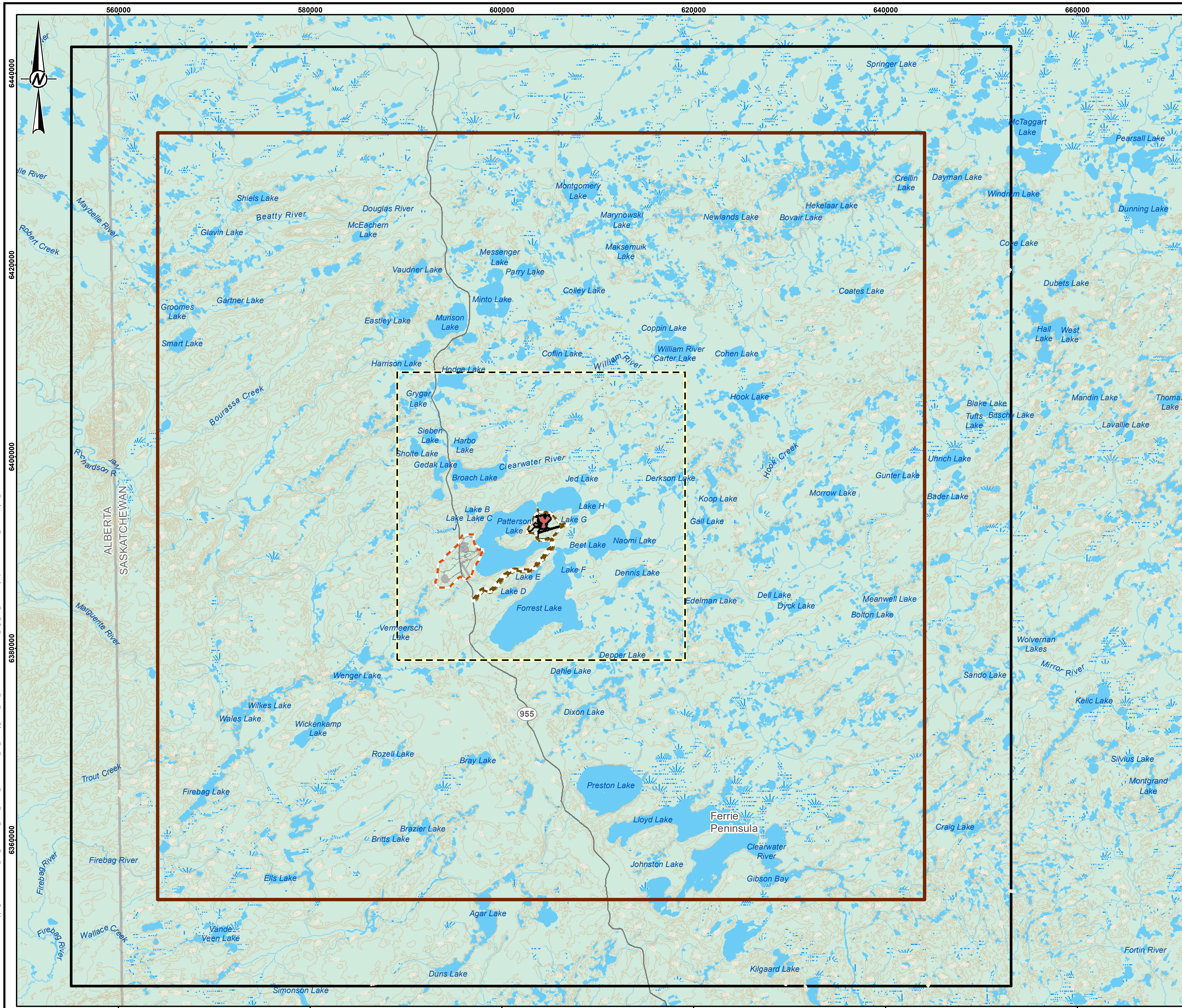
The air dispersion modelling domain is defined as a 1,000,000 ha (10,000 km^2) area centred on Project. This area has been designed to be large enough so that the predictions made within the RSA either reach background levels or are less than 10% of the air quality criteria. The modelling domain is large enough to include the entire LSA and RSA.

Table 7.2-2: Spatial Boundaries for Assessment of Air Quality

Study Area	Area	Description/Rationale
LSA	90,000 ha (900 km^2)	▪ The LSA is the area within which air quality effects may be greater and can be predicted or measured with reasonable certainty
RSA	640,000 ha (6,400 km^2)	▪ The RSA was designed to provide broader context for the assessment of Project effects on air quality and was the appropriate scale for the assessment of cumulative effects
Air dispersion modelling domain	1,000,000 ha (10,000 km^2)	▪ The air dispersion modelling domain was designed to be large enough so that the predictions made within the smaller RSA either reach background levels or are less than 10% of the air quality criteria

LSA = local study area; RSA = regional study area.

The air quality assessment also refers to a maximum disturbance area to provide information to support the assessments of terrestrial disciplines but does not explicitly assess effects on air quality inside this boundary. The maximum disturbance area was used in the terrain and soils (Section 12), vegetation (Section 13), and wildlife and wildlife habitat (Section 14) assessments. The maximum disturbance area, which covers 981 ha (9.8 km^2), was delineated by applying buffers to the outer edges of the anticipated Project infrastructure (Section 6.4.1, Spatial Boundaries), and was also constrained to the shoreline of Patterson Lake.



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- LOCAL ROAD
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- AIR LOCAL STUDY
- AIR REGIONAL STUDY
- AIR QUALITY MODELLING STUDY

0 12 24
1:400,000 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).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

AIR QUALITY SPATIAL BOUNDARIES

CONSULTANT

wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	SB/ZY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-07	**FIGURE 7.2-2**	
CHECK	ZY	2023-02-07		
REVIEW	CM	2023-02-07		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B 25mm 0

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7.2.2.4 Temporal Boundaries

The temporal scope of the assessment focuses on the 43-year period from initial Construction to the end of Decommissioning and Reclamation (i.e., Closure) as defined by the following Project phases (Section 6.4.2, Temporal Boundaries):

- **Construction Phase (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. The duration of Construction is expected to be four years.
- **Operations Phase (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. The duration of Operations is expected to be 24 years.
- **Decommissioning and Reclamation Phase (Closure):** includes two stages expected to occur over 15 years:
  - **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 and 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. The duration of the Active Closure Stage is expected to be five years.
  - **Transitional Monitoring Stage:** includes monitoring and reporting activities that occur post-Active Closure that 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 back under Provincial management through the Institutional Control Program. The duration of the Transitional Monitoring Stage is nominally 10 years; however, NexGen acknowledges this duration would be dependent on the achievement of performance criteria.

The temporal boundaries applied to cumulative effects assessments include the duration of residual effects from previous and existing developments that overlap with effects from the Project, and the period during which the residual effects from RFDs overlap with the Project.

The air quality assessment was conducted using a temporal snapshot approach (e.g., a single calendar year) during both Construction and Operations when the maximum emission intensity from the Project activities would be expected within each period. The emission intensity from Closure is expected to be lower than that of Construction and Operations. As emission intensity would be less during Closure, modelling and assessment of Closure was not conducted.

7.2.2.5 Assessment Cases

The concept of assessment cases was applied to the air quality assessment to estimate the incremental and cumulative effects from the Project and other developments (Section 6.5, Assessment Cases). The approach incorporated temporal boundaries for analyzing the potential effects from previous, existing, and approved projects and RFDs before, during, and after the anticipated lifespan of the Project. There are no known approved (but not yet constructed) projects in the LSA and RSA for air quality. Assessment cases for the Project included a Base Case, Application Case, and RFD Case.

Base Case for air quality is represented by existing conditions. The Base Case describes the existing environment in the RSA and LSA before application of the proposed Project to provide an understanding of the current conditions that may be influenced by the Project. The temporal boundary of the Base Case includes the combined effects from previous and existing human disturbances and natural factors (e.g., fire, precipitation, wind) on air quality. As such, existing conditions represent the cumulative effects of historical and current environmental pressures that have influenced the observed condition and patterns of air quality (CEA Agency 2018).

Application Case for air quality represents predictions of the combined effects of the previous and existing projects/activities and natural factors in the Base Case plus the potential effects from the proposed Project. This case was also used to identify and assess incremental, Project-specific changes that are predicted to occur to air quality. To support the Application Case, air quality modelling was completed for the predictions of the Project emissions alone to aid in understanding the predicted Project effects on air quality (i.e., Project-only simulation).

Reasonably Foreseeable Development Case for air quality includes the Base Case, Application Case, and RFDs that have not yet been approved. Reasonably foreseeable developments are defined as projects and activities that fit any of the first three and both of the last two criteria from the list below:

- are currently under regulatory review or have officially entered a formal regulatory application process;
- have been publicly disclosed by other proponents;
- may be induced by the Project;
- have the potential to change the Project or the effects predictions; and
- occur in the spatial assessment boundary defined by air quality.

A key criterion for selecting other projects to include in the RFD Case was that the projects must cause similar effects on air quality influenced by the Project (Hegmann et al. 1999). The Fission Patterson Lake South Property, which is planned by Fission Uranium Corp. (Fission 2019, 2021), was included in the RFD Case (Figure 7.2-2). Public information describes a projected three-year construction period and seven-year operating period (production and processing; Fission 2019, 2021). The anticipated start of construction and duration of active decommissioning at the Fission Patterson Lake South Property were not publicly available at the time this assessment was completed. For the assessment, it was assumed that the duration of active decommissioning for the Fission Patterson Lake South Property would be similar to the Active Closure Stage for the Project (i.e., five years; Section 6.5.3, Reasonably Foreseeable Development Case).

The proposed surface infrastructure layout plan (Fission 2019, 2021) is the anticipated physical footprint of the Fission Patterson Lake South Property and includes the proposed highway bypass, airstrip, and all proposed mine site infrastructure. A hypothetical maximum disturbance area, as applied in Section 7.2.2.3, Spatial Boundaries, to the Project footprint, was also used for the Fission Patterson Lake South Property to address uncertainty in project design. The CRDN and MN-S specifically mentioned the potential for of cumulative effects from the Project and the nearby proposed Patterson Lake South Property (CRDN 2019b; MN-S-JWG 2020; CRDN-JWG 2021).

The assessment included a quantitative analysis of predicted changes on measurement indicators and associated effects from the Fission Patterson Lake South Property on air quality in the RSA.

7.2.2.6 Existing Conditions

Existing conditions include both air quality and meteorology. Representative, existing air quality and meteorology in the modelling domain were determined based on an atmospheric baseline study (Annex I, Atmospheric Baseline Report) that included two components:

- A desktop review of publicly available ambient air quality, meteorological, and climate data that are representative of the atmospheric conditions within the RSA.
- A field program at the Project that monitored both continuous and intermittent meteorology and air quality.

7.2.2.6.1 Meteorology

Meteorological conditions are necessary to properly contextualize the air quality data and provide an objective comparison to the meteorological data used to drive the dispersion model.

On-site meteorological data, including temperature, precipitation, wind speed and wind direction, relative humidity, and incoming solar radiation were measured using the Rook I Meteorological Station. The data were measured and recorded in the LSA during the baseline monitoring program.

Long-term measurements of temperature, precipitation, wind speed and wind direction, and relative humidity were also downloaded and compiled from two long-term climate normal monitoring stations: the Cluff Lake Station, located approximately 82 km north-northwest of the existing exploration camp; and the Fort McMurray A Station, located approximately 164 km to the southwest of the existing exploration camp. The data from the Cluff Lake Station and Fort McMurray A station were collected by Environment and Climate Change Canada (ECCC). Such datasets are typically used to derive long-term weather trends that are referred to as climate normals. In the case of this assessment, ECCC data were compared to the locally collected data to validate the on-site data and to help determine its suitability for use in the assessment.

7.2.2.6.2 Air Quality

Local air quality was monitored through a baseline program that began in September 2018. Monitoring continues at the time of writing of this assessment; all data available at the end of 2020 were incorporated into the baseline study. The data were collected in the LSA at one location where the main Project facilities are proposed to be constructed. This location is cleared, but otherwise undeveloped. Siting the monitoring station in accordance with the Air Monitoring Guideline for Saskatchewan (ENV 2012a) to the extent possible at this location provides confidence that the data expected to be collected in the future near the Project can be compared to spatially representative baseline conditions.

Continuous particulate monitoring was conducted for TSP and $PM_{2.5}$. Continuous monitoring yields data with a high temporal resolution. It is conducted by a monitoring device that samples continuously by using pumps to cycle air through its sensor, then provides the data over a longer averaging period (e.g., hourly data). Thus, data collected using continuous samplers can be compared to criteria of any averaging period (e.g., one-hour, 24-hour, annual).

Passive sampling of nitrogen dioxide and sulphur dioxide was conducted monthly. Passive sampling uses a reagent in a cartridge that is exposed to the atmosphere behind a semi-permeable membrane for a known period of time. The target atmospheric gas (e.g., nitrogen dioxide, sulphur dioxide) reacts with the reagent, forming a secondary compound. The cartridges are returned to the providing laboratory, where the secondary compound is extracted and analyzed. The laboratory provides a composite concentration of the target gas based on the analysis of the amount of secondary compound that is detected. Because the data are typically processed monthly, direct comparison to averaging periods shorter than one month are not made. Instead, comparisons between passive sampling data and ambient air quality standards are limited to the annual averaging period.

Regional air quality monitoring data from other programs at four remote locations outside the air dispersion modelling domain were used to supplement data collected in the LSA and were used to additionally characterize baseline air quality conditions. Data from as far away as 210 km were used in this characterization because they were the closest available data sources. The stations are as follows:

- Fort Chipewyan Station, located in the Lower Athabasca air zone, approximately 160 km northwest of LSA. The station is located near the small community of Fort Chipewyan and may be influenced by community-related emissions (e.g., local traffic, building heating, airstrip) more than might be reasonably expected under existing conditions in the LSA. However, the Fort Chipewyan Station was considered a reasonable surrogate for existing atmospheric conditions within the RSA due to its position typically upwind from the existing exploration camp and large oil sands developments in the Athabasca Oil Sands Region.
- Buffalo Narrows Station, located near the community of Buffalo Narrows, approximately 210 km south-southeast of the existing exploration camp: This station is part of the ECCC National Air Pollution Surveillance program, which collects air quality data across Canada.
- JP205 Station, a passive monitoring station operated by the Wood Buffalo Environmental Association, located approximately 73 km west-northwest of the existing exploration camp.
- JP213 Station, a passive monitoring station operated by the Wood Buffalo Environmental Association, located approximately 75 km southwest of the existing exploration camp.

The ENV typically requires that air quality assessors use Saskatchewan government-supplied background air quality values. The background values are added to the incremental concentration values predicted by the dispersion model for each compound to arrive at air quality values representing project scenarios. These values are prescribed based on the provincial zone within which the assessment is being conducted. This provincial background value is designed to account for distant or otherwise un-accounted concentrations of the assessed compounds that are present in the atmosphere. The air quality baseline study included a review of the ENV-prescribed background concentrations for the northern air dispersion modelling zone of Saskatchewan. The data from the air quality monitoring program were used to evaluate and support an update of the government-supplied background air quality concentrations, which were then used in the air quality assessment to characterize existing air quality conditions.

7.2.2.7 Project Interactions and Mitigations

Interactions (i.e., linkages) between Project components or activities, and the corresponding potential changes to measurement indicators, were identified by a pathway analysis that was then used to inform the residual effects analysis for air quality (Section 6.7, Pathways Analysis). The first part of the analysis was to identify all potential effects pathways for all phases of the Project (Section 6.7.1, Identification of Project Interactions). Each pathway was initially assumed to have a linkage to potential effects on air quality.

Potential pathways from Project activities to air quality were identified using the following:

- review of the Project description (Section 5) and potential effects scoping by the project development, environmental, and socio-economic teams for the Project;
- input from Indigenous, regulatory, and public engagement (Section 2) and Indigenous and Local Knowledge (Section 3);
- scientific knowledge;
- previous experience with mining projects; and
- consideration of potential effects identified from the Terms of Reference (Section 1, Appendix 1A).

Potential adverse effects of the Project were then identified, and practicable mitigation was applied to avoid, minimize, and/or rehabilitate adverse effects on air quality (Section 6.7.2, Identification of Mitigation). Avoidance and minimization are widely recognized as the most important approach for biodiversity conservation (BBOP 2021). Avoidance designs and actions integrated into the Project were developed iteratively between the Project's environmental and project development teams. Minimization techniques and technology were also identified and implemented collaboratively between Project teams.

Each potential effect pathway was evaluated using proposed mitigation to predict whether the pathway had the potential to cause residual adverse effects (Section 6.7.3, Pathway Screening). A screening-level assessment was applied using Indigenous and Local Knowledge, scientific knowledge, logic, experience with similar developments, and an understanding of the effectiveness of mitigation (i.e., level of certainty that mitigation would work) to assign each pathway to one of the following categories:

- **No pathway:** Analysis reveals that the pathway could be removed (i.e., the effect is avoided) by mitigation so that the Project would result in no measurable environmental change relative to existing conditions or guideline values and, therefore, would have no residual effect on air quality.
- **Secondary pathway:** The pathway could result in a measurable but minor environmental change relative to existing conditions or guideline values, but this change would be sufficiently small that it would have a negligible residual effect on air quality. Therefore, the pathway is not expected to contribute to effects of RFDs to cause a significant effect.
- **Primary pathway:** The pathway is likely to result in an environmental change relative to existing conditions or guideline values and could cause a greater than negligible effect on air quality.

Project interactions determined as no pathway or secondary pathways were not carried forward for further assessment (Section 6.7.3). Primary pathways that could result in changes to the environment with one or more associated measurement indicator and have the potential to cause a greater than negligible effect on air quality were carried forward to the residual effects analysis (Section 7.2.5) and residual effects classification (Section 7.2.6).

7.2.2.8 Residual Effects Analysis

The residual effects analysis measures and describes the effects of the proposed Project on air quality relative to existing conditions. The residual effects analysis was conducted using the spatial boundaries (Section 7.2.2.3, Spatial Boundaries) and temporal boundaries (Section 7.2.2.4, Temporal Boundaries) identified for the assessment. Residual effects are described for each of the measurement indicators for the primary pathways identified for air quality in the LSA and RSA (Section 7.2.4.3, Primary Pathways). The residual effects analysis was completed for the Application Case and the RFD Case (Section 6.8, Residual Effects Analysis). The residual effects analysis was undertaken by using air dispersion modelling to predict ambient concentrations of CACs and then quantitatively comparing these concentrations to existing conditions and the applicable ambient air quality criteria. The ambient air quality criteria are presented in Table 7.2-3.

The approach to evaluating air quality follows the guidance provided by the Province of Saskatchewan for air quality dispersion modelling, the Saskatchewan Air Quality Model Guideline (SAQMG; ENV 2012b). The general approach used to evaluate the changes in CACs from the Project included the following steps:

1. Establish the existing air quality and meteorological conditions in the air dispersion modelling domain, including the representation of the existing conditions in the airshed on CACs. Modelled predictions were subsequently contextualized against this Base Case.
2. Quantify air emissions from the Project and other developments identified in the RFD Case; this entailed developing an inventory of the emissions expected to be released from the Project and any RFDs (Section 7.2.2.5, Assessment Cases). The inventory is inclusive of all facilities and activities of the Project and RFDs that would release emissions to the atmosphere either through combustion (e.g., engines) or by mechanical means (e.g., earth moving and road traffic). This step involves considering the appropriate mitigation measures to reduce emissions in accordance with the regulatory guidance and calculating emissions conservatively such that the dispersion modelling that follows also predicts conservative concentrations that are unlikely to be exceeded during Project Construction, Operations, or Closure.
3. Develop a representative, site-specific, meteorological dataset for use in the dispersion modelling; this step involved gathering and preparing the appropriate meteorological data that were input to the dispersion model in accordance with Saskatchewan guidance. Meteorology is a key input to dispersion modelling and a site-specific meteorological dataset was developed along with the data provided by Province of Saskatchewan after direct consultation with ENV. The meteorological dataset includes five years' worth of one-hour-frequency data. Including the leap-year (i.e., 2016), this dataset amounts to consideration of 43,824 hours of meteorological data, which provides enough meteorological data that all reasonably foreseeable meteorological conditions that could be present at the site are evaluated in the dispersion model. A baseline meteorological monitoring program was conducted in the LSA and provides additional context for the site-specific dataset. The baseline monitored meteorological parameters were compared with those derived from the site-specific meteorological datasets for air dispersion to evaluate the representativeness of the site-specific datasets.
4. Conduct computer air dispersion modelling to predict the concentrations of CACs released from the Project and other developments in the RFD Case. When running an approved dispersion model in Saskatchewan, the regulatory model of choice is the American Meteorological Society / Environmental Protection Agency Regulatory Model (AERMOD). The output of the AERMOD model is a series of predictions of concentrations of the air quality compounds being evaluated, presented in a grid pattern. The grid of predictions is dense near to the proposed Project and becomes less dense with distance from the proposed Project.
5. Combine the modelled CAC concentrations with background values and compare the result to the applicable ambient air quality criteria. Present the data in tables and figures that allows all organizations and people interested in the Project to review and understand the data.
6. Provide the air quality data to other intermediate components and VCs to be used as input data for those assessments.

The residual effects analysis was completed for the Application Case and the RFD Case (Section 6.8). The residual effects analysis draws upon results from the following cases or modelled simulations:

- **Base Case:** normally a modelled simulation inclusive of all existing and approved nearby projects plus the background concentration, in the absence of the Project; however, because there are no other nearby projects to model for the Base Case, this case consists only of the background concentrations and does not require modelling.
- **Project-Only Simulation:** a modelled simulation of the predicted concentrations of the Project emissions only.
- **Application Case:** a modelled simulation of the Base Case (i.e., background concentration) plus the Project. The Application Case spans the entire Project lifespan including Construction and Operations. As noted in Section 7.2.2.4, Closure was assessed but not modelled.
- **RFD Case:** includes the Project and the Fission Patterson Lake South Property and the background concentration.

The Application Case and RFD Case predictions were then evaluated against the baseline conditions and the appropriate air quality standards. During Closure, Project components or activities that contribute to CAC emissions include removal of infrastructure, restoration and revegetation of facility sites and infrastructure, transportation of personnel and material to and from the site, power generation, and non-hazardous waste incineration. The intensity, duration, and spatial extent of CAC emissions during Closure would be reduced relative to that of Construction and Operations. Because Construction and Operations are assessed and the emissions intensity, duration, and geographic extent would all be reduced in Closure relative to these other periods, no additional emission inventory and air dispersion modelling was conducted for Closure. The residual effects of Closure were conservatively assessed based on the results of Application Case during Construction.

7.2.2.8.1 Comparison to Saskatchewan Ambient Air Quality Standards

Residual effects of the air quality assessment were evaluated through a comparison of the model-predicted concentrations to the applicable ambient air quality standards. The primary standards against which comparisons were made were the Saskatchewan Ambient Air Quality Standards (SAAQS; Government of Saskatchewan 2015a). These standards applied to the measurement indicators for the air quality assessment and are provided in Table 7.2-3. For sulphuric acid, there are no SAAQS; therefore, the Alberta Ambient Air Quality Objectives (AAAQOs) for sulphuric acid were used as a substitute in this assessment for this measurement indicator (Government of Alberta 2019).

Table 7.2-3: Applicable Saskatchewan Ambient Air Quality Standards

Compound	Concentrations (µg/m³)			
	1 h	8 h	24 h	Annual
Nitrogen dioxide	300	n/a	200	45[(a)]
Sulphur dioxide	450	n/a	125	20[(a)]
Sulphuric acid[(b)]	10	5	n/a	n/a
Carbon monoxide	15,000	6,000	n/a	n/a
$PM_{2.5}$	n/a	n/a	28[(c)]	10[(a)]
PM_{10}	n/a	n/a	50	n/a
TSP	n/a	n/a	100	60[(d)]

Source: Government of Saskatchewan 2015a.
a) Arithmetic mean.
b) There are no SAAQS for sulphuric acid; therefore, AAAQOs for sulphuric acid are used as surrogates.
c) Average of the annual 98th percentile of the daily 24-hour average concentrations for three consecutive years.
d) Geometric mean.
n/a = not applicable; $PM_{2.5}$ = particulate matter with nominal diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal diameter of 10 µm or less; TSP = total suspended particulates; SAAQS = Saskatchewan Ambient Air Quality Standards; AAAQO = Alberta Ambient Air Quality Objectives.

7.2.2.8.2 Comparison to Canadian Ambient Air Quality Standards

In 2012, the Canadian Council of Ministers of the Environment and the Canadian provinces and territories, excluding Quebec, agreed to implement a national Air Quality Management System (CCME 2012). The framework resulted in the development of the Canadian Ambient Air Quality Standards (CAAQS) for $PM_{2.5}$, ozone, nitrogen dioxide, and sulphur dioxide. The CAAQS are human health-based air quality objectives for compound concentrations in ambient air. The CAAQS were implemented to follow a two-phased approach for achievement, setting 2015 and 2020 standards for $PM_{2.5}$ and ozone (CCME 2012) and 2020 and 2025 standards for nitrogen dioxide and sulphur dioxide (CCME 2020a,b). The CAAQS are presented in Table 7.2-4. The SAAQS for $PM_{2.5}$ are equivalent to the 2015 CAAQS, so they are not re-presented here. Ozone is not a measurement indicator for the Project because ozone is not directly emitted from the Project, so the CAAQS for ozone is not presented here.

The Canadian Council of Ministers of the Environment has developed guidance documents on achievement determination of CAAQS for $PM_{2.5}$, nitrogen dioxide, and sulphur dioxide (CCME 2012, 2020a,b). The CAAQS achievement is determined by provinces and territories using ambient concentrations measured in the air zones for a three-year period, not by comparison of modelled predictions at or beyond a facility boundary. Measurements made in populated areas using the National Air Pollution Surveillance monitoring network is the appropriate way to evaluate compliance with the CAAQS. Comparison of dispersion modelling results from a single facility to CAAQS is not directly applicable (CCME 2012). Accordingly, such comparisons made in this assessment are for information only and are not indicative of compliance.

Table 7.2-4: Applicable Canadian Ambient Air Quality Standards

Compound	Averaging Period	Concentration			Unit	Statistic Form
		2015	2020	2025		
Nitrogen dioxide	1-hour	n/a	60	42	ppb	The 3-year average of the annual 98th percentile of the daily maximum 1-hour average concentrations.
		n/a	113	79	µg/m³	
	Annual	n/a	17	12	ppb	The average over a single calendar year of all 1-hour average concentrations.
		n/a	32	22.6	µg/m³	
Sulphur dioxide	1-hour	n/a	70	65	ppb	The 3-year average of the annual 99th percentile of the daily maximum 1-hour average concentrations.
		n/a	183	170	µg/m³	
	Annual	n/a	5	4	ppb	The average over a single calendar year of all 1-hour average concentrations.
		n/a	13	10.5	µg/m³	
$PM_{2.5}$	24-hour	28	27	n/a	µg/m³	The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations.
	Annual	10	8.8	n/a	µg/m³	The average over a single calendar year of all 1-hour average concentrations.

Source: CCME 2021.
n/a = not applicable; $PM_{2.5}$ = particulate matter with a nominal diameter of 2.5 µm or less; ppb = parts per billion.

7.2.2.8.3 Dispersion Modelling

To assess the effects from the Project on air quality, the AERMOD dispersion model was used. The AERMOD was specially developed to support the United States Environmental Protection Agency (USEPA) regulatory modelling programs, and it has been adopted by the ENV as the preferred air dispersion model for air quality studies in Saskatchewan. As described in the USEPA's user guide (USEPA 2021), AERMOD is a multi-source air dispersion model that incorporates concepts such as planetary boundary layer theory and advanced methods of handling complex terrain.

The AERMOD system has two input data processors: AERMET and AERMAP. The AERMET is a meteorological data processor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts. The AERMAP is a terrain data preprocessor that incorporates complex terrain using digital elevation data. The air dispersion model used inputs including emissions from the Project and other developments, and meteorological and terrain data to simulate the atmospheric processes and make predictions about what the maximum concentrations of CACs would be over a broad area. In this case, the area over which predictions are made was inclusive of the 100 km by 100 km air dispersion modelling domain that included both the RSA and LSA. The air dispersion modelling approach followed the SAQMG (ENV 2012b). Details of the air dispersion modelling approach are provided in Appendix 7A.

An air emissions inventory was developed for Project Construction and Operations. Project air emissions were quantified based on Project design data available at the time the assessment was being completed. The emission inventory process included developing a comprehensive list of equipment planned for use at the Project site and calculating potential emissions to be simulated in the model. Potential emissions would include combustion-related emissions from on-site equipment such as the power generators and heaters, the mining activity underground, and surface activities including vehicle traffic, earth moving activities, and waste management. The air emission rates were estimated using various approaches that were deemed to be most appropriate and representative for each source. Where applicable, the approaches that would achieve conservative emission rate estimates were applied. The approaches included engineering estimates, mass balance, site-specific emission factors, and published emission factors (e.g., USEPA AP-42 emission factors [USEPA 1995]). Details of the Project emission quantification are provided in Appendix 7A.

The air emission sources from the Fission Patterson Lake South Property were assumed to be similar to those from the Project during Operations in the most emission-intensive years. The emission rates of the Fission Patterson Lake South Property were predicted by assuming they were equivalent to the Project, by using scaling ratios of maximum ore processed, uranium concentrate production, maximum materials movement, or power plant capacity. Details of the emission quantification are provided in Appendix 7A. In the absence of detailed information, the operating period (i.e., production and processing) of Fission Patterson Lake South Property was assumed to be seven years. The RFD Case air dispersion modelling represents the most emission-intensive year during operations of both projects.

A five-year (2012 to 2016) meteorological dataset was developed specifically for the Project based on the ENV's Weather Research Forecast model output and with direct consultation with the ENV. More detailed information on air dispersion modelling methods can be found in Appendix 7A.

Results of the air dispersion modelling for the measurement indicators were averaged over the appropriate time periods for comparison to the air quality standards. Changes in concentration between the Base Case, Application Case, and RFD Case were compiled for each CAC and compared to standards in tabular or graphical format.

Hourly concentration predictions were obtained from the dispersion model as either 8,760 or 8,784 (leap-year) hourly predictions for each year in the modelling period (2012 to 2016). When comparing model-predicted maximum concentrations against the SAAQS, not every predicted value in the model-predicted dataset is used. The SAQMG (ENV 2012b) allows the elimination of a small number of model predictions expected to be caused by rare and unusual meteorological conditions that are considered outliers in the predicted concentration data. For a refined model such as AERMOD, the SAQMG allows the elimination of these outliers by using the following 'nth' highest concentrations predictions for each receptor location as follows:

- one-hour average – use the ninth highest concentration;
- eight-hour average – use the fifth highest concentration; and
- twenty-four-hour average – use the second highest concentration.

For all other time averaging periods greater than 24 hours, no modelled concentration may be eliminated. This recommended approach by the SAQMG was followed in the post-processing of the dispersion model output when comparing the model predictions with the SAAQS.

All model-predicted concentrations exclude receptors inside of the maximum disturbance area, as the ambient criteria do not apply within the maximum disturbance area, as public access would be restricted. Within the maximum disturbance area, potential health risk from air quality to workers located at the camp was assessed in Section 15, Human Health. Airborne radiological, chemical, physical, and biological hazards associated with Project activities that pose risks to the health and safety of workers were systematically assessed as part of risk assessments to support the licence application (e.g., radiological exposure assessments, industrial hygiene exposure assessments, hazard and operability studies) and would be routinely evaluated as part of Radiation Protection Program and Health and Safety Program processes described in Section 5.7, Integrated Management System to determine the nature and significance of the risk, identify and implement measures to mitigate effects, and keep radiological exposures to workers as low as reasonably achievable. Ambient air quality criteria such as the SAAQS are applicable beyond the maximum disturbance area. Ground-level concentrations were predicted by the AERMOD model at selected locations, referred to as receptors, within the air dispersion modelling domain. There are two categories of receptors: gridded receptors and discrete receptors. Gridded receptors are receptors placed in a Cartesian grid pattern at specific spacing between the receptors. The gridded receptors were selected based on requirements in the SAQMG (ENV 2012b) as follows:

- 20 m receptor spacing along the Project maximum disturbance area;
- 50 m receptor spacing within 0.5 km beyond the maximum disturbance area;
- 250 m receptor spacing beyond 0.5 km and within 2 km beyond the maximum disturbance area;
- 500 m receptor spacing beyond 2 km and within 5 km beyond the maximum disturbance area;
- 1,000 m receptor spacing beyond 5 km and within 10 km beyond the maximum disturbance area; and
- 2,000 m receptor spacing beyond 10 km from the maximum disturbance area to the edge of the RSA.

7.2.2.8.3.1 Supplementary Modelling with Updated Emission Inventory

The Project air emission inventory and air dispersion modelling was conducted with the Project engineering design information that was available at the time these tasks were initiated. Late in EIS development, updated engineering design information became available that would cause modifications to the modelled emissions. An updated air emission inventory was created, and the air dispersion model was rerun for the Application Case during Construction and Operations with the updated air emission inventory. The overall maximum model predictions for CACs were compared to the original simulation results to determine whether the new design information would have a material effect on the emissions modelling results and the residual effects analysis for the air quality assessment as well as the assessments completed by other disciplines. The supplementary modelling was conducted with the changes in emission rates as calculated, with all other settings and the modelling approach remaining unchanged. The original simulation results are presented in the EIS for the residual effects analysis, while the results of the comparison are additionally presented; these updated results indicate that the updated Project design information would not materially affect the results of the assessment.

7.2.2.9 Residual Effects Classification

The residual effects analysis uses a reasoned narrative to describe anticipated changes to each measurement indicator caused by the proposed Project and the associated effects on air quality. The residual effects analysis also considers effects from both the Project and RFDs. These narrative descriptions of anticipated effects represent the foundation for the residual effects classification. Residual effects are summarized or classified in tabular form using effects criteria, which is intended to provide structure and comparability across VCs and intermediate components assessed for the Project (Section 6.9.1, Residual Effects Classification).

The residual effects classification uses direction, magnitude, geographic extent, duration, reversibility, frequency, and probability of occurrence as criteria. The approach to classify each residual effect criterion is provided in Table 7.2-5.

Table 7.2-5: Definitions Applied to Effects Criteria Classifications for the Assessment of Air Quality

Criterion	Rating	Definition
Direction	Positive	Change in measurement indicator results in net improvement of air quality
	Neutral	Change in measurement indicator results in no net change in air quality
	Negative	Change in measurement indicator results in net degradation of air quality
Magnitude	Qualitative narrative or numeric quantification	Change in measurement indicator (e.g., maximum concentration) is described by effect size with consideration of the applicable regulatory criteria (i.e., SAAQS)
Geographic extent	Maximum disturbance area	Change in measurement indicator is confined to the maximum disturbance area
	Local	Change in measurement indicator is beyond the maximum disturbance area and within the LSA
	Regional	Change in measurement indicator extends beyond the LSA but is confined to the RSA
	Beyond regional	Change in measurement indicator extends beyond the RSA
Duration	Qualitative narrative or numeric quantification	Change in measurement indicator is described by effect duration (e.g., months, years, decades, permanent)
Reversibility	Reversible	Change in measurement indicator is reversible within a clearly defined time period
	Irreversible	Change in measurement indicator is predicted to influence air quality indefinitely
Frequency	Occasional	Change in measurement indicator is expected to occur rarely (e.g., once or a few times)
	Periodic	Change in measurement indicator is expected to occur consistently at regular intervals or associated with temporal events (e.g., during dry summers)
	Continuous	Change in measurement indicator is expected to occur all the time
Probability of occurrence	Unlikely	Change in measurement indicator is not expected to occur, but not impossible
	Possible	Change in measurement indicator may occur but is not likely
	Probable	Change in measurement indicator is likely to occur but is uncertain
	Certain	Change in measurement indicator will occur

LSA = local study area; RSA = regional study area; SAAQS = Saskatchewan Ambient Air Quality Standards.

While most criteria could be assigned categorical ratings for air quality, predicted effect sizes were provided in specific terms (i.e., narrative or numeric quantification) in the residual effects characterization (Table 7.2-5). Applying a category rating to a criterion such as magnitude might lead to confusion or misinterpretation of the effects assessment, or result in the criterion not being easily categorized in a meaningful way. Characterizing magnitude solely using an ordinal scale (i.e., low, moderate, or high) for air quality is challenging. Universal effect size boundaries, such as a 20% change in a measurement indicator at the LSA or RSA scale used to define a high magnitude effect, work poorly because they fail to consider context. Depending on the context from the cumulative effects from previous and existing developments and activities that also interact with air quality, a 20% change from existing conditions in the study area may be required to cause a high magnitude effect for one CAC, whereas a 2% change in the study area may be sufficient to cause a high magnitude effect for another CAC. Instead, magnitude is described based on the predicted change of measurement indicators from existing conditions and compliance with applicable air quality criteria. When categorical definitions were used, magnitude was classified as negligible, low, moderate, or high and supported by a reasoned narrative (Section 6.9, Residual Effects Classification and Determination of Significance). The magnitude of change in air quality measurement indicators was defined as:

- **Negligible:** The predicted change in measurement indicator (e.g., maximum concentration) is less than or equal to 1% of the applicable regulatory criteria (i.e., SAAQS).

- **Low:** The predicted change in the measurement indicator is between 1% and 10% of the applicable criteria and the Application Case or the RFD Case measurement indicator is still in compliance with the applicable regulatory criteria; or the predicted change in the measurement indicator is between 1% and 10% of the applicable regulatory criteria and the Base Case measurement indicator already exceeds the applicable regulatory criteria.
- **Moderate:** The predicted change in the measurement indicator is greater than 10% of the applicable regulatory criteria and the Application Case or the RFD Case measurement indicator is still in compliance with the applicable regulatory criteria; or the predicted change in the measurement indicator is between 10% and 50% of the applicable regulatory criteria and the Base Case measurement indicator already exceeds the applicable regulatory criteria.
- **High:** The predicted change in the measurement indicator is greater than 10% of the applicable regulatory criteria and the Application Case or the RFD Case measurement indicator exceeds the applicable regulatory criteria; or the predicted change in the measurement indicator is greater than 50% of the applicable regulatory criteria and the measurement indicator in the Base Case and the Application Case or RFD Case exceeds the applicable regulatory criteria.

The change in measurement indicator when defining the geographic extent is the change in measurement indictor (e.g., maximum concentration at each receptor) over 10% of the applicable regulatory criteria. For example, if the predicted change in concentration exceeds 10% of the regulatory criteria within the LSA boundary and outside the Project maximum disturbance area, the geographic extent is defined as the LSA.

7.2.2.10 Prediction Confidence and Uncertainty

The purpose of the assessment is to predict the future conditions for air quality with the addition of the Project and the Fission Patterson Lake South Property. As with all predictions of future conditions, the predictions made in this assessment embody some degree of uncertainty. The assessment applied a precautionary (i.e., conservative) approach to address uncertainty by identifying the greatest magnitude, duration, and geographic extent of potential adverse effects when a range of outcomes were possible. Consequently, uncertainty was addressed in a manner that increased the level of confidence that residual effects were conservatively estimated. The key uncertainties for air quality and the way they were addressed are presented as part of this assessment (Section 7.2.7).

7.2.2.11 Monitoring, Follow-Up, and Adaptive Management

Monitoring programs are proposed to address the uncertainties associated with the effects predictions and to evaluate the performance of mitigation. In general, monitoring is used to verify the effects predictions. Monitoring is also used to identify any unanticipated effects and to support the implementation of adaptive management to limit these effects. Typically, monitoring includes one or both of the following categories that may be applied during the Project lifespan:

- **Regulatory compliance monitoring:** monitoring activities, procedures, and programs undertaken to confirm the implementation of approved design standards, mitigation and conditions of approval, and NexGen commitments (e.g., stack testing to confirm emissions meets applicable air emission guidelines, ambient air quality monitoring).

- **Follow-up monitoring:** programs designed to test the accuracy of effects predictions, reduce or address uncertainties, determine the effectiveness of mitigation, or provide appropriate feedback to operations for modifying or adopting new mitigation designs, policies, and practices (e.g., implementation of adaptive management). Results from these programs can be used to increase the certainty of effect predictions in future EAs.

Where relevant, conceptual monitoring programs would be proposed to confirm predictions and to address the uncertainties associated with the effects predictions and mitigation, and upon Project approval, would be included in the Integrated Management System.

The implementation of robust and long-term environmental testing and monitoring has also been requested by Indigenous Groups to verify protection of the environment, including community-led monitoring during Construction and Operations of the proposed Project (TSD IV: MN-S; TSD V.2: CRDN; TSD VI: YNLR).

In addition to environmental monitoring programs typically implemented for projects (i.e., as noted above), NexGen is working with local Indigenous Groups to implement independent environmental monitoring. In combination with standard Project monitoring processes, independent Indigenous monitoring would be used to verify Project performance and to determine if mitigations and controls are effective in protecting the receiving environment.

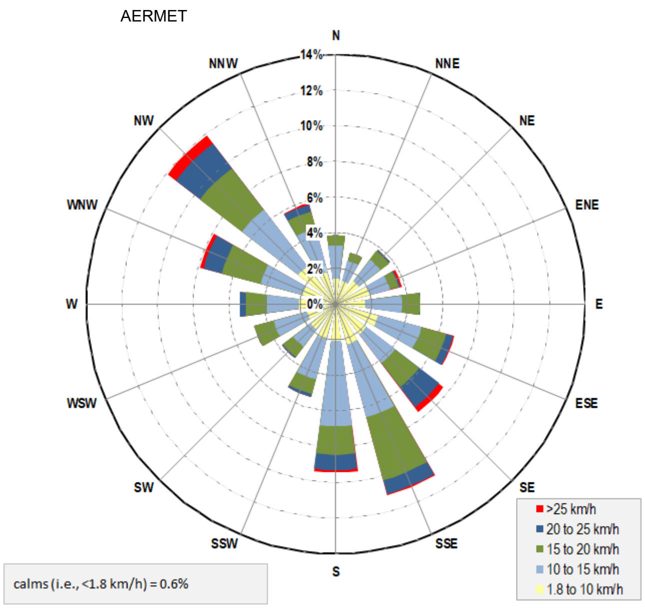
Adaptive management measures may also be proposed to address the uncertainties associated with the effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

7.2.3 Existing Conditions

7.2.3.1 Meteorology and Climate

Atmospheric transport and aerial deposition are controlled by local meteorology, especially wind speed and direction. As described in Section 7.2.2.8.3, Dispersion Modelling, ENV requires the use of an approved meteorological dataset in modelling completed for projects in Saskatchewan. To confirm the representativeness of this input dataset, the annual wind roses generated for the modelling domain were compared to the wind roses from the on-site meteorological observations from 2016 (Figure 7.2-3). The comparison indicates that the AERMET dataset reasonably simulated winds at the proposed Project location and is appropriate for use in the model.

Figure 7.2-3: Comparison of Annual Wind Roses Generated Using AERMET and Data from On-Site Observation



N = north; NNE = north-northeast; NE = northeast; ENE = east-northeast; E = east; ESE = east-southeast; SE = southeast; SSE = south-southeast; S = south; SSW = south-southwest; SW = southwest; WSW = west-southwest; W = west; WNW = west-northwest; NW = northwest; NNW = north-northwest.

Indigenous Groups have indicated the importance of wind as a factor contributing to changes in air quality and transportation of pollutants over long distances. Some members of the CRDN and BRDN feel that prevailing winds coming from Fort McMurray are bringing contamination to the area (BRDN-JWG 2019a; CRDN-JWG 2021). Members of the MN-S and BRDN specifically commented on the effects of sulphur originating from the oil sands region near Fort McMurray on local air and water quality, which they feel comes down as acid rain (BRDN-JWG 2020a; MN-S-JWG 2019b; MN-S-JWG 2020).

The meteorology and climate data from the baseline study were used to characterize existing meteorology and climate conditions in the LSA (Annex I, Atmospheric Baseline Report). The data presented herein are a subset of the larger ongoing baseline air quality study. The following is a summary of data from the baseline study that describe the LSA conditions:

- **Temperature:** Mean ambient temperatures in the LSA ranged from a daily average low of -18.1°C in February to a high of 17.1°C in July. Temperatures at the Rook I Meteorological Station were similar to temperatures recorded at the Fort McMurray A Station. Winters in the anticipated area of the Project are marginally milder than those recorded at the Cluff Lake Station, while summer temperatures are similar.
- **Precipitation:** Two complete calendar years (i.e., 2019 and 2020) of total precipitation data were recorded at the Rook I Meteorological Station. The total precipitation including rain and snow recorded in 2019 was 570.1 mm, and in 2020 the total was 650.0 mm. In both years, the total precipitation recorded at the Rook I Meteorological Station was higher than the Cluff Lake Station (451 mm) and Fort McMurray A Station (418.6 mm) climate normal total precipitation. In the RSA, the driest months of the year are typically between December and February, and the wettest months are generally in the summer between June and August.

- **Wind speed and direction:** Prevailing winds and the strongest winds at the Rook I Meteorological Station were from the northwest throughout the years of the measurement program. A considerable portion of the winds (i.e., more than 9%) were also observed from the south, west-northwest, and south-southeast. Over the monitoring period, calm wind conditions (i.e., winds less than 0.5 m/s) were observed approximately 1.1% of the time. Low wind conditions (i.e., winds less than 10 km/h), which tend to result in elevated ground-level concentrations of air pollutants, were observed 37.6% of the time. Low winds were observed most frequently from the south-southeast 3.3% of the time. This observation is consistent with the dominant wind direction for maximum wind speeds at the Cluff Lake Station. The same wind pattern was not observed at the Fort McMurray A Station due to the influence of the local topography of the Athabasca River Valley and the Clearwater Valley near that station. A depiction of the wind information used in the assessment is presented in Figure 7.2-3.
- **Relative humidity:** There is substantial seasonal variation in the relative humidity recorded at the Rook I Meteorological Station, with the lowest measurements, sometimes below 50%, occurring in the spring and higher relative humidity, sometimes above 90%, recorded during the winter months. This trend is consistent with the relative humidity trends observed in the Fort McMurray A Station climate normals.
- **Solar radiation:** Average daily solar radiation at the Rook I Meteorological Station varied seasonally with the highest solar radiation recorded between April and September, and peak solar radiation of more than 20 megajoules per square metre (MJ/m²) in May. Solar radiation was found to be the weakest in January and December, with values often below 1 MJ/m² at the Rook I Meteorological Station.

7.2.3.2 Air Quality

Air quality measurement indicators (i.e., CACs) in the LSA and RSA were anticipated to be below applicable air quality standards based on the limited amount of human development in the LSA and RSA. While some Indigenous Group members note that one of the things they appreciate about where they live is the presence of clean, fresh air (Section 7.2.2.2.1), other Indigenous Group and LPA community members commented that air quality is an issue in their communities. Some Indigenous Group members have commented that they have observed the effects of air pollution, which has affected aquatic and terrestrial environmental health (TSD II: BNDN, TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; BNDN-JWG 2019; BRDN-JWG 2019a; BRDN-JWG 2019b; CRDN-JWG 2021; MN-S-JWG 2019b). For example, members of the BRDN noted that half the trees are different colours and that the trees are dying from the “to down”, which is a sign of poor air quality that they attribute to the oil sands operations in Alberta (BRDN-JWG 2019a; BRDN-JWG 2019b). Members of the MN-S stated that the trees on the side of the road near the Cluff Lake Mine were dying, which was attributed to carbon emissions or dust from increased traffic (MN-S-JWG 2019a). The CRDN noted that the area around the Cluff lake Mine has “unclean conditions”, which is attributed in part to air pollution (TSD V.2: CRDN).

Section 7.2.3.2.1, Nitrogen Dioxide and Sulphur Dioxide, Section 7.2.3.2.2, Particulate Matter, and Section 7.2.3.2.3, Background Concentrations, provide a summary of existing air quality conditions in the LSA and RSA. Additional details on the baseline monitoring program can be found in the baseline monitoring report (Annex I, Atmospheric Baseline Report).

7.2.3.2.1 Nitrogen Dioxide and Sulphur Dioxide

The passive sampling data collected in the LSA for nitrogen dioxide and sulphur dioxide indicated that concentrations remained below the annual SAAQS for each compound. The annual SAAQS is used for comparison, as the monthly passive data are not directly applicable to averaging periods shorter than one month. The measured data are presented in Table 7.2-6.

Table 7.2-6: Nitrogen Dioxide and Sulphur Dioxide Existing Conditions in the Local Study Area

Month and Year[a]	Concentration (µg/m^3)[b]	
	Nitrogen Dioxide	Sulphur Dioxide
September 2018	**0.38**	**0.52**
October 2018	**0.47**	**0.65**
November 2018	**1.69**	**2.49**
December 2018	**0.85**	**0.79**
January 2019	**1.41**	**1.83**
February 2019	0.09	**1.05**
March 2019	0.09	**0.65**
April 2019	**0.14**	0.13
May 2019	0.09	**0.39**
June 2019	0.09	0.13
July 2019	0.09	**0.26**
August 2019	0.09	**0.26**
September 2019	**0.38**	**0.52**
November 2019	**0.42**	**1.05**
December 2019	**0.19**	**0.92**
January 2020	**0.14**	**1.83**
February 2020	**0.14**	**0.79**
April 2020	0.09	**0.65**
May 2020	0.12	**0.39**
June 2020	0.09	**0.52**
July 2020	**0.38**	**0.52**
August 2020	**0.19**	**0.79**
October 2020	**0.47**	**0.92**
November 2020	**1.13**	**1.83**
Average[c]	**0.39**	**0.83**
SAAQS	**45**	**20**

Note: **Bold values** indicate concentrations above the lower detection limit.
a) The month and year indicate the date when the samples were retrieved. Although the passive sampling was performed approximately monthly, it was not for the calendar month, Thus, some months were not shown in the table.
b) Duplicate samples were taken at this station. The average value is presented.
c) Laboratory concentrations were measured in ppb and converted to µg/m^3. Values below the lower detection limit of 0.1 ppb were treated as one-half of the detection limit (0.05 ppb).
ppb = parts per billion; SAAQS = Saskatchewan Ambient Air Quality Standards.

Measured nitrogen dioxide concentrations were well below the prescribed SAQMG annual background concentration of 3.8 µg/m^3 that must be added to modelled predictions as described in Section 7.2.2.6.2, Air Quality.

The measured sulphur dioxide data indicate that local activities in the area (e.g., traffic, fuel combustion) may be contributing to ambient sulphur dioxide levels above the SAQMG annual background concentration for sulphur dioxide of 0 µg/m^3, though levels remain low.

Baseline passive nitrogen dioxide and sulphur dioxide monitoring was supplemented by the regional passive nitrogen dioxide and sulphur dioxide data available from the JP205 Station and the JP213 Station. The regional surrogate passive monitoring indicated that ambient nitrogen dioxide and sulphur dioxide concentrations in RSA are below the respective ambient air quality criteria.

Baseline passive nitrogen dioxide and sulphur dioxide monitoring was further supplemented by the regional continuous nitrogen dioxide and sulphur dioxide data available from the Fort Chipewyan Station and the Buffalo Narrows Station operated by the Wood Buffalo Environmental Association and ECCC, respectively. Generally, nitrogen dioxide and sulphur dioxide concentrations at the regional surrogate stations suggest that the air quality in the RSA would remain below the SAAQS. This prediction is supported by the Rook I passive nitrogen dioxide and sulphur dioxide monitoring stations. No exceedance of the one-hour, 24-hour, and annual nitrogen dioxide SAAQS was recorded at either station. The derived background concentrations were similar to the prescribed background concentrations:

- The derived background concentrations from Fort Chipewyan Station and Buffalo Narrows Station for one-hour nitrogen dioxide are 7.9 µg/m^3 and 2.8 µg/m^3, respectively, which are lower than the prescribed background concentration of 11.3 µg/m^3.
- The derived background concentrations from Fort Chipewyan Station and Buffalo Narrows Station for 24-hour nitrogen dioxide are 8.3 µg/m^3 and 2.6 µg/m^3, respectively, which are lower than the prescribed background concentration of 9.4 µg/m^3.
- The derived background concentrations from Fort Chipewyan Station and Buffalo Narrows Station for annual nitrogen dioxide are 2.4 µg/m^3 and 0.8 µg/m^3, which are lower than the prescribed background concentration of 3.8 µg/m^3.
- The derived one-hour, 24-hour, and annual sulphur dioxide background concentrations from monitoring data at both stations were slightly above the prescribed background sulphur dioxide concentrations of zero. Since the background concentrations listed in SAQMG are shown in the units of parts per million, the slight differences between derived and prescribed background concentrations might have been influenced by rounding with loss of precision. For example, the 90th percentile concentration in 2020 at Fort Chipewyan Station was 1.1 µg/m^3, which can be converted to 0.00042 parts per million.

7.2.3.2.2 Particulate Matter

Calculations of 24-hour $PM_{2.5}$ concentrations relative to the SAAQS, which are equivalent to the CAAQS, for $PM_{2.5}$ were based on three years of continuous monitoring data (i.e., the three-year average of the 98th percentile of 24-hour average concentrations), and the annual $PM_{2.5}$ SAAQS were based on the average of one calendar year. These metrics were used to align with the SAAQS. The $PM_{2.5}$ data recorded at the Rook I Particulate Monitoring Station are presented in Table 7.2-7.

Table 7.2-7: Rook I Particulate Monitoring Station 24-Hour Fine Particulate Matter Monitoring Results

Month and Year[(a)]	Fine PM Concentration (µg/m³)		
	Maximum 24 h	90th Percentile 24 h	50th Percentile 24 h
September 2018	1.6	0.9	0.3
October 2018	2.7	1.6	0.1
November 2018	2.1	2.0	0.0
May 2019	17.9	13.6	0.1
June 2019	19.5	10.3	2.4
July 2019	28.5	10.7	2.7
August 2019	9.3	6.3	1.3
September 2019	3.4	2.4	1.0
October 2019	1.9	1.2	0.1
April 2019	1.7	1.1	0.5
May 2020	1.1	0.5	0.0
June 2020	1.2	0.8	0.0
July 2020	3.7	1.5	0.6
August 2020	4.1	2.7	0.3
September 2020	23.7	4.0	0.1
All data	28.5	4.1	0.3

a) The PM monitors were offline during winter due to inadequate solar energy.
PM = particulate matter.

Baseline continuous $PM_{2.5}$ monitoring was supplemented by the regional continuous $PM_{2.5}$ data available from the Fort Chipewyan Station and Buffalo Narrows Station. Measured $PM_{2.5}$ was generally below the 24-hour and annual air quality standards in the most recent five years of monitoring, except for the Fort Chipewyan Station between 2016 and 2017 and for the Buffalo Narrows Station in 2018, which both had measurements exceeding the 24-hour SAAQS. Intense and extensive wildfire activity was likely the primary contributor to the high recorded concentrations of $PM_{2.5}$ during these periods. The wildfire-influenced $PM_{2.5}$ concentrations were considered as exceptional events and were removed from the dataset when deriving the background concentration. The derived background concentrations from local and regional monitoring data were similar to the prescribed background concentrations.

As PM_{10} was not monitored in the LSA, background measurement data were established using monitoring data from the Buffalo Narrows station from 2019 and 2020. Three exceedances of the 24-hour SAAQS were recorded at the Buffalo Narrows Station in 2019, which were likely attributable to wildfire smoke. There were no exceedances of SAAQS in 2020. The 90th percentile concentration of 24-hour PM_{10} data from the Buffalo Narrows station is 14.4 µg/m³, which is below the prescribed PM_{10} background concentration (i.e., 23.1 µg/m³).

The TSP monitoring was conducted at the Rook I Particulate Monitoring Station. No exceedances of the 24-hour SAAQS for TSP were recorded over the monitoring period between September 2018 and December 2020; the monitoring was demobilized over the winter seasons due to inadequate solar energy. The 24-hour TSP concentrations remained below the 24-hour SAAQS with the highest 24-hour TSP concentration in July 2020, which was primarily due to several hours of high concentrations, with the days preceding and following measured typical background levels. Annual TSP concentrations are not presented, as the baseline program did not capture a full calendar year of data for comparison to the annual SAAQS of 60 µg/m³.

The prescribed background concentration of PM_{10} (23.1 µg/m^3) was used as surrogate for TSP background concentrations due to the absence of a prescribed TSP background concentration. It is assumed that the annual background concentration is half of the 24-hour background concentrations (i.e., 11.6 µg/m^3). The 90th percentile 24-hour TSP concentration of all valid data collected by the end of 2020 was 9.7 µg/m^3, which is below the assumed 24-hour TSP background concentration. The average of all 24-hour TSP concentrations from all data was 3.4 µg/m^3, which is well below the assumed annual TSP background concentration of 11.6 µg/m^3. The TSP data are presented in Table 7.2-8.

Table 7.2-8: Rook I Particulate Monitoring Station 24-Hour Total Suspended Particulates Monitoring Results

Month and Year	TSP Concentration (µg/m^3)			
	Maximum 24 h	90th Percentile 24 h	50th Percentile 24 h	Number of Days >100 µg/m^3
September 2018	5.1	2.6	1.0	0
October 2018	13.7	7.8	0.8	0
November 2018	4.7	4.6	1.3	0
May 2019	37.6	28.4	1.3	0
June 2019	55.4	23.7	5.5	0
July 2019	56.5	26.4	4.7	0
August 2019	30.7	12.9	1.4	0
September 2019	4.5	3.0	0.9	0
October 2019	20.8	7.3	0.1	0
April 2019	5.5	1.2	0.4	0
May 2020	6.0	1.7	0.3	0
June 2020	5.6	2.1	0.8	0
July 2020	13.6	3.0	1.9	0
August 2020	3.7	2.7	0.1	0
September 2020	21.9	1.9	0.0	0
All data	56.5	9.7	0.7	0

TSP = total suspended particulates; > = greater than.

7.2.3.2.3 Background Concentrations

Although a robust baseline ambient air quality monitoring program has been conducted in the LSA over several years, background concentration data required to be added to the modelled predictions remains largely mandated by ENV. The data collected provide for a good comparison and validation that the ENV-mandated values are appropriate for use in the assessment. The provincially prescribed background concentrations provided in the SAQMG for $PM_{2.5}$, nitrogen dioxide, and sulphur dioxide were adopted for use in the air quality assessment. The exception is the PM_{10} background data; the prescribed PM_{10} background concentration is an overestimate of the true rural background in the area of the Project as it is 60% higher than the background concentration derived using data from the regional Buffalo Narrows station from 2019 and 2020. The 90th percentile concentration of 24-hour PM_{10} data from the Buffalo Narrows station is 14.4 µg/m^3, which is below the prescribed PM_{10} background concentration (i.e., 23.1 µg/m^3).

After consultation with the ENV, the 90th percentile of the PM_{10} data from 2019 at the Buffalo Narrows Station (i.e., 14.4 µg/m³) was determined to be a more reasonable background value to use in the air quality assessment. The same 90th percentile of the Buffalo Narrows PM_{10} 24-hour background value was used as the

24-hour TSP background in the absence of a prescribed value for 24-hour TSP background. The 50th percentile of the PM_{10} monitoring data from Buffalo Narrows from 2019 (i.e., 6.2 µg/m³) was used for the annual TSP background in the absence of a prescribed value for annual TSP background. The background concentrations used in the air quality assessment are summarized in Table 7.2-9.

The background concentrations of the compounds being evaluated are indicative of a rural setting, relatively unaffected by outside influences on air quality. Air quality at existing conditions can generally be classified as good based on the monitoring conducted.

Table 7.2-9: Background Air Compound Concentrations

Compound	Background Concentration for Air Dispersion Modelling (µg/m³)(a)			
	1 h	8 h	24 h	Annual
$PM_{2.5}$	n/a	n/a	6.5	3.1
PM_{10}	n/a	n/a	14.4	n/a
TSP	n/a	n/a	14.4	6.2
Carbon monoxide	527.5 (500 ppb)	527.5 (500 ppb)	n/a	n/a
Nitrogen dioxide	11.3 (6 ppb)	n/a	9.4 (5 ppb)	3.8 (2 ppb)
Sulphur dioxide	0	n/a	0	0

a) The 90th percentile value of monitoring data is added to the one-hour and 24-hour predictions and 50th percentile value of the monitoring data is added to the annual predictions per the SAQMG guidance.

n/a = not applicable; ppb = parts per billion; $PM_{2.5}$ = particulate matter with a nominal diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal diameter of 10 µm or less; TSP = total suspended particulates; SAQMG = Saskatchewan Air Quality Model Guideline.

7.2.4 Project Interactions and Mitigations

The pathways analysis identified potential adverse effects of the Project on air quality, identified practicable mitigation for these potential effects, and determined whether potential effects could be sufficiently mitigated such that they are not expected to cause a residual adverse effect. As described in Section 7.2.2.7, Project Interactions and Mitigations, the pathways analysis assigned each potential effect as:

- no pathway (i.e., mitigation results in no effect on air quality);
- secondary pathway (i.e., mitigation results in a negligible effect on air quality); or
- primary pathway (i.e., effect that is greater than negligible and carried forward for further assessment).

The pathway analysis is summarized in Table 7.2-10. Section 7.2.4.1, No Pathways, Section 7.2.4.2, Secondary Pathways, and Section 7.2.4.3, Primary Pathways, following the table and provide the rationale used to assign potential effects to the no pathway and secondary pathway categories and list primary pathways. Each Project interaction identified as a primary pathway was carried forward for detailed assessment in Section 7.2.5. Effects pathways apply to all Project phases unless otherwise noted.

The environmental design features and mitigations in Table 7.2-10 represent the list of actions and features used to inform the pathway analysis as part of preparing the EIS. In addition to this list of key actions, NexGen would implement the Environmental Protection Program, which would describe the processes required to monitor and characterize emissions from Project facilities and activities. This program would be used to periodically evaluate mitigation performance and identify additional mitigation, where required, and prompt potential adaptive management measures (Section 7.2.8, Monitoring, Follow-Up, and Adaptive Management). Where relevant, adaptive management measures may also be proposed to address uncertainties associated with effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

Potential accidents and malfunctions that have the capability to influence biophysical or human environments are discussed in Section 21, Accidents and Malfunctions.

Table 7.2-10: Potential Effects Pathways for Air Quality

Pathway ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
AQ-01	Project components/activities that contribute to CAC emissions during **Construction and Operations**: ▪ combustion of fossil fuels in mobile vehicles and heavy equipment for the following: o land clearing, site preparation, and construction of facilities and infrastructure o underground shaft development o site traffic o transportation of personnel and materials to and from the site o process plant and underground operations ▪ handling and stockpiling of waste rock, special waste rock, and ore ▪ combustion of fossil fuels in stationary equipment (e.g., power generators, calciners, mine heaters) ▪ drilling and blasting ▪ waste incineration	**Construction and Operations CAC emissions:** ▪ Emissions of CACs from Project activities can affect air quality during Construction and Operations	▪ **Primarily use LNG**, which generates lower emissions per unit of energy produced than diesel, for on-site power generation ▪ Evaluate opportunities to **reduce fuel combustion requirements** of infrastructure and equipment, to the extent practical, during detailed design ▪ **Optimize haul routes** to reduce fuel consumption and emissions from equipment ▪ **Recover heat from the LNG power plant** exhaust and use to heat other process and ancillary buildings, to the extent practical ▪ Use **pollution control technology** on process plant exhaust stacks with preventative maintenance and stack testing, as well as adaptive management, if necessary ▪ **Use Tier 4 diesel mobile equipment for underground operations**, whenever practical, with applicable mine ventilation airflow rates specified by Canada Centre for Mineral and Energy Technology, when available ▪ **Apply water and/or suppressants to site roads, access road, and airstrip**, as necessary ▪ **Use dust suppressants** that minimize environmental risk and are government approved for use ▪ **Limit idling of vehicles and equipment** to the extent practical ▪ **Limit vehicle speed** on unpaved site roads to reduce fugitive dust during Construction and Operations ▪ **Use and maintain emissions control devices** on combustion-based equipment ▪ **Maintain mobile mining equipment and vehicles** and operate the equipment within parameters for engine exhaust system design ▪ Identify and implement **procurement criteria** to confirm stationary and mobile engines meet applicable performance standards ▪ Implement a Project-specific **Environmental Protection Program** ▪ Implement a Project-specific **Environmental Monitoring Plan** that includes ambient air monitoring	Primary pathway
AQ-02	Project components/activities that contribute to CAC emissions during **Closure:** ▪ combustion of fossil fuels in stationary equipment (e.g., power generators, calciners, mine heaters) ▪ combustion of fossil fuels in mobile vehicles and heavy equipment for the following: o land clearing, site preparation, and construction of facilities and infrastructure o underground shaft development o process plant and underground operations o site traffic o transportation of personnel and materials to and from the site ▪ handling and stockpiling of waste rock, special waste rock, and ore ▪ drilling and blasting ▪ waste incineration	**Closure CAC emissions:** ▪ Emissions of CACs from mobile and stationary combustion sources can affect air quality during Closure	▪ **Primarily use LNG**, which generates lower emissions per unit of energy produced than diesel, for on-site power generation. ▪ **Optimize haul routes** to reduce fuel consumption and emissions from equipment ▪ **Apply water and/or suppressants to site roads, access road, and airstrip**, as necessary. Use dust suppressants that minimize environmental risk and are government approved for use ▪ **Use and maintain emissions control devices** on combustion-based equipment ▪ **Maintain mobile mining equipment and vehicles** and operate the equipment within parameters for engine exhaust system design ▪ **Limit idling of vehicles and equipment** to the extent practical ▪ Identify and implement **procurement criteria** to confirm stationary and mobile engines meet applicable performance standards ▪ Implement a Project-specific **Environmental Protection Program** ▪ Implement a Project-specific **Environmental Monitoring Plan** that includes ambient air monitoring	Primary pathway

Bolded text represents the key topic of the environmental design features and mitigation.
CAC = criteria air contaminant; LNG = liquified natural gas.

7.2.4.1 No Pathways

There are no Project-environment interactions that result in no pathways for air quality.

7.2.4.2 Secondary Pathways

There are no Project-environment interactions that result in secondary pathways for air quality.

7.2.4.3 Primary Pathways

The following Project interactions were predicted to be primary pathways to air quality:

AQ-01: Construction and Operations CAC emissions:

- Emissions of CACs from Project activities can affect air quality during Construction and Operations.

AQ-02: Closure CAC emissions:

- Emissions of CACs from mobile and stationary combustion sources can affect air quality during Closure.

As discussed in Section 7.2.2.7, Project interactions that have the potential for a greater than negligible effect on air quality (i.e., primary pathways) require further consideration and were advanced for assessment of residual effects (Section 7.2.5). The classification of primary pathways and the need to complete a detailed and comprehensive analysis was supported by Indigenous and Local Knowledge provided in the IKTLU Studies, JWG meetings, and community engagement.

Indigenous Groups and LPA community members have expressed concerns related to air pollution from Project activities, affecting aquatic and terrestrial environmental health. These concerns include factors that could affect the safety of wild foods and human health, as well as hunting, trapping, and plant gathering activities (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; BNDN-JWG 2020; BNDN-JWG 2021a; BNDN-JWG 2021b; CRDN-JWG 2021). For example, the CRDN expressed concerns about Project-related air emissions, "containing an unknown combination of toxins and contaminants", and water pollution at Patterson and Forrest lakes affecting surface and underground waters within the Clearwater River watershed as well as adjoining watersheds, which could affect harvesting activities (TSD V.2: CRDN). The LPA community members commented on the effects of Project activities on air quality in general (NexGen 2019). Comments made by members of the BRDN and CRDN on air quality include the following:

> Well, my only concern is the air quality, I don't know how that's going to affect our people down this way. (TSD III: BRDN)

> And when they build a plant . . . just what kind of filtration system does it have for exhaust when you're burning your fuels to run your equipment and stuff like that. Just what kind of safety precautions are there? . . . Little things like that that would harm the environment, that's where my main concerns are, what if scenario. (TSD III: BRDN)

> If that [NexGen] mine upgrades, it will probably cause air pollution too, you know. Because we don't know what's - how they're going to do it. And that air they're going to be breathing - that air [at Broach Lake]. (TSD V.2: CRDN)

> And how far does that [air emissions] affect the area around, you know what I mean. (TSD V.2: CRDN)

Specific concerns were raised about the effects of dust in general from Project activities on vegetation, including berry patches (TSD IV: MN-S), and the potential effects of uranium dust on the environment, which some Indigenous Group members believe could travel hundreds of kilometres with the wind and affect the air, water, and vegetation (TSD II: BNDN; TSD IV: MN-S; TSD V.2: CRDN; MN-S-JWG 2019b). Specific concerns were also raised with respect to exhaust and carbon emissions from vehicles and machinery and coming through the headframes or shafts (TSD III: BRDN; BRDN-JWG 2019b; MN-S-JWG 2019a; NexGen 2019).

As part of the proposed EA approach for the Project, which includes consideration of Indigenous Group and LPA community members' concerns within the effects assessments, predicted changes to air quality presented in Section 7.2.5 were carried through to the assessments of water quality (Section 10), fish and fish habitat (Section 11), terrain and soils (Section 12), vegetation (Section 13), wildlife and wildlife habitat (Section 14), human health (Section 15), cultural and heritage resources and Indigenous land and resource use (Section 16), and other land and resource use (Section 17; Figure 7.2-1).

7.2.5 Residual Effects Analysis

The residual effects analysis has been developed using a dispersion modelling approach to predict concentrations of CACs and then to compare the predictions to baseline conditions and the relevant air quality criteria.

7.2.5.1 Application Case

7.2.5.1.1 Construction and Operations

The Application Case entailed a modelling assessment of the Project emissions to predict ground-level concentrations of the CACs. The emissions inputs to the model have been calculated to represent the reasonably conservative emissions from the Project after applying mitigation actions and policies to reduce emissions. A summary of emissions inputs are provided in Section 7.2.5.1.1.1, Project Emission Inventory, and in detail in the emissions Appendix 7A. The resulting modelling predictions are presented in Section 7.2.5.1.1.2, Air Dispersion Modelling Predictions, in tabular form and descriptive text bullets, and in Figure 7.2-5 through Figure 7.2-21.

7.2.5.1.1.1 Project Emission Inventory

The Project maximum emissions under the Application Case were estimated for a series of emission sources for Construction and/or Operations. The emission sources and activities include the following:

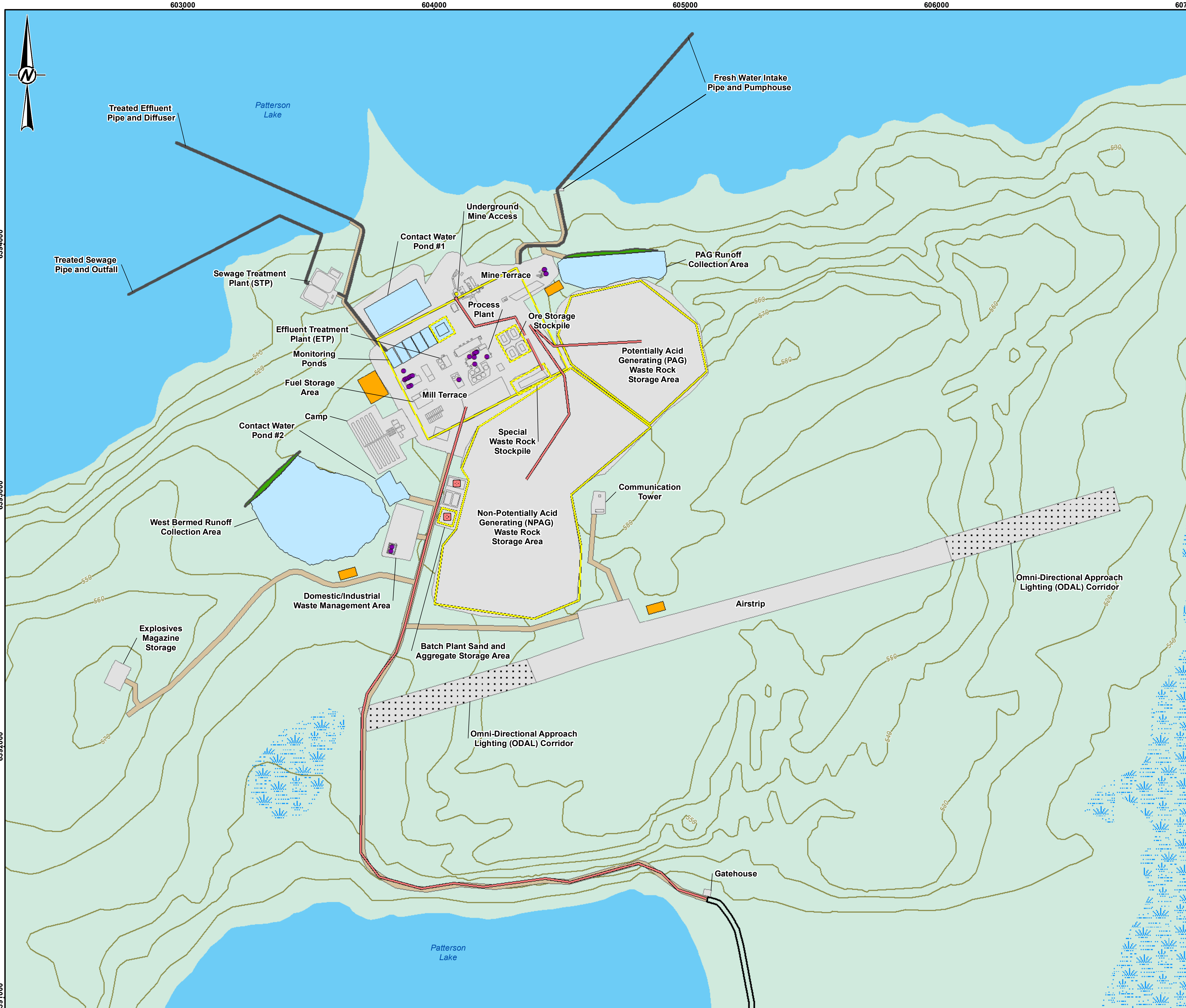
- Construction only:
  - power plant, which would be mainly fired by diesel fuel;
  - frost fighters;
  - aggregate crushing; and
  - general construction emissions to account for general area construction activities.
- Construction and Operations:
  - concrete batch plant;

- dozing (i.e., material placement and contouring) operations at the waste rock storage areas and ore storage stockpile pad;
- grading of roads on the surface and underground;
- material handling (i.e., ore, waste, and aggregate; loading and drops) on the surface and underground;
- drilling and blasting underground;
- non-low level radioactive waste incinerator for domestic and industrial waste;
- mine fleet exhaust for both surface and underground fleet;
- mine heaters and small heaters;
- road dust from vehicles travelling on surface and underground roads; and
- wind erosion of the ore storage pad, waste rock storage areas (i.e., special waste rock stockpile, potentially acid generating waste rock storage area, and non-potentially acid generating waste rock storage area) and aggregate storage area.

- Operations only:
  - acid plant;
  - calciner stacks including a natural gas burner stack, a calciner exhaust stack with a scrubber, and the calciner bin baghouse exhaust stack;
  - crushing in the semi-autogenous grinding and ball process plant, and aggregate crushing;
  - power plant, fired by liquified natural gas (LNG);
  - a low-level radioactive waste incinerator;
  - lime silo baghouse; and
  - triuranium octoxide and uranium concentrate handling during Operations.

The air emissions from these sources were modelled as point, area, or volume sources in the AERMOD model. The location of the sources is shown in Figure 7.2-4.

The maximum annual emissions for the Construction and Operations of the Project are provided in Table 7.2-11. There are higher emissions of nitrogen oxides, $PM_{2.5}$, PM_{10}, and TSP during Construction than Operations due to the use of diesel rather than LNG as the primary fuel for on-site power generation and more site preparation activities on the surface.



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
- POINT SOURCES
- VOLUME SOURCES
- AREA SOURCES

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

ROOK I PROJECT EMISSION SOURCES

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	SB/ZY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-07	**FIGURE 7.2-4**	
CHECK	ZY	2023-02-07		
REVIEW	CM	2023-02-07		

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\07_Air_Quality_Noise_and_Climate\17x11\20144150_Fig7_2-4_Emission_Sources_Rook_I_Project_Rev0.mxd PRINTED ON: 2023-02-07 AT: 1:11:10 PM

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Table 7.2-11: Comparison of Predicted Rook I Project Emissions by Phase

Phase	Construction Maximum Annual Emission Rates (t/yr)							Operations Maximum Annual Emission Rates (t/yr)						
	Nitrogen Oxide	Sulphur Dioxide	Sulphuric Acid	Carbon Monoxide	$PM_{2.5}$	PM_{10}	TSP	Nitrogen Oxide	Sulphur Dioxide	Sulphuric Acid	Carbon Monoxide	$PM_{2.5}$	PM_{10}	TSP
Acid plant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.71	0.35	n/a	n/a	n/a	n/a
Calciner stacks	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.13	0.06	n/a	10.50	3.32	9.44	17.70
Batch plant	n/a	n/a	n/a	n/a	0.87	1.56	5.83	n/a	n/a	n/a	n/a	0.01	0.02	0.08
Semi-autogenous grinding and ball process plant	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.33	1.12	2.19
Aggregate operations	n/a	n/a	n/a	n/a	3.17	8.10	19.62	n/a	n/a	n/a	n/a	0.23	0.41	1.48
Dozing	n/a	n/a	n/a	n/a	0.66	1.19	6.28	n/a	n/a	n/a	n/a	0.99	1.78	9.42
Material handling	n/a	n/a	n/a	n/a	0.01	0.05	0.09	n/a	n/a	n/a	n/a	0.48	1.65	3.23
Small heaters	1.47	0.00	n/a	4.27	0.05	0.18	0.35	0.26	0.00	n/a	0.17	0.01	0.01	0.01
Underground grading	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.03	0.47	0.95
Underground diesel mine fleet	0.07	0.00	n/a	0.08	0.00	0.00	0.00	1.87	0.02	n/a	0.18	0.01	0.10	0.10
Underground hauling	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.73	7.25	28.22
Underground material handling	n/a	n/a	n/a	n/a	0.01	0.04	0.08	n/a	n/a	n/a	n/a	0.01	0.04	0.08
Underground drilling	n/a	n/a	n/a	n/a	0.00	0.00	0.01	n/a	n/a	n/a	n/a	0.40	0.40	0.50
Underground blasting	0.24	0.01	n/a	6.72	0.00	0.01	0.01	0.24	0.02	n/a	49.77	0.02	0.26	0.50
Power plant	26.08	0.00	n/a	14.92	0.78	0.78	0.78	156.92	0.02	n/a	89.81	4.67	4.67	4.67
Road dust	n/a	n/a	n/a	n/a	2.79	27.92	103.95	n/a	n/a	n/a	n/a	2.38	23.77	92.38
Grading	n/a	n/a	n/a	n/a	0.19	2.14	6.12	n/a	n/a	n/a	n/a	0.19	2.20	6.29
Non-low-level radioactive waste incinerator	1.00	0.59	n/a	0.16	0.35	0.46	0.70	1.00	0.59	n/a	0.16	0.35	0.46	0.70
Low-level radioactive waste incinerator	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.86	1.47	n/a	0.24	0.85	1.09	1.64
Lime silos	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.17	0.17	0.17
Mine fleet	17.25	0.05	n/a	10.82	1.68	1.73	1.73	9.14	0.05	n/a	5.35	0.95	0.98	0.98
Mine heater	0.20	0.00	n/a	1.58	0.01	0.01	0.01	3.64	0.08	n/a	28.51	0.14	0.14	0.14
Wind erosion	n/a	n/a	n/a	n/a	1.52	3.80	7.61	n/a	n/a	n/a	n/a	1.61	4.04	8.07
Uranium concentrate handling	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.20	0.56	0.66
Construction activity	n/a	n/a	n/a	n/a	2.10	20.95	41.08	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Construction gensets	224.85	0.38	n/a	18.73	6.28	6.50	6.50	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total	**271.17**	**1.03**	n/a	**57.27**	**20.47**	**75.41**	**200.72**	**175.07**	**5.03**	**0.35**	**184.70**	**18.08**	**61.01**	**180.16**

$PM_{2.5}$ = particulate matter with a nominal diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal diameter of 10 µm or less; TSP = total suspended particulates; n/a = not applicable.

7.2.5.1.1.2 Air Dispersion Modelling Predictions

A summary of the Application Case maximum concentration predictions for the CACs is presented in Table 7.2-12. The table summarizes the predicted maximum concentrations for the Base Case and the predicted maximum concentrations during Construction and Operations for the Application Case. The change due to the Project, which by definition is the Base Case predictions subtracted from the Application Case predictions, is further expressed as Project-only model predictions. These Project-only model predictions are provided as additional information to clearly describe the predicted changes to air quality arising from the Project. The change in air quality predictions between the Base Case and the Application Case (i.e., Project-only simulation) is also described in terms of how much change the Project induces as a relative percentage of the relevant ambient air quality criteria (Table 7.2-12). The changes expressed as a relative percentage of the relevant ambient air quality criteria were used to determine the magnitude and geographic extent of the measurement indicators as discussed in Section 7.2.2.9, Residual Effects Classification. The comparisons made to the CAAQSs are for information purposes only and are not indicative of Project compliance.

Table 7.2-12: Application Case Criteria Air Contaminant Prediction Summary

Compound	Averaging Period	Criteria ($\mu g/m^3$)	Base Case Maximum Concentration ($\mu g/m^3$)	Project-Only Maximum Concentration ($\mu g/m^3$)(a,b)		Application Case Maximum Concentration ($\mu g/m^3$)(a,b)		Change as Percent of Criteria (%)	
				Construction	Operations	Construction	Operations	Construction	Operations
Nitrogen dioxide	1-hour	300 (SAAQS)(c)	11.3	265.6 (446.4)	155.6 (193.6)	276.9 (457.7)	167.0 (205.0)	88.5	51.9
		79.2 (CAAQS)(d)	11.3	218.6	141.9	230.0	153.3	275.9	179.1
	24-hour	200 (SAAQS)(e)	9.4	70.5 (85.9)	52.5 (63.8)	79.9 (95.3)	61.9 (73.3)	35.2	26.2
	Annual	45 (SAAQS)(f)	3.8	5.9	2.9	9.7	6.7	13.1	6.5
		22.6 (CAAQS)(f)	3.8	5.9	2.9	9.7	6.7	26.1	12.9
Nitrogen oxides(g)	1-hour	n/a	11.3	2,063.7 (4,398.0)	564.3 (903.4)	2,075.0 (4,409.3)	575.7 (914.7)	n/a	n/a
	24-hour	n/a	9.4	314.8 (405.6)	78.5 (119.7)	324.2 (415.1)	87.9 (129.1)	n/a	n/a
	Annual	n/a	3.8	12.1	3.3	15.9	7.1	n/a	n/a
Sulphur dioxide	1-hour	450 (SAAQS)(c)	0	4.5 (19.7)	9.4 (19.7)	4.5 (19.7)	9.4 (19.7)	1.0	2.1
		170.1 (CAAQS)(h)	0	5.1	10.4	5.1	10.4	3.0	6.1
	24-hour	125 (SAAQS)(e)	0	0.7 (0.8)	1.8 (3.1)	0.7 (0.8)	1.8 (3.1)	0.6	1.4
	Annual	20 (SAAQS)(f)	0	0.0	0.1	0.0	0.1	0.1	0.5
		10.5 (CAAQS)(f)	0	0.0	0.1	0.0	0.1	0.2	1.0
Sulphuric acid	1-hour	10 (AAAQO)(c)	0	n/a	1.2 (2.0)	n/a	1.2 (2.0)	n/a	12.1
	24-hour	5 (AAAQO)(e)	0	n/a	0.2 (0.4)	n/a	0.2 (0.4)	n/a	4.6
Carbon monoxide	1-hour	15,000 (SAAQS)(c)	572.5	1,082 (2,120)	683 (8,187)	1,655 (2,693)	1,256 (8,759)	7.2	4.6
	8-hour	6,000 (SAAQS)(i)	572.5	259 (1,083)	220 (1,057)	831 (1,656)	792 (1,629)	4.3	3.7
$PM_{2.5}$	24-hour	28 (SAAQS)(j)	6.5	10.1	4.0	16.6	10.5	36.2	14.4
		27 (CAAQS)(j)	6.5	10.1	4.0	16.6	10.5	37.6	15.0
	Annual	10.0 (SAAQS)(f)	3.1	1.0	0.6	4.1	3.7	9.0	5.6
		8.8 (CAAQS)(k)	3.1	1.0	0.6	4.1	3.7	11.0	6.9
PM_{10}	24-hour	50 (SAAQS)(e)	14.4	132.6 (189.5)	51.0 (72.2)	147.0 (203.9)	65.4 (86.6)	265.3	102.0

Table 7.2-12: Application Case Criteria Air Contaminant Prediction Summary

Compound	Averaging Period	Criteria (µg/m³)	Base Case Maximum Concentration (µg/m³)	Project-Only Maximum Concentration (µg/m³)[a,b]		Application Case Maximum Concentration (µg/m³)[a,b]		Change as Percent of Criteria (%)	
				Construction	Operations	Construction	Operations	Construction	Operations
TSP	24-hour	100 (SAAQS)[e]	14.4	170.9 (219.9)	94.8 (158.8)	185.3 (234.3)	109.2 (173.2)	170.9	94.8
	Annual	60 (SAAQS)[f]	6.2	7.0	5.0	13.2	11.2	11.7	8.4

a) All predicted concentrations exclude receptor locations inside the Project footprint where the SAAQS and the CAAQS do not apply.
b) Project-only predictions do not include background concentration, whereas Application Case predictions include background concentrations.
c) Predicted concentration comparison with the one-hour SAAQS and AAAQO is based on the annual ninth highest one-hour model prediction at each receptor location per the SAQMG (ENV 2012b). The first highest model prediction is presented in parentheses.
d) Predicted concentration comparison with the one-hour CAAQS is based on the three-year average of the annual 98th percentile of the daily maximum one-hour average concentrations at each receptor location. Comparison to the CAAQS is intended for information purposes only and is not indicative of a non-compliance because the CAAQS metrics are properly evaluated against community monitoring data, not modelled projections.
e) Predicted concentration comparison with the 24-hour SAAQS and AAAQO are based on the annual second highest 24-hour model prediction at each receptor per the SAQMG (ENV 2012b). The first highest model prediction is presented in parentheses.
f) Predicted concentration comparison with the annual SAAQS and CAAQS is based on the average of all one-hour model predictions in a single calendar year and does not exclude any one-hour model predictions.
g) Predicted one-hour concentrations are based on the annual ninth highest one-hour model prediction at each receptor location per the SAQMG (ENV 2012b). Predicted 24-hour concentrations are based on the annual second highest 24-hour model prediction at each receptor location per the SAQMG (ENV 2012b). The first highest one-hour and 24-hour model predictions are presented in parentheses. Predicted annual concentrations are based on the average of all one-hour model predictions in a single calendar year and does not exclude any one-hour model predictions.
h) Predicted concentration comparison with the one-hour CAAQS is based on the three-year average of the annual 99th percentile of the daily maximum one-hour average concentrations at each receptor location.
i) Predicted concentration comparison with the eight-hour SAAQS is based on the annual fifth highest eight-hour model prediction at each receptor per the SAQMG (ENV 2012b). The first highest model prediction is presented in parentheses.
j) Predicted concentration comparison with the 24-hour SAAQS and CAAQS is based on the three-year average of the annual 98th percentile of the daily 24-hour average concentrations at each receptor location.
k) Predicted concentration comparison with the annual CAAQS is based on the three-year average of the annual average of the daily 24-hour average concentrations at each receptor location.
AAAQO = Alberta Ambient Air Quality Objective; CAAQS = Canadian Ambient Air Quality Standards; SAAQS = Saskatchewan Ambient Air Quality Standards; TSP = total suspended particulates; SAQMG = Saskatchewan Air Quality Model Guideline; n/a = not applicable; $PM_{2.5}$ = particulate matter with a nominal aerodynamic diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal aerodynamic diameter of 10 µm or less.

The Application Case predictions in the RSA are shown graphically in the left and centre panels of Figure 7.2-5 through Figure 7.2-21 in comparison to the relevant air quality standards for the specific CAC (e.g., one-hour, 24-hour, annual). The model predictions are displayed as the coloured area in the figures. The figures show the area where model predictions exceed the applicable air quality criteria.

For nitrogen dioxide, $PM_{2.5}$, PM_{10}, and TSP, the lowest level of the colour scale was set as the sum of Base Case concentrations plus 10% of the applicable criteria. This colour scale was selected to help visually determine the geographic extent of the residual effects for these CACs. The 10% of the applicable criteria threshold is not an effects level, rather, it is a change in the measurement indicator value used to support the determination of magnitude and geographic extent as discussed in Section 7.2.2.9. In Application Case figures where the predicted concentrations are low (e.g., sulphur dioxide, sulphuric acid, carbon monoxide), the contours showing the extent of the predictions cannot be perceived because the predicted values are less than the Base Case concentrations plus 10% of applicable criteria. The effect of using the chosen method (Base Case concentrations plus 10% of applicable criteria) as the lowest level of the colour scale to present predicted concentrations in the figures, where concentrations are below Base Case concentrations plus 10% of the applicable criteria, is that the predicted values are obscured by the higher concentrations represented by the Base Case concentrations plus 10% of the applicable criteria value contour. In these cases, an alternative background scale (e.g., 1% of the applicable criteria) was used so that background concentrations do not obscure the predicted concentrations. The figures also show the location and concentration of the overall predicted maximum concentration in the RSA (i.e., outside of the maximum disturbance area) and at the maximum disturbance area.

The Application Case predictions for each measurement indicator are also summarized below.

Nitrogen Dioxide Concentration Predictions

- All predicted maximum nitrogen dioxide concentrations are in compliance with the SAAQS throughout Construction and Operations.
- Predicted maximum nitrogen dioxide concentrations are higher in Construction than in Operations. This is related to the use of diesel as a primary fuel source, rather than LNG, in the power generators.
- All predicted nitrogen dioxide concentrations are below the CAAQS levels, except for one-hour nitrogen dioxide concentrations. As discussed in Section 7.2.2.8.2, Comparison to Canadian Ambient Air Quality Standards, the comparison to CAAQS is provided for information only and does not represent a compliance metric or environmental risk.
- The area within which predicted nitrogen dioxide concentrations due to the Project emissions that result in concentrations above 10% of the SAAQS is confined to the RSA (i.e., regional geographic extent) as shown in Figure 7.2-5 through Figure 7.2-8.
- The direction of change due to the Project related to nitrogen dioxide predictions is negative for Construction and Operations. The magnitude of the change is moderate:
  - For the one-hour averaging period during Construction, the change in maximum nitrogen dioxide concentration is 88.5% of the SAAQS.
  - For the one-hour averaging period during Operations, the change in maximum nitrogen dioxide concentration is 51.9% of the SAAQS.
- Because the effects of CACs on air quality cease as soon as the emissions stop, the duration of the effect is limited to the period when emissions are being released. In the case of Construction, this period is four years, and in Operations, the duration of the predicted effect is 24 years.

- The effects for nitrogen dioxide are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from nitrogen dioxide would be continuous and probable.

Sulphur Dioxide Concentration Predictions

- All predicted maximum sulphur dioxide concentrations are in compliance with the SAAQS and are below the CAAQS levels throughout Construction and Operations.
- Predicted maximum sulphur dioxide concentrations are higher in Operations than in Construction. The acid plant (the primary sulphur dioxide emissions source) would not be operational during the Construction modelling year.
- The area within which predicted sulphur dioxide concentrations due to the Project emissions that result in concentrations above 10% of the SAAQS is confined to the maximum disturbance area as shown in Figure 7.2-9 through Figure 7.2-12.
- The direction of change due to the Project related to sulphur dioxide predictions is negative for Construction and Operations. The magnitude of the change is low:
  - For the one-hour averaging period during Construction, the change in maximum sulphur dioxide concentration is 1.0% of the SAAQS.
  - For the one-hour averaging period during Operations, the change in maximum sulphur dioxide concentration is 2.1% of the SAAQS.
- Because the effects of CACs on air quality cease as soon as the emissions stop, the duration of the effect is limited to the period when emissions are being released. In the case of Construction, this period is four years, and in Operations, the duration of the predicted effect is 24 years.
- The effects for sulphur dioxide are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from sulphur dioxide would be continuous and probable.

Sulphuric Acid Concentration Predictions

- The Project would not emit any sulphuric acid during Construction because the acid plant would not be operational.
- All predicted maximum sulphuric acid concentrations during Operations are below the AAAQO. The maximum one-hour and annual sulphuric acid concentrations are at 12% and 5% of the AAAQO, respectively.
- The area within which predicted sulphuric acid concentrations due to the Project emissions that result in concentrations above 10% of the AAAQO is confined to the LSA (i.e., local geographic extent), as shown in Figure 7.2-13 and Figure 7.2-14.
- The direction of change due to the Project related to sulphuric acid predictions is negative during Operations. The magnitude of the change is low:
  - For the one-hour averaging period during Operations, the change in maximum sulphuric acid concentration is 12.1% of the AAAQO.

- Because the effects of CACs on air quality cease as soon as the emissions stop, the duration of the effect is limited to the period when emissions are being released (i.e., is not applicable in Construction). During Operations, the duration of the predicted effect is 24 years.
- The effects for sulphuric acid are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from sulphuric acid would be continuous and probable.

Carbon Monoxide Concentration Predictions

- All predicted maximum carbon monoxide concentrations are in compliance with the SAAQS. All maximum carbon monoxide concentrations are below 20% of the SAAQS.
- Maximum carbon monoxide concentrations are predicted to be higher in Construction than in Operations. Although predicted Operations total carbon monoxide emissions are higher than those of Construction, 91% of Operations carbon monoxide emissions would be from power plant stacks and mine vents, which are elevated sources with high exit velocities. The emissions from these stacks would travel higher and disperse more before reaching ground level. During Construction, the small heaters considered in the model were conservatively assumed to release their emissions from large, near ground-level area sources. The differences in the way these emissions are expected to be released and their subsequent treatment in the model contributes to the higher maximum concentrations predicted during Construction than Operations.
- The area within which predicted carbon monoxide concentrations due to the Project emissions that result in concentrations above 10% of the SAAQS is confined to the maximum disturbance area as shown in Figure 7.2-15 and Figure 7.2-16.
- The direction of change due to the Project-related carbon monoxide predictions is negative for Construction and Operations. The magnitude of the change is low:
  - For the one-hour averaging period during Construction, the change in maximum carbon monoxide concentration is 7.2% of the SAAQS.
  - For the one-hour averaging period during Operations, the change in maximum carbon monoxide concentration is 4.6% of the SAAQS.
- Because the effects of CACs on air quality cease as soon as the emissions stop, the duration of the effect is limited to the period when emissions are being released. In the case of Construction, this period is four years, and in Operations, the duration of the predicted effect is 24 years.
- The effects for carbon monoxide are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from carbon monoxide would be continuous and probable.

$PM_{2.5}$ Concentration Predictions

- All predicted maximum $PM_{2.5}$ concentrations are in compliance with the SAAQS and are below the CAAQS levels.
- Maximum $PM_{2.5}$ concentrations are higher in Construction than in Operations due to sources of fugitive dust from construction activities that would not be present during Operations (e.g., construction gensets and construction activity).

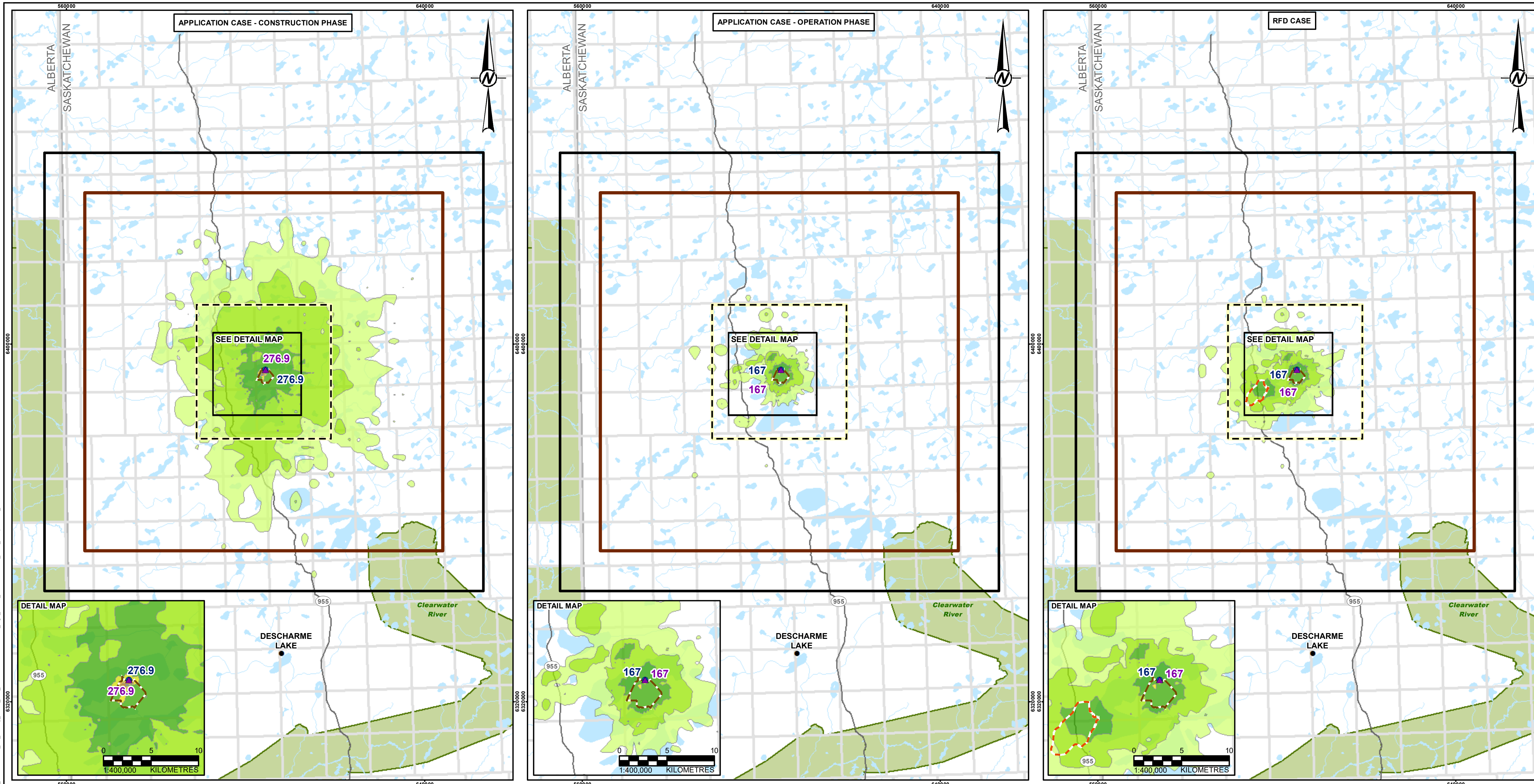
- The area within which predicted $PM_{2.5}$ concentrations due to the Project emissions that result in concentrations above 10% of the SAAQS is confined to the LSA (i.e., local geographic extent) as shown in Figure 7.2-17 and Figure 7.2-18.
- The direction of change due to the Project related to $PM_{2.5}$ predictions is negative for Construction and Operations. The magnitude of the change is moderate:
  - For the 24-hour averaging period during Construction, the change in maximum $PM_{2.5}$ concentration is 36.2% of the SAAQS.
  - For the 24-hour averaging period, the change in maximum $PM_{2.5}$ concentration is 14.4% of the SAAQS.
- Because the effects of CACs on air quality cease as soon as the emissions stop, the duration of the effect is limited to the period when emissions are being released. In the case of Construction, this period is four years, and in Operations, the duration of the predicted effect is 24 years.
- The effects for $PM_{2.5}$ are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from $PM_{2.5}$ would be continuous and probable.

PM_{10} Concentrations Predictions

- Maximum PM_{10} concentrations are higher than the SAAQS. The maximum frequency of exceedance is 2.7% (10 days per year) and occurs during Construction. The frequency of exceedance is predicted to be 0.5% (two days per year) during Operations.
- The maximum exceedance areas outside of the maximum disturbance area, where PM_{10} concentrations are higher than the SAAQS, are 279.1 ha and 9.1 ha for Construction and Operations, respectively. The maximum distances from the exceedance area to the maximum disturbance area is 1,185 m for Construction and 203 m for Operations.
- Maximum PM_{10} concentrations are higher in Construction than in Operations due to sources of fugitive dust from general Construction activities that were modelled as an area source emitted near ground level and were not present during Operations.
- The area within which predicted PM_{10} concentrations due to the Project emissions that result in concentrations above 10% of the ambient air quality standard is confined to the LSA (i.e., local geographic extent) as shown in Figure 7.2-19.
- The direction of change due to the Project related to PM_{10} predictions is negative for Construction and Operations. The magnitude of the change is high as the predicted maximum concentrations exceed the SAAQS for both:
  - Construction 24-hour PM_{10} prediction exceeds the SAAQS.
  - Operations 24-hour PM_{10} prediction exceeds the SAAQS.
- Because the effects of CACs on air quality cease as soon as the emissions stop, the duration of the effect is limited to the period when emissions are being released. In the case of Construction, this period is four years, and in Operations, the duration of the predicted effect is 24 years.
- The effects for PM_{10} are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from PM_{10} would be continuous and probable.

Total Suspended Particulates Concentration Predictions

- Maximum 24-hour TSP concentrations are higher than the SAAQS. The maximum exceedance frequencies are 1.1% (four days per year) during Construction and 0.5% (2 days per year) during Operations.
- The maximum exceedance areas outside of the maximum disturbance area, where 24-hour TSP concentrations are higher than SAAQS, are 41.9 ha and 0.3 ha for Construction and Operations, respectively. The maximum distances from the exceedance area to the maximum disturbance area are 310 m for Construction and 26 m for Operations.
- Maximum annual TSP concentrations are in compliance with the SAAQS.
- Maximum TSP concentrations are higher in Construction than in Operations due to sources of fugitive dust from general construction activities that were modelled as an area source emitted near ground level and were not present during Operations.
- The area within which predicted TSP concentrations due to the Project emissions that result in concentrations above 10% of the ambient air quality standard is confined to the LSA (i.e., local geographic extent) as shown in Figure 7.2-20 and Figure 7.2-21.
- The direction of change due to the Project related to TSP predictions is negative for Construction and Operations. The magnitude of the change is high as the predicted maximum concentrations exceed the SAAQS for both:
  - Construction 24-hour maximum TSP prediction exceeds the SAAQS.
  - Operations 24-hour maximum TSP prediction exceeds the SAAQS.
- Because the effects of CACs on air quality cease as soon as the emissions stop, the duration of the effect is limited to the period when emissions are being released. In the case of Construction, this period is four years, and in Operations, the duration of the predicted effect is 24 years.
- The effects for TSP are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from TSP would be continuous and probable.



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 300
- >= 240 to < 300
- >= 180 to < 240
- >= 120 to < 180
- >= 60 to < 120
- >= 41.3 to < 60
- < 41.3

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [μg/m³] = 300
3. BACKGROUND CONCENTRATION [μg/m³] = 11.3

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

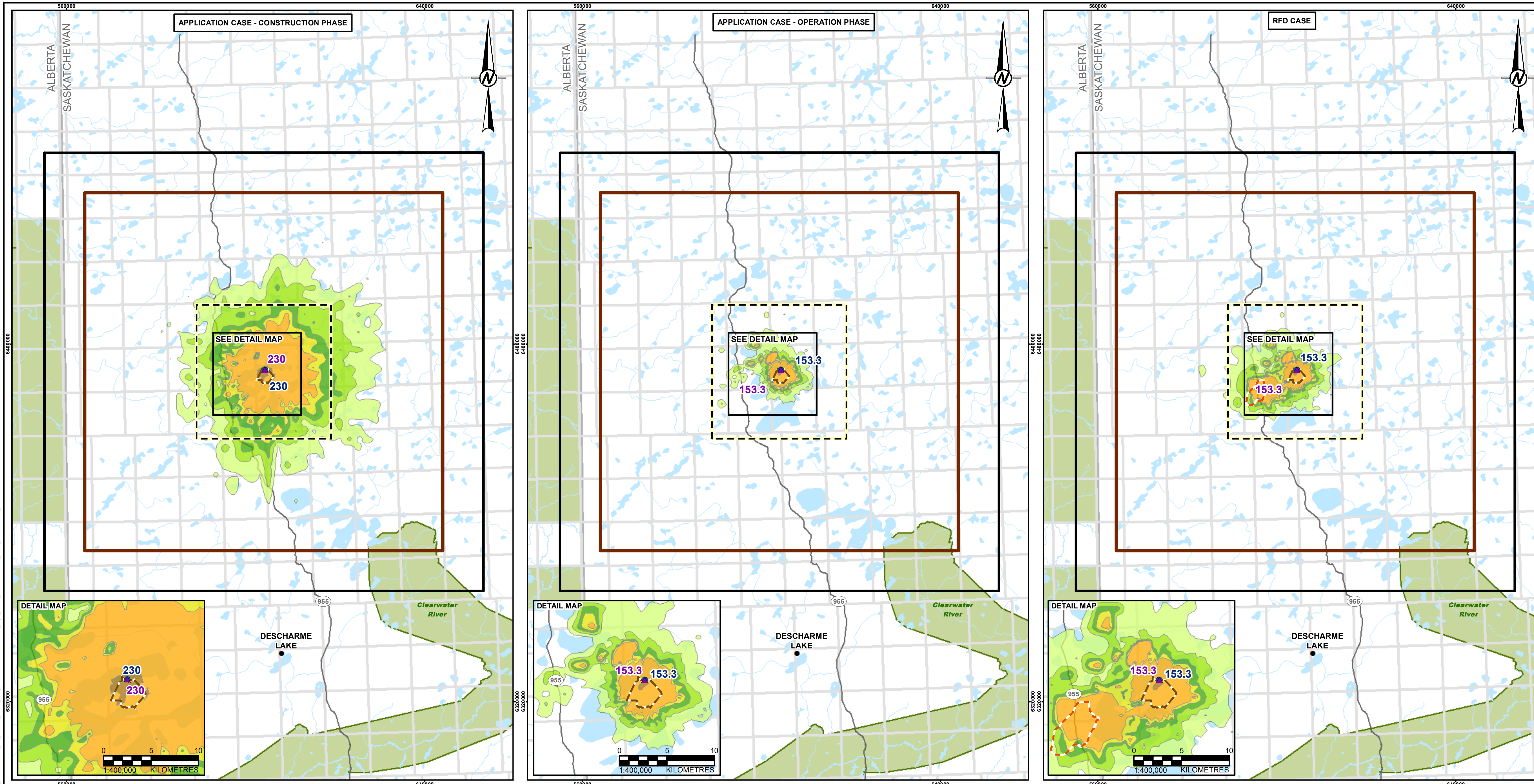
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
MAXIMUM 1-HOUR NITROGEN DIOXIDE CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24	**FIGURE 7.2-5**	
CHECK	ZY	2023-02-24		
REVIEW	CM	2023-02-24		



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [µg/m³]
- OVERALL MAXIMUM CONCENTRATION [µg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [µg/m³]

- >= 160
- >= 79.2 to < 160
- >= 68.85 to < 79.2
- >= 58.5 to < 68.85
- >= 48.1 to < 58.5
- >= 37.7 to < 48.1
- < 37.7

0 20 40
1:850,000 KILOMETRES

NOTE(S)
1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 CANADIAN AMBIENT AIR QUALITY STANDARD [µg/m³] = 79.2
3. BACKGROUND CONCENTRATION [µg/m³] = 11.3

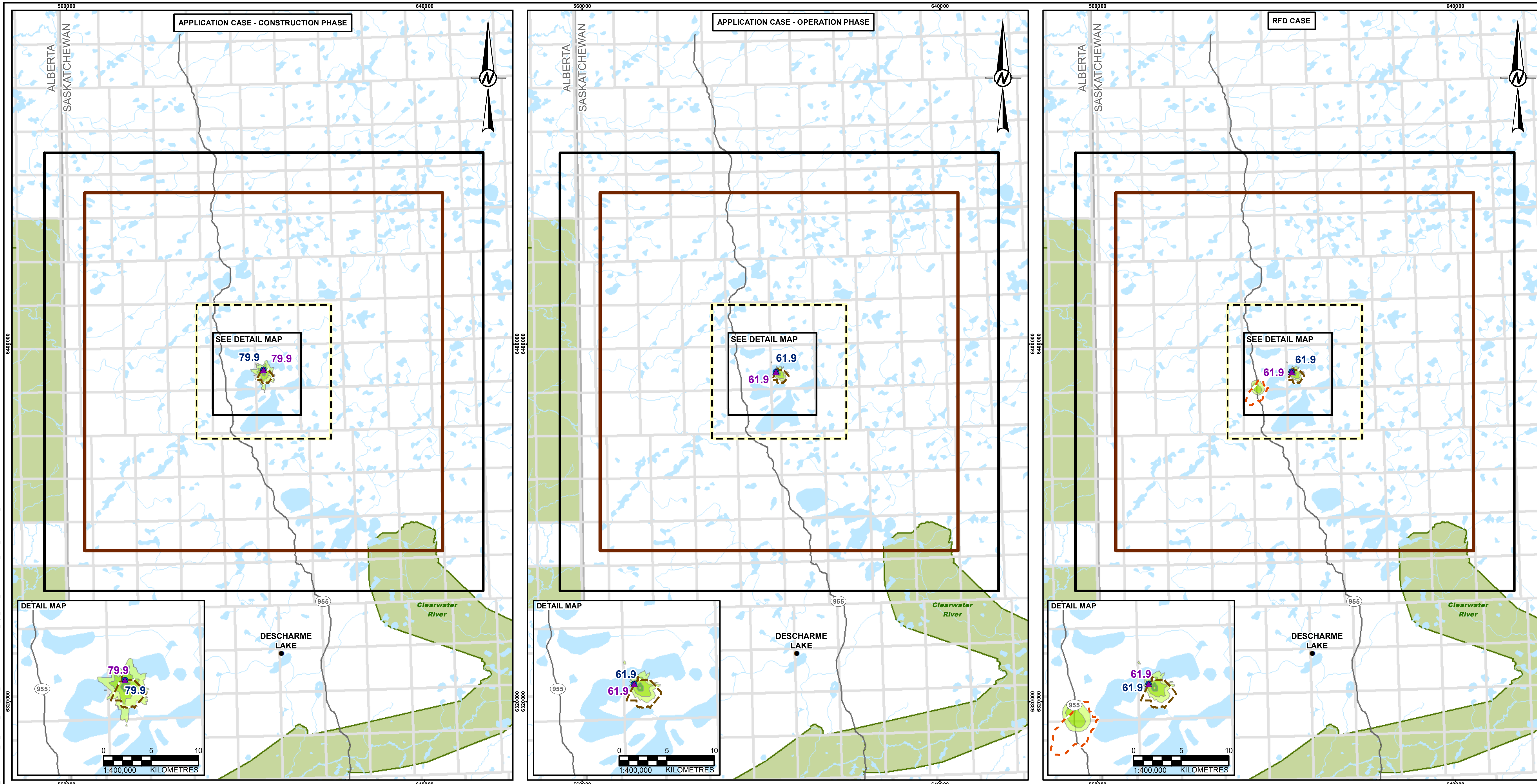
REFERENCE(S)
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
MAXIMUM 1-HOUR NITROGEN DIOXIDE CONCENTRATIONS BASED ON CAAQS STATISTICAL METRIC

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	FIGURE 7.2-6	
REVIEW	CM	2023-02-24		



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 200
- >= 160 to < 200
- >= 120 to < 160
- >= 80 to < 120
- >= 40 to < 80
- >= 29.4 to < 40
- < 29.4

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [μg/m³] = 200
3. BACKGROUND CONCENTRATION [μg/m³] = 9.4

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

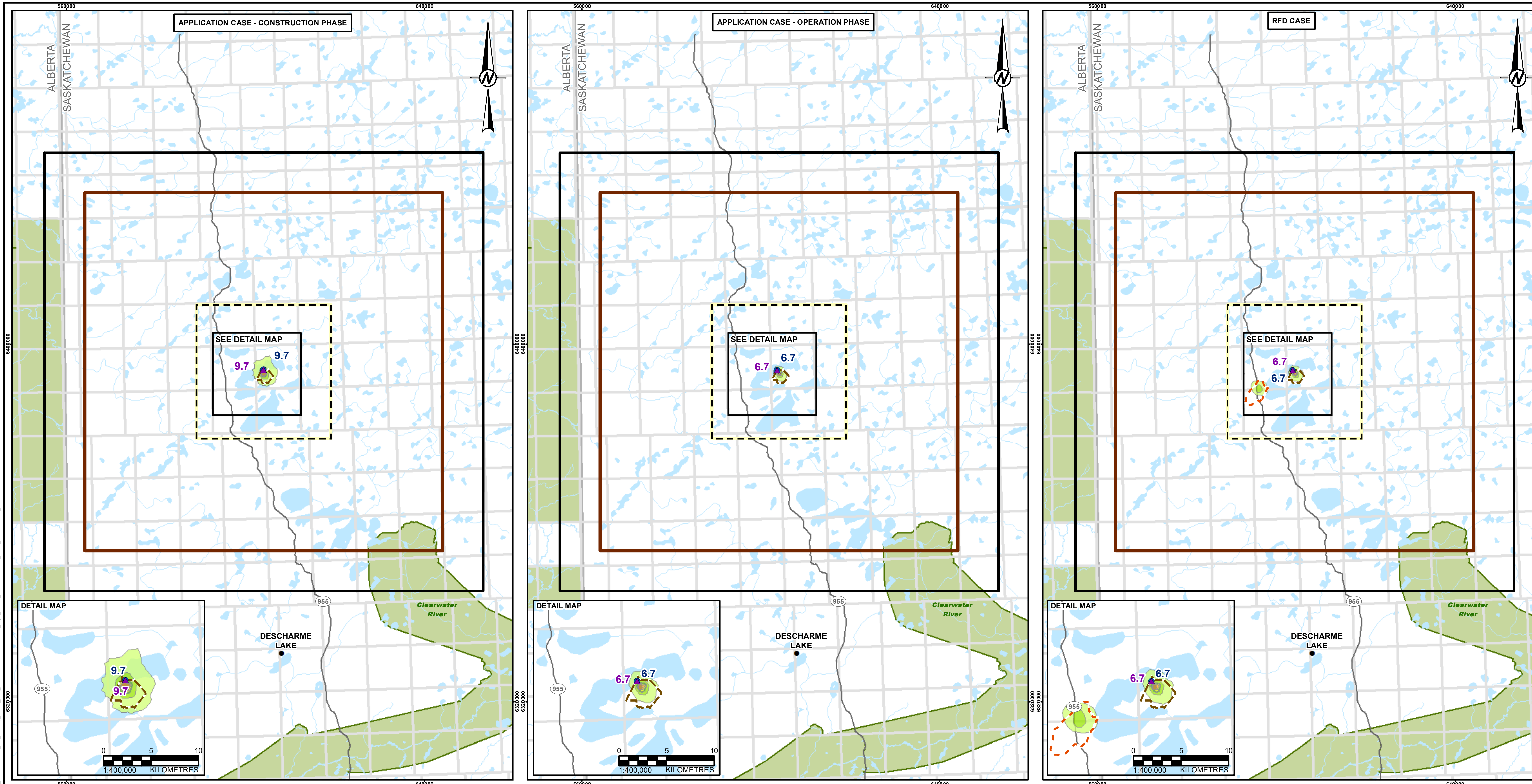
PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
MAXIMUM 24-HOUR NITROGEN DIOXIDE CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24	FIGURE 7.2-7	
CHECK	ZY	2023-02-24		
REVIEW	CM	2023-02-24		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [µg/m³]
- OVERALL MAXIMUM CONCENTRATION [µg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [µg/m³]

- >= 14
- >= 12 to < 14
- >= 10 to < 12
- >= 8 to < 10
- >= 6 to < 8
- >= 4.5 to < 6
- < 4.5

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [µg/m³] = 45
3. BACKGROUND CONCENTRATION [µg/m³] = 3.8

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
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PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

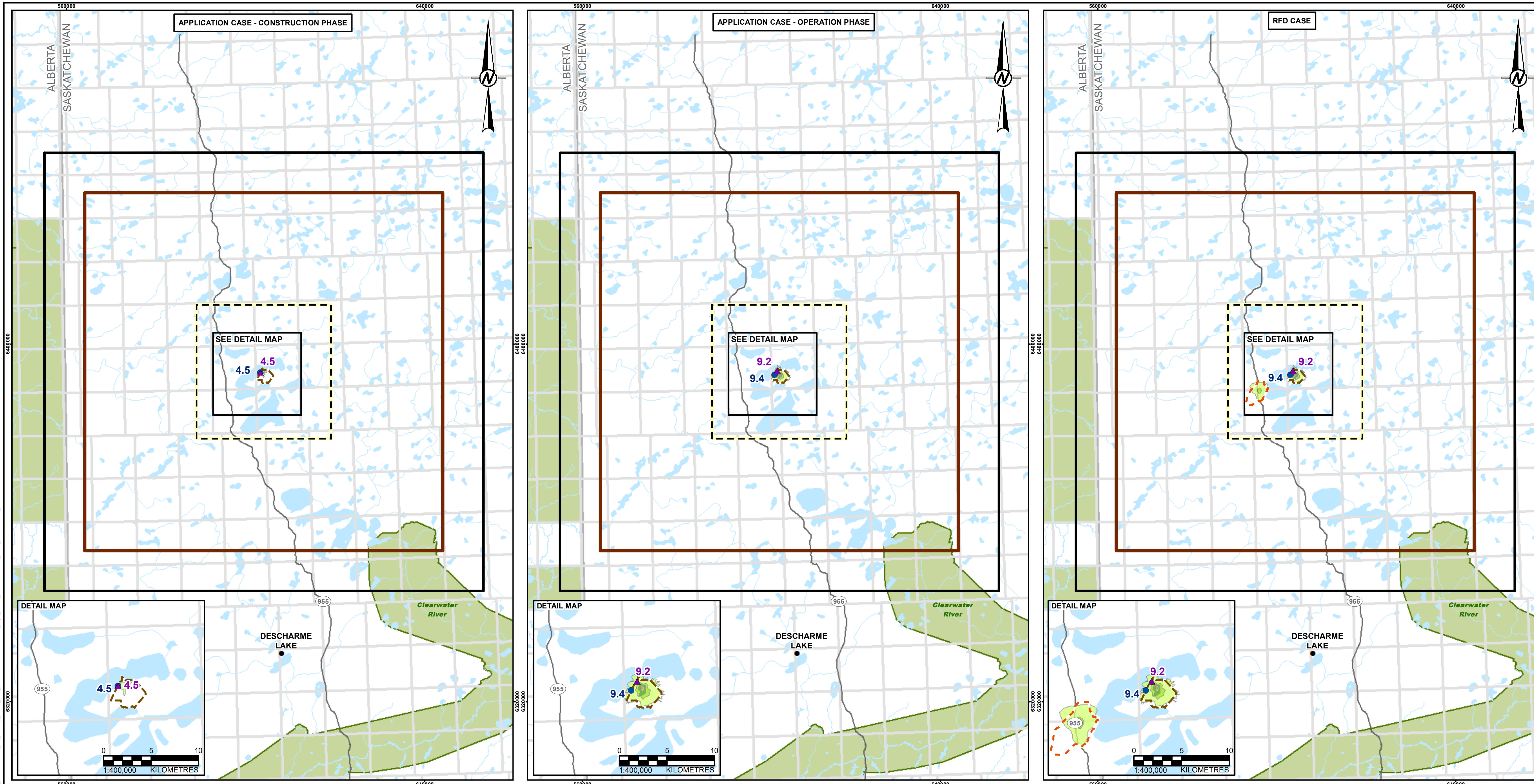
MAXIMUM ANNUAL NITROGEN DIOXIDE CONCENTRATIONS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24		
REVIEW	CM	2023-02-24		

FIGURE 7.2-8



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 30
- >= 25 to < 30
- >= 20 to < 25
- >= 15 to < 20
- >= 10 to < 15
- >= 4.5 to < 10
- < 4.5

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICTED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [μg/m³] = 450
3. BACKGROUND CONCENTRATION [μg/m³] = 0

REFERENCE(S)

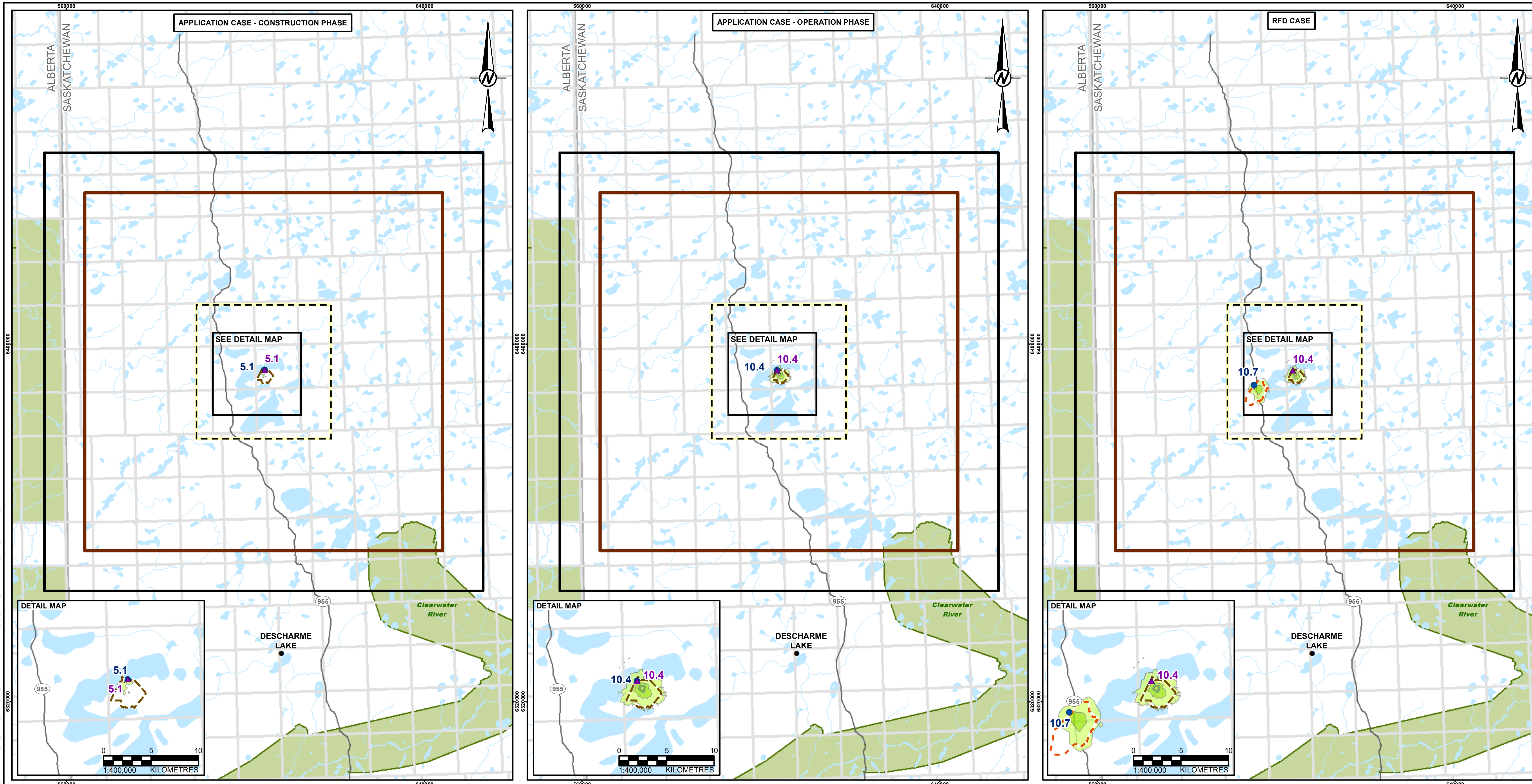
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
MAXIMUM 1-HOUR SULPHUR DIOXIDE CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24	**FIGURE 7.2-9**	
CHECK	ZY	2023-02-24		
REVIEW	CM	2023-02-24		



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m^3]
- OVERALL MAXIMUM CONCENTRATION [μg/m^3]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m^3]

- >= 78.5
- >= 50 to < 78.5
- >= 25 to < 50
- >= 17 to < 25
- >= 10 to < 17
- >= 4.5 to < 10
- < 4.5

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 CANADIAN AMBIENT AIR QUALITY STANDARD [μg/m^3] = 170
3. BACKGROUND CONCENTRATION [μg/m^3] = 0

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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

MAXIMUM 1-HOUR SULPHUR DIOXIDE CONCENTRATIONS BASED ON CAAQS STATISTICAL METRIC

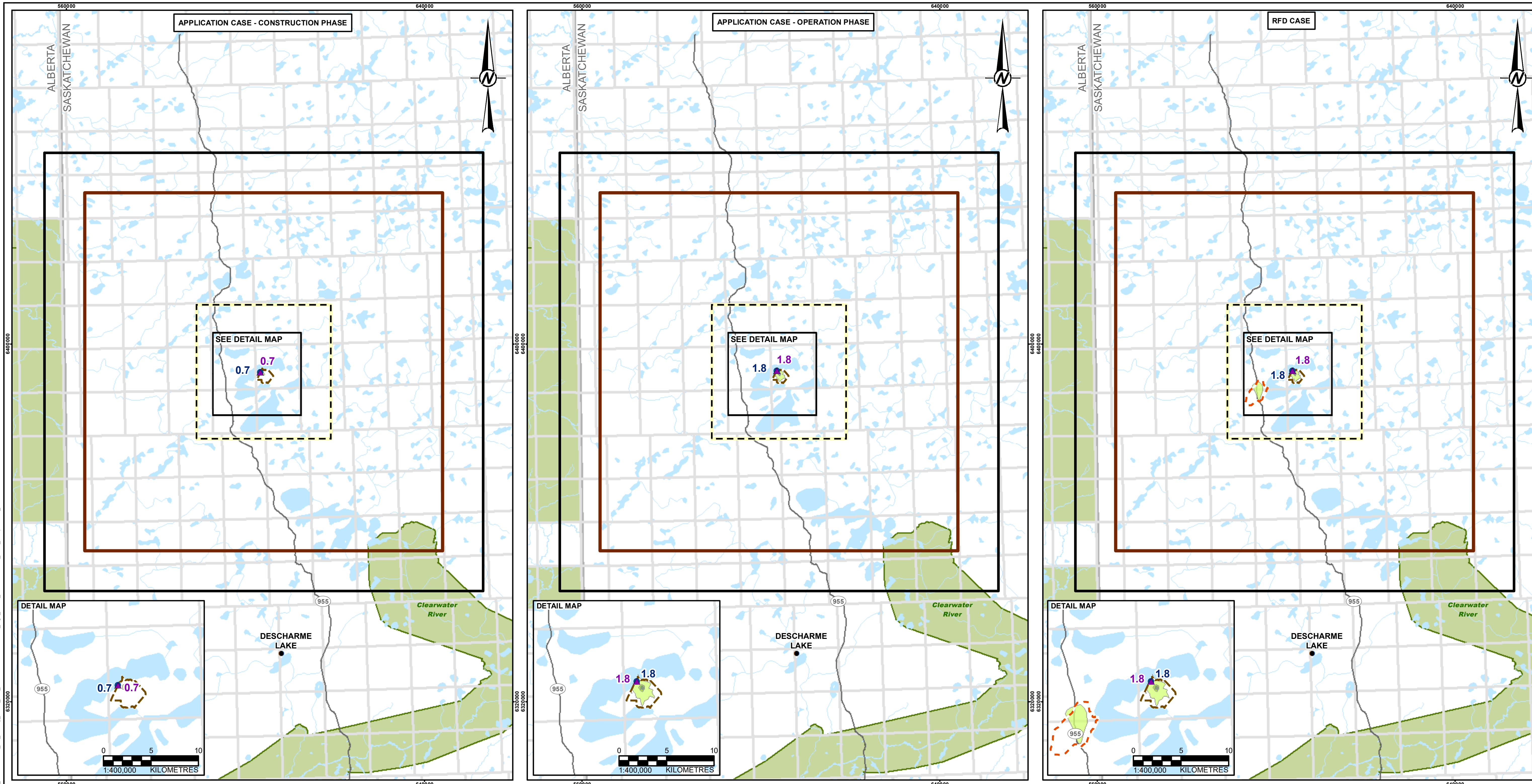
CONSULTANT

wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24	**FIGURE 7.2-10**	
CHECK	ZY	2023-02-24		
REVIEW	CM	2023-02-24		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 16
- >= 13 to < 16
- >= 10 to < 13
- >= 7 to < 10
- >= 4 to < 7
- >= 1 to < 4
- < 1

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [μg/m³] = 125
3. BACKGROUND CONCENTRATION [μg/m³] = 0

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

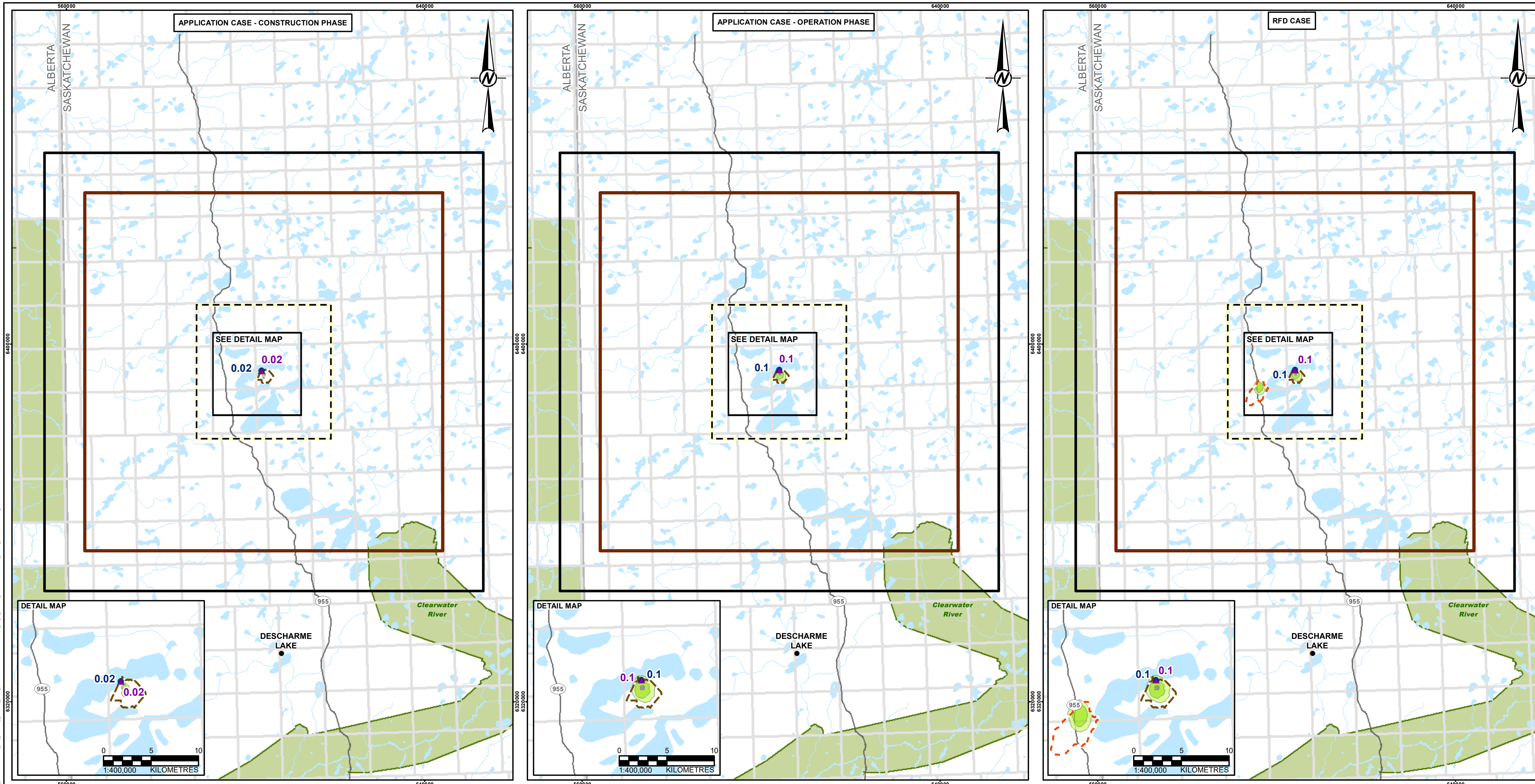
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
MAXIMUM 24-HOUR SULPHUR DIOXIDE CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	**FIGURE 7.2-11**	
REVIEW	CM	2023-02-24		



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 2
- >= 1.5 to < 2
- >= 1 to < 1.5
- >= 0.5 to < 1
- >= 0.1 to < 0.5
- >= 0.05 to < 0.1
- < 0.05

0 20 40
1:850,000 KILOMETRES

NOTE(S)
1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICTED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [μg/m³] = 20
3. BACKGROUND CONCENTRATION [μg/m³] = 0

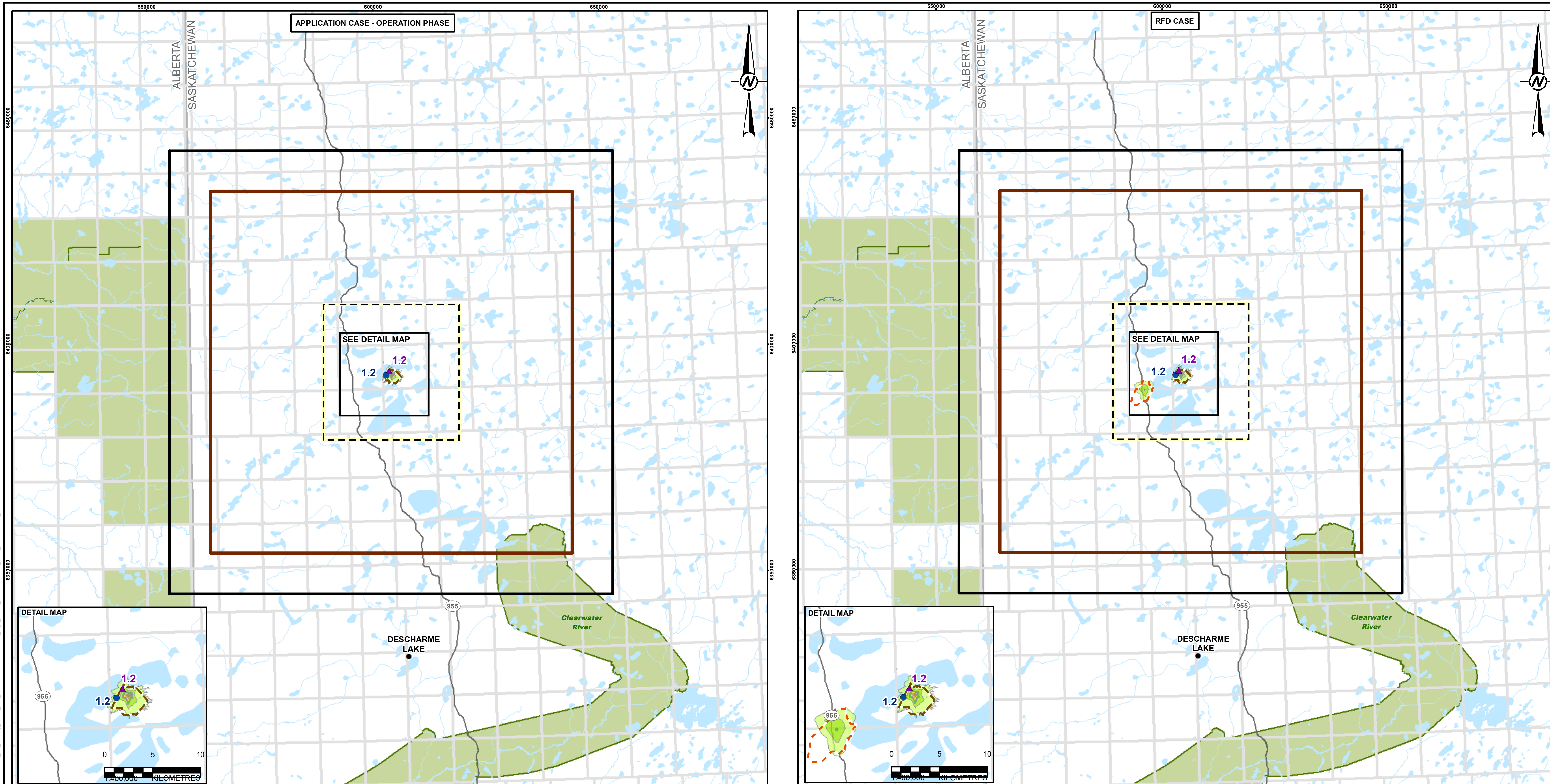
REFERENCE(S)
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
MAXIMUM ANNUAL SULPHUR DIOXIDE CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	**FIGURE 7.2-12**	
REVIEW	CM	2023-02-24		



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 3
- >= 2.5 to < 3
- >= 2 to < 2.5
- >= 1.5 to < 2
- >= 1 to < 1.5
- >= 0.5 to < 1
- < 0.5

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 ALBERTA AMBIENT AIR QUALITY STANDARD [μg/m³] = 10
3. BACKGROUND CONCENTRATION [μg/m³] = 0

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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

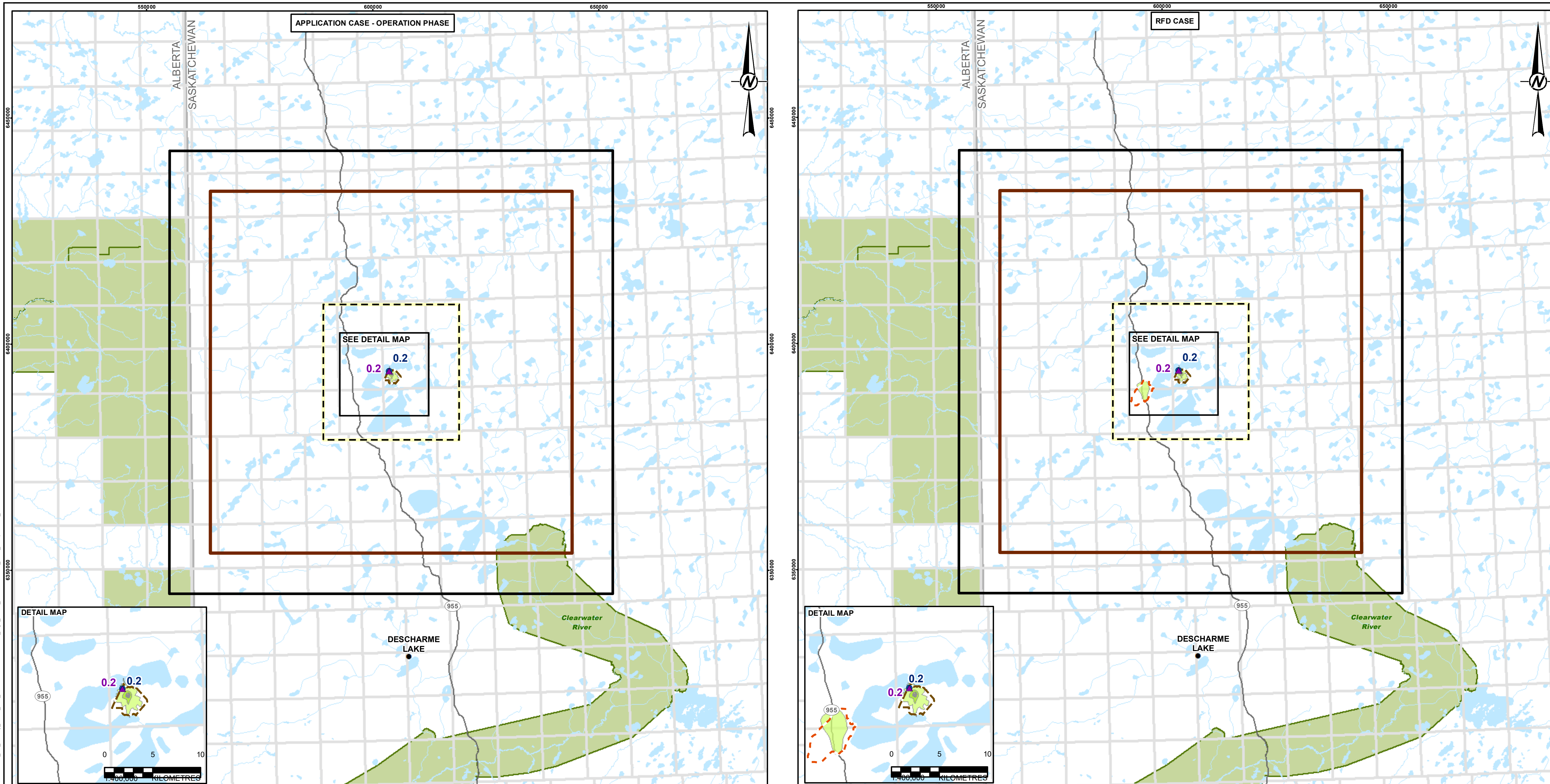
MAXIMUM 1-HOUR SULPHURIC ACID CONCENTRATIONS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24	FIGURE 7.2-13	
CHECK	ZY	2023-02-24		
REVIEW	CM	2023-02-24		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25mm
0



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 1.5
- >= 1.2 to < 1.5
- >= 0.9 to < 1.2
- >= 0.6 to < 0.9
- >= 0.3 to < 0.6
- >= 0.1 to < 0.3
- < 0.1

0 20 40
1:850,000 KILOMETRES

NOTE(S)
1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 ALBERTA AMBIENT AIR QUALITY STANDARD [μg/m³] = 5
3. BACKGROUND CONCENTRATION [μg/m³] = 0

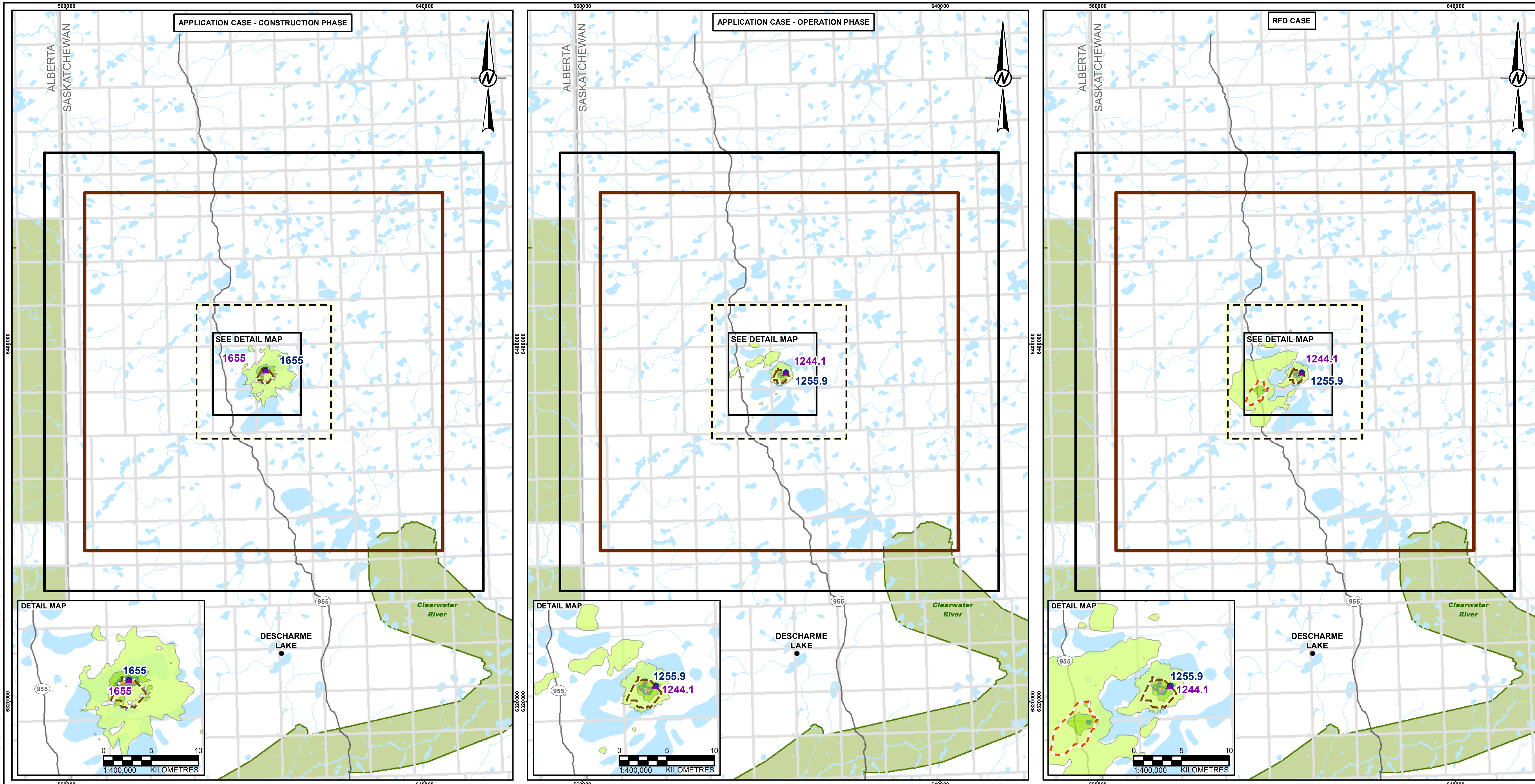
REFERENCE(S)
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
MAXIMUM 24-HOUR SULPHURIC ACID CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	FIGURE 7.2-14	
REVIEW	CM	2023-02-24		



LEGEND

- ● POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- ▲ PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- ● OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 1650
- >= 1450 to < 1650
- >= 1250 to < 1450
- >= 1050 to < 1250
- >= 850 to < 1050
- >= 650 to < 850
- < 650

0 20 40
1:850,000 KILOMETRES

NOTE(S)
1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [μg/m³] = 15,000
3. BACKGROUND CONCENTRATION [μg/m³] = 572.5

REFERENCE(S)
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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
MAXIMUM 1-HOUR CARBON MONOXIDE CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	**FIGURE 7.2-15**	
REVIEW	CM	2023-02-24		

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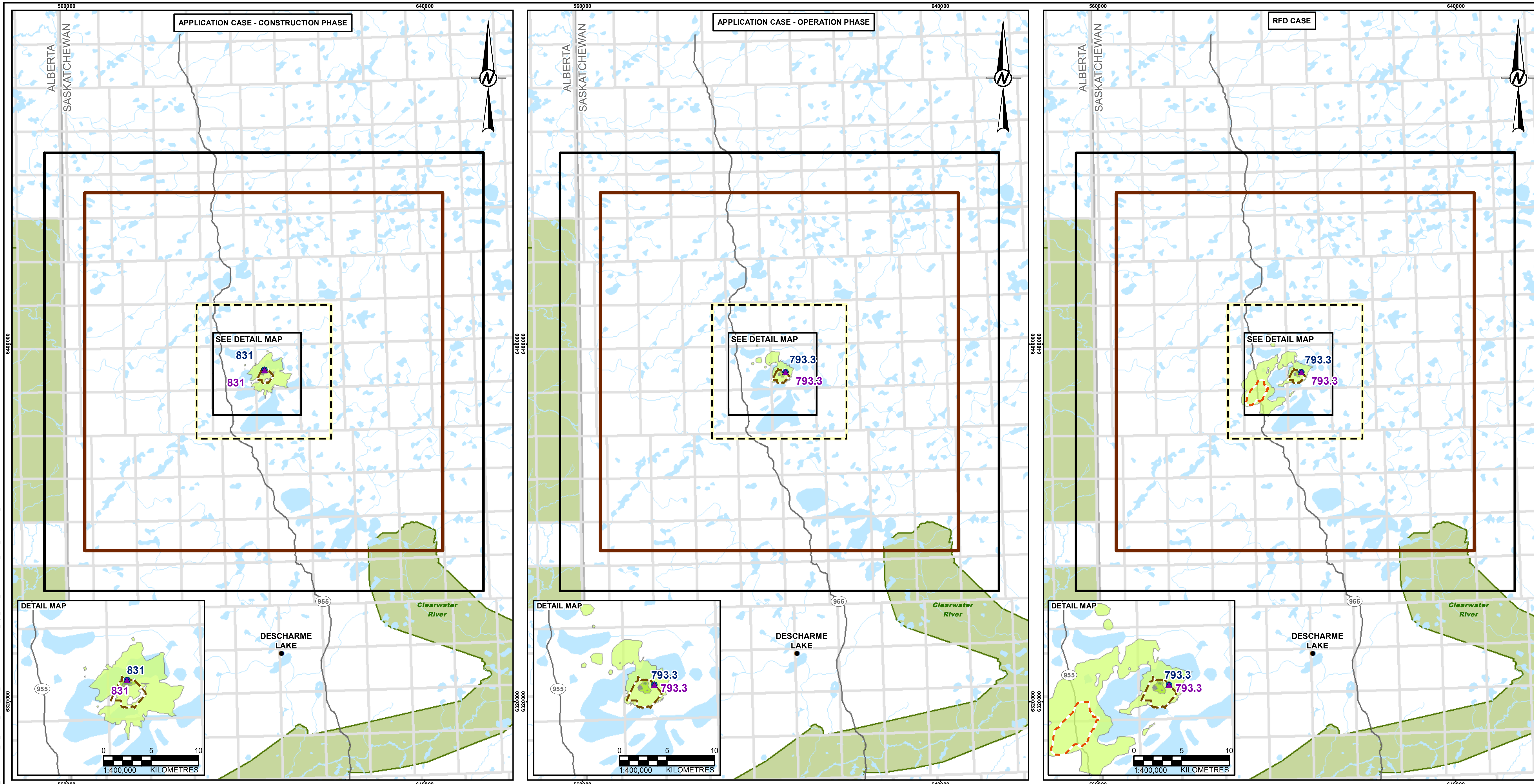
25mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [µg/m³]
- OVERALL MAXIMUM CONCENTRATION [µg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [µg/m³]

- >= 1350
- >= 1200 to < 1350
- >= 1050 to < 1200
- >= 900 to < 1050
- >= 750 to < 900
- >= 600 to < 750
- < 600

0 20 40
1:850,000 KILOMETRES

NOTE(S)
1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [µg/m³] = 6,000
3. BACKGROUND CONCENTRATION [µg/m³] = 572.5

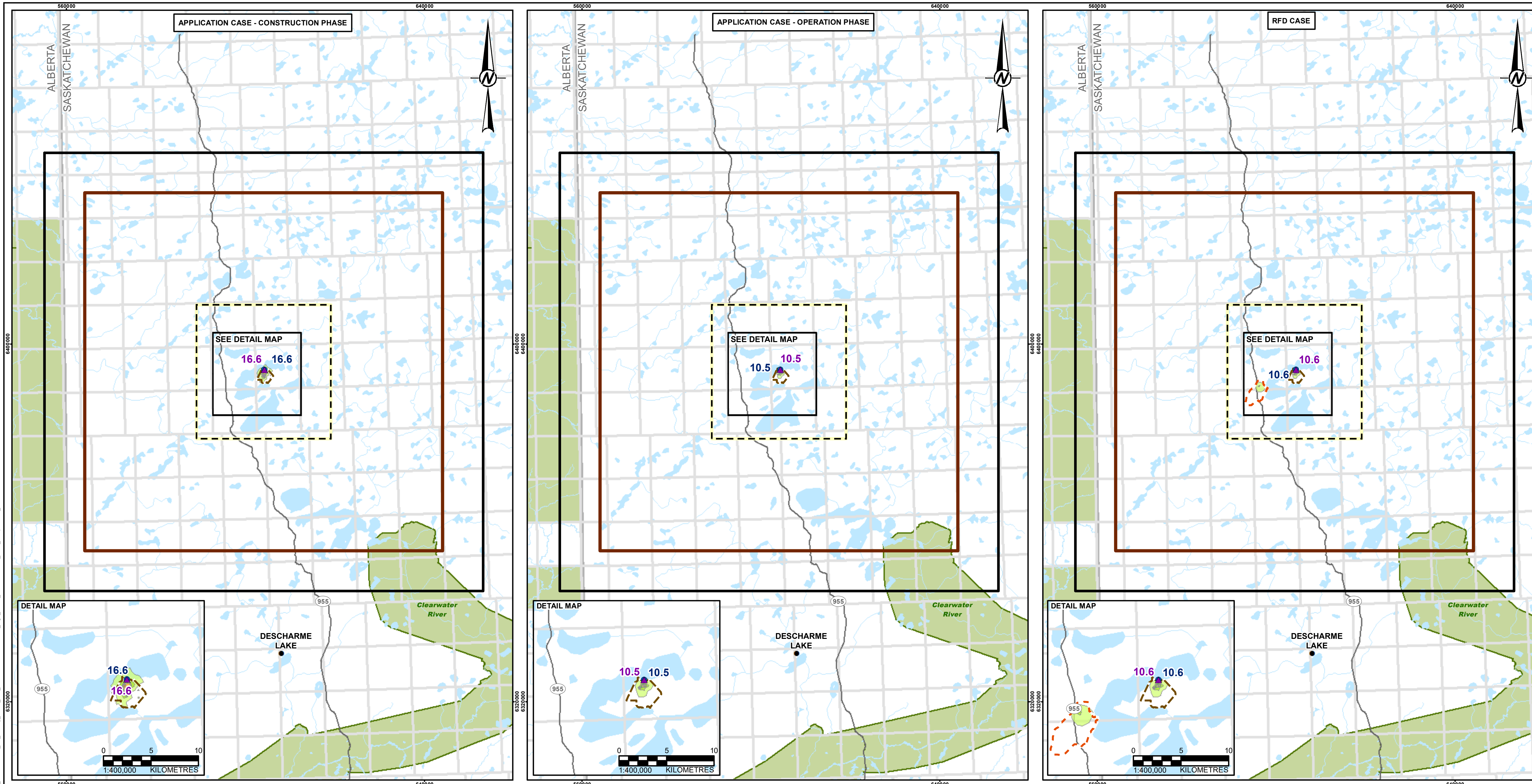
REFERENCE(S)
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
MAXIMUM 8-HOUR CARBON MONOXIDE CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24	**FIGURE 7.2-16**	
CHECK	ZY	2023-02-24		
REVIEW	CM	2023-02-24		



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [µg/m³]
- OVERALL MAXIMUM CONCENTRATION [µg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [µg/m³]

- >= 35
- >= 28 to < 35
- >= 25 to < 28
- >= 20 to < 25
- >= 15 to < 20
- >= 9.3 to < 15
- < 9.3

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [µg/m³] = 28
3. BACKGROUND CONCENTRATION [µg/m³] = 6.5

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.

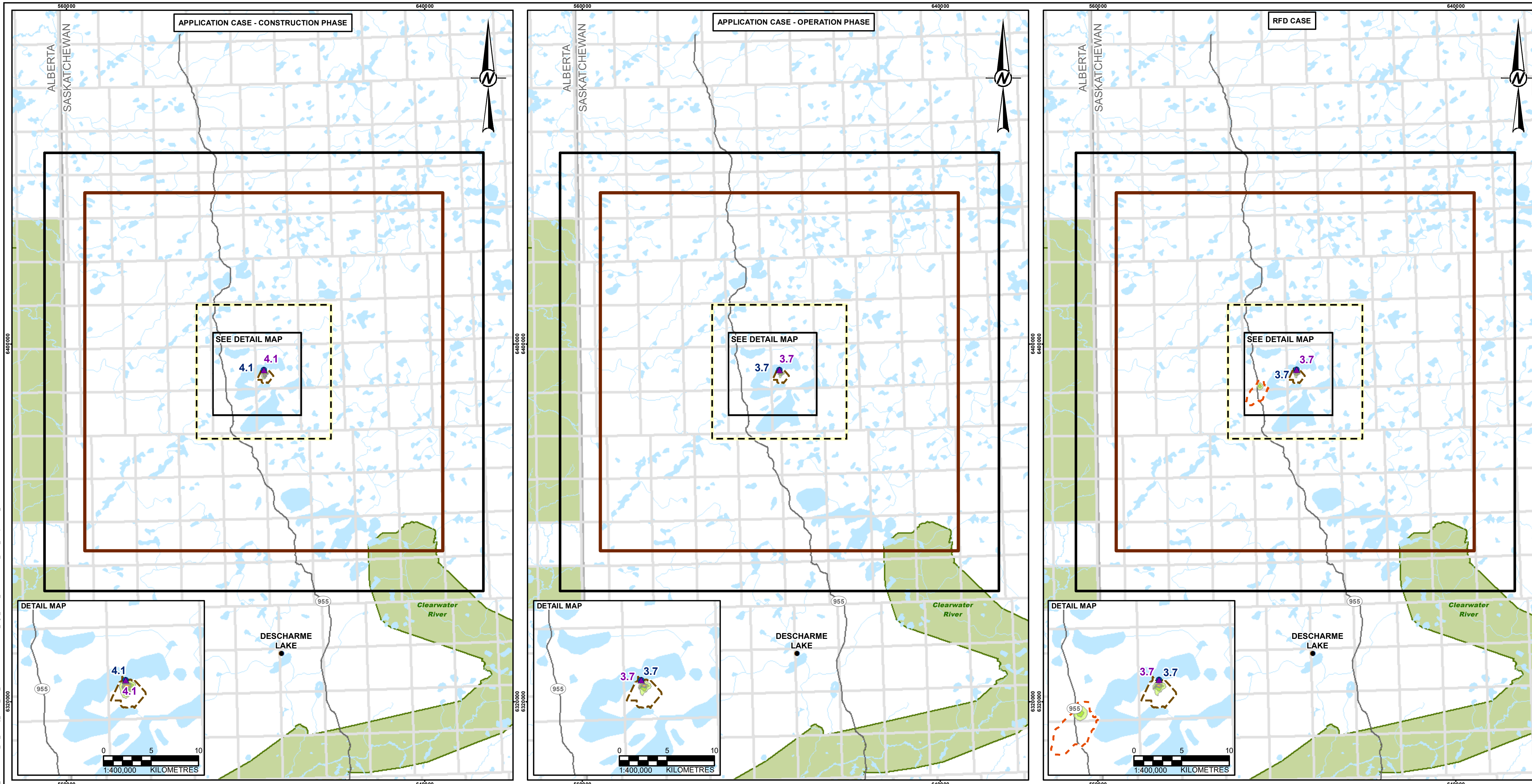
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
MAXIMUM 24-HOUR PM2.5 CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	**FIGURE 7.2-17**	
REVIEW	CM	2023-02-24		



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 10
- >= 8 to < 10
- >= 7 to < 8
- >= 6 to < 7
- >= 5 to < 6
- >= 4.1 to < 5
- < 4.1

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [μg/m³] = 10
3. BACKGROUND CONCENTRATION [μg/m³] = 3.1

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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
MAXIMUM ANNUAL PM2.5 CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	**FIGURE 7.2-18**	
REVIEW	CM	2023-02-24		

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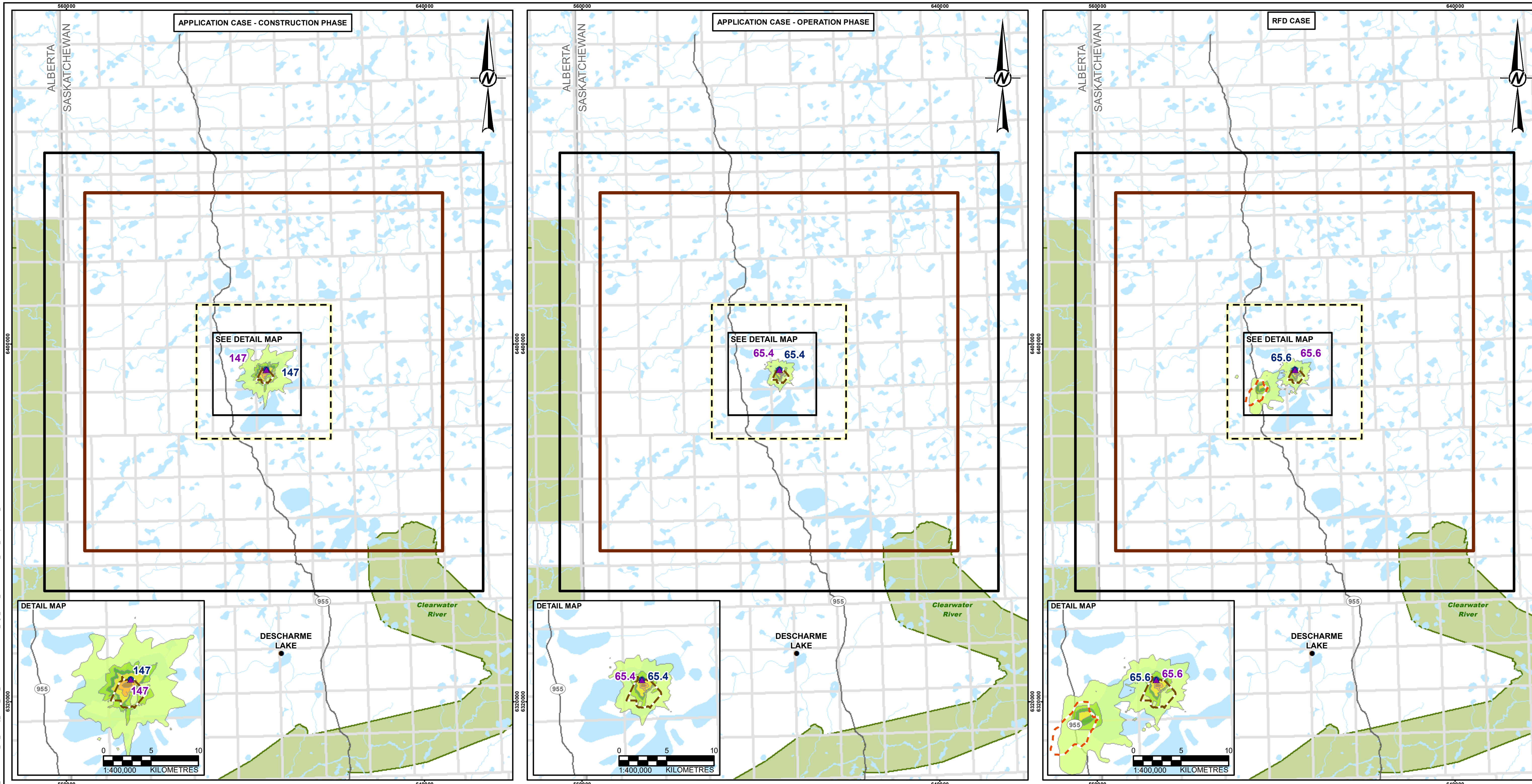

LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [μg/m³]
- OVERALL MAXIMUM CONCENTRATION [μg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [μg/m³]

- >= 200
- >= 100 to < 200
- >= 50 to < 100
- >= 40 to < 50
- >= 30 to < 40
- >= 19.4 to < 30
- < 19.4

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [μg/m³] = 50
3. BACKGROUND CONCENTRATION [μg/m³] = 14.4

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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

MAXIMUM 24-HOUR PM10 CONCENTRATIONS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	FIGURE 7.2-19	
REVIEW	CM	2023-02-24		

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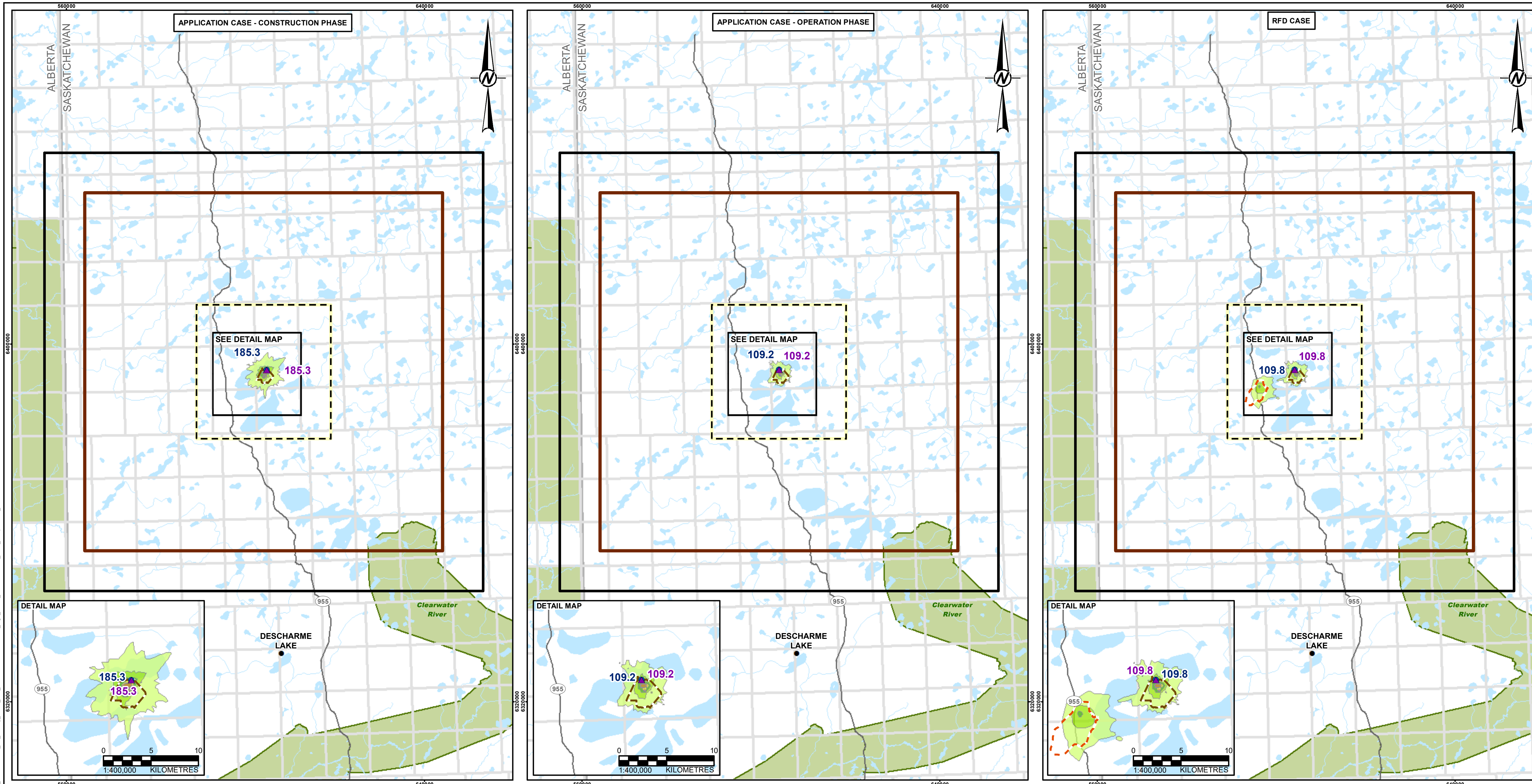


LEGEND

- ● POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- ▲ PROJECT BOUNDARY MAXIMUM CONCENTRATION [µg/m³]
- ● OVERALL MAXIMUM CONCENTRATION [µg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [µg/m³]

- >= 400
- >= 300 to < 400
- >= 200 to < 300
- >= 100 to < 200
- >= 50 to < 100
- >= 24.4 to < 50
- < 24.4

0 20 40
1:850,000 KILOMETRES

NOTE(S)

1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICTED
2. SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [µg/m³] = 100
3. BACKGROUND CONCENTRATION [µg/m³] = 14.4

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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

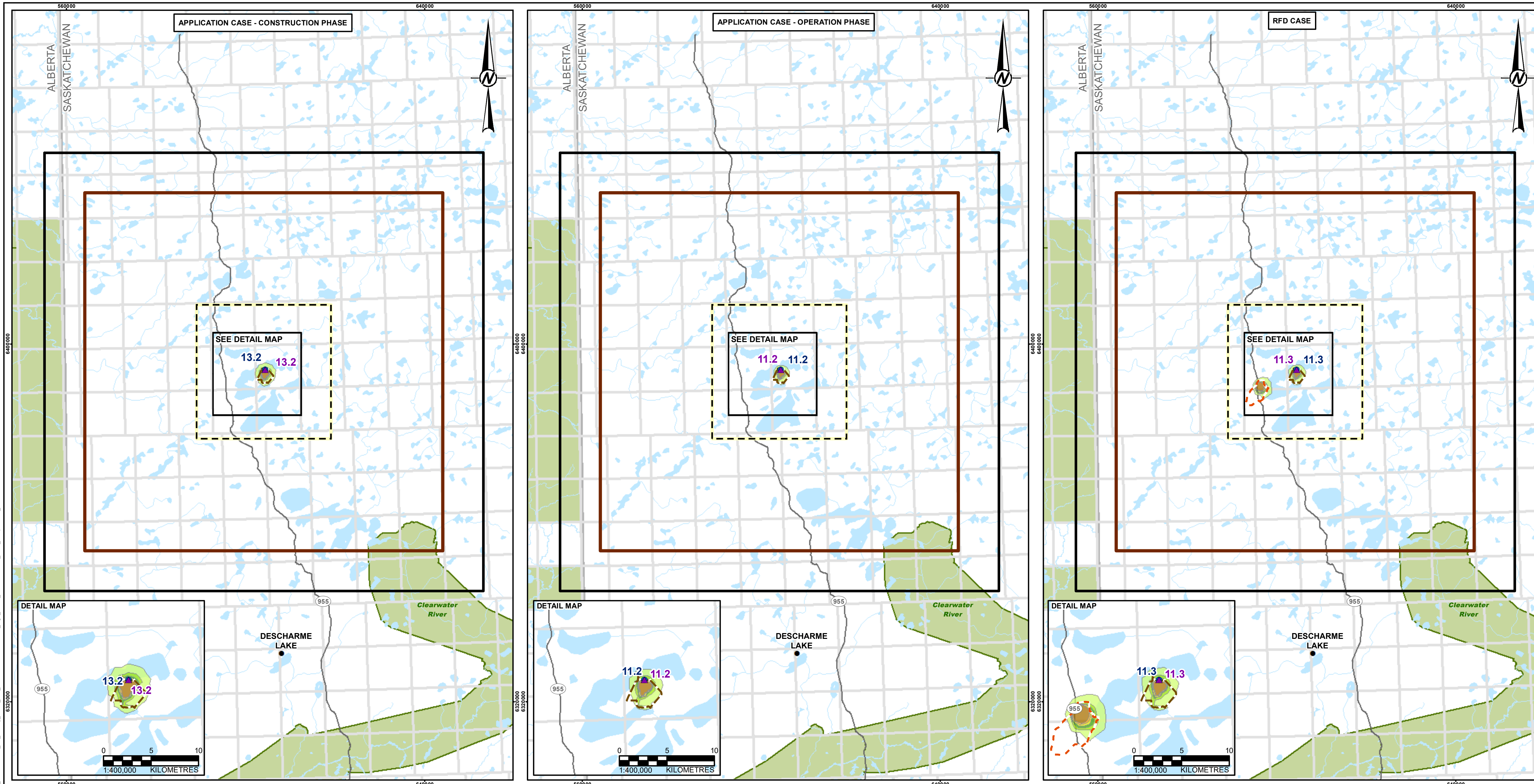
TITLE

MAXIMUM 24-HOUR TOTAL SUSPENDED PARTICLES CONCENTRATIONS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	**FIGURE 7.2-20**	
REVIEW	CM	2023-02-24		



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [µg/m³]
- OVERALL MAXIMUM CONCENTRATION [µg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [µg/m³]

- >= 12
- >= 11 to < 12
- >= 10 to < 11
- >= 9 to < 10
- >= 8 to < 9
- >= 7 to < 8
- < 7

0 20 40
1:850,000 KILOMETRES

NOTE(S)
1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 SASKATCHEWAN AMBIENT AIR QUALITY STANDARD [µg/m³] = 60
3. BACKGROUND CONCENTRATION [µg/m³] = 6.2

REFERENCE(S)
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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
MAXIMUM ANNUAL TOTAL SUSPENDED PARTICLES CONCENTRATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24	FIGURE 7.2-21	
CHECK	ZY	2023-02-24		
REVIEW	CM	2023-02-24		

7.2.5.1.2 Closure

As discussed in Section 7.2.2.8, Residual Effects Analysis, throughout Closure, the intensity, duration, and spatial extent of CAC emissions would be similar or reduced relative to Construction and Operations. Closure would include two stages expected to occur over 15 years (i.e., Active Closure Stage [five years] and Transitional Monitoring Stage [10 years]) as described in Section 7.2.2.4. The Active Closure Stage would include active decommissioning and reclamation activities that would occur post-Operations, such as backfilling mine workings, removal of physical infrastructure, recontouring and revegetating disturbed areas, waste disposal and removal, and any other activities deemed necessary to achieve decommissioning objectives and return the site to a safe and stable condition prior to Transitional Monitoring Stage.

During the Active Closure Stage, CAC emissions would be generated from fuel combustion and fugitive dust from activities such as removal of infrastructure, restoration, and revegetation of facility sites and infrastructure, transportation of personnel and material to and from the site, power generation, and non-hazardous waste incineration. These activities are similar to activities during Construction; however, the intensity, duration, and areal extent of CAC emissions during the Active Closure Stage would likely be lower than during Construction. For example, equipment would be used to dismantle buildings and decommission site roads and pads, but there would be no to little land clearing required, and major earthworks would be substantially reduced as compared to Construction, with the focus being revegetation.

During the Transitional Monitoring Stage, CAC emissions associated with fuel combustion and fugitive dust from the small number of vehicles operating would be negligible relative to the Active Closure Stage. Dispersion modelling results from Construction were, therefore, used as a conservative surrogate for assessing effects during Closure (i.e., Closure was not modelled separately [Section 7.2.2.8.1, Comparison to Saskatchewan Ambient Air Quality Standards]). The residual effects analysis results of Construction in terms of magnitude and geographic extent were conservatively applied to Closure. The duration of the residual effects would be the duration of the Active Closure Stage (i.e., five years).

7.2.5.2 Reasonably Foreseeable Development Case

The RFD Case consisted of a modelling assessment of the Project emissions during Operations combined with the operations emissions from the Fission Patterson Lake South Property that resulted in predictions of ground-level concentrations of the CACs that reflect the cumulative effects of both projects. The emissions inputs to the model for operations represent the highest cumulative reasonably foreseeable emissions from both projects. A summary of emissions inputs is provided in Section 7.2.5.2.1, Emission Inventory, and in detail in the emissions Appendix 7A. The resulting modelling predictions are presented in Section 7.2.5.2.2, Air Dispersion Modelling Predictions, in tabular form and descriptive text bullets, and in Figure 7.2-5 through Figure 7.2-21.

7.2.5.2.1 Emission Inventory

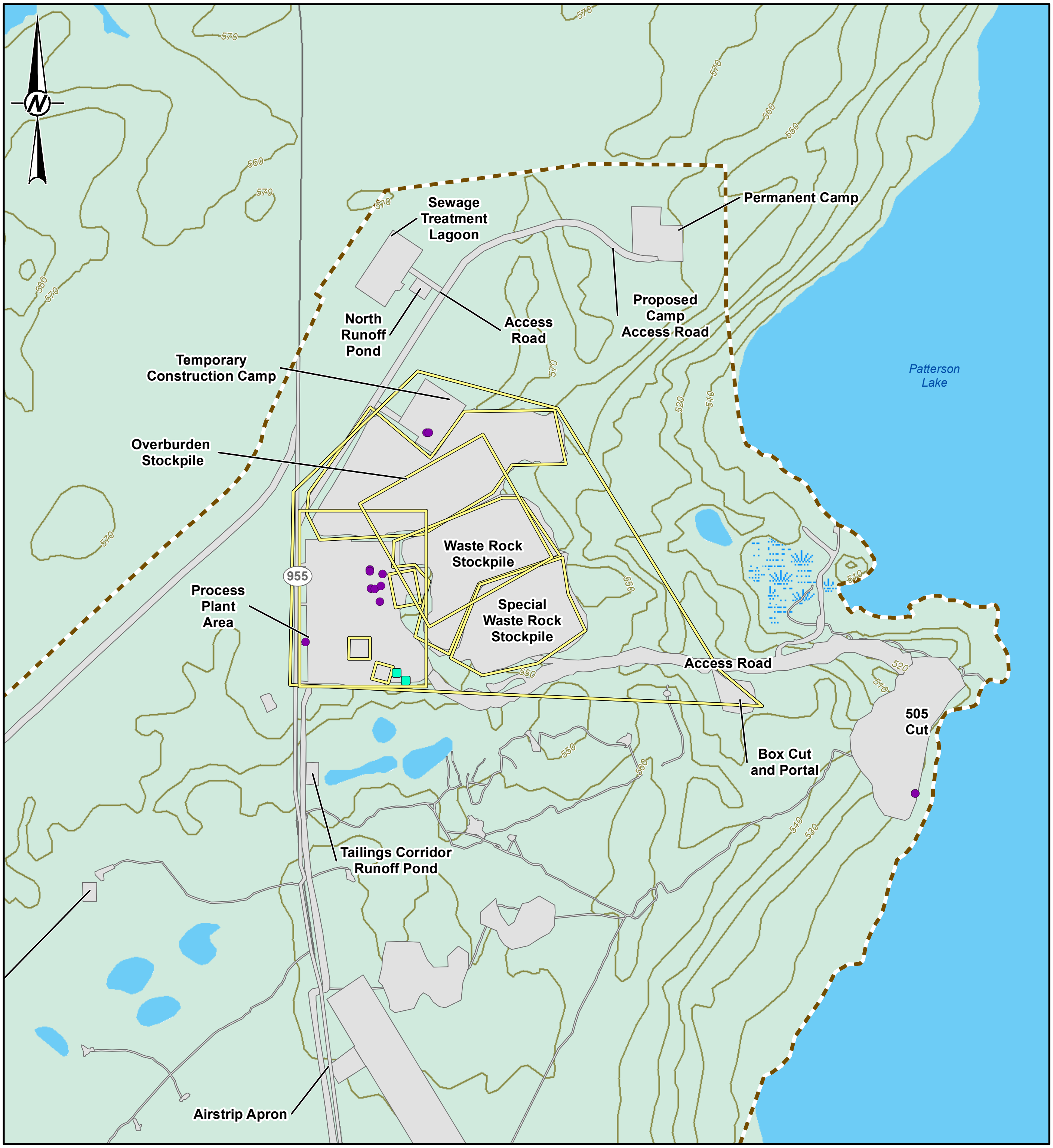
The air emissions sources from the Fission Patterson Lake South Property are assumed to be similar to those from the Project during Operations. The annual emission rates predicted for the Fission Patterson Lake South Property are presented in Table 7.2-13. The annual emission rates of sulphur dioxide and sulphuric acid are assumed to be comparable to of the Project because the emissions from the acid plant were assumed to be identical for both projects. The emission rates of other CACs (i.e., nitrogen oxides, carbon monoxide, $PM_{2.5}$, PM_{10}, and TSP) are lower than those of the Project because the Fission Patterson Lake South Property would have lower power capacity, lower ore mined and processed, and lower material movement as compared to the

Project. The locations of the air emission sources of the Fission Patterson Lake South Property were modelled as point, area, or volume sources and are shown in Figure 7.2-22.

Table 7.2-13: Fission Patterson Lake South Property Predicted Annual Emission Rates

Phase	Nitrogen Oxides (t/yr)	Sulphur Dioxide (t/yr)	Sulphuric Acid (t/yr)	Carbon Monoxide (t/yr)	$PM_{2.5}$ (t/yr)	PM_{10} (t/yr)	TSP (t/yr)
Acid plant	n/a	2.71	0.35	n/a	n/a	n/a	n/a
Calciner stacks	0.07	0.03	n/a	5.13	1.68	4.67	8.70
Batch plant	n/a	n/a	n/a	n/a	0.01	0.02	0.08
Semi-autogenous grinding and ball process plant	n/a	n/a	n/a	n/a	0.25	0.86	1.68
Aggregate operations	n/a	n/a	n/a	n/a	0.23	0.41	1.48
Dozing	n/a	n/a	n/a	n/a	0.99	1.78	9.42
Material handling	n/a	n/a	n/a	n/a	0.21	0.72	1.42
Small heaters	0.26	0.00	n/a	0.17	0.01	0.01	0.01
Underground grading	n/a	n/a	n/a	n/a	0.03	0.47	0.95
Underground diesel mine fleet	5.67	0.03	n/a	0.18	0.26	0.36	0.36
Underground hauling	n/a	n/a	n/a	n/a	1.31	13.14	51.13
Underground material handling	n/a	n/a	n/a	n/a	0.01	0.02	0.04
Underground drilling	n/a	n/a	n/a	n/a	0.20	0.20	0.25
Underground blasting	11.29	0.02	n/a	49.77	0.02	0.26	0.50
Power plant	130.77	0.02	n/a	74.85	3.89	3.89	3.89
Road dust	n/a	n/a	n/a	n/a	1.59	15.93	62.01
Grading	n/a	n/a	n/a	n/a	0.19	2.20	6.29
Incinerator	1.00	0.59	n/a	0.16	0.35	0.46	0.70
Low-level radioactive waste incinerator	1.86	1.47	n/a	0.24	0.85	1.09	1.64
Lime silos	n/a	n/a	n/a	n/a	0.17	0.17	0.17
Mine fleet	12.93	0.05	n/a	6.81	1.19	1.10	1.10
Mine heater	3.64	0.08	n/a	28.51	0.14	0.14	0.14
Wind erosion	n/a	n/a	n/a	n/a	0.71	1.79	3.57
Uranium concentrate handling	n/a	n/a	n/a	n/a	0.10	0.28	0.32
Total	**156.4**	**5.0**	**0.35**	**124.2**	**14.4**	**50.0**	**155.9**

$PM_{2.5}$ = particulate matter with a nominal diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal diameter of 10 µm or less; TSP = total suspended particulates; n/a = not applicable.



LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- SECONDARY HIGHWAY
- WATERBODY
- WETLAND
- WOODED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- POINT SOURCES
- VOLUME SOURCES
- AREA SOURCES

0 0.5 1
1:20,000 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.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
FISSION PATTERSON LAKE SOUTH PROPERTY EMISSION SOURCES

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	SB/ZY	2023-02-07	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-07	FIGURE 7.2-22	
CHECK	ZY	2023-02-07		
REVIEW	CM	2023-02-07		

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7.2.5.2.2 Air Dispersion Modelling Predictions

A comparison of the Application Case and the RFD Case maximum concentration predictions is provided in Table 7.2-14. The predicted concentrations were compared with the applicable SAAQS and CAAQS. The RFD Case maximum predictions are similar or slightly higher than the maximum predictions of the Application Case Operations (Table 7.2-12). The change in air quality predictions between the Base Case and the RFD Case is also described in terms of how much change the Project is expected to induce as a relative percentage of the relevant ambient air quality criteria (Table 7.2-14). The comparisons made to the CAAQSs are for information purposes only and are not indicative of Project compliance.

Table 7.2-14: Reasonably Foreseeable Development Case Prediction Summary

Compound	Averaging Period	Criteria (µg/m³)	Base Case Maximum Concentration (µg/m³)	Application Case Maximum Concentration (µg/m³)[a]	RFD Case Maximum Concentration (µg/m³)[a]	Change Between Base Case and RFD Case (µg/m³)	Percent Change Between Base Case and RFD Case as Percentage of Criteria (%)
Nitrogen dioxide	1-hour	300 (SAAQS)[b]	11.3	167.0 (205.0)	167.0 (205.0)	155.7	51.9
		79.2 (CAAQS)[c]	11.3	153.3	153.3	142.0	179.2
	24-hour	200 (SAAQS)[d]	9.4	61.9 (73.3)	61.9 (73.3)	52.5	26.2
	Annual	45 (SAAQS)[e]	3.8	6.7	6.7	2.9	6.5
		22.6 (CAAQS)[e]	3.8	6.7	6.7	2.9	12.9
Nitrogen oxides[f]	1-hour	n/a	11.3	575.7 (914.7)	575.7 (914.7)	564.3	n/a
	24-hour	n/a	9.4	87.9 (129.1)	88.4 (129.1)	79.0	n/a
	Annual	n/a	3.8	7.1	7.1	3.4	n/a
Sulphur dioxide	1-hour	450 (SAAQS)[b]	0	9.4 (19.7)	9.4 (19.7)	9.4	2.1
		170.1 (CAAQS)[g]	0	10.4	10.7	10.7	6.3
	24-hour	125 (SAAQS)[d]	0	1.8 (3.1)	1.8 (3.1)	1.8	1.4
	Annual	20 (SAAQS)[e]	0	0.1	0.1	0.1	0.5
		10.5 (CAAQS)[e]	0	0.1	0.1	0.1	1.0
Sulphuric acid	1-hour	10 (AAAQO)[b]	0	1.2 (2.0)	1.2 (2.0)	1.2	12.1
	24-hour	5 (AAAQO)[d]	0	0.2 (0.4)	0.2 (0.4)	0.2	4.6
Carbon monoxide	1-hour	15,000 (SAAQS)[b]	572.5	1,255.9 (8,759)	1,256 (8,761)	683.5	4.6
	8-hour	6,000 (SAAQS)[h]	572.5	792.5 (1,629)	793 (1,632)	220.5	3.7
$PM_{2.5}$	24-hour	28 (SAAQS)[i]	6.5	10.5	10.6	4.1	14.6
		27 (CAAQS)[i]	6.5	10.5	10.6	4.1	15.2
	Annual	10.0 (SAAQS)[e]	3.1	3.7	3.7	0.6	5.8
		8.8 (CAAQS)[j]	3.1	3.7	3.7	0.6	7.1

Table 7.2-14: Reasonably Foreseeable Development Case Prediction Summary

Compound	Averaging Period	Criteria (µg/m³)	Base Case Maximum Concentration (µg/m³)	Application Case Maximum Concentration (µg/m³)[(a)]	RFD Case Maximum Concentration (µg/m³)[(a)]	Change Between Base Case and RFD Case (µg/m³)	Percent Change Between Base Case and RFD Case as Percentage of Criteria (%)
PM_{10}	24-hour	50 (SAAQS)[(d)]	14.4	65.4 (86.6)	65.6 (86.6)	51.2	102.4
TSP	24-hour	100 (SAAQS)[(d)]	14.4	109.2 (173.2)	109.8 (173.2)	95.4	95.4
	Annual	60 (SAAQS)[(e)]	6.2	11.2	11.3	5.1	8.6

a) All predicted concentrations exclude receptor locations inside the Project footprint where the SAAQS and the CAAQS do not apply.
b) Predicted concentration comparison with the one-hour SAAQS and AAAQO is based on the annual ninth highest one-hour model prediction at each receptor location per the SAQMG (ENV 2012b). The first highest model prediction was presented in parentheses.
c) Predicted concentration comparison with the one-hour CAAQS is based on the three-year average of the annual 98th percentile of the daily maximum one-hour average concentrations at each receptor location. Comparison to the CAAQS is intended for information purposes only and is not indicative of a non-compliance because the CAAQs metrics are properly evaluated against community monitoring data, not modelled projections.
d) Predicted concentration comparison with the 24-hour SAAQS and AAAQO are based on the annual second highest 24-hour model prediction at each receptor per the SAQMG (ENV 2012). The first highest model prediction was presented in parentheses.
e) Predicted concentration comparison with the annual SAAQS and CAAQS is based on the average of all one-hour model predictions in a single calendar year and does not exclude any one-hour model predictions.
f) Predicted one-hour concentrations are based on the annual ninth highest one-hour model prediction at each receptor location per the SAQMG (ENV 2012b). Predicted 24-hour concentrations are based on the annual second highest 24-hour model prediction at each receptor location per the SAQMG (ENV 2012b). The first highest one-hour and 24-hour model predictions are presented in parentheses. Predicted annual concentrations are based on the average of all one-hour model predictions in a single calendar year and does not exclude any one-hour model predictions.
g) Predicted concentration comparison with the one-hour CAAQS is based on the three-year average of the annual 99th percentile of the daily maximum one-hour average concentrations at each receptor location.
h) Predicted concentration comparison with the eight-hour SAAQS is based on the annual fifth highest eight-hour model prediction at each receptor per the SAQMG (ENV 2012). The first highest model prediction is presented in parentheses.
i) Predicted concentration comparison with the 24-hour SAAQS and CAAQS is based on the three-year average of the annual 98th percentile of the daily 24-hour average concentrations at each receptor location.
j) Predicted concentration comparison with the annual CAAQS is based on the three-year average of the annual average of the daily 24-hour average concentrations at each receptor location.
AAAQO = Alberta Ambient Air Quality Objective; CAAQS = Canadian Ambient Air Quality Standards; SAAQS = Saskatchewan Ambient Air Quality Standards; RFD = reasonably foreseeable development; TSP = total suspended particulates; SAQMG = Saskatchewan Air Quality Model Guideline; $PM_{2.5}$ = particulate matter with a nominal diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal diameter of 10 µm or less.

The RFD Case maximum concentrations in the RSA are also graphically shown in the right panel of Figure 7.2-5 through Figure 7.2-21 and summarized in the subsections below. A description of what is presented in the figures is provided in Section 7.2.5.1.1.2.

Nitrogen Dioxide Concentration Predictions

- All predicted maximum nitrogen dioxide concentrations for the RFD Case are in compliance with the SAAQS.
- The area within which nitrogen dioxide concentrations predicted due to the cumulative emissions from the Project and the Fission Patterson Lake South Property that result in concentrations above 10% of the SAAQS is confined to the RSA (i.e., regional geographic extent), as shown in Figure 7.2-5 through Figure 7.2-8.
- The direction of change related to nitrogen dioxide predictions is negative. The magnitude of the change is moderate.
- The period of maximum concentrations is the assumed overlapping period of Project Operations and the operating period of the Fission Patterson Lake South Property (i.e., seven years). However, the overall duration of effects on air quality may be greater when taking into account construction and active decommissioning of both projects (i.e., maximum of 15 years [Section 7.2.2.5], depending on amount of temporal overlap between projects).
- The effects for nitrogen dioxide are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from nitrogen dioxide would be continuous and probable.

Sulphur Dioxide Concentration Predictions

- All predicted maximum sulphur dioxide concentrations for the RFD Case are in compliance with the SAAQS and are below the CAAQS levels.
- The area within which sulphur dioxide concentrations predicted due to the Project cumulative emissions from the Project and the Fission Patterson Lake South Property that result in concentrations above 10% of the SAAQS is confined to the maximum disturbance area for each project, as shown in Figure 7.2-9 through Figure 7.2-12.
- The direction of change related to sulphur dioxide predictions is negative. The magnitude of the change is low.
- The period of maximum concentrations is the assumed overlapping period of Project Operations and the operating period of the Fission Patterson Lake South Property (i.e., seven years). However, the overall duration of effects on air quality may be greater when taking into account construction and active decommissioning of both projects (i.e., maximum of 15 years [Section 7.2.2.5], depending on amount of temporal overlap between projects).
- The effects for sulphur dioxide are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from sulphur dioxide would be continuous and probable.

Sulphuric Acid Concentration Predictions

- All predicted maximum concentrations for the RFD Case are below the AAAQO.
- The area within which sulphuric acid concentrations predicted due to the Project cumulative emissions from the Project and the Fission Patterson Lake South Property that result in concentrations above 10% of the AAAQO is confined to the LSA (i.e., local geographic extent), as shown in Figure 7.2-13 and Figure 7.2-14.
- The direction of change related to sulphuric acid predictions is negative. The magnitude of the change is low.
- The period of maximum concentrations is the assumed overlapping period of Project Operations and the operating period of the Fission Patterson Lake South Property (i.e., seven years). However, the overall duration of effects on air quality may be greater when taking into account construction and active decommissioning of both projects (i.e., maximum of 15 years [Section 7.2.2.5], depending on amount of temporal overlap between projects).
- The effects for sulphuric acid are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from sulphuric acid would be continuous and probable.

Carbon Monoxide Concentration Predictions

- All predicted maximum carbon monoxide concentrations for the RFD Case are in compliance with the SAAQS.
- The area within which carbon monoxide concentrations predicted due to the Project cumulative emissions from the Project and the Fission Patterson Lake South Property that result in concentrations above 10% of the SAAQS is confined to the maximum disturbance area for each project, as shown in Figure 7.2-15 and Figure 7.2-16.
- The direction of change related to carbon monoxide predictions is negative. The magnitude of the change is low. The period of maximum concentrations is the assumed overlapping period of Project Operations and the operating period of the Fission Patterson Lake South Property (i.e., seven years). However, the overall duration of effects on air quality may be greater when taking into account construction and active decommissioning of both projects (i.e., maximum of 15 years [Section 7.2.2.5], depending on amount of temporal overlap between projects).
- The effects for carbon monoxide are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from carbon monoxide would be continuous and probable.

$PM_{2.5}$ Concentration Predictions

- All predicted maximum $PM_{2.5}$ concentrations for the RFD Case are in compliance with the SAAQS and are below the CAAQS levels.
- The area within which $PM_{2.5}$ concentrations predicted due to the Project cumulative emissions from the Project and the Fission Patterson Lake South Property that result in concentrations above 10% of the SAAQS is confined to the LSA (i.e., local geographic extent), as shown in Figure 7.2-17 and Figure 7.2-18.
- The direction of change related to $PM_{2.5}$ predictions is negative. The magnitude of the change is moderate.

- The period of maximum concentrations is the overlapping period of Project Operations and the operating period of the Fission Patterson Lake South Property (i.e., six years [2028 to 2033]). However, the overall duration of effects on air quality may be greater when taking into account construction and active decommissioning of both projects (i.e., maximum of 15 years [Section 7.2.2.5], depending on amount of temporal overlap between projects).
- The effects for $PM_{2.5}$ are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from $PM_{2.5}$ would be continuous and probable.

PM_{10} Concentrations Predictions

- In the RFD Case, maximum PM_{10} concentrations are higher than the SAAQS. The maximum exceedance frequency is 1.1% (four days per year). The maximum exceedance area outside of the maximum disturbance area, where PM_{10} concentrations are higher than SAAQS, is 9.5 ha. The maximum exceedance area outside of the Project maximum disturbance area, where PM_{10} concentrations are higher than SAAQS, is 9.5 ha. The maximum distance from the exceedance area to the Project maximum disturbance boundary is 202 m.
- The area within which PM_{10} concentrations predicted due to the Project cumulative emissions from the Project and the Fission Patterson Lake South Property that result in concentrations above 10% of the SAAQS is confined to the LSA (i.e., local geographic extent), as shown in Figure 7.2-19.
- The direction of change related to PM_{10} predictions is negative. The magnitude of the change is high, as the RFD Case 24-hour PM_{10} prediction exceeds the SAAQS.
- The period of maximum concentrations is the overlapping period of Project Operations and the operating period of the Fission Patterson Lake South Property (i.e., seven years). However, the overall duration of effects on air quality may be greater when considering construction and active decommissioning of both projects (i.e., maximum of 15 years [Section 7.2.2.5] depending on amount of temporal overlap between projects).
- The effects for PM_{10} are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from PM_{10} would be continuous and probable.

TSP Concentration Predictions

- Maximum annual TSP concentrations for the RFD Case are in compliance with the SAAQS.
- Maximum 24-hour TSP concentrations are higher than the SAAQS. The maximum exceedance frequency is 0.8% (three days per year). The maximum exceedance area outside of the Project maximum disturbance area, where 24-hour TSP concentrations are higher than SAAQS, is 0.3 ha. The maximum distance from the exceedance area to the Project maximum disturbance area is 31 m.
- The area within which TSP concentrations predicted due to the Project cumulative emissions from the Project and the Fission Patterson Lake South Property that result in concentrations above 10% of the SAAQS is confined to the LSA (i.e., local geographic extent), as shown in Figure 7.2-20 and Figure 7.2-21.
- The direction of change related to TSP predictions is negative. The magnitude of the change is high, as the RFD Case 24-hour maximum TSP prediction exceeds the SAAQS.

- The period of maximum concentrations is the overlapping period of Project Operations and the operating period of the Fission Patterson Lake South Property (i.e., seven years). However, the overall duration of effects on air quality may be greater when taking into account construction and active decommissioning of both projects (i.e., maximum of 15 years [Section 7.2.2.5], depending on amount of temporal overlap between projects).
- The effects for TSP are reversible. The maximum effects predicted by the dispersion modelling would be rare, but some level of effect on air quality from TSP would be continuous and probable.

7.2.5.3 Updated Emission Inventory and Supplementary Modelling Results

As discussed in Section 7.2.2.8.3.1, Supplementary Modelling with Updated Emission Inventory, new engineering design information was made available that would cause modifications to the modelled emissions, including:

- Power plant gensets (i.e., generator and engine) hourly natural gas fuel consumption reduced from 811 to 776 L/h.
- The modelled annual natural gas fuel consumption of the power plant in second year of Construction increased from 355,496 to 384,856 gigajoules (GJ).
- The maximum annual natural gas fuel consumption of the power plant increased from 586,086 to 999,400 GJ during Operations.
- The maximum calciner natural gas fuel consumption decreased from 83,957 to 63,096 GJ during Operations.
- The blasting plan and associated information, including blasting days, average blasts per day, and explosive usage per blast, were updated.

These updates resulted in changes to the Project's total CAC emissions as summarized in Table 7.2-15. The overall maximum model predictions from the current modelling and the supplemental modelling are summarized in Table 7.2-16. The change in maximum overall predictions for all CACs and all averaging periods was less than 0.5% during Construction. The change in maximum overall predictions for all CACs and all averaging periods was less than 0.6% during Operations, except for annual nitrogen dioxide and annual sulphur dioxide. However, the annual overall maximum predictions of nitrogen dioxide and sulphur dioxide from the supplemental modelling were still substantially lower than their respective applicable ambient air quality criteria.

Due to the small changes in maximum overall predictions for CACs, it was concluded that the new information had a negligible effect on the air quality modelling results and would not change the conclusions of the assessment for air quality or any other discipline that relied on the results. As a result, the air quality predictions in the air quality residual effects analysis and the residual effects analysis of other VCs and intermediate components were not updated based on the new design information.

Table 7.2-15: Changes in Rook I Project Total Emissions with Updated Engineering Design Information from the Values Used in the Current Assessment

CACs	Nitrogen Oxides			Sulphur Dioxide			Carbon Monoxide		$PM_{2.5}$		PM_{10}	TSP	
Averaging Period	1 h	24 h	Annual	1 h	24 h	Annual	1 h	8 h	24 h	Annual	24 h	24 h	Annual
Construction	0.0%	2.1%	-0.8%	0.0%	17.2%	-0.6%	-0.5%	-0.5%	0.0%	0.0%	0.3%	0.2%	0.2%
Operations	0.3%	5.5%	58.6%	0.0%	11.0%	6.1%	-1.8%	-1.8%	-1.7%	12.7%	-0.2%	0.0%	0.9%

CAC = criteria air contaminant; TSP = total suspended particulates; $PM_{2.5}$ = particulate matter with a nominal diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal diameter of 10 µm or less.

Table 7.2-16: Summary of Overall Maximum Model Predictions for the Application Case

Project Phase	Model Results	Nitrogen Oxides			Sulphur Dioxide			Carbon Monoxide		$PM_{2.5}$		PM_{10}	TSP	
		1 h	24 h	Annual	1 h	24 h	Annual	1 h	8 h	24 h	Annual	24 h	24 h	Annual
Construction	Current (µg/m^3)	276.9	79.9	9.7	4.5	0.7	0.0	1,654.7	831.4	185.3	13.2	147.0	16.6	4.1
	Re-modelled (µg/m^3)	276.9	79.9	9.7	4.5	0.7	0.0	1,654.7	831.4	185.3	13.2	147.3	16.7	4.1
	Change	0.00%	0.00%	-0.16%	0.00%	0.00%	-0.12%	0.00%	0.00%	0.02%	0.11%	0.21%	0.06%	0.06%
Operations	Current (µg/m^3)	167.0	61.9	6.7	9.4	1.8	0.1	1,255.9	792.5	109.2	11.2	65.4	10.5	3.7
	Re-modelled (µg/m^3)	167.0	61.9	7.9	9.4	1.8	0.1	1,256.5	791.8	109.2	11.3	65.4	10.5	3.7
	Change	0.00%	0.05%	18.74%	-0.01%	-0.01%	3.67%	0.05%	-0.09%	0.00%	0.12%	-0.01%	-0.02%	0.59%
Applicable ambient air quality criteria (µg/m^3)		300	200	45	450	125	20	15,000	6,000	100	60	50	28	10

TSP = total suspended particulates; $PM_{2.5}$ = particulate matter with a nominal diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal diameter of 10 µm or less.

7.2.6 Residual Effects Classification

Residual effects on air quality from changes in CACs during Project Construction, Operations, and Closure (Application Case) and the RFD Case are summarized in Table 7.2-17, providing information on direction, magnitude, geographic extent, duration/reversibility, frequency, and probability of occurrence following the methods described in Section 7.2.2.8. Effective implementation of mitigation outlined in Section 7.2.4 is expected to reduce the magnitude and duration of residual effects on air quality. The residual effects classification takes a conservative approach in addition to the conservative air quality modelling results as discussed in Section 7.2.7, Prediction Confidence and Uncertainty. The conservatism of the approach includes the following:

- The residual effects classification for air quality measurement indicators was determined from the highest level of effects among the different averaging periods (e.g., one-hour, 24-hour, annual) when applicable.
- Magnitude is applied to the maximum predictions outside of the Project maximum disturbance area while at any other locations, predictions are expected to result in a smaller change.
- The geographic extent determination is based on moderate magnitude changes instead of the highest magnitude. This results in a larger geographic extent determination.
- Duration considers the lifespan of the Project, even though the exceedances or high magnitude of changes occur for short term and at low frequency within the worst-case year.

Table 7.2-17: Classification of Residual Effects on Air Quality Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case

Measurement Indicator (CAC)	Criterion	Rating / Effect Size			
		Application Case – Construction	Application Case – Operations	Application Case – Closure	RFD Case
Nitrogen dioxide	Direction	▪ Negative	▪ Negative	▪ Negative	▪ Negative
	Magnitude	▪ For the 1-hour averaging period, the change in maximum nitrogen dioxide concentration is 88.5% of the SAAQS and the Application Case Construction prediction is in compliance with the SAAQS (i.e., moderate magnitude)	▪ For the 1-hour averaging period, the change in maximum nitrogen dioxide concentration is 51.9% of the SAAQS and the Application Case Operations prediction is in compliance with the SAAQS (i.e., moderate magnitude)	▪ Expected to be similar to or less than Construction (i.e., moderate magnitude)[a]	▪ For the 1-hour averaging period, the change in maximum nitrogen dioxide concentration is 51.9% of the SAAQS and the RFD Case prediction is in compliance with the SAAQS (i.e., moderate magnitude)
	Geographic extent	▪ Regional	▪ Regional	▪ Regional	▪ Regional
	Duration	▪ 4 years during Construction	▪ 24 years during Operations	▪ 5 years during Active Closure Stage	▪ 7 years for maximum concentrations during overlapping period of Project Operations and operating phase of Fission Patterson Lake South Property[b]
	Reversibility	▪ Reversible	▪ Reversible	▪ Reversible	▪ Reversible
	Frequency	▪ Continuous	▪ Continuous	▪ Continuous	▪ Continuous
	Probability of occurrence	▪ Probable	▪ Probable	▪ Probable	▪ Probable

Table 7.2-17: Classification of Residual Effects on Air Quality Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case

Measurement Indicator (CAC)	Criterion	Rating / Effect Size			
		Application Case – Construction	Application Case – Operations	Application Case – Closure	RFD Case
Sulphur dioxide	Direction	▪ Negative	▪ Negative	▪ Negative	▪ Negative
	Magnitude	▪ For the 1-hour averaging period, the change in maximum sulphur dioxide concentration is 1.0% of the SAAQS and the Application Case Construction prediction is in compliance with SAAQS (i.e., low magnitude)	▪ For the 1-hour averaging period, the change in maximum sulphur dioxide concentration is 2.1% of the SAAQS and the Application Case Operations prediction is in compliance with SAAQS (i.e., low magnitude)	▪ Expected to be similar to or less than Construction (i.e., low magnitude)[(a)]	▪ For the 1-hour averaging period, the change in maximum sulphur dioxide concentration is 2.1% of the SAAQS and the RFD Case prediction is in compliance with SAAQS (i.e., low magnitude)
	Geographic extent	▪ Project maximum disturbance area	▪ Project maximum disturbance area	▪ Project maximum disturbance area	▪ Maximum disturbance area for each project
	Duration	▪ 4 years during Construction	▪ 24 years during Operations	▪ 5 years during Active Closure Stage	▪ 7 years for maximum concentrations during overlapping period of Project Operations and operating phase of Fission Patterson Lake South Property[(b)]
	Reversibility	▪ Reversible	▪ Reversible	▪ Reversible	▪ Reversible
	Frequency	▪ Continuous	▪ Continuous	▪ Continuous	▪ Continuous
	Probability of occurrence	▪ Probable	▪ Probable	▪ Probable	▪ Probable

Table 7.2-17: Classification of Residual Effects on Air Quality Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case

Measurement Indicator (CAC)	Criterion	Rating / Effect Size			
		Application Case – Construction	Application Case – Operations	Application Case – Closure	RFD Case
Sulphuric acid	Direction	▪ n/a	▪ Negative	▪ n/a	▪ Negative
	Magnitude	▪ n/a	▪ For the 1-hour averaging period, the change in maximum sulphuric acid concentration is 12.1% of the AAAQO and the Application Case Operations prediction is below AAAQO (i.e., low magnitude)	▪ n/a	▪ For the 1-hour averaging period, the change in maximum sulphuric acid concentration is 15.9% of the AAAQO and the RFD Case prediction is below AAAQO (i.e., low magnitude)
	Geographic extent	▪ n/a	▪ Local	▪ n/a	▪ Local
	Duration	▪ n/a	▪ 24 years during Operations	▪ n/a	▪ 7 years for maximum concentrations during overlapping period of Project Operations and operating phase of Fission Patterson Lake South Property[(b)]
	Reversibility	▪ n/a	▪ Reversible	▪ n/a	▪ Reversible
	Frequency	▪ n/a	▪ Continuous	▪ n/a	▪ Continuous
	Probability of occurrence	▪ n/a	▪ Probable	▪ n/a	▪ Probable

Table 7.2-17: Classification of Residual Effects on Air Quality Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case

Measurement Indicator (CAC)	Criterion	Rating / Effect Size			
		Application Case – Construction	Application Case – Operations	Application Case – Closure	RFD Case
Carbon monoxide	Direction	▪ Negative	▪ Negative	▪ Negative	▪ Negative
	Magnitude	▪ For the 1-hour averaging period, the change in maximum carbon monoxide concentration is 7.2% of the SAAQS and the Application Case Construction prediction is in compliance with SAAQS (i.e., low magnitude)	▪ For the 1-hour averaging period, the change in maximum carbon monoxide concentration is 4.6% of the SAAQS and the Application Case Operations prediction is in compliance with SAAQS (i.e., low magnitude)	▪ Expected to be similar to or less than Construction (i.e., low magnitude)[a]	▪ For the 1-hour averaging period, the change in maximum carbon monoxide concentration is 4.6% of the SAAQS and the RFD Case prediction is in compliance with SAAQS (i.e., low magnitude)
	Geographic extent	▪ Project maximum disturbance area	▪ Project maximum disturbance area	▪ Project maximum disturbance area	▪ Maximum disturbance area for each project
	Duration	▪ 4 years during Construction	▪ 24 years during Operations	▪ 5 years during Active Closure Stage	▪ 7 years for maximum concentrations during overlapping period of Project Operations and operating phase of Fission Patterson Lake South Property[b]
	Reversibility	▪ Reversible	▪ Reversible	▪ Reversible	▪ Reversible
	Frequency	▪ Continuous	▪ Continuous	▪ Continuous	▪ Continuous
	Probability of occurrence	▪ Probable	▪ Probable	▪ Probable	▪ Probable

Table 7.2-17: Classification of Residual Effects on Air Quality Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case

Measurement Indicator (CAC)	Criterion	Rating / Effect Size			
		Application Case – Construction	Application Case – Operations	Application Case – Closure	RFD Case
$PM_{2.5}$	Direction	▪ Negative	▪ Negative	▪ Negative	▪ Negative
	Magnitude	▪ For the 24-hour averaging period, the change in maximum $PM_{2.5}$ concentration is 36.2% of the SAAQS and the Application Case Construction prediction is in compliance with SAAQS (i.e., moderate magnitude)	▪ For the 24-hour averaging period, the change in maximum $PM_{2.5}$ concentration is 14.4% of the SAAQS and the Application Case Operations prediction is in compliance with SAAQS (i.e., moderate magnitude)	▪ Expected to be similar to or less than Construction (i.e., moderate magnitude)[a]	▪ For the 24-hour averaging period, the change in maximum $PM_{2.5}$ concentration is 14.6% of the SAAQS and the RFD Case prediction is in compliance with SAAQS (i.e., moderate magnitude)
	Geographic extent	▪ Local	▪ Local	▪ Local	▪ Local
	Duration	▪ 4 years during Construction	▪ 24 years during Operations	▪ 5 years during Active Closure Stage	▪ 7 years for maximum concentrations during overlapping period of Project Operations and operating phase of Fission Patterson Lake South Property[b]
	Reversibility	▪ Reversible	▪ Reversible	▪ Reversible	▪ Reversible
	Frequency	▪ Continuous	▪ Continuous	▪ Continuous	▪ Continuous
	Probability of occurrence	▪ Probable	▪ Probable	▪ Probable	▪ Probable

Table 7.2-17: Classification of Residual Effects on Air Quality Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case

Measurement Indicator (CAC)	Criterion	Rating / Effect Size			
		Application Case – Construction	Application Case – Operations	Application Case – Closure	RFD Case
PM_{10}	Direction	▪ Negative	▪ Negative	▪ Negative	▪ Negative
	Magnitude	▪ The Application Case Construction 24-hour PM_{10} prediction exceeds the SAAQS (i.e., high magnitude)	▪ The Application Case Operations 24-hour PM_{10} prediction exceeds the SAAQS (i.e., high magnitude)	▪ Expected to be similar to or less than Construction (i.e., high magnitude)[a]	▪ The RFD Case 24-hour PM_{10} prediction exceeds the SAAQS (i.e., high magnitude)
	Geographic extent	▪ Local	▪ Local	▪ Local	▪ Local
	Duration	▪ 4 years during Construction	▪ 24 years during Operations	▪ 5 years during Active Closure Stage	▪ 7 years for maximum concentrations during overlapping period of Project Operations and operating phase of Fission Patterson Lake South Property[b]
	Reversibility	▪ Reversible	▪ Reversible	▪ Reversible	▪ Reversible
	Frequency	▪ Continuous	▪ Continuous	▪ Continuous	▪ Continuous
	Probability of occurrence	▪ Probable	▪ Probable	▪ Probable	▪ Probable

Table 7.2-17: Classification of Residual Effects on Air Quality Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case

Measurement Indicator (CAC)	Criterion	Rating / Effect Size			
		Application Case – Construction	Application Case – Operations	Application Case – Closure	RFD Case
TSP	Direction	▪ Negative	▪ Negative	▪ Negative	▪ Negative
	Magnitude	▪ The Application Case Construction 24-hour maximum TSP prediction exceeds the SAAQS (i.e., high magnitude)	▪ The Application Case Operations 24-hour maximum TSP prediction exceeds the SAAQS (i.e., high magnitude)	▪ Expected to be similar to or less than Construction (i.e., high magnitude)(a)	▪ The RFD Case 24-hour maximum TSP prediction exceeds the SAAQS (i.e., high magnitude)
	Geographic extent	▪ Local	▪ Local	▪ Local	▪ Local
	Duration	▪ 4 years during Construction	▪ 24 years during Operations	▪ 5 years during Active Closure Stage	▪ 7 years for maximum concentrations during overlapping period of Project Operations and operating phase of Fission Patterson Lake South Property(b)
	Reversibility	▪ Reversible	▪ Reversible	▪ Reversible	▪ Reversible
	Frequency	▪ Continuous	▪ Continuous	▪ Continuous	▪ Continuous
	Probability of occurrence	▪ Probable	▪ Probable	▪ Probable	▪ Probable

a) Dispersion modelling results from Project Construction were used as a conservative surrogate when assessing Project Closure (Section 7.2.5.1.2, Application Case during Closure).
b) Seven years is the period of predicted maximum concentrations during the overlapping operational periods for Project Operations and Fission Patterson Lake South Property. However, the overall duration of effects on air quality may be greater when taking into account construction and active decommissioning of both projects (i.e., maximum duration of 15 years depending on amount of temporal overlap between projects).
n/a = not applicable; AAAQO = Alberta Ambient Air Quality Objective; SAAQS = Saskatchewan Ambient Air Quality Standards; CAC = criteria air contaminant; RFD = reasonably foreseeable development; TSP = total suspended particulates; $PM_{2.5}$ = particulate matter with a nominal aerodynamic diameter of 2.5 µm or less; PM_{10} = particulate matter with a nominal aerodynamic diameter of 10 µm or less.

7.2.7 Prediction Confidence and Uncertainty

The AERMOD model is the refined model approved by the Government of Saskatchewan to conduct air quality modelling exercises in Saskatchewan. The AERMOD modelling process has followed the SAQMG to the extent practicable. Any deviations from the SAQMG have been the subject of consultation with and approval by the ENV. The main sources of uncertainty associated with the air quality predictions for CACs are as follows:

- Project design (e.g., actual fuel consumption versus proposed fuel consumption) and Project activity levels (e.g., actual operating hours of heavy equipment versus proposed operating hours) associated with the emissions;
- variability in local-scale meteorology (e.g., local wind fields and precipitation versus modelled wind fields and precipitation); and
- emission source representation (e.g., assuming all underground PM is emitted from the mine vents) in the air dispersion modelling.

These uncertainties are addressed through conservatism in the emissions inventory and air dispersion model. Conservative assumptions were used to create the emissions inventory as inputs to the air dispersion model (Appendix 7A). Key areas of conservatism included the following:

- The emissions inventory was created for the highest intensity year of Construction and Operations. Emissions in other years would have lower emissions rates for CACs.
- When applicable, conservative assumptions and approaches were used to estimate the emissions from the Project. Examples include the following:
  - The power plant was assumed to be operating at 90% load hourly and 70% load daily continuously throughout the year. The actual operating loads are expected to be lower than these rates most of the time.
  - As underground sources do not occur at the mine vent, but emit via the mine vent, the assumption that emission rates at the source are equal to emission rates at the mine vent is conservative, particularly for heavier PM that would partially settle out along lateral development and ramps before being entrained in the high velocity vertical air shaft.
  - All mobile equipment was assumed to operate simultaneously, while in reality, it is not expected that all mobile equipment would be operating at same time.
  - For most of the emission sources, the emission inventory used emission factors (e.g., USEPA AP-42 emission factors) that were developed decades ago. With the new regulations and technologies, it is expected that the application of these emission factors is conservative.

To account for the variability of meteorological parameters (e.g., local wind speed and direction), a five-year meteorological dataset was used in the modelling. The five-year meteorological dataset would represent most plausible meteorological conditions, and a wide range of combinations of wind, temperature, and atmospheric stability. Thus, the maximum predictions would represent the concentrations under the worst-case meteorological conditions. The air dispersion model is inherently conservative when configured to predict maximum concentrations as completed for this assessment. When combined with the additional conservatism assumed for emissions of PM, there is a high degree of confidence that observed concentrations of CACs would not exceed the predicted values.

Overall, there is a moderate to high degree of confidence in the predictions related to the assessment of air quality.

7.2.8 Monitoring, Follow-Up, and Adaptive Management

Monitoring and follow-up programs would be used to:

- Verify the predictions through monitoring of air quality during Construction, Operations, and Closure. The current baseline monitoring program that monitors meteorological parameters, nitrogen dioxide, sulphur dioxide, TSP, and $PM_{2.5}$ would be continued, likely with some modification through the licensing and provincial permitting processes, through all phases of the Project.
- Evaluate the effectiveness of mitigation actions and modify or enhance as necessary through monitoring and developing updated mitigation measures, if needed.
- Identify unanticipated negative effects, including possible accidents and malfunctions.

NexGen would implement the Environmental Protection Program, which describes the processes required to monitor and characterize emissions from Project facilities and activities, to monitor and characterize the quality of the environment to assess the effectiveness of mitigations, and to continually improve environmental protection performance throughout all Project phases. The Effluent and Emissions Plan and Environmental Monitoring Plan would be components of the Environmental Protection Program.

Where relevant, adaptive management measures may also be proposed to address the uncertainties associated with the effects predictions and mitigation. The process for determining when, how, and where adaptive management would be used would be described within the Integrated Management System Manual.

In addition, Environmental Committees (i.e., one per primary Indigenous Group) composed of two NexGen and two Indigenous Group representatives would be established to act in an oversight manner to monitor the environmental performance of the Project and verify the parties are implementing the regulatory and environmental commitments made in respect of the Project.

Indigenous Groups have made recommendations related to mitigating the effects of the Project on the environment, including community-led long-term environmental testing and monitoring during Construction and Operations of the Project (TSD IV: MN-S; TSD V.2: CRDN; YNLRO 2019). NexGen has committed to provide funding for the lifespan of the Project for a full-time independent Indigenous Monitor chosen by each primary Indigenous Group; this Indigenous Monitor would have access to conduct environmental sampling for the Project, subject to the Indigenous Monitor complying with appropriate health and safety and other reasonable site-specific policies. The Indigenous Monitor would be able to report openly and without restriction to the Environmental Committee and Indigenous Group's community members on the performance of the Project. The Indigenous Monitor would also provide regular reports to the Environmental Committee who, in turn, would report to the Implementation Committee and provide regular reports to the Environmental Committee.

7.2.9 Key Findings

Potential effects from the Project on air quality were assessed within the RSA by modelling Project emissions and dispersion of CACs and investigating the predicted ambient air concentrations. Criteria air contaminant concentrations were predicted using standardized and accepted models and approaches in accordance with the applicable provincial guideline (ENV 2012b). Air quality effects were assessed using thresholds derived from the applicable ambient air quality criteria and the existing conditions. Air concentrations were calculated, and effects were assessed for the Project (i.e., Application Case) and for the Project in combination with the Fission Patterson Lake South Property (i.e., RFD Case).

Air quality from the Project and from the Fission Patterson Lake South Property is predicted to reflect detectable changes from existing conditions. However, most of the CACs (i.e., nitrogen dioxide, sulphur dioxide, sulphuric acid, carbon monoxide, and $PM_{2.5}$) are predicted to remain compliant with the SAAQS throughout all phases of the Project within the RSA.

Short-term concentrations of 24-hour PM_{10} and 24-hour TSP are predicted to be above the SAAQS but the exceedance frequencies remain low, and the exceedance areas are localized to the Project. For example, the maximum frequency of exceedance of 24-hour PM_{10} is 2.7% (10 days per year) and occurs during Construction. Maximum exceedance areas outside of the maximum disturbance area, where PM_{10} concentrations are higher than the SAAQS, are 279.1 ha during Construction. The maximum distances from the exceedance area to the maximum disturbance area is 1,185 m for Construction. The air dispersion model is conservative when configured to predict maximum concentrations as completed for this assessment. When combined with the additional conservatism assumed for emissions of PM, there is a high degree of confidence that observed concentrations of CACs would not exceed the predicted values. An appropriate monitoring program for compounds anticipated to exceed their relative criteria would be developed during the licencing phase of the Project, should the Project be approved.

Changes in air quality could influence biophysical VCs and intermediate components and socio-economic VCs. The air quality assessment therefore provides information that is used to support the ERA and the assessments of the following biophysical, cultural, and socio-economic intermediate components and VCs:

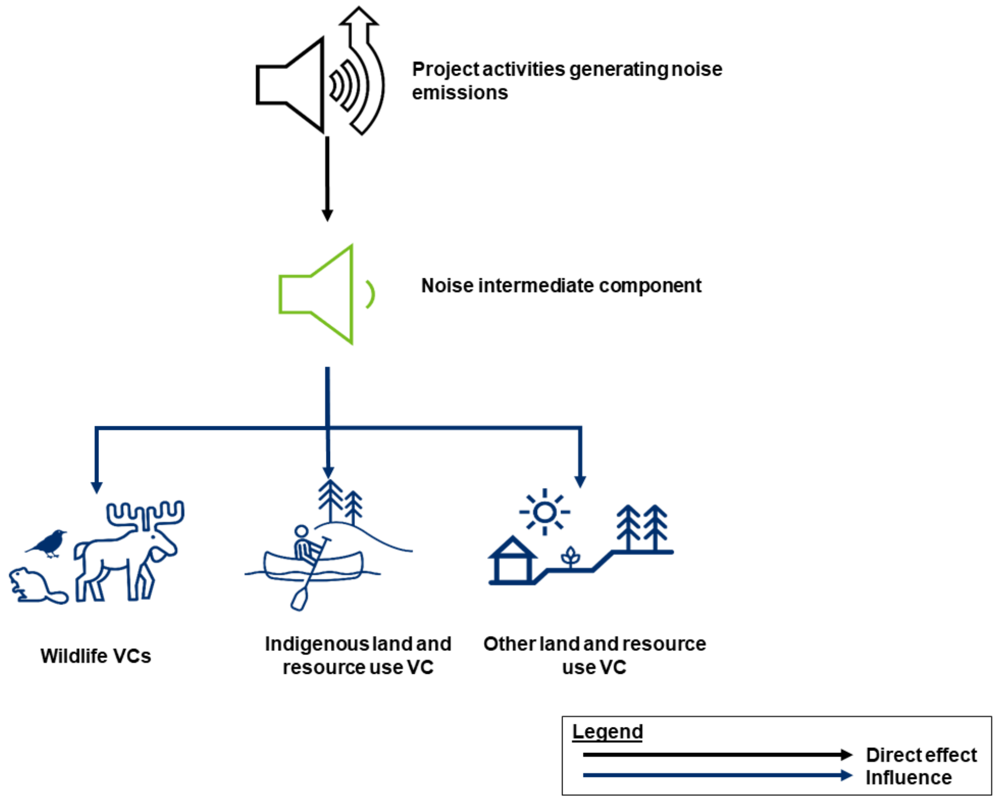
- surface water quality and sediment quality (Section 10);
- fish and fish habitat (Section 11);
- terrain and soils (Section 12);
- vegetation (Section 13);
- wildlife and wildlife habitat (Section 14);
- human health (Section 15);
- Indigenous land and resource use (Section 16); and
- other land and resource use (Section 17).

7.3 Noise

7.3.1 Introduction

Section 7.3, Noise, of the Environmental Impact Statement (EIS) characterizes the potential residual effects of the Rook I Project (Project) on noise, which is an attribute of the atmospheric environment. Noise represents an intermediate component for the Environmental Assessment (EA). Relative to background levels, increased noise emissions from the Project could influence wildlife and wildlife habitat (Section 14, Wildlife and Wildlife Habitat), Indigenous land and resource use (Section 16, Cultural and Heritage Resources and Indigenous Land and Resource Use), and other land and resource use (Section 17, Other Land and Resource Use). The noise assessment therefore provides information that is used to support the assessments of wildlife and land and resource use valued components (VCs). A simplified linkage diagram, Figure 7.3-1, illustrates how increased noise emissions from proposed Project activities could influence VCs through changes to background noise levels.

Figure 7.3-1: Linkage Diagram of Project Effects on Noise and Influenced Valued Components



VC = valued component.

7.3.1.1 *Purpose and Approach to the Assessment*

The purpose of Section 7.3 is to provide a detailed and comprehensive assessment of all potential Project-specific effects and cumulative effects from the Project and other previous, existing, and reasonably foreseeable developments (RFDs), if applicable, on noise. This subsection meets the Terms of Reference for the Project submitted to the Saskatchewan Ministry of Environment (ENV) and the Canadian Nuclear Safety Commission (CNSC) *Generic Guidelines for the Preparation of an Environmental Impact Statement – Pursuant to the Canadian Environmental Assessment Act, 2012* (Appendix 1A, Concordance Tables). The assessment of noise followed the overall EA approach and methods (Section 6) and includes the following primary steps:

Step 1 – Define component-specific methods (Section 7.3.2): presents the specific approaches and methods used to measure and assess the effects of the Project on noise as well as cumulative effects from the Project, other previous and existing projects and activities, and RFDs, if applicable.

Step 2 – Characterize existing conditions (Section 7.3.3): describes and characterizes existing conditions to provide both context and a basis for evaluating potential changes to noise caused by the Project.

Step 3 – Evaluate Project interactions and mitigations (Section 7.3.4): identifies Project components and/or activities with the potential to affect noise and provides environmental design features and mitigation policies and actions committed to by NexGen to avoid or minimize potential adverse effects. A pathways analysis was used to focus further assessment on key interactions between the Project and noise by evaluating the different effects pathways to determine if, after incorporation of mitigation, there is still potential to cause residual adverse effects. Primary pathways anticipated to result in residual adverse effects after incorporation of mitigation are carried forward to Step 4 for further analysis. Where potential adverse effects are adequately mitigated and thus not forwarded for further analysis (i.e., where mitigation results in negligible effects or avoids the pathway altogether), the reasons for concluding the assessment at this stage are provided.

Step 4 – Analyze residual effects (Section 7.3.5): evaluates and describes the potential Project effects on noise that are anticipated to occur through the primary pathways. The residual effects analysis is presented as an integrated narrative that describes the effects of the Project over time and highlights predicted effects at the point when adverse effects of the Project are expected to be greatest. This step also includes an analysis of residual cumulative effects from the Project, other previous and existing projects and activities, and RFDs. Residual effects are classified and tabulated using the criteria direction, magnitude, geographic extent, duration, reversibility, and frequency to provide structure and comparability across all VCs and intermediate components in the EA.

Step 5 – Describe uncertainty and define prediction confidence (Section 7.3.7): identifies key uncertainties and explains how these uncertainties have been addressed to achieve a conservative, precautionary assessment. The implications of the approaches used to address uncertainties and the level of confidence in the residual effects analysis are discussed.

Step 6 – Identify monitoring and follow-up (Section 7.3.8): outlines the proposed actions to verify predicted residual effects. The purpose of these actions is to evaluate effectiveness of planned mitigation designs, policies, and practices, and address key sources of uncertainty.

7.3.2 Component Methods

7.3.2.1 Incorporation of Indigenous and Local Knowledge

Indigenous and Local Knowledge included in the assessment of noise was shared by potentially affected First Nations and Métis Groups (collectively referred to as Indigenous Groups) and local priority area (LPA)[3] community members through the Project engagement process. The overall approach and methods for the incorporation of Indigenous and Local Knowledge into the EA is discussed in detail in Section 3. Issues and concerns related to noise raised by Indigenous Groups and LPA community members, and how these comments were addressed, are summarized in Appendix 2B, Summary of Issues and Concerns Identified by Indigenous Groups, and identified and addressed in this assessment, where applicable.

A key source of Indigenous and Local Knowledge is the Project-specific studies completed by Indigenous Groups, including Traditional Land Use and Occupancy studies, Traditional Knowledge and Use studies, and Indigenous Rights and Knowledge studies (henceforth referred to collectively as Indigenous Knowledge and

[3] The LPA consists of the local communities closest to the Project that would experience most of the Project effects and for which NexGen would prioritize local training, employment, and business opportunities for the Project. These communities are located along, or accessed via, Highways 155 and 955 north of the intersection of Highways 155 and 925.

Traditional Land Use [IKTLU] Studies). The IKTLU Studies that were reviewed and referenced in the EIS as technical support documents (TSDs) are listed below:

- TSD II (BNDN), Birch Narrows Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD III (BRDN), Buffalo River Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD IV (MN-S), Métis Nation – Saskatchewan Northern Region 2 Traditional Land Use & Diet Study for the NexGen Rook I Project;
- TSD V.1 (CRDN), Preliminary Identification of Issues and Concerns Related to the Proposed NexGen Energy Ltd. Rook I Project in the Patterson Lake Area; A Review; Clearwater River Dene Nation; Traditional Land Use and Occupancy Mapping Interviews; 2010 – 2016;
- TSD V.2 (CRDN), Clearwater River Dene Nation Indigenous Rights and Knowledge Survey related to the proposed NexGen Energy Ltd. Rook 1 Project in the Patterson Lake Area;
- TSD V.3 (CRDN), Socio-economic and Harvest Study; Clearwater River Dene Nation; NexGen Rook 1 Project; and
- TSD VI (YNLR), Provision of Athabasca Denesųłiné Traditional Knowledge, Land Use and Occupancy Information for the NexGen Rook I Project Environmental Assessment.

Another key source of Indigenous and Local Knowledge was information shared by Indigenous Group representatives during Joint Working Group (JWG) meetings. The JWGs represent an agreed-upon primary engagement mechanism as outlined in the Study Agreements signed by each Indigenous Group and NexGen. More details regarding the JWGs can be found in Section 2 and Section 3. There are four JWGs with the Project's primary Indigenous Groups (Section 2.4.1, Identification of Indigenous Groups for Engagement):

- Clearwater River Dene Nation (CRDN) JWG;
- Métis Nation – Saskatchewan (MN-S) JWG representing MN-S Northern Region 2 (NR2);
- Birch Narrows Dene Nation (BNDN) JWG; and
- Buffalo River Dene Nation (BRDN) JWG.

The leadership of each Indigenous Group selected their JWG participants with consideration of group diversity; where possible, members included Elders, youth, different genders, a range of ages, and land users around Patterson Lake.

In addition to the IKTLU Studies and JWGs, Indigenous and Local Knowledge shared during specific engagement activities undertaken through the EA development process was incorporated into the assessment, where appropriate. These engagement activities included, but were not limited to:

- community information sessions held in four locations in 2019 (NexGen 2019);
- site tours;
- comments from the CRDN (2019a) on the Cluff Lake Mine licence renewal;
- other formal and informal meetings;
- workshops with specific groups (e.g., Fur Block N-19 trapper's workshop); and

- environmental and socio-economic baseline data collection.

Comments submitted by Indigenous Groups on the Project Description (CRDN 2019b; MN-S 2019; YNLRO 2019; ACFN 2019; CNSC 2019) were also reviewed for applicable Indigenous and Local Knowledge.

Indigenous and Local Knowledge related to noise was incorporated into the assessment by viewing the information as complementary and influential alongside scientific information. Where possible, knowledge from each potentially affected Indigenous Group or LPA community member was described separately and cited accordingly. Where information is described for multiple potentially affected Indigenous Groups, they are collectively referred to as “Indigenous Groups” throughout the assessment.

Indigenous and Local Knowledge was included in the noise assessment in the following ways:

- **Component Methods – Valued components and Intermediate Components:** Indigenous and Local Knowledge informed the selection of the intermediate component of noise and reflects the importance of the land use experience and enjoyment (e.g., peacefulness, solitude, sense of place) found while practicing Indigenous and other land and resource use activities. Experience and enjoyment also influence the spiritual and cultural value of some traditional use sites (Section 7.3.2.2.1).
- **Component Methods – Existing Conditions:** Indigenous and Local Knowledge informed the identification of receptors in the local study area (LSA) and regional study area (RSA) for the noise analysis (Section 7.3.2.6). During engagement activities, Indigenous Groups were provided with maps of the Patterson Lake area and asked to mark locations of active or historical cabins, campsites, hunting sites, and fishing sites, as well as any areas of recreational, cultural, or spiritual importance. This information is considered confidential and therefore not presented in this report; however, it was used to inform the approximate locations of selected receptors for the noise assessment.
- **Existing Conditions:** Indigenous and Local Knowledge was shared about existing noise conditions in the LSA and RSA and larger region (Section 7.3.3), including the experiences of Indigenous land users with noise disturbances in the area of the Project. This includes observations regarding the cumulative effects of noise from industrial activities and increased traffic on traditional use and wildlife abundance and distribution in the region.
- **Project Interactions and Mitigation:** Indigenous and Local Knowledge helped to inform the scoping of Project interactions and pathway analysis and consideration of mitigation measures (Section 7.3.4). This included observations and experiences of land users related to the cumulative effects of noise from industry and increased traffic on wildlife abundance and distribution and subsequent effects on traditional hunting and trapping, as well as the effects of sensory disturbance on the experience and enjoyment of Indigenous and other land and resource use.
- **Monitoring, Follow-Up, and Management:** Feedback provided by Indigenous Groups during engagement, including recommendations, were considered in the development of monitoring and follow-up activities (Section 7.3.8). For example, Indigenous Groups recommended that noise levels are monitored at specific locations reflecting traditional land use sites of cultural importance. These sites were then included in the monitoring plans. In addition, it is planned that ongoing feedback from Indigenous Groups on the effectiveness of mitigations would be considered when updating monitoring and management plans. Independent environmental monitors are also planned to participate in monitoring programs for the Project.

Specific references to Indigenous and Local Knowledge, and Project comments and concerns related to noise raised by Indigenous Groups and LPA community members, are included in the applicable subsections of this assessment.

7.3.2.2 Valued Components, Intermediate Components, and Measurement Indicators

7.3.2.2.1 Valued Components and Intermediate Components

Valued components are aspects of the biophysical, cultural, and socio-economic environments that are considered to have scientific, social, cultural, economic, historical, archaeological, or aesthetic importance (Beanlands and Duinker 1983; CNSC 2021). Intermediate components include physical attributes of the biophysical environment or media upon which VCs rely, such as air quality, terrain and soils, hydrogeology, and hydrology (Section 6.3.3). Valued components and intermediate components are assessed using the same steps; however, unlike VCs, intermediate components do not have assessment endpoints or significance criteria. Instead, the significance of changes in intermediate components is evaluated in the context of related influences to VCs, which are the ultimate receptors.

Noise was selected as an intermediate component due to the potential influence on the following VCs:

- wildlife and wildlife habitat (Section 14);
- Indigenous land and resource use (Section 16); and
- other land and resource use (Section 17).

The rationale for the selection of noise as an intermediate component is provided in Table 7.3-1.

Noise is critical to the assessment of VCs for the EA; however, the importance or significance of changes in noise can only be evaluated in context of the related influences on a VC, which is the ultimate receptor of value to humans and the environment. As an example, changes in noise were not evaluated without the context of what these changes would mean to wildlife and Indigenous and other land and resource use. Therefore, the assessment of noise is fundamental to understanding the total effects of the proposed Project on the biophysical environment (Section 6.3.3).

The noise intermediate component was analyzed to determine the Project-specific and cumulative changes, if applicable, in measurement indicators using a science-based approach.

During information sessions with LPA communities, noise was reported as a key interest and concern (NexGen 2019). Indigenous Groups have emphasized the importance of experiencing peace, quiet, and enjoyment while out on the land, and the ability to practice traditional activities in an environment without sensory disturbances (TSD II: BNDN; TSD III: BRDN; TSD V.1: CRDN; TSD V.2: CRDN; MN-S-JWG 2020). For example, a member of MN-S noted how much they love the silence of the north, and how in the wilderness you can only hear the grass rustling and the wind blowing (MN-S-JWG 2020). The CRDN described the value of experiencing peace and quiet while out on the land and at cabins and harvesting camps:

> Because it's such a beautiful place. Like, even the land, just sitting there and looking at the lake, and . . . . Just everything about the North is just beautiful. Quiet. Nature and - When you're up there for, even for a few days, like, I don't know, there's nothing compared to that feeling of just being where everything is just so peaceful. (TSD V.2: CRDN)

Sensory disturbances can affect sense of place, which is described as the attachment or affiliation that people have for the land, and "depends on particular places . . . along with their particular features (physical, social, and symbolic) and the values and activities those features foster and enable. Sense of place is created through personal and collective experiences-memories that become embedded in place" (TSD II: BNDN). The BRDN also described the importance of sense of place as an intangible value related to their culture, which, along with knowledge transmission, identity, ceremonial practice, spirituality, and place names, among others, is "intricately connected to land and place, and thus largely dependent on community members' ability to access their territory and practice peaceful enjoyment of undisturbed areas of their land" (TSD III: BRDN).

7.3.2.2.2 Measurement Indicators

Measurement indicators are used to characterize changes to attributes of the environment from the Project, other human developments, and natural factors. The changes in measurement indicators are used to predict overall effects on VCs and intermediate components (Section 6.3.2). Four measurement indicators were identified and used for the noise assessment (Table 7.3-1):

- **Energy equivalent sound level for the daytime period ($L_{eq,day}$):** expressed in A-weighted decibels (dBA) and C-weighted decibels (dBC). This indicator represents the average noise level over the 15-hour daytime period, which begins at 07:00 and ends at 22:00 (Health Canada 2017; AER 2007).
- **Energy equivalent sound level for the nighttime period ($L_{eq,night}$):** expressed in dBA and dBC. This indicator represents the average noise level over the nine-hour nighttime period, which begins at 22:00 and ends at 07:00 (Health Canada 2017; AER 2007).
- **Combined day-night sound level (L_{dn}):** expressed in dBA. This indicator reflects the average of $L_{eq,day}$ and $L_{eq,night}$, after adding a 10 dBA penalty to the $L_{eq,night}$ value since nighttime noise is generally considered more disruptive than daytime noise (Health Canada 2017). The L_{dn} noise level expressed in dBC was not considered a measurement indicator since there is no regulatory threshold or limit applicable to L_{dn} expressed in dBC.
- **Maximum sound level (L_{max}):** expressed in dBA. This indicator represents the maximum noise level over a particular time interval. The L_{max} noise level expressed in dBC was not considered a measurement indicator since there is no regulatory threshold or limit applicable to L_{max} expressed in dBC.

Table 7.3-1: Rationale and Measurement Indicators for the Noise Intermediate Component

Intermediate Components	Rationale	Measurement Indicators
Noise	▪ Influence on Indigenous and other land and resource use ▪ Sensitivity of some wildlife species to noise ▪ Presence of cabins/camp sites historically/currently in the area	▪ $L_{eq,day}$ and $L_{eq,night}$, expressed in dBA and dBC ▪ L_{dn}, expressed in dBA ▪ L_{max}, expressed in dBA

$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel; L_{max} = maximum sound level.

Noise levels expressed in dBA units have been scaled to reflect the frequency sensitivity of the human auditory system. Noise levels expressed in dBC units have been scaled such that low frequency contributions are less heavily discounted than in dBA units. Table 7.3-2 presents A-weights and C-weights for the octave band frequencies considered in the noise assessment (i.e., 31.5 Hz to 8 kHz).

Table 7.3-2: A-Weighting and C-Weighting Adjustments

Type of Weighting	Octave Band Frequency								
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
A	-39.4	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1
C	-3.0	-0.8	-0.2	0.0	0.0	0.0	-0.2	-0.8	-3.0

Source: IEC 2003.

Representative noise levels for several common situations and environments are provided in Table 7.3-3; this information provides context to the noise thresholds and noise predictions that appear elsewhere in the noise assessment.

Table 7.3-3: Noise Levels for Common Situations and Environments

Sample Situation/Environment	Noise Level (dBA)
Leaves rustling, soft music, whisper	30
Average home noise	40
Normal conversation, background music	60
Office noise, inside car at 60 miles per hour	70
Vacuum cleaner, average radio	75
Heavy traffic, window air conditioner, noisy restaurant, power lawnmower	80 to 89
Subway, shouted conversation	90 to 95
Boom box, ATV, motorcycle	96 to 100
School dance	101 to 105
Chainsaw, leaf blower, snowmobile	106 to 115
Sports crowd, rock concert, loud symphony	120 to 129
Stock car races	130
Gun shot, siren at 100 feet	140

Source: Health Link BC 2021.
dBA = A-weighted decibel.

7.3.2.3 Spatial Boundaries

The spatial boundaries selected for the noise assessment support a characterization of the existing environment in sufficient detail to identify, understand, and assess potential Project interactions with the noise intermediate component, including the contribution of the Project to residual effects (Table 7.3-4). The assessment of noise included a site study area, maximum disturbance area, LSA, and RSA (Figure 7.3-2).

The site study area is equivalent to the anticipated area of the Project footprint, which covers 228 ha and includes the access road and bridge, and all proposed Project infrastructure. To the degree possible, the Project footprint was minimized to reduce both the area of restricted access to Indigenous and other land users and the effects on the terrestrial environment.

The maximum disturbance area was used for the assessment to address uncertainty in the final design of the Project and to verify that adverse effects on VCs were not underestimated. The spatial boundary of the maximum disturbance area was delineated by applying a 100 m buffer to the access road, a 50 m buffer to the surface explosives magazine, a 100 m buffer to sewage treatment facilities, and a 50 m buffer to the omni-directional lights corridor at the eastern edge of the airstrip. Where possible, the boundary was delineated using straight lines (i.e., nearest distance) between the outermost proposed Project infrastructure and facilities. The spatial boundary was also constrained to the shoreline of Patterson Lake (Figure 7.3-2). The total area of the maximum disturbance area is 981 ha.

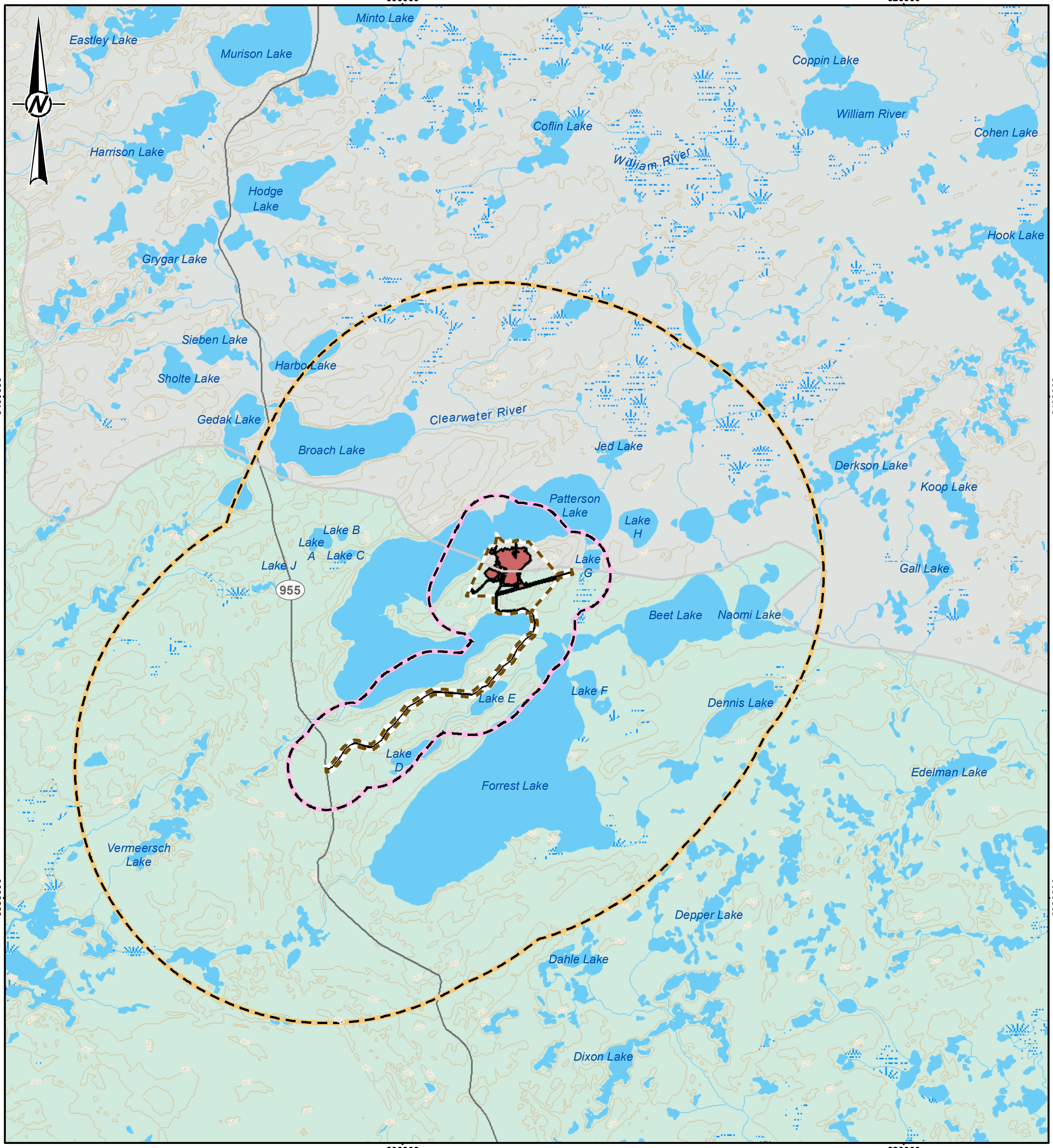
The LSA for the noise analysis was defined as a 1.5 km buffer surrounding the maximum disturbance area for the Project. The LSA was defined in accordance with Alberta Energy Regulator (AER) *Directive 038: Noise Control* (AER 2007), which states that noise effects should be analyzed at receptors located within 1.5 km of a project. The LSA was defined at a scale that captures most of the expected noise effects from the Project (Section 6.4.1, Spatial Boundaries).

The RSA for the noise analysis was defined as a 10 km buffer surrounding the maximum disturbance area for the Project. This buffer distance includes data collected during the baseline study, which characterized existing noise and light conditions (Annex II, Noise and Light Baseline Report). Based on professional judgment, the RSA is an appropriate scale for the analysis of potential cumulative effects from the Project; and other previous, existing projects and activities, and RFDs.

Table 7.3-4: Spatial Boundaries for the Assessment of Noise

Spatial Boundary	Surface Area	Description
Site study area	228 ha (2.3 km^2)	▪ Equivalent to the anticipated Project footprint, which includes all proposed mine infrastructure and facilities (199 ha) and the access road (29 ha)
Maximum disturbance area	981 ha (9.8 km^2)	▪ Incorporates a level of uncertainty into the Project design so that effects are not underestimated ▪ Maximum disturbance area was selected using bounding points around the outermost components of the Project footprint
LSA	6,629 ha (66 km^2)	▪ 1.5 km buffer around the maximum disturbance area ▪ Defined to capture most of the expected noise effects from the Project (AER 2007) ▪ Provides local context for assessing the residual effects
RSA	61,544 ha (615 km^2)	▪ 10 km buffer around the maximum disturbance area ▪ Defined to capture potential cumulative effects from the Project and other previous, existing, and RFDs ▪ Provides broader scale context to capture and assess Project effects

Note: Numbers are rounded for presentation purposes.
LSA = local study area; RSA = regional study area; RFD = reasonably foreseeable development.



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN
- WATERBODY
- WETLAND
- WOODED AREA
- MAXIMUM DISTURBANCE AREA
- PROPOSED PROJECT FOOTPRINT
- NOISE LOCAL STUDY AREA
- NOISE REGIONAL STUDY AREA

0 5 10
1:225,000 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.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

SPATIAL BOUNDARIES FOR THE NOISE ASSESSMENT

CONSULTANT

wsp

PROJECT		20144150	PHASE 3102 - 3
DESIGN	VY	2023-02-27	SCALE AS SHOWN REV. 0
GIS	NO	2023-02-27	
CHECK	VY	2023-02-27	FIGURE 7.3-2
REVIEW	AF	2023-02-27	

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7.3.2.4 Temporal Boundaries

The temporal scope of the assessment focuses on the 43-year period from initial Construction to the end of Decommissioning and Reclamation (i.e., Closure) as defined by the following Project phases (Section 6.4.2):

- **Construction Phase (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. The duration of Construction is expected to be four years.
- **Operations Phase (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. The duration of Operations is expected to be 24 years.
- **Decommissioning and Reclamation Phase (Closure):** includes two stages expected to occur over 15 years:
    - **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 and 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. The duration of the Active Closure Stage is expected to be five years.
    - **Transitional Monitoring Stage:** includes monitoring and reporting activities that occur post-Active Closure Stage that 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 back under Provincial management through the Institutional Control Program. The duration of the Transitional Monitoring Stage is nominally 10 years; however, NexGen acknowledges this duration would be dependent on the achievement of performance criteria.

The temporal boundaries applied to the cumulative effects assessment includes the duration of residual effects from previous and existing developments that overlap with effects from the Project, and the period during which the residual effects from RFDs overlap with the Project, if applicable.

Quantitative noise modelling focused on one temporal snapshot during Construction and one temporal snapshot during Operations. These temporal snapshots were selected to capture maximum predicted noise effects from Project-related activities. A temporal snapshot for Closure was not included because activities during the Active Closure Stage would be similar, but less intense, relative to activities during Construction. The level of activities during the Transitional Monitoring Stage of Closure would be further reduced and are expected to generate negligible noise levels relative to ambient (i.e., background) conditions. Year 2 of Construction was modelled as it would have the largest number of equipment-hours. The temporal snapshot for Operations reflects a period when all surface and underground equipment would be operating but does not represent a specific year.

7.3.2.5 Assessment Cases

The concept of assessment cases was applied to the noise assessment to estimate the incremental and cumulative effects from the Project and other developments (Section 6.5). The approach incorporated temporal boundaries for analyzing the potential effects from previous, existing, and approved projects and RFDs before, during, and after the anticipated lifespan of the Project. There are no known approved (but not yet constructed) projects in the LSA and RSA for noise. Assessment cases for the Project included a Base Case, Application Case, and RFD Case.

Base Case for noise is represented by existing conditions. The Base Case describes the existing environment in the LSA and RSA before application of the proposed Project to provide an understanding of the current conditions that may be influenced by the Project. The temporal boundary of the Base Case includes the combined effects from previous and existing human disturbances and natural factors (e.g., fire, precipitation, wind) on noise. As such, existing conditions represent the cumulative effects of historical and current environmental pressures that have influenced the observed condition and patterns of noise (CEA Agency 2018).

Application Case for noise represents predictions of the combined effects of the previous and existing projects/activities and natural factors in the Base Case plus the potential effects from the proposed Project. This case was also used to identify and assess incremental, Project-specific changes that are predicted to occur noise.

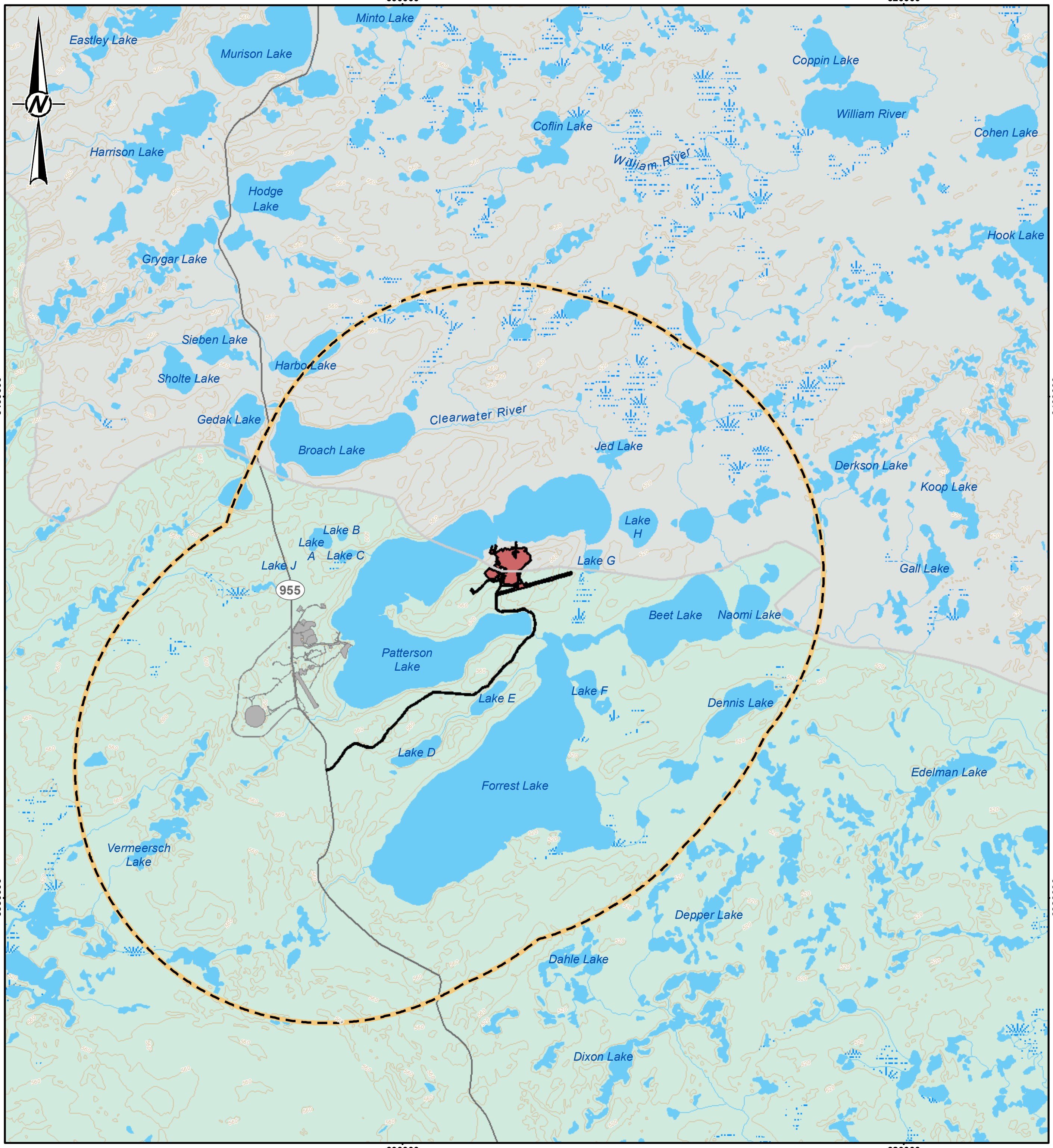
Reasonably Foreseeable Development Case for noise includes the Base Case, Application Case, and RFDs that have not yet been approved. Reasonably foreseeable developments are defined as projects and activities that fit any of the first three and both of the last two criteria from the list below:

- are currently under regulatory review or have officially entered a formal regulatory application process;
- have been publicly disclosed by other proponents;
- may be induced by the Project;
- have the potential to change the Project or the effects predictions; and
- occur in the spatial assessment boundary defined by noise.

A key criterion for selecting other projects to include in the RFD Case was that the projects must cause similar effects on noise influenced by the Project (Hegmann et al. 1999). The Fission Patterson Lake South Property, which is planned by Fission Uranium Corp. (Fission 2019, 2021), was included in the RFD Case (Figure 7.3-3). Public information describes a projected three-year construction period and seven-year operating period (production and processing; Fission 2019, 2021). The anticipated start of construction and duration of active decommissioning at the Fission Patterson Lake South Property were not publicly available at the time this assessment was completed. For the assessment, it was assumed that the duration of active decommissioning for the Fission Patterson Lake South Property would be similar to the Active Closure Stage for the Project (i.e., five years; Section 6.5.3, Reasonably Foreseeable Development Case).

The proposed surface infrastructure layout plan (Fission 2019, 2021) is the anticipated physical footprint of the Fission Patterson Lake South Property and includes the proposed highway bypass, airstrip, and all proposed mine site infrastructure. A hypothetical maximum disturbance area, as applied in Section 7.3.2.3, Spatial Boundaries, to the Project footprint, was also used for the Fission Patterson Lake South Property to address uncertainty in project design. The CRDN and MN-S specifically mentioned the potential for of cumulative effects from the Project and the nearby proposed Fission Patterson Lake South Property (CRDN 2019b; MN-S-JWG 2020; CRDN-JWG 2021).

The noise assessment includes a quantitative analysis of predicted changes on measurement indicators and associated effects from the Fission Patterson Lake South Property on noise receptors.



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- NOISE REGIONAL STUDY AREA

0 5 10

1:225,000 KILOMETRES

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

NOISE REGIONAL STUDY AREA AND FISSION PATTERSON LAKE SOUTH PROPERTY

CONSULTANT

wsp

PROJECT		20144150	PHASE 3102 - 3
DESIGN	VY	2023-02-27	SCALE AS SHOWN REV. 0
GIS	NO	2023-02-27	FIGURE 7.3-3
CHECK	VY	2023-02-27	
REVIEW	AF	2023-02-27	

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7.3.2.6 Existing Conditions

Representative existing noise levels were measured during a baseline field study in September 2018 (Annex II). The objective of the baseline field study was to gather information about representative existing noise levels in the absence of the proposed Project.

The baseline study measured representative existing noise levels using methods from AER Directive 038 (AER 2007). Representative existing noise levels were measured for a minimum of 24 hours at three locations within the LSA and RSA:

- Noise 1: north shore of Forrest Lake:
  - Conditions at this location are generally representative of existing noise levels experienced by wildlife, Indigenous Peoples, and recreational fisherman that make use of swampy areas near Forrest Lake and similar waterbodies within the LSA and RSA.
- Noise 2: south shore of Patterson Lake:
  - Conditions at this location are generally representative of existing noise levels experienced by wildlife, Indigenous Peoples, and recreational fisherman that make use of rocky areas near Patterson Lake and similar waterbodies within the LSA and RSA.
- Noise 3: forested area northwest of Patterson Lake, far from the nearest waterbody:
  - Conditions at this location are generally representative of existing noise levels experienced by wildlife, Indigenous Peoples, and recreational hunters that make use of forest environments in the LSA and RSA.

In the absence of Saskatchewan-specific regulations or guidelines, existing noise levels were characterized in the context of thresholds from AER Directive 038 (AER 2007) and from the following federal guidance documents:

- Environmental Code of Practice for Metal Mines (Environment Canada 2009); and
- *Guidance for Evaluating Human Health Impacts in Environmental Assessment – Noise* (Health Canada 2017).

Receptors for the noise analysis were identified through engagement activities with Indigenous Groups (Section 7.3.2.1, Incorporation of Indigenous and Local Knowledge). In total, 16 noise receptors were identified in the LSA and RSA and include active and historical cabins, lodges, and campgrounds, as well as known locations used for fishing.

Additional Indigenous and Local Knowledge provided by Indigenous Groups in IKTLU Studies supported the selection of receptor sites in the LSA and RSA. The Patterson Lake area was noted by Indigenous Groups as a particularly important area with both historical and current cultural value where hunting, trapping, fishing, and plant gathering is still practiced (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN).

Existing noise levels at the 16 receptors were estimated based on noise levels measured during the baseline field survey. Noise levels were assigned to individual receptors based on their similarity to the baseline measurement locations. For example, measurement data from the Noise 2 location were considered representative of existing noise levels at receptors corresponding to rocky areas near bodies of water. Similarly, measurement data from the Noise 3 location were considered representative of existing noise levels at receptors corresponding to forested areas.

7.3.2.7 Project Interactions and Mitigations

Interactions (i.e., linkages) between Project components or activities, and the corresponding potential changes to measurement indicators, were identified by a pathway analysis that was then used to inform the residual effects analysis for noise (Section 6.7). The first part of the analysis was to identify all potential effects pathways for all phases of the Project (Section 6.7.1). Each pathway was initially assumed to have a linkage to potential effects on receptors from changes in noise levels.

Potential pathways from Project activities to noise were identified using the following:

- review of the Project description (Section 5) and potential effects scoping by the project development, environmental, and socio-economic teams for the Project;
- input from Indigenous, regulatory, and public engagement (Section 2) and Indigenous and Local Knowledge (Section 3);
- scientific knowledge;
- previous experience with mining projects; and
- consideration of potential effects identified from the Terms of Reference (Section 1, Appendix 1A).

Potential adverse effects of the Project were then identified, and practicable mitigation was applied to avoid, minimize, and/or rehabilitate adverse effects on receptors from changes in noise levels (Section 6.7.2, Identification of Mitigation). Avoidance and minimization are widely recognized as the most important approach for biodiversity conservation (BBOP 2021). Avoidance designs and actions integrated into the Project were developed iteratively between the Project's environmental and project development teams. Minimization techniques and technology were also identified and implemented collaboratively between Project teams.

Each potential effect pathway was evaluated using proposed mitigation to predict whether the pathway had the potential to cause residual adverse effects (Section 6.7.3, Pathway Screening). A screening-level assessment was applied using Indigenous and Local Knowledge, scientific knowledge, logic, experience with similar developments, and an understanding of the effectiveness of mitigation (i.e., level of certainty that mitigation would work) to assign each pathway to one of the following categories:

- **No pathway:** Analysis reveals that the pathway could be removed (i.e., the effect is avoided) by mitigation so that the Project would result in no measurable environmental change relative to existing conditions or guideline values and, therefore, would have no residual effect on receptors from changes in noise levels.
- **Secondary pathway:** The pathway could result in a measurable but minor environmental change relative to existing conditions or guideline values, but this change would be sufficiently small that it would have a negligible residual effect on receptors from changes in noise levels. Therefore, the pathway is not expected to contribute to effects of RFDs to cause a significant effect.
- **Primary pathway:** The pathway is likely to result in an environmental change relative to existing conditions or guideline values and could cause a greater than negligible effect on receptors from changes in noise levels.

Project interactions determined as no pathway or secondary pathways were not carried forward for further assessment (Section 6.7.3). Primary pathways that could result in changes to the environment with one or more associated measurement indicator and have the potential to cause a greater than negligible effect on noise were carried forward to the residual effects analysis and residual effects classification (Section 7.3.5).

7.3.2.8 Residual Effects Analysis

The residual effects analysis measures and describes the effects of the proposed Project on receptors from changes in noise levels. The residual effects analysis was conducted using the spatial boundaries (Section 7.3.2.3, Spatial Boundaries) and temporal boundaries (Section 7.3.2.4, Temporal Boundaries) identified for the assessment. Residual effects are described for each of the measurement indicators for the primary pathways identified for noise in the LSA and RSA (Section 7.3.4.3, Primary Pathways). The residual effects analysis was completed for the Application Case and the RFD Case (Section 6.8).

The Application Case represents predictions of the cumulative effects of the previous and existing conditions combined with the effects from the proposed Project. This case was also used to identify the incremental changes from the Project that are predicted to occur between the Base Case and the Application Case. The RFD Case includes the Application Case plus the Fission Patterson Lake South Property.

Computer models were used to predict Project noise levels at the 16 receptors located within the LSA and RSA; these models were developed for one temporal snapshot during Construction of the Project and one temporal snapshot during Operations. Temporal snapshots were selected to capture maximum noise effects from the Project (Section 7.3.2.4).

Most Project noise sources would be effectively continuous or steady state. Sources in this category include equipment noise associated with the following activities: land clearing; site preparation; construction of facilities and infrastructure; underground shaft/mine development; site traffic; power generation; and process plant and underground operations. These types of sources would emit noise into the environment continuously throughout the daytime and nighttime periods as the proposed Project is planned to operate as a 24-hour per day operation. In contrast, noise associated with the Project airstrip would be intermittent. The airstrip would emit noise into the environment when airplanes take off or land, but the airstrip would be effectively silent at other times. Because noise emissions and noise effects from the Project airstrip are qualitatively different than noise emissions and noise effects from other Project equipment and activities, separate computer models were developed to predict and analyze noise effects from these two groups of sources.

Computer models of continuous noise sources were based on an algorithm from the International Organization for Standardization (ISO) 9613-2 technical standard (ISO 1996). Inputs to the ISO 9613-2 models consisted of source emissions in the form of octave band sound power levels, as well as environmental parameters that could influence propagation (e.g., wind speed, wind direction, temperature, ground cover). For each temporal snapshot, the ISO 9613-2 models were used to predict Project noise levels for the measurement indicators $L_{eq,day}$, $L_{eq,night}$, and L_{dn}. Project noise levels were predicted for the 16 discrete receptors and for a grid covering the LSA and RSA. The ISO 9613-2 models were used to predict Project noise levels outdoors. The ISO 9613-2 standard does not account for attenuation resulting from outdoor-to-indoor propagation, and so these models cannot be used to predict indoor noise levels. Nonetheless, the thresholds used to assess potential noise effects are primarily applicable to outdoor noise levels (Environment Canada 2009; Health Canada 2017; AER 2007). Additional details on the ISO 9613-2 noise models are presented in Appendix 7B, Noise Modelling Summary Report.

Computer models of airstrip noise sources were based on an algorithm from European Civil Aviation Conference (ECAC) Document 29 (ECAC 2016). Inputs to the ECAC models consisted of aircraft types and takeoff/landing frequencies. For each temporal snapshot, the ECAC models were used to predict noise levels for individual takeoff and landing events for the measurement indicator L_{max}. Takeoff and landing noise levels were predicted for the 16 discrete receptors. The ECAC models were used to predict Project noise levels outdoors. The ECAC algorithm does not account for attenuation resulting from outdoor-to-indoor propagation, and so these models cannot be used to predict indoor noise levels. Additional details on the ECAC noise models are presented in Appendix 7B.

For the RFD Case, computer models of the Fission Patterson Lake South Property were developed using preliminary design information presented in the prefeasibility study report for that property (Fission 2019). Where detailed information required for noise modelling was not publicly available, computer models of the Fission Patterson Lake South Property were developed using inputs and parameters comparable to those used for the proposed Project; this approach was taken because, based on publicly available information, the Fission Patterson Lake South Property is a similar type of development to the Project and is anticipated to have similar equipment and noise emissions.

Noise levels were predicted using computer models that represent the most intense period of construction at the Fission Patterson Lake South Property and full-scale operations at that property. Noise levels were predicted at each of the 16 receptors located within the RSA (Table 7.3-5).

For each receptor, the magnitude of noise effects from the Project and from the Fission Patterson Lake South Property was established by comparing noise level predictions to thresholds from:

- Environment and Climate Change Canada (Environment Canada 2009);
- Health Canada (Health Canada 2017); and
- AER Directive 038 (AER 2007).

Environment and Climate Change Canada (ECCC) recommends that noise levels from all considered project activities not exceed 55 dBA during the daytime period and not exceed 45 dBA during the nighttime period at offsite receptors (Environment Canada 2009). The ECCC thresholds are understood to apply to continuous noise from industrial activities in isolation from other sources. Therefore, existing noise levels and predicted periodic and short-duration noise from the Project airstrip and the Fission Patterson Lake South Property airstrip were not considered when analyzing noise effects in the context of ECCC thresholds.

Health Canada provides a formula for calculating the percentage of a typical population that would be highly annoyed (%HA) by a given L_{dn} noise level and recommends that changes in %HA not exceed 6.5% at offsite receptors (Health Canada 2017). Formulae for calculating %HA based on noise level have been established through statistical analysis of dose-response data for large populations (Health Canada 2017); however, use of the %HA parameter is not limited to large populations. In accordance with Health Canada guidance:

- Percent highly annoyed (%HA) values were calculated based on existing L_{dn} noise levels.
- Cumulative L_{dn} noise levels for the Application Case were predicted by summing existing L_{dn} noise levels with model predictions of Project L_{dn} noise levels.
- Cumulative L_{dn} noise levels for the RFD Case were predicted by summing existing L_{dn} noise levels, model predictions of Project L_{dn} noise levels, and model predictions of Fission Patterson Lake South Property L_{dn} noise levels.

- The %HA values were calculated based on Application Case and RFD Case cumulative L_{dn} noise levels.
- Increases in %HA resulting from the Project and from the Project in combination with the Fission Patterson Lake South Property were calculated and compared to the 6.5% threshold.

The Health Canada %HA approach is understood to apply to continuous noise. Therefore, the Project airstrip and the Fission Patterson Lake South Property airstrip were not considered when analyzing noise effects in the context of Health Canada %HA thresholds.

To protect against sleep disturbance from continuous noise, Health Canada recommends that annual average nighttime noise levels not exceed 40 dBA at offsite receptors where people sleep. This sleep disturbance threshold is understood to apply to noise from industrial activities in combination with existing noise levels. Therefore, before comparing to the 40 dBA sleep disturbance threshold, cumulative noise levels for the Application Case were calculated by summing existing noise levels with Project noise level predictions, and cumulative noise levels for the RFD Case were calculated by summing noise level predictions for the Fission Patterson Lake South Property with Application Case cumulative noise levels. Intermittent noise from the Project and Fission Patterson Lake South Property airstrips was not considered in this analysis of sleep disturbance from continuous noise.

To protect against sleep disturbance from intermittent noise, Health Canada recommends that indoor L_{max} noise levels not exceed 45 dBA more than 10 to 15 times per nighttime period at offsite receptors where people sleep (Health Canada 2017). Health Canada further recommends that an outdoor-to-indoor transmission loss of 15 dBA be used to simulate a bedroom with partially open windows (Health Canada 2017). Combining these two Health Canada recommendations yields a L_{max} sleep disturbance target of 60 dBA outdoors (i.e., 45 dBA indoors plus 15 dBA transmission loss). When assessing sleep disturbance effects from the Project airstrip and the Fission Patterson Lake South Property airstrip, the noise analysis compared predicted outdoor L_{max} noise levels to both the 45 dBA and 60 dBA thresholds because tents or other temporary structures with very low transmission loss values may be used for sleeping at some receptor locations.

Low frequency noise (LFN) refers to noise that is perceived by human listeners as being low in pitch; for example, the musical notes produced by a tuba have greater LFN content than the musical notes produced by a flute. Low frequency noise can have adverse effects even when overall or total noise levels are otherwise acceptable.

7.3.2.9 Residual Effects Classification

The residual effects analysis uses a reasoned narrative to describe anticipated changes to each measurement indicator caused by the proposed Project and the associated effects on noise receptors. The residual effects analysis also considers effects from both the Project and RFDs. These narrative descriptions of anticipated effects represent the foundation for the residual effects classification. Residual effects are summarized or classified in tabular form using effects criteria, which are intended to provide structure and comparability across VCs and intermediate components assessed for the Project (Section 6.9.1, Residual Effects Classification).

The residual effects classification uses direction, magnitude, geographic extent, duration, reversibility, frequency, and probability of occurrence as criteria. The approach to classify each residual effect criterion is provided in Table 7.3-5.

Table 7.3-5: Definitions Applied to Effects Criteria Classifications for the Assessment of Noise

Criterion	Rating	Definition
Direction	Positive	Change in measurement indicator results in net improvement or benefit to the component
	Neutral	Change in measurement indicator results in net balance to the component
	Negative	Change in measurement indicator results in net degradation or loss to the component
Magnitude	Qualitative narrative or numeric quantification	Change in measurement indicator is described by effect size (e.g., equivalent sound level and dBA)
Geographic extent	Maximum disturbance area	Change in measurement indicator is confined to the maximum disturbance area
	Local	Change in measurement indicator extends outside the maximum disturbance area but within the LSA
	Regional	Change in measurement indicator extends beyond the LSA but is confined to the RSA
	Beyond regional	Change in measurement indicator extends beyond the RSA
Duration	Numeric quantification	Change in measurement indicator is described by effect duration (e.g., months, years, decades, permanent)
Reversibility	Reversible	Change in measurement indicator is reversible within a clearly defined time period
	Irreversible	Change in measurement indicator is predicted to influence the component indefinitely
Frequency	Occasional	Change in measurement indicator is expected to occur rarely (e.g., once or a few times during a defined period of time)
	Periodic	Change in measurement indicator is expected to occur consistently at regular intervals or associated with temporal events (e.g., during dry summers)
	Continuous	Change in measurement indicator is expected to occur all the time
Probability of occurrence	Unlikely	Change in measurement indicator is not expected to occur, but not impossible
	Possible	Change in measurement indicator may occur, but is not likely
	Probable	Change in measurement indicator is likely to occur, but is uncertain
	Certain	Change in measurement indicator will occur

dBA = A-weighted decibel; LSA = local study area; RSA = regional study area.

While most criteria could be assigned categorical ratings for noise, predicted effect sizes were provided in specific terms (i.e., narrative or numeric quantification) in the residual effects characterization (Table 7.3-5). Similarly, duration was described in quantitative terms (e.g., months, years). Categorization of duration (e.g., short term, long term) and magnitude (e.g., negligible, low, high) can lead to confusion or misinterpretation of the effects assessment without appropriate context. When categorical definitions were used, they were supported by a reasoned narrative (Section 6.9.1).

7.3.2.10 Prediction Confidence and Uncertainty

The purpose of the assessment is to predict the future conditions for noise with the addition of the Project and the Fission Patterson Lake South Property. As with all predictions of future conditions, the predictions made in this assessment embody some degree of uncertainty. The assessment applied a precautionary (i.e., conservative) approach to address uncertainty by identifying the greatest magnitude, duration, and geographic extent of potential adverse effects when a range of outcomes were possible. Consequently, uncertainty was addressed in a manner that increased the level of confidence that residual effects were conservatively estimated. The key uncertainties for noise and the way they were addressed are presented as part of this assessment (Section 7.3.6).

7.3.2.11 Monitoring, Follow-Up, and Adaptive Management

Monitoring programs are proposed to address the uncertainties associated with the effects predictions and to evaluate the performance of mitigation. In general, monitoring is used to verify the effects predictions. Monitoring is also used to identify any unanticipated effects and to support the implementation of adaptive management to limit these effects. Typically, monitoring includes one or both of the following categories that may be applied during the Project lifespan:

- **Regulatory compliance monitoring:** monitoring activities, procedures, and programs undertaken to confirm the implementation of approved design standards, mitigation and conditions of approval, and NexGen commitments (e.g., inspecting construction equipment for cleanliness prior to arriving on site, inspecting noise suppression [mufflers] on vehicles to make sure they are functioning properly).
- **Follow-up monitoring:** programs designed to test the accuracy of effects predictions, reduce or address uncertainties, determine the effectiveness of mitigation, or provide appropriate feedback to operations for modifying or adopting new mitigation designs, policies, and practices (e.g., implementation of adaptive management). Results from these programs can be used to increase the certainty of effect predictions in future EAs.

Where relevant, conceptual monitoring programs would be proposed to confirm predictions and to address the uncertainties associated with the effects predictions and mitigation, and upon Project approval, would be included in the Integrated Management System.

The implementation of robust and long-term environmental testing and monitoring has also been requested by Indigenous Groups to verify protection of the environment, including community-led monitoring during Construction and Operations of the Project (TSD IV: MN-S; TSD V.2: CRDN; TSD VI: YNLR).

In addition to environmental monitoring programs typically implemented for projects (i.e., as noted above), NexGen is working with local Indigenous Groups to implement independent environmental monitoring. In combination with standard Project monitoring processes, independent Indigenous monitoring would be used to verify Project performance and to determine if mitigations and controls are effective in protecting the receiving environment.

Adaptive management measures may also be proposed to address the uncertainties associated with the effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

7.3.3 Existing Conditions

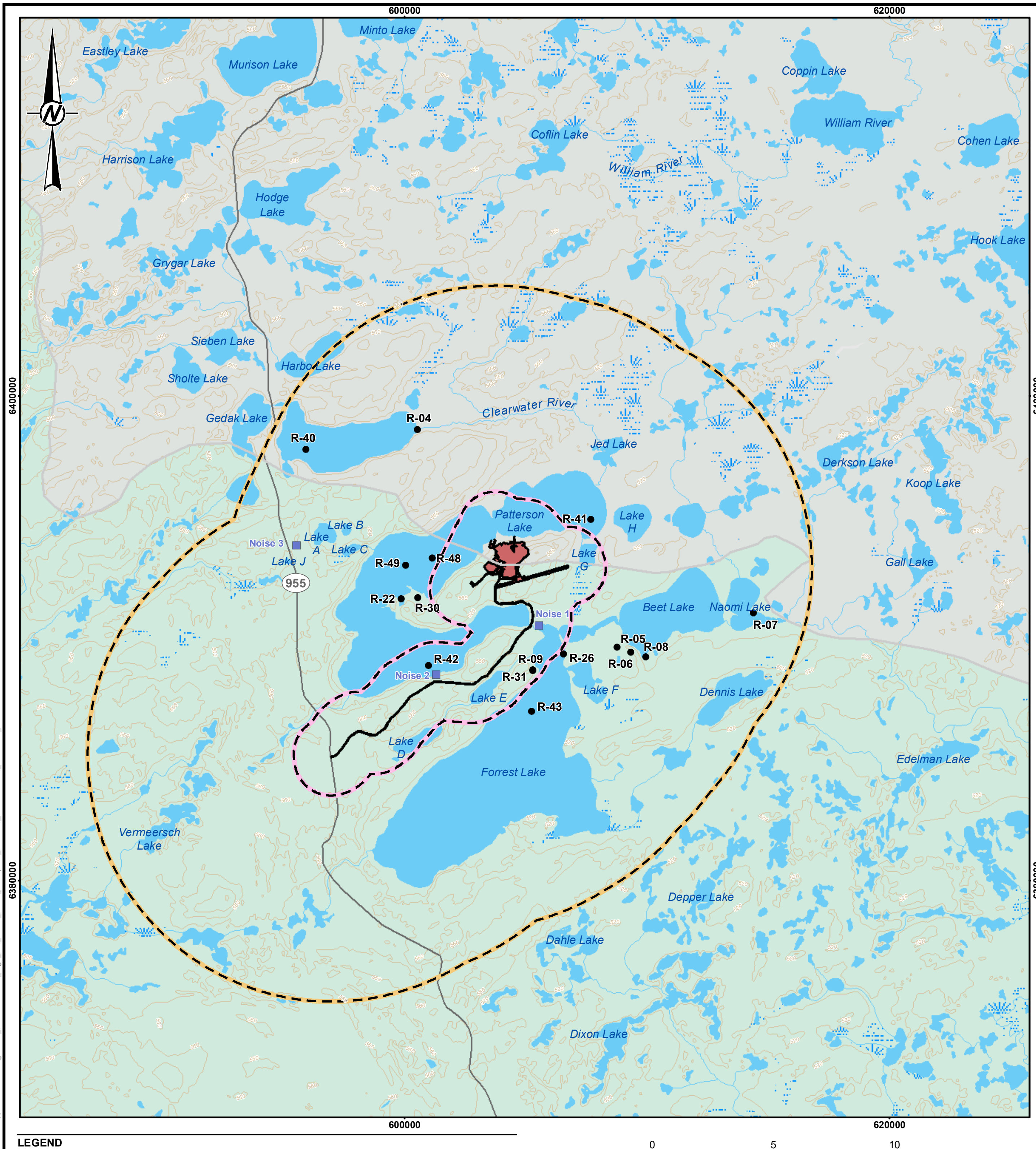
A baseline field study characterizing existing noise conditions was completed in September 2018 (Annex II), with measurements taken at three locations (i.e., Noise 1, Noise 2, and Noise 3). For each measurement location, Table 7.3-6 presents average existing noise levels in the form of $L_{eq,day}$ and $L_{eq,night}$, where the daytime period begins at 07:00 and ends at 22:00 and the nighttime period begins at 22:00 and ends at 07:00. In accordance with guidance from AER Directive 038 (AER 2007), average existing noise levels are presented in both dBA and dBC units. In addition, Table 7.3-6 presents the results of a spectral test to identify low frequency tonal components in the measurement data (AER 2007). In accordance with Health Canada guidance (Health Canada 2017), the average L_{dn} is presented for each measurement location in dBA units; L_{dn} values are calculated by combining $L_{eq,day}$ and $L_{eq,night}$ values after applying a 10 dBA penalty to the $L_{eq,night}$ value, since nighttime noise is generally considered more disruptive than daytime noise. Table 7.3-3 also provides a qualitative description of the sources that were observed to influence existing noise levels at each measurement location.

Table 7.3-6: Summary of Baseline Field Study

Measurement Location	Average Existing Noise Level					Number of Low Frequency Tones(a)	Contributing Noise Sources
	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)		
Noise 1: north shore of Forrest Lake	30	26	47	36	33	0	▪ birds ▪ splashes and wave action ▪ wind in vegetation ▪ power boat and fishermen ▪ animal footsteps and breathing ▪ animal howling and vocalizing
Noise 2: south shore of Patterson Lake	42	39	46	42	46	0	▪ wave action ▪ wind in vegetation ▪ birds
Noise 3: forested area (far from waterbodies)	30	21	41	31	30	0	▪ wind in vegetation ▪ birds

a) Low frequency tones identified in accordance with AER Directive 038 (AER 2007).
$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period;
L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel; AER = Alberta Energy Regulator.

Sixteen noise receptors were identified in the LSA and RSA. Figure 7.3-4 shows the locations of these noise receptors and the three locations where noise measurements were collected during the baseline field study.



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- BASELINE NOISE MEASUREMENT LOCATIONS
- NOISE RECEPTORS
- NOISE LOCAL STUDY AREA
- NOISE REGIONAL STUDY AREA

REFERENCE(S)

1. 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

NOISE RECEPTORS AND BASELINE MEASUREMENT LOCATIONS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3102 - 3
DESIGN	VY	2023-02-27	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-27	**FIGURE 7.3-4**	
CHECK	VY	2023-02-27		
REVIEW	AF	2023-02-27		

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\Noise\NoiseAssessmentTechnicalSupportDocument\Figures\8_5x11\20144150_Fig7_3-4_RookI_Noise_Receptors_Baseline_Measurement_Locations_Rev0.mxd PRINTED ON: 2023-02-27 AT: 4:11:25 PM

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25mm

Existing noise levels at the 16 receptors were estimated based on noise levels measured during the baseline field survey (Table 7.3-7). Noise levels were assigned to individual receptors based on their similarity to the baseline measurement locations. For example, measurement data from the Noise 2 location were considered representative of existing noise levels at receptor R-49 since this receptor is located on Patterson Lake and Noise 2 is immediately adjacent to Patterson Lake. Similarly, measurement data from the Noise 3 location were considered representative of existing noise levels at receptor R-04 since this receptor is also located within a forested area.

Table 7.3-7 presents representative existing noise levels for each of the 16 receptors located within the LSA and RSA and provides a brief description of each receptor. Existing daytime noise levels ($L_{eq,day}$) range from 30 dBA in forested locations to 42 dBA in locations near a large body of water. Existing nighttime noise levels ($L_{eq,night}$) range from 21 dBA in forested locations to 39 dBA in locations near a large body of water. Existing daytime and nighttime noise levels near large waterbodies in the LSA and RSA are generally consistent with noise levels one would expect to observe within an average home (Table 7.3-3). Existing daytime and nighttime noise levels at forested locations in the LSA and RSA are generally less than noise levels from rustling leaves, soft music, or whispering (Table 7.3-3). Existing noise levels at all locations in the LSA and RSA are less than noise thresholds from Environment Canada (2009), Health Canada (2017), and AER (2007; Annex II).

Table 7.3-7: Representative Existing Noise Levels at Receptors

Noise Receptor	Description[a]	Representative Measurement Location	Representative Existing Noise Level				
			$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-04	Cabin	Noise 3	30	21	41	31	30
R-05	Lodge	Noise 3	30	21	41	31	30
R-06	Cabin (old cabin)	Noise 3	30	21	41	31	30
R-07	Cabin	Noise 1	30	26	47	36	33
R-08	Camp (tourist camp)	Noise 1	30	26	47	36	33
R-09	Camp (tourist camp)	Noise 3	30	21	41	31	30
R-22	Fishing (nets)	Noise 2	42	39	46	42	46
R-26	Plane crash	Noise 3	30	21	41	31	30
R-30	Historical camp	Noise 3	30	21	41	31	30
R-31	Camp (rough camp)	Noise 3	30	21	41	31	30
R-40	Fishing	Noise 1	30	26	47	36	33
R-41	Fishing	Noise 2	42	39	46	42	46
R-42	Fishing	Noise 2	42	39	46	42	46
R-43	Fishing	Noise 2	42	39	46	42	46
R-48	Fishing	Noise 2	42	39	46	42	46
R-49	Fishing	Noise 2	42	39	46	42	46

a) Receptor description provided during JWG meetings.
$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel; JWG = Joint Working Group.

Indigenous Groups have noted experiencing increased noise levels up north due to mineral exploration activities, including in the Patterson Lake area, which in certain areas has disturbed their peace and quiet on the land (TSD II: BNDN; TSD III: BRDN; TSD V.1: CRDN; TSD V.2: CRDN). For example, the CRDN has reported increased noise levels in the Patterson Lake area from increased traffic along Highway 955, increased drilling operations, camps, and human activity (TSD V.1: CRDN; TSD V.2: CRDN). Indigenous Groups also commented that higher noise levels from increased traffic and exploration and mining activities in the RSA and larger regions has led to changes in wildlife populations and movement patterns, including to caribou, which are particularly sensitive to noise disturbance (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; BNDN-JWG 2020; BRDN-JWG 2020; CRDN-JWG 2020a; MN-S-JWG 2020). As examples:

> [The ability to trap has changed over time]. Because of all the exploration and that, I have to switch routes once in a while . . . . Less animals . . . . The more activity you have up there, the less animals are on your trail. There's less animals up there. Not like other years when it's quiet, I leave my traps for four days . . . . and it's nice and quiet. Now these people are up there day after day and night. I had less fur last winter. (TSD II: BNDN)

> [The traffic] It's like chasing moose and rabbits and everything off the roads. Now I can't usually; I hardly see moose up north now. I think they are chasing them away, or I don't know what's going on. That noise is chasing them away . . . . It used to be really quiet but now it's just like driving from here to town. Same as that. Between Patterson to Saskatoon Lake, it's just like driving from here to La Loche, the traffic . . . . I believe it's going to be hard to shoot a moose now, or even anything . . . . The noise is chasing them away. All that drilling noise, all the generators, all the banging noise. (TSD V.2: CRDN)

> There's Cluff Lake and the mine is right here . . . . They had a camp right here, that's where we went . . . . It's mostly that time they told us there were caribous there, we went there and it was too late, they'd already – they went back . . . because . . . all that noise . . . (TSD II: BNDN)

The information provided by Indigenous Groups was incorporated into the pathways analysis (Section 7.3.4) for the noise assessment.

7.3.4 Project Interactions and Mitigations

The pathways analysis identified potential adverse effects of the Project on noise, identified practicable mitigation for these potential effects, and determined whether potential effects could be sufficiently mitigated such that they are not expected to cause a residual adverse effect. As described in Section 7.3.2.7, Project Interactions and Mitigations, the pathways analysis assigned each potential effect as:

- no pathway (i.e., mitigation results in no effect on noise);
- secondary pathway (i.e., mitigation results in a negligible effect on noise); or
- primary pathway (i.e., effect that is greater than negligible and carried forward for further assessment).

The pathway analysis for noise is summarized in Table 7.3-8. The subsections following the table provide the rationale used to assign potential effects to the no pathway and secondary pathway categories and list primary pathways. Each Project interaction identified as a primary pathway was carried forward for detailed assessment in Section 7.3.5. Effects pathways apply to all Project phases unless otherwise noted.

The environmental design features and mitigations in Table 7.3-8 represent the list of key actions used to inform the pathway analysis as part of preparing the EIS. In addition to this list of key actions, NexGen would implement the Environmental Protection Program, which would describe the processes required to monitor and characterize noise emissions from Project facilities and activities. This program would be used to periodically evaluate mitigation performance and identify additional mitigation, where required, and prompt potential adaptive management measures (Section 7.3.8, Monitoring, Follow-Up, and Adaptive Management). Where relevant, adaptive management measures may also be proposed to address uncertainties associated with effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

Potential accidents and malfunctions that have the capability to influence biophysical or human environments are discussed in Section 21, Accidents and Malfunctions.

Table 7.3-8: Potential Effects Pathways for Noise

Pathway ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
N-01	Project components/activities that contribute to noise emissions during **Construction and Operations**: ▪ land clearing, site preparation, and construction of facilities and infrastructure ▪ underground shaft and mine development ▪ power generation plant ▪ power plant and underground operations ▪ additional infrastructure (e.g., camp, maintenance shop, and offices) ▪ site traffic ▪ transportation of personnel and materials to and from the site ▪ on-site airstrip ▪ explosive blasting[a]	**Noise during Construction and Operations:** ▪ Noise emissions from Project equipment and activities would increase noise levels during Construction and Operations	▪ **Enclose or dampen equipment in process buildings** where the total sound power level is expected to be more than approximately 80 dBA, where feasible ▪ **Outfit internal combustion engines with muffler systems** ▪ **Install noise dampening structures** in power plant generator facilities; install silencers in surface and underground large vent fans ▪ **Maintain roads to minimize ruts** and consequently reduce noise emissions from vehicles ▪ Implement Project-specific **Health and Safety Program**	Primary pathway
N-02	Project components/activities that contribute to noise emissions during **Closure**: ▪ removal of infrastructure ▪ restoration and revegetation of facilities and infrastructure ▪ power generation plant ▪ additional infrastructure (e.g., camp, maintenance shop, and offices) ▪ camp ▪ site traffic ▪ transportation of personnel and material to and from the site ▪ on-site airstrip	**Noise during Closure:** ▪ Noise emissions from Project equipment and activities would increase noise levels during Closure	▪ **Enclose or dampen equipment in process buildings** where the total sound power level is expected to be more than approximately 80 dBA, where feasible ▪ Outfit internal **combustion engines with muffler systems** ▪ **Install noise dampening structures** in power plant generator facilities; install silencers in surface and underground large vent fans ▪ **Maintain roads to minimize ruts** and consequently reduce noise emissions from vehicles ▪ Implement Project-specific **Health and Safety Program**	Primary pathway

Bolded text represents the key topic of the environmental design features and mitigation.
a) Potential effects from explosive blasting are addressed within TSD X, Vibration Effects Analysis Report.
dBA = A-weighted decibel.

7.3.4.1 No Pathways

There were no Project-environment interactions that result in no effects pathways for noise.

7.3.4.2 Secondary Pathways

There were no Project-environment interactions that result in secondary pathways for noise.

7.3.4.3 Primary Pathways

The following Project interaction is predicted to be a primary pathway affecting noise (Table 7.3-8) and was carried forward for further assessment in the residual effects analysis (Section 7.3.5):

N-01 and N-02: Noise during Construction, Operations and Closure:

- Noise emissions from Project equipment and activities would increase noise levels during Construction and Operations.
- Noise emissions from Project equipment and activities would increase noise levels during Closure.

Indigenous Groups have expressed concerns about Project-related noise affecting their peaceful enjoyment on the land, potentially displacing traditional land use activities in the Patterson Lake area. The CRDN, BNDN, and BRDN have reported they have already experienced increases in noise associated with previous developments, which has disrupted areas that community members previously experienced as peaceful and quiet. They are concerned that Project-related noise disturbance would further affect their enjoyment on the land, sense of place, and connection to their traditional lands (TSD II: BNDN; TSD III: BRDN; TSD V.1: CRDN; TSD V.2: CRDN; CRDN 2019b). For example, during the time the Cluff Lake Mine was in operation in the 1980s and 1990s, CRDN community members began to hunt, fish and camp in areas away from the mine because of high noise levels, and because there were “quieter and nicer places” to be (CRDN 2019b). The CRDN are concerned about the effects of noise and light from Project facilities on both sides of Patterson Lake and community members’ ability to connect with the area, particularly if they choose to bring their children to the area in the future (CRDN-JWG 2020b).

Concerns were also expressed by Indigenous Groups and LPA community members about noise disturbance from Project activities affecting wildlife populations, including from increased traffic, which may lead to decreased hunting and trapping opportunities (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; TSD VI: YNLR; NexGen 2019). For example, a member of the Ya’thi Néné Lands and Resources stated:

> Noise, no animals. This will affect his way of trapping because of the loud noise, and vehicle traffic and that’s how the fur bearing animals will disappear. (TSD VI: YNLR)

These comments and concerns regarding noise emphasize the importance of conducting assessments of the potential effects of the Project during Construction, Operations, and Closure, and potential cumulative effects from the Project and RFDs. These assessments are provided in Section 7.3.5.1, Application Case and Section 7.3.5.2, Reasonably Foreseeable Development Case, respectively.

7.3.5 Residual Effects Analysis

7.3.5.1 Application Case

Existing noise levels in the LSA and RSA vary based on time of day and local conditions. Existing noise levels are generally greater during the daytime period (i.e., 07:00 to 22:00) than during the nighttime period (i.e., 22:00 to 07:00) and are generally greater near waterbodies than in forested areas. The maximum existing noise level measured during the baseline field study was 42 dBA (Table 7.3-6); this maximum level was measured during the daytime period in a rocky area on the south shore of Patterson Lake (Noise 2). The minimum existing noise level measured during the baseline field study was 21 dBA (Section 7.3.3, Table 7.3-6); this minimum level was measured during the nighttime period in a forested area (Noise 3).

During Construction and Operations, the following activities and equipment would increase noise levels in the study areas:

- Dozers, graders, excavators, and other types of large mobile equipment would be used for various tasks.
- Electricity would be produced by generators, and electrical voltage would be adjusted using transformers.
- Fans, compressors, and pumps would be used to control the flow of air, water, and other fluids.
- Workers and supplies would be transported to and from the Project site using trucks, buses, and aircraft.
- Cranes and hoists would be used to lift construction materials, ore, and other loads.
- Conveyors would be used to move ore and waste around the Project site.

Computer models were used to predict noise levels resulting from the proposed Project Construction and Operations (Section 7.3.2.8, Residual Effects Analysis). Project activities during the Active Closure Stage of Decommissioning and Reclamation are expected to be similar with less intensity (i.e., magnitude) relative to Construction. For example, equipment would be used to dismantle buildings and decommission site roads and pads, but there would be no to little land clearing required and major earthworks would be substantially reduced. Therefore, computer models of Project Construction were used as a conservative surrogate when assessing Project Closure, and Project Closure was not modelled separately.

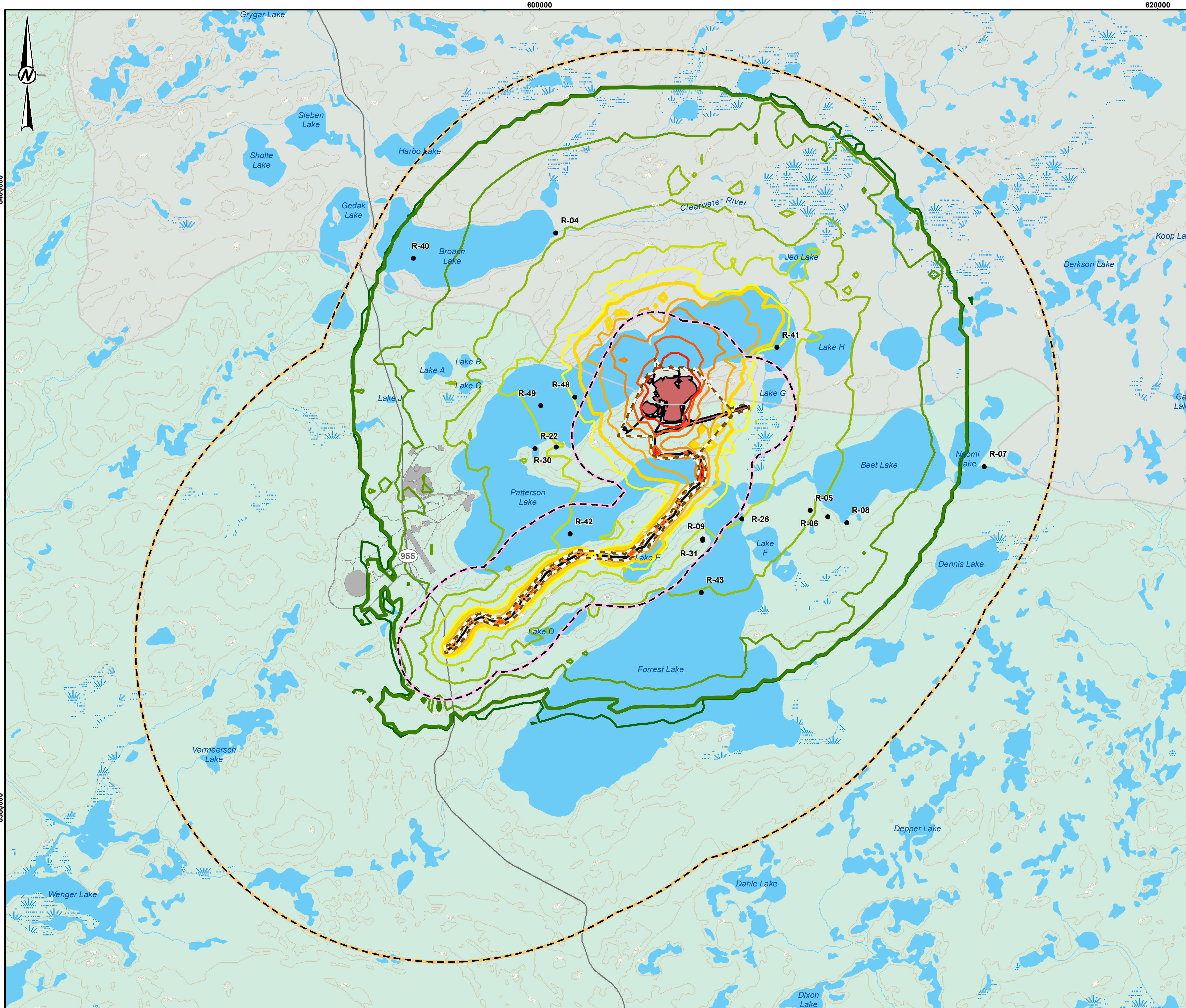
Figure 7.3-5 presents a map showing predicted Project noise level contours for the temporal snapshot during Construction. Figure 7.3-6 presents a map showing predicted Project noise level contours for the temporal snapshot during Operations. Activities during Construction and Operations would occur continuously 24 hours per day, so the noise level contours in Figure 7.3-5 and Figure 7.3-6 represent both $L_{eq,day}$ and $L_{eq,night}$ values. Both Figure 7.3-5 and Figure 7.3-6 show incremental Project noise level predictions in isolation from other sources (i.e., existing noise levels have not been included in these figures).

The noise level contours presented in Figure 7.3-5 (Construction) show that:

- Noise during Construction is predicted to attenuate to 42 dBA (i.e., the maximum existing noise level) within 2.1 km of the maximum disturbance area.
- Noise during Construction is predicted to attenuate to 21 dBA (i.e., the minimum existing noise level) within 9.2 km of the maximum disturbance area.

The noise level contours presented in Figure 7.3-6 (Operations) show that:

- Noise during Operations is predicted to attenuate to 42 dBA (i.e., the maximum existing noise level) within 2.2 km of the maximum disturbance area.
- Noise during Operations is predicted to attenuate to 21 dBA (i.e., the minimum existing noise level) within 9.2 km of the maximum disturbance area.



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- NOISE RECEPTORS
- NOISE LOCAL STUDY AREA
- NOISE REGIONAL STUDY AREA

PREDICTED PROJECT NOISE LEVEL [dBA]

- 20
- 21 (MINIMUM EXISTING NOISE LEVEL)
- 25
- 30
- 35
- 40
- 42 (MAXIMUM EXISTING NOISE LEVEL)
- 45
- 50
- 55
- 60

0 4 8

1:126,000 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).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

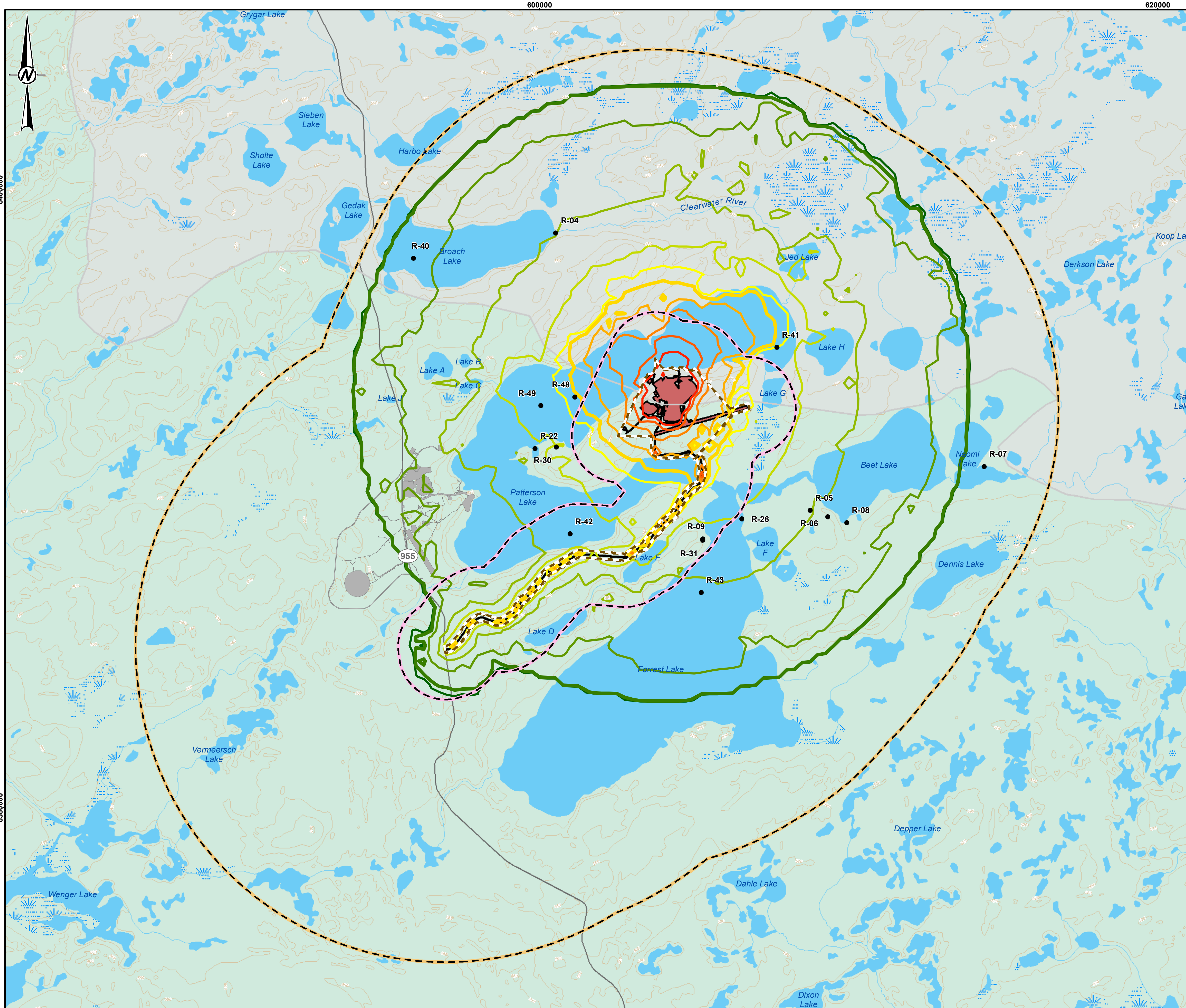
TITLE

ROOK I PROJECT CONSTRUCTION NOISE LEVELS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3102 - 3
DESIGN	VY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-27		
CHECK	VY	2023-02-27	FIGURE 7.3-5	
REVIEW	AF	2023-02-27		



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- NOISE RECEPTORS
- NOISE LOCAL STUDY AREA
- NOISE REGIONAL STUDY AREA

PREDICTED PROJECT NOISE LEVEL [dBA]

- 20
- 21 (MINIMUM EXISTING NOISE LEVEL)
- 25
- 30
- 35
- 40
- 42 (MAXIMUM EXISTING NOISE LEVEL)
- 45
- 50
- 55
- 60

0 4 8

1:126,000 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).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

ROOK I PROJECT OPERATIONS NOISE LEVELS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3102 - 3
DESIGN	VY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-27	FIGURE 7.3-6	
CHECK	VY	2023-02-27		
REVIEW	AF	2023-02-27		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Table 7.3-9 presents predicted Construction noise levels for each receptor in the LSA and RSA. Project noise levels are predicted to range from a minimum of 14 dBA at receptor R-07 to a maximum of 41 dBA at receptor R-48. Noise levels during Project Closure are expected to be less than Construction noise levels presented in Table 7.3-9.

Table 7.3-10 presents predicated cumulative noise levels from existing conditions and activities during Construction. Application Case cumulative noise levels are predicted to range from a minimum of 26 dBA at receptor R-07 during the nighttime period, which represents an increase of 0 dBA relative to existing conditions, to a maximum of 45 dBA at receptor R-48 during the daytime period, which represents an increase of 3 dBA relative to the maximum measured noise under existing conditions.

Table 7.3-9: Predicted Noise Levels from Rook I Project Construction for the Application Case

Noise Receptor	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-04 (cabin)	29	29	47	47	35
R-05 (lodge)	31	31	52	52	37
R-06 (old cabin)	29	29	51	51	35
R-07 (cabin)	14	14	38	38	20
R-08 (tourist camp)	27	27	46	46	33
R-09 (tourist camp)	35	35	56	56	41
R-22 (fishing nets)	33	33	50	50	39
R-26 (plane crash)	35	35	56	56	41
R-30 (historical camp)	34	34	51	51	40
R-31 (rough camp)	35	35	56	56	41
R-40 (fishing)	24	24	43	43	30
R-41 (fishing)	39	39	54	54	45
R-42 (fishing)	37	37	57	57	43
R-43 (fishing)	30	30	49	49	36
R-48 (fishing)	41	41	55	55	47
R-49 (fishing)	36	36	53	53	42

$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel.

Table 7.3-10: Predicted Cumulative Noise Levels from Existing Conditions and Rook I Project Construction for the Application Case

Noise Receptor	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-04 (cabin)	33	30	48	47	37
R-05 (lodge)	34	31	52	52	38
R-06 (old cabin)	33	30	51	51	37
R-07 (cabin)	30	26	48	40	33
R-08 (tourist camp)	32	30	50	46	37
R-09 (tourist camp)	36	35	56	56	42
R-22 (fishing nets)	43	40	51	51	47
R-26 (plane crash)	36	35	56	56	42
R-30 (historical camp)	35	34	51	51	41
R-31 (rough camp)	36	35	56	56	42
R-40 (fishing)	31	28	48	44	35
R-41 (fishing)	44	42	55	54	49

Table 7.3-10: Predicted Cumulative Noise Levels from Existing Conditions and Rook I Project Construction for the Application Case

Noise Receptor	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-42 (fishing)	43	41	57	57	48
R-43 (fishing)	42	40	51	50	47
R-48 (fishing)	45	43	56	55	50
R-49 (fishing)	43	41	54	53	48

$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel.

Table 7.3-11 presents predicted noise levels during Operations for each receptor in the LSA and RSA. Project noise levels are predicted to range from a minimum of 7 dBA at receptor R-07 to a maximum of 41 dBA at receptor R-48.

Table 7.3-12 presents predicted cumulative noise levels from existing conditions and activities during Operations. Application Case cumulative noise levels are predicted to range from a minimum of 26 dBA at receptor R-07 during the nighttime period, which represents an increase of 0 dBA relative to existing conditions, to a maximum of 45 dBA at receptor R-48 during the daytime period, which represents an increase of 3 dBA relative to the maximum measured noise under existing conditions.

Table 7.3-11: Predicted Noise Levels from Rook I Project Operations for the Application Case

Noise Receptor	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-04 (cabin)	30	30	48	48	36
R-05 (lodge)	30	30	49	49	36
R-06 (old cabin)	29	29	48	48	35
R-07 (cabin)	7	7	30	30	13
R-08 (tourist camp)	27	27	46	46	33
R-09 (tourist camp)	34	34	52	52	40
R-22 (fishing nets)	33	33	50	50	39
R-26 (plane crash)	34	34	52	52	40
R-30 (historical camp)	34	34	51	51	40
R-31 (rough camp)	34	34	52	52	40
R-40 (fishing)	24	24	44	44	30
R-41 (fishing)	40	40	55	55	46
R-42 (fishing)	33	33	52	52	39
R-43 (fishing)	29	29	48	48	35
R-48 (fishing)	41	41	56	56	47
R-49 (fishing)	37	37	55	55	43

$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel.

Table 7.3-12: Predicted Cumulative Noise Levels from Existing Conditions and Rook I Project Operations for the Application Case

Noise Receptor	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-04 (cabin)	33	31	49	48	38
R-05 (lodge)	33	31	50	49	38
R-06 (old cabin)	33	30	49	48	37
R-07 (cabin)	30	26	47	37	33
R-08 (tourist camp)	32	30	50	46	37
R-09 (tourist camp)	35	34	52	52	41
R-22 (fishing nets)	43	40	51	51	47
R-26 (plane crash)	35	34	52	52	41
R-30 (historical camp)	35	34	51	51	41
R-31 (rough camp)	35	34	52	52	41
R-40 (fishing)	31	28	49	45	35
R-41 (fishing)	44	43	56	55	50
R-42 (fishing)	43	40	53	52	47
R-43 (fishing)	42	39	50	49	46
R-48 (fishing)	45	43	56	56	50
R-49 (fishing)	43	41	56	55	48

$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel.

Environment and Climate Change Canada Analysis

Table 7.3-13 compares Project Construction and Operations noise level predictions to thresholds from ECCC guidance (Environment Canada 2009). The results presented in Table 7.3-13 show that noise levels from Project activities during Construction and Operations are predicted to comply with ECCC thresholds for all 16 receptors in the LSA and RSA. The margin of compliance (i.e., the difference between the Project noise level and the ECCC threshold) is predicted to range from a minimum of 4 dBA at receptor R-48 during the nighttime period to a maximum of 48 dBA at receptor R-07 during the daytime period.

Table 7.3-13: Environment and Climate Change Canada Noise Analysis for the Application Case

Noise Receptor	ECCC Noise Threshold[(a)] (dBA)		Predicted Project Construction Noise Level (dBA)		Predicted Project Operations Noise Level (dBA)	
	Daytime	Nighttime	Daytime ($L_{eq,day}$)	Nighttime ($L_{eq,night}$)	Daytime ($L_{eq,day}$)	Nighttime ($L_{eq,night}$)
R-04 (cabin)	55	45	29	29	30	30
R-05 (lodge)	55	45	31	31	30	30
R-06 (old cabin)	55	45	29	29	29	29
R-07 (cabin)	55	45	14	14	7	7
R-08 (tourist camp)	55	45	27	27	27	27
R-09 (tourist camp)	55	45	35	35	34	34
R-22 (fishing nets)	55	45	33	33	33	33
R-26 (plane crash)	55	45	35	35	34	34
R-30 (historical camp)	55	45	34	34	34	34
R-31 (rough camp)	55	45	35	35	34	34
R-40 (fishing)	55	45	24	24	24	24
R-41 (fishing)	55	45	39	39	40	40

Table 7.3-13: Environment and Climate Change Canada Noise Analysis for the Application Case

Noise Receptor	ECCC Noise Threshold[a] (dBA)		Predicted Project Construction Noise Level (dBA)		Predicted Project Operations Noise Level (dBA)	
	Daytime	Nighttime	Daytime ($L_{eq,day}$)	Nighttime ($L_{eq,night}$)	Daytime ($L_{eq,day}$)	Nighttime ($L_{eq,night}$)
R-42 (fishing)	55	45	37	37	33	33
R-43 (fishing)	55	45	30	30	29	29
R-48 (fishing)	55	45	41	41	41	41
R-49 (fishing)	55	45	36	36	37	37

a) Source: Environment Canada 2009.
$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; dBA = A-weighted decibel; ECCC = Environment and Climate Change Canada.

Health Canada High Annoyance Analysis

Table 7.3-14 presents %HA values calculated based on L_{dn} values under existing conditions (Table 7.3-7), as well as the %HA values based on the Application Case cumulative L_{dn} values during Construction (Table 7.3-9) and Operations (Table 7.3-12). For both Construction and Operations, Table 7.3-14 also presents the Project-related changes in %HA and compares these changes to the 6.5% threshold value from Health Canada guidance. The results presented in Table 7.3-14 show that Project-related changes in %HA are predicted to comply with the Health Canada threshold for all 16 receptors in the LSA and RSA. The margin of compliance (i.e., the difference between the Project-related change in %HA and the 6.5% Health Canada threshold) is predicted to range from a minimum of 3.5% at receptors R-41 and R-48 to a maximum of 6.5% at receptors R-07 and R-43.

Table 7.3-14: Health Canada High Annoyance Analysis for the Application Case

Noise Receptor	Percent Highly Annoyed (%HA)			Health Canada %HA Threshold[a]	Project-Related Change in %HA	
	Existing Noise	Cumulative Noise during Project Construction	Cumulative Noise during Project Operations		Construction	Operations
R-04 (cabin)	0.6	1.5	1.7	6.5	0.9	1.1
R-05 (lodge)	0.6	1.7	1.7	6.5	1.1	1.1
R-06 (old cabin)	0.6	1.5	1.5	6.5	0.9	0.9
R-07 (cabin)	0.9	0.9	0.9	6.5	0.0	0.0
R-08 (tourist camp)	0.9	1.5	1.5	6.5	0.6	0.6
R-09 (tourist camp)	0.6	2.8	2.5	6.5	2.2	1.9
R-22 (fishing nets)	4.7	5.3	5.3	6.5	0.6	0.6
R-26 (plane crash)	0.6	2.8	2.5	6.5	2.2	1.9
R-30 (historical camp)	0.6	2.5	2.5	6.5	1.9	1.9
R-31 (rough camp)	0.6	2.8	2.5	6.5	2.2	1.9
R-40 (fishing)	0.9	1.1	1.1	6.5	0.2	0.2
R-41 (fishing)	4.7	6.8	7.7	6.5	2.1	3.0
R-42 (fishing)	4.7	6.0	5.3	6.5	1.3	0.6
R-43 (fishing)	4.7	5.3	4.7	6.5	0.6	0.0
R-48 (fishing)	4.7	7.7	7.7	6.5	3.0	3.0
R-49 (fishing)	4.7	6.0	6.0	6.5	1.3	1.3

a) Source: Health Canada 2017.
%HA = percentage of a typical population that would be highly annoyed by a given noise level.

Health Canada Sleep Disturbance Analysis

Table 7.3-15 compares cumulative noise level predictions during Construction and Operations to the continuous noise sleep disturbance threshold from Health Canada (2017). The results presented in Table 7.3-15 show that cumulative noise levels during Construction and Operations are predicted to comply with the 40 dBA Health Canada sleep disturbance threshold for each of the eight receptor locations in the LSA and RSA where people may sleep (e.g., cabins, camps). The margin of compliance (i.e., the difference between the Application Case cumulative noise level and the Health Canada threshold) is predicted to range from a minimum of 5 dBA at receptors R-09 and R-31 to a maximum of 14 dBA at receptor R-07.

Table 7.3-15: Health Canada Sleep Disturbance Analysis – Continuous Noise for the Application Case

Noise Receptor	Health Canada Sleep Disturbance Threshold – Continuous Noise[a] (dBA)	Predicted Cumulative Noise Level during Project Construction (dBA)	Predicted Cumulative Noise Level during Project Operations (dBA)
	Nighttime[b]	Nighttime ($L_{eq,night}$)	Nighttime ($L_{eq,night}$)
R-04 (cabin)	40	30	31
R-05 (lodge)	40	31	31
R-06 (old cabin)	40	30	30
R-07 (cabin)	40	26	26
R-08 (tourist camp)	40	30	30
R-09 (tourist camp)	40	35	34
R-22 (fishing nets)	n/a[c]	40	40
R-26 (plane crash)	n/a[c]	35	34
R-30 (historical camp)	40	34	34
R-31 (rough camp)	40	35	34
R-40 (fishing)	n/a[c]	28	28
R-41 (fishing)	n/a[c]	42	43
R-42 (fishing)	n/a[c]	41	40
R-43 (fishing)	n/a[c]	40	39
R-48 (fishing)	n/a[c]	43	43
R-49 (fishing)	n/a[c]	41	41

Grey shading indicates threshold does not apply at this noise receptor.
a) Source: Health Canada 2017.
b) The sleep disturbance threshold only applies during the nighttime period.
c) The sleep disturbance threshold only applies at receptors where people may sleep.
$L_{eq,night}$ = energy equivalent sound level for the nighttime period; dBA = A-weighted decibel; n/a = not applicable.

Table 7.3-16 presents an analysis of sleep disturbance associated with noise from the proposed Project airstrip. For Construction and Operations, L_{max} noise levels (i.e., the maximum noise level expected during aircraft takeoff and landing activities) are presented with the number of times during a typical nighttime period that L_{max} noise levels are predicted to exceed Health Canada sleep disturbance thresholds. Table 7.3-16 presents L_{max} values for all 16 receptors within the LSA and RSA, but only presents Health Canada exceedance values for the eight receptors where sleep disturbance thresholds were applicable (i.e., the eight receptor locations where people may sleep). The results presented in Table 7.3-16 show that L_{max} noise levels associated with the Project airstrip are predicted to comply with Health Canada guidance for intermittent noise at each of the eight receptor locations in the LSA and RSA where people may sleep. At each of these receptors, L_{max} values are predicted to exceed the sleep disturbance thresholds of 45 dBA and 60 dBA fewer than 10 times per nighttime period.

Table 7.3-16: Health Canada Sleep Disturbance Analysis – Intermittent Noise for the Application Case

Noise Receptor	Predicted L_{max} from Project Airstrip (dBA)		Number of L_{max} Exceedances of Health Canada Sleep Disturbance Thresholds during Typical Nighttime[a]			
	Construction	Operations	Construction		Operations	
			45 dBA[b]	60 dBA[c]	45 dBA[b]	60 dBA[c]
R-04 (cabin)	≤40	≤40	0	0	0	0
R-05 (lodge)	46	46	0	0	0	0
R-06 (old cabin)	44	43	0	0	0	0
R-07 (cabin)	42	42	0	0	0	0
R-08 (tourist camp)	42	42	0	0	0	0
R-09 (tourist camp)	49	49	0	0	0	0
R-22 (fishing nets)	71	71	n/a[d]	n/a[d]	n/a[d]	n/a[d]
R-26 (plane crash)	49	49	n/a[d]	n/a[d]	n/a[d]	n/a[d]
R-30 (historical camp)	73	73	3	1	2	1
R-31 (rough camp)	49	49	0	0	0	0
R-40 (fishing)	≤40	≤40	n/a[d]	n/a[d]	n/a[d]	n/a[d]
R-41 (fishing)	54	54	n/a[d]	n/a[d]	n/a[d]	n/a[d]
R-42 (fishing)	59	59	n/a[d]	n/a[d]	n/a[d]	n/a[d]
R-43 (fishing)	44	44	n/a[d]	n/a[d]	n/a[d]	n/a[d]
R-48 (fishing)	65	64	n/a[d]	n/a[d]	n/a[d]	n/a[d]
R-49 (fishing)	62	62	n/a[d]	n/a[d]	n/a[d]	n/a[d]

Grey shading indicates threshold does not apply at this noise receptor.
a) Source: Health Canada 2017.
b) The L_{max} threshold of 45 dBA applies in cases where people sleep in tents or other structures with very low transmission loss values.
c) The L_{max} threshold of 60 dBA applies in cases where people sleep in a building with partially open windows.
d) Health Canada sleep disturbance thresholds do not apply at this receptor since people do not sleep at this location.
L_{max} = maximum sound level; dBA = A-weighted decibel; ≤ = less than or equal to; n/a = not applicable.

Alberta Energy Regulator Low Frequency Noise Analysis

Table 7.3-17 presents an analysis of LFN from continuous noise sources associated with Construction and Operations. The LFN analysis was primarily based on the first part of a two-part test from AER Directive 038 (AER 2007), which considers the difference between noise levels expressed in dBC and dBA. A difference between dBA and dBC noise levels greater than 20 indicates a potential LFN issue (AER 2007). The second part of the LFN test, which focused on tonal components, cannot be applied to results from predictive noise models and so was only applied to the measured existing noise levels (Table 7.3-6). The second part of the LFN test compares noise levels in adjacent one-third octave spectral bands between 20 Hz and 250 Hz. A low frequency tone is present if the noise level in one of these spectral bands is 10 dBA or more than the noise level in at least one of the adjacent bands within two one-third octave bandwidths and there is a minimum 5 dBA drop within two one-third octave bandwidths on the other side (AER 2007).

The results presented in Table 7.3-17 indicate that the difference between Application Case cumulative noise levels expressed in dBA and dBC is predicted to be greater than or equal to 20 at five receptors (i.e., R-05, R-06, R-09, R-26, and R-31) during Construction. However, the difference between cumulative noise levels expressed in dBA and dBC is predicted to be less than 20 at all 16 receptors during Operations.

At receptors R-05, R-06, R-09, R-26, and R-31, there is a potential LFN effect during Construction based on the first part of the two-part test from AER Directive 038. However, because there are no clear tonal components in the existing noise levels at these receptors (Table 7.3-6), and because there is no reason to expect clear tonal components in the noise emissions from Project equipment (i.e., modern industrial equipment is designed to avoid tonal noise emissions), it is unlikely that LFN effects would be present at these receptors. The absence of clear tonal components in Project noise emissions can be confirmed as part of monitoring and follow-up activities (Section 7.3.8, Monitoring, Follow-Up and Adaptive Management). Furthermore, the LFN test from AER Directive 038 is only applicable to noise from Operations (AER 2007); application of the LFN test to noise from Construction is provided for information purposes and does not affect residual effects classification.

Table 7.3-17: Alberta Energy Regulator Low Frequency Noise Analysis for the Application Case

Noise Receptor	Difference between Predicted Cumulative Noise Levels in dBC and dBA				LFN Threshold[a]	Comment on Clear Tonal Components
	Construction		Operations			
	Daytime	Nighttime	Daytime	Nighttime		
R-04 (cabin)	15	17	16	17	20	No tone in existing noise
R-05 (lodge)	18	**21**	17	18		
R-06 (old cabin)	18	**21**	16	18		
R-07 (cabin)	18	14	17	11		
R-08 (tourist camp)	18	16	18	16		
R-09 (tourist camp)	**20**	**21**	17	18		
R-22 (fishing nets)	8	11	8	11		
R-26 (plane crash)	**20**	**21**	17	18		
R-30 (historical camp)	16	17	16	17		
R-31 (rough camp)	**20**	**21**	17	18		
R-40 (fishing)	17	16	18	17		
R-41 (fishing)	11	12	12	12		
R-42 (fishing)	14	16	10	12		
R-43 (fishing)	9	10	8	10		
R-48 (fishing)	11	12	11	13		
R-49 (fishing)	11	12	13	14		

Bold font used to identify differences that exceed LFN threshold.
a) Source: AER 2007.
dBA = A-weighted decibel; dBC = C-weighted decibel; LFN = low frequency noise.

Project equipment and activities would increase $L_{eq,day}$, $L_{eq,night}$, L_{dn}, and L_{max} noise levels during the four years of Construction, 24 years of Operations, and five years of the Active Closure Stage. Noise levels are expected to be continuous throughout these phases then return to existing conditions during the Transitional Monitoring Stage (i.e., duration of noise effects is reversible after 33 years). The increase in noise levels from the Project is certain and would be confined to the RSA. Increased noise levels are predicted to be detectable relative to existing conditions but remain compliant with thresholds outlined in ECCC, Health Canada, and AER guidance documents (Environment Canada 2009; Health Canada 2017; AER 2007).

Findings suggest that the Project would result in measurable changes to existing noise levels in the noise LSA and RSA; however, Project noise levels are predicted to comply with thresholds set out in ECCC, Health Canada, and AER guidance documents. While noise levels are measured to confirm that health and safety noise exceedances do not occur for workers or other receptors such as Indigenous and other land and resource users, noise can have a qualitative effect on the aesthetics of resource use. For a discussion on the residual effects of noise in the Application Case on Indigenous land and resource users and other resource users refer to Section 16.5.1.3.1, Noise and Section 17.5.1.2, Quality of the Resource Use Experience, respectively.

7.3.5.2 Reasonably Foreseeable Development Case

The proposed Fission Patterson Lake South Property is the only RFD with the potential to influence cumulative noise levels at receptors in the RSA (Section 7.3.2.5, Assessment Cases). Noise-emitting activities during construction and operations of the Fission Patterson Lake South Property are expected to be similar to noise-emitting activities during the Project Construction and Operations (Section 7.3.5.1).

Computer models were used to predict incremental and cumulative noise levels resulting from construction and operations activities at the Fission Patterson Lake South Property and the proposed Project (Section 7.3.2.8). Figure 7.3-7 presents a map showing predicted Fission Patterson Lake South Property noise level contours during the most intense period of construction. Figure 7.3-8 presents a map showing predicted Fission Patterson Lake South Property noise level contours during full-scale operations. The noise level contours in Figure 7.3-7 and Figure 7.3-8 represent both $L_{eq,day}$ and $L_{eq,night}$ values in isolation from other sources (i.e., existing noise levels and the noise contribution from the Project have not been included in these figures).

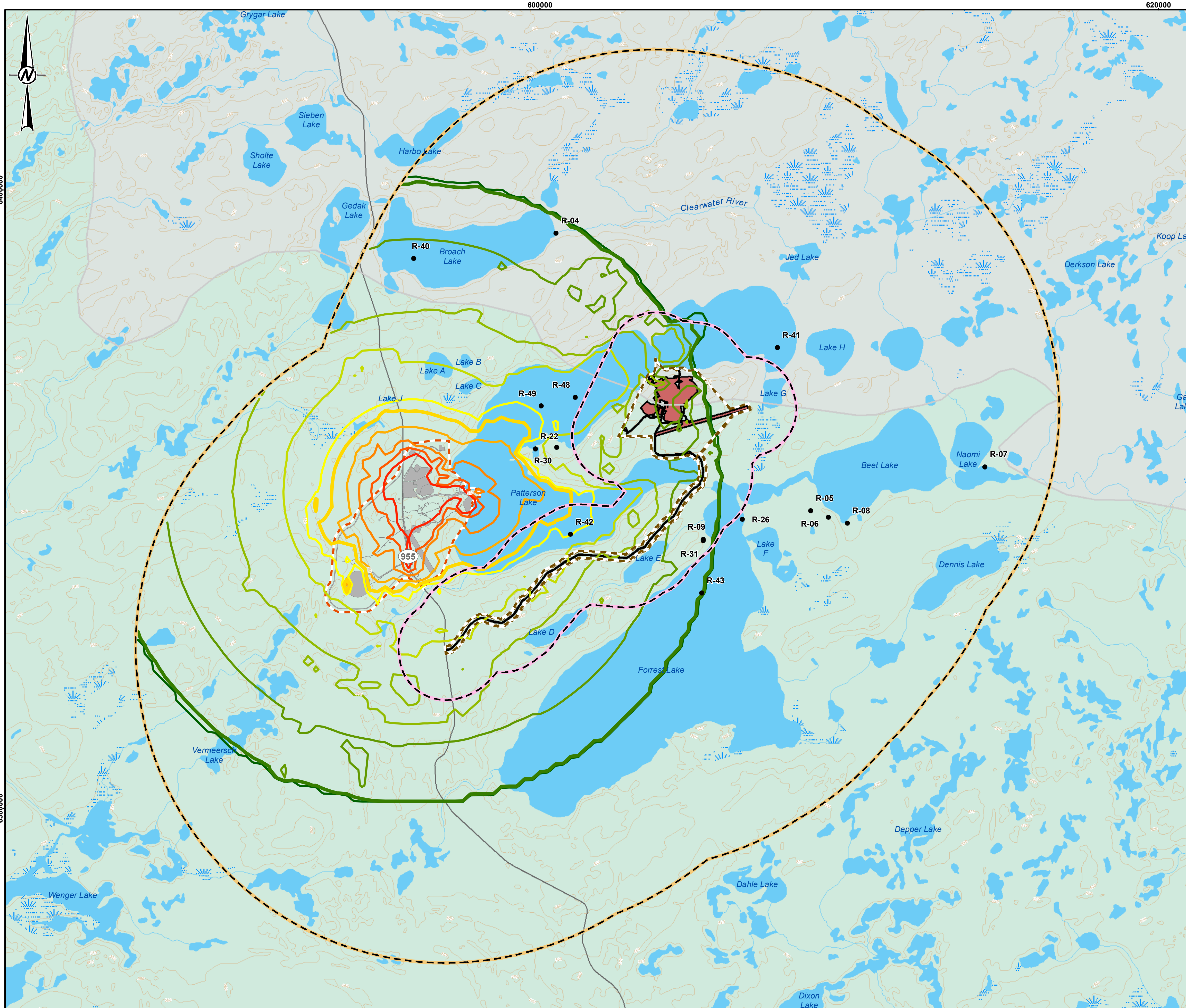
The noise level contours presented in Figure 7.3-7 (Construction) show that:

- noise from construction of the Fission Patterson Lake South Property is predicted to attenuate to 42 dBA (i.e., the maximum existing noise level) within 2 km of the hypothetical maximum disturbance area; and
- noise from construction of the Fission Patterson Lake South Property is predicted to attenuate to 21 dBA (i.e., the minimum existing noise level) within 9.5 km of the hypothetical maximum disturbance area.

The noise level contours presented in Figure 7.3-8 (Operations) show that:

- noise from operation of the Fission Patterson Lake South Property is predicted to attenuate to 42 dBA (i.e., the maximum existing noise level) within 2.1 km of the hypothetical maximum disturbance area; and
- noise from operation of the Fission Patterson Lake South Property is predicted to attenuate to 21 dBA (i.e., the minimum existing noise level) within 8.8 km of the hypothetical maximum disturbance area.

Figure 7.3-9 presents a map showing predicted noise levels from the Project Construction in combination with full-scale operations at the Fission Patterson Lake South Property. Noise contours from other combinations of activities at the two facilities (i.e., Project Construction plus Fission Patterson Lake South Property construction, Project Operations plus Fission Patterson Lake South Property construction, and Project Operations plus Fission Patterson Lake South Property operations) would be similar.



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- NOISE RECEPTORS
- NOISE LOCAL STUDY AREA
- NOISE REGIONAL STUDY AREA

PREDICTED NOISE LEVEL FROM FISSION PATTERSON LAKE SOUTH PROPERTY [dBA]

- 20
- 21 (MINIMUM EXISTING NOISE LEVEL)
- 25
- 30
- 35
- 40
- 42 (MAXIMUM EXISTING NOISE LEVEL)
- 45
- 50
- 55
- 60

0 4 8
1:126,000 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).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
FISSION PATTERSON LAKE SOUTH PROPERTY CONSTRUCTION NOISE LEVELS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3102 - 3
DESIGN	VY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-27	FIGURE 7.3-7	
CHECK	VY	2023-02-27		
REVIEW	AF	2023-02-27		

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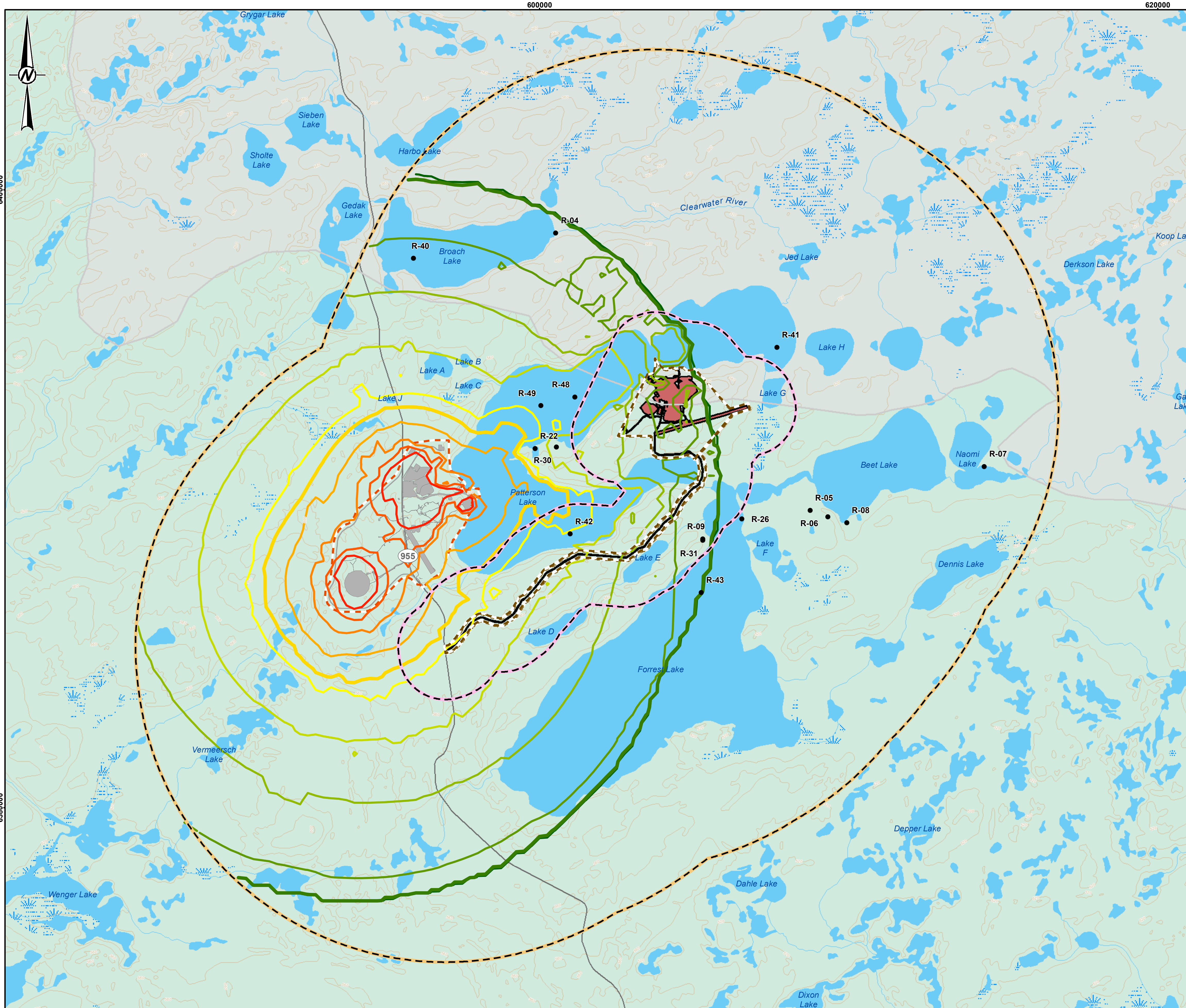

LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- NOISE RECEPTORS
- NOISE LOCAL STUDY
- NOISE REGIONAL STUDY

PREDICTED NOISE LEVEL FROM FISSION PATTERSON LAKE SOUTH PROPERTY [dBA]

- 20
- 21 (MINIMUM EXISTING NOISE LEVEL)
- 25
- 30
- 35
- 40
- 42 (MAXIMUM EXISTING NOISE LEVEL)
- 45
- 50
- 55
- 60

0 4 8

1:126,000 KILOMETRES

REFERENCE(S)

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2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. ECOZONES OBTAINED FROM AGRICULTURE AND AGRI-FOOD CANADA (AAFC).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

FISSION PATTERSON LAKE SOUTH PROPERTY OPERATIONS NOISE LEVELS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3102 - 3
DESIGN	VY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-27	**FIGURE 7.3-8**	
CHECK	VY	2023-02-27		
REVIEW	AF	2023-02-27		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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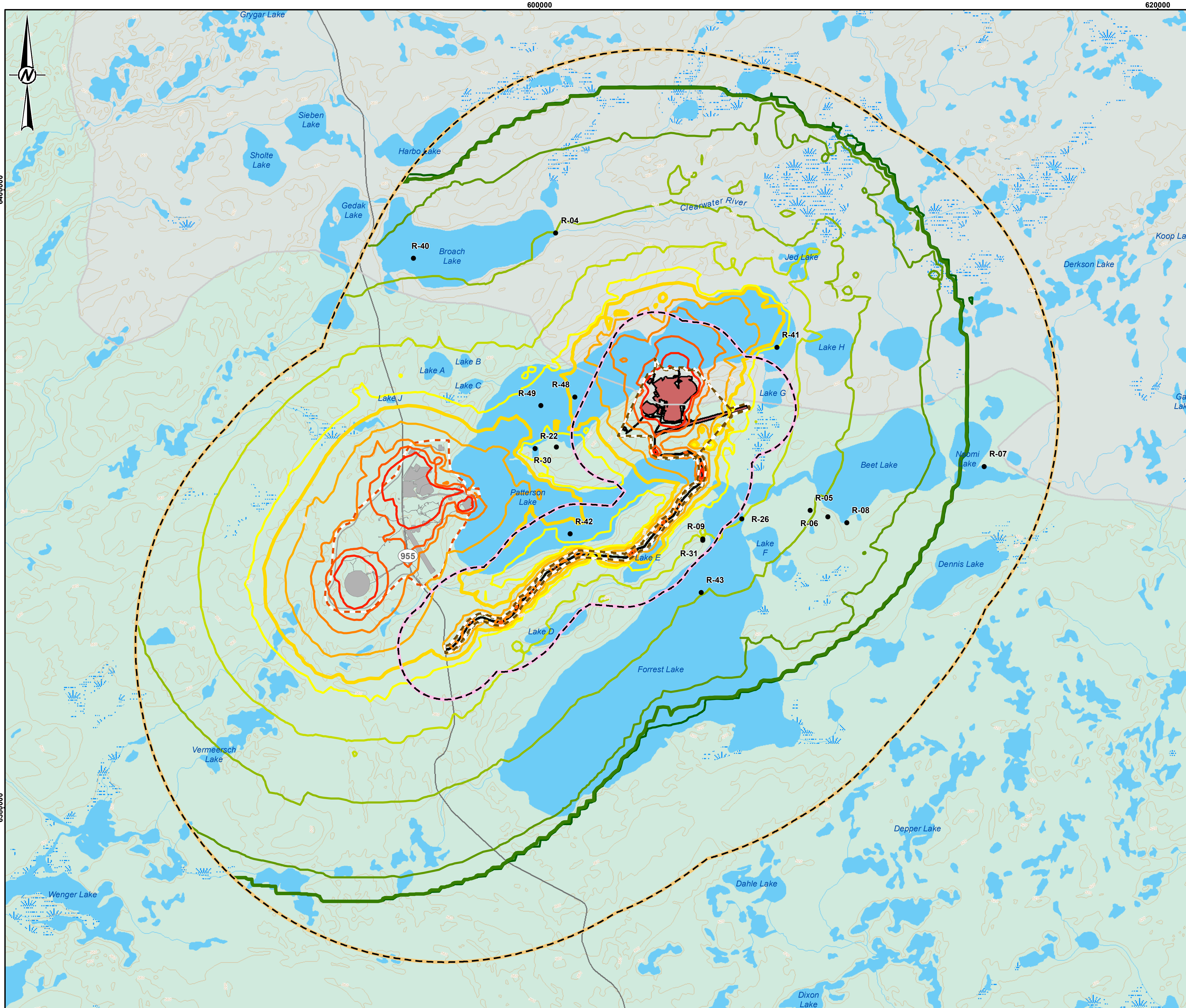

LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- ATHABASCA BASIN
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- NOISE RECEPTORS
- NOISE LOCAL STUDY AREA
- NOISE REGIONAL STUDY AREA

PREDICTED NOISE LEVEL FROM PROJECT CONSTRUCTION IN COMBINATION WITH FISSION PATTERSON LAKE SOUTH PROPERTY OPERATIONS [dBA]

- 20
- 21 (MINIMUM EXISTING NOISE LEVEL)
- 25
- 30
- 35
- 40
- 42 (MAXIMUM EXISTING NOISE LEVEL)
- 45
- 50
- 55
- 60

0 4 8

1:126,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021.
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3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

COMBINED NOISE LEVELS FROM PROJECT CONSTRUCTION AND FISSION PATTERSON LAKE SOUTH PROPERTY OPERATIONS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3102 - 3
DESIGN	VY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-27	**FIGURE 7.3-9**	
CHECK	VY	2023-02-27		
REVIEW	AF	2023-02-27		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

For each receptor in the RSA, Table 7.3-18 presents predicted Fission Patterson Lake South Property noise levels during the most intense period of construction and Table 7.3-19 presents predicted Fission Patterson Lake South Property noise levels during full-scale operations; these noise levels were predicted using ISO 9613-2 computer models. Fission Patterson Lake South Property noise levels are predicted to range from a minimum that is too small to be meaningfully quantified at receptors R-05, R-06, R-07, R-08, and R-41 to a maximum of 40 dBA at receptor R-42.

Table 7.3-20 presents predicted cumulative noise levels from existing conditions, Project Construction, and maximum Fission Patterson Lake South Property noise levels during construction and full-scale operations (i.e., maximum value for each receptor from Table 7.3-18 and Table 7.3-19). Table 7.3-21 presents predicted cumulative noise levels from existing conditions, Project Operations, and maximum Fission Patterson Lake South Property noise levels during construction and full-scale operations (i.e., maximum value for each receptor from Table 7.3-18 and Table 7.3-19). Cumulative noise levels during the RFD Case are predicted to range from a minimum of 26 dBA at receptor R-07 during the nighttime period, which represents an increase of 0 dBA relative to existing conditions, to a maximum of 45 dBA at receptors R-42, R-48, and R-49 during the daytime period, which represents an increase of 3 dBA relative to existing conditions.

Table 7.3-18: Predicted Noise Levels from Fission Patterson Lake South Property Construction for the Reasonably Foreseeable Development Case

Noise Receptor	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-04 (cabin)	22	22	42	42	28
R-05 (lodge)	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]
R-06 (old cabin)	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]
R-07 (cabin)	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]
R-08 (tourist camp)	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]
R-09 (tourist camp)	23	23	43	43	29
R-22 (fishing nets)	36	36	51	51	42
R-26 (plane crash)	14	14	32	32	20
R-30 (historical camp)	33	33	49	49	39
R-31 (rough camp)	23	23	43	43	29
R-40 (fishing)	26	26	45	45	32
R-41 (fishing)	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]	n/c[(a)]
R-42 (fishing)	40	40	56	56	46
R-43 (fishing)	22	22	42	42	28
R-48 (fishing)	38	38	55	55	44
R-49 (fishing)	39	39	55	55	45

a) Noise level too small to be meaningfully quantified.
$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel; n/c = not calculated.

Table 7.3-19: Predicted Noise Levels from Fission Patterson Lake South Property Operations for the Reasonably Foreseeable Development Case

Noise Receptor	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-04 (cabin)	22	22	42	42	28
R-05 (lodge)	n/c[a]	n/c[a]	n/c[a]	n/c[a]	n/c[a]
R-06 (old cabin)	n/c[a]	n/c[a]	n/c[a]	n/c[a]	n/c[a]
R-07 (cabin)	n/c[a]	n/c[a]	n/c[a]	n/c[a]	n/c[a]
R-08 (tourist camp)	n/c[a]	n/c[a]	n/c[a]	n/c[a]	n/c[a]
R-09 (tourist camp)	23	23	42	42	29
R-22 (fishing nets)	36	36	51	51	42
R-26 (plane crash)	11	11	31	31	17
R-30 (historical camp)	34	34	50	50	40
R-31 (rough camp)	23	23	42	42	29
R-40 (fishing)	26	26	45	45	32
R-41 (fishing)	n/c[a]	n/c[a]	n/c[a]	n/c[a]	n/c[a]
R-42 (fishing)	40	40	56	56	46
R-43 (fishing)	22	22	42	42	28
R-48 (fishing)	38	38	56	56	44
R-49 (fishing)	39	39	56	56	45

a) Noise level too small to be meaningfully quantified.
$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel; n/c = not calculated.

Table 7.3-20: Predicted Cumulative Noise Levels for the Reasonably Foreseeable Development Case (Project Construction)

Noise Receptor	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-04 (cabin)	33	30	49	48	37
R-05 (lodge)	34	31	52	52	38
R-06 (old cabin)	33	30	51	51	37
R-07 (cabin)	30	26	48	40	33
R-08 (tourist camp)	32	30	50	46	37
R-09 (tourist camp)	36	35	56	56	42
R-22 (fishing nets)	43	41	54	54	48
R-26 (plane crash)	36	35	56	56	42
R-30 (historical camp)	38	37	54	54	44
R-31 (rough camp)	36	35	56	56	42
R-40 (fishing)	32	30	50	47	37
R-41 (fishing)	44	42	55	54	49
R-42 (fishing)	45	44	60	60	51
R-43 (fishing)	42	40	51	50	47
R-48 (fishing)	45	44	59	59	51
R-49 (fishing)	44	43	58	58	50

$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel.

Table 7.3-21: Predicted Cumulative Noise Levels the Reasonably Foreseeable Development Case (Project Operations)

Noise Receptor	$L_{eq,day}$ (dBA)	$L_{eq,night}$ (dBA)	$L_{eq,day}$ (dBC)	$L_{eq,night}$ (dBC)	L_{dn} (dBA)
R-04 (cabin)	33	31	50	49	38
R-05 (lodge)	33	31	50	49	38
R-06 (old cabin)	33	30	49	48	37
R-07 (cabin)	30	26	47	37	33
R-08 (tourist camp)	32	30	50	46	37
R-09 (tourist camp)	36	35	53	53	42
R-22 (fishing nets)	43	41	54	54	48
R-26 (plane crash)	35	34	52	52	41
R-30 (historical camp)	38	37	54	54	44
R-31 (rough camp)	36	35	53	53	42
R-40 (fishing)	32	30	50	48	37
R-41 (fishing)	44	43	56	55	50
R-42 (fishing)	44	43	58	58	50
R-43 (fishing)	42	39	51	50	46
R-48 (fishing)	45	44	59	59	51
R-49 (fishing)	45	43	59	59	50

$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; dBA = A-weighted decibel; dBC = C-weighted decibel; RFD = reasonably foreseeable development.

Environment and Climate Change Canada Analysis

Table 7.3-22 compares noise level predictions for the Fission Patterson Lake South Property in combination with Project Construction to thresholds from ECCC guidance (Environment Canada 2009). Table 7.3-22 also compares noise level predictions for the Fission Patterson Lake South Property in combination with Project Operations to thresholds from ECCC guidance (Environment Canada 2009). The results show that noise levels from the Fission Patterson Lake South Property in combination with either Project Construction or Operations activities are predicted to comply with ECCC thresholds for all 16 receptors in the RSA. The margin of compliance (i.e., the difference between the combined noise level and the ECCC threshold) is predicted to range from a minimum of 2 dBA at receptor R-48 during the nighttime period to a maximum of 48 dBA at receptor R-07 during the daytime period.

Table 7.3-22: Environment and Climate Change Canada Noise Analysis for the Reasonably Foreseeable Development Case

Noise Receptor	ECCC Noise Threshold[a] (dBA)		Predicted Noise Level: Fission Patterson Lake South Property Plus Project Activities (dBA)			
			Project Construction[b]		Project Operations[c]	
	Daytime	Nighttime	Daytime ($L_{eq,day}$)	Nighttime ($L_{eq,night}$)	Daytime ($L_{eq,day}$)	Nighttime ($L_{eq,night}$)
R-04 (cabin)	55	45	30	30	31	31
R-05 (lodge)	55	45	31	31	30	30
R-06 (old cabin)	55	45	29	29	29	29
R-07 (cabin)	55	45	14	14	7	7
R-08 (tourist camp)	55	45	27	27	27	27
R-09 (tourist camp)	55	45	35	35	34	34
R-22 (fishing nets)	55	45	38	38	38	38
R-26 (plane crash)	55	45	35	35	34	34
R-30 (historical camp)	55	45	37	37	37	37
R-31 (rough camp)	55	45	35	35	34	34
R-40 (fishing)	55	45	28	28	28	28
R-41 (fishing)	55	45	39	39	40	40
R-42 (fishing)	55	45	42	42	41	41
R-43 (fishing)	55	45	31	31	30	30
R-48 (fishing)	55	45	43	43	43	43
R-49 (fishing)	55	45	41	41	41	41

a) Source: Environment Canada 2009.
b) These values obtained by summing predicted noise levels from the Fission Patterson Lake South Property (Table 7.3-18 or Table 7.3-19) with predicted noise levels from Project Construction (Table 7.3-9).
c) These values obtained by summing predicted noise levels from the Fission Patterson Lake South Property (Table 7.3-18 or Table 7.3-19) with predicted noise levels from Project Operations (Table 7.3-11).
$L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; dBA = A-weighted decibel; ECCC = Environment and Climate Change Canada.

Health Canada High Annoyance Analysis

Table 7.3-23 presents %HA values (based on L_{dn} values) for existing conditions and the RFD Case during Project Construction (Table 7.3-20) and Project Operations (Table 7.3-21). All %HA values were calculated using formulae provided in Health Canada (2017) guidance. Table 7.3-23 also presents the change in %HA resulting from the cumulative increase in noise from the Fission Patterson Lake South Property and the Project and compares this change to the 6.5% threshold value from Health Canada guidance. The results show that changes in %HA for the RFD Case are predicted to comply with the Health Canada threshold for all 16 receptors in the RSA. The margin of compliance (i.e., the difference between the change in %HA and the 6.5% Health Canada threshold) is predicted to range from a minimum of 2.5% at receptors R-42 and R-48 to a maximum of 6.5% at receptors R-07 and R-43.

Table 7.3-23: Health Canada High Annoyance Analysis for the Reasonably Foreseeable Development Case

Noise Receptor	Percent Highly Annoyed (%HA)			Health Canada %HA Threshold(a)	Change in %HA	
	Existing Noise	RFD Case Cumulative Noise during Project Construction	RFD Case Cumulative Noise during Project Operations		RFD Case during Project Construction	RFD Case during Project Operations
R-04 (cabin)	0.6	1.5	1.7	6.5	0.9	1.1
R-05 (lodge)	0.6	1.7	1.7	6.5	1.1	1.1
R-06 (old cabin)	0.6	1.5	1.5	6.5	0.9	0.9
R-07 (cabin)	0.9	0.9	0.9	6.5	0.0	0.0
R-08 (tourist camp)	0.9	1.5	1.5	6.5	0.6	0.6
R-09 (tourist camp)	0.6	2.8	2.8	6.5	2.2	2.2
R-22 (fishing nets)	4.7	6.0	6.0	6.5	1.3	1.3
R-26 (plane crash)	0.6	2.8	2.5	6.5	2.2	1.9
R-30 (historical camp)	0.6	3.7	3.7	6.5	3.1	3.1
R-31 (rough camp)	0.6	2.8	2.8	6.5	2.2	2.2
R-40 (fishing)	0.9	1.5	1.5	6.5	0.6	0.6
R-41 (fishing)	4.7	6.8	7.7	6.5	2.1	3.0
R-42 (fishing)	4.7	8.7	7.7	6.5	4.0	3.0
R-43 (fishing)	4.7	5.3	4.7	6.5	0.6	0.0
R-48 (fishing)	4.7	8.7	8.7	6.5	4.0	4.0
R-49 (fishing)	4.7	7.7	7.7	6.5	3.0	3.0

a) Source: Health Canada 2017.
%HA = percentage of a typical population that would be highly annoyed by a given noise level; RFD = reasonably foreseeable development.

Health Canada Sleep Disturbance Analysis

Table 7.3-24 compares RFD Case cumulative noise level predictions during Project Construction and Operations to the continuous noise sleep disturbance threshold from Health Canada (2017). The results show that RFD Case cumulative noise levels are predicted to comply with the Health Canada sleep disturbance threshold for each of the eight receptors in the LSA / RSA where people may sleep. The margin of compliance (i.e., the difference between the RFD Case cumulative noise level and the Health Canada threshold) is predicted to range from a minimum of 3 dBA at receptor R-30 to a maximum of 14 dBA at receptor R-07.

Table 7.3-24: Sleep Disturbance Analysis – Continuous Noise for the Reasonably Foreseeable Development Case

Noise Receptor	Health Canada Sleep Disturbance Threshold – Continuous Noise[(a)] (dBA)	Predicted RFD Case Cumulative Noise Level during Project Construction (dBA)	Predicted RFD Case Cumulative Noise Level during Project Operations (dBA)
	Nighttime[(b)]	Nighttime ($L_{eq,night}$)	Nighttime ($L_{eq,night}$)
R-04 (cabin)	40	30	31
R-05 (lodge)	40	31	31
R-06 (old cabin)	40	30	30
R-07 (cabin)	40	26	26
R-08 (tourist camp)	40	30	30
R-09 (tourist camp)	40	35	35
R-22 (fishing nets)	n/a[(c)]	41	41
R-26 (plane crash)	n/a[(c)]	35	34
R-30 (historical camp)	40	37	37
R-31 (rough camp)	40	35	35
R-40 (fishing)	n/a[(c)]	30	30
R-41 (fishing)	n/a[(c)]	42	43
R-42 (fishing)	n/a[(c)]	44	43
R-43 (fishing)	n/a[(c)]	40	39
R-48 (fishing)	n/a[(c)]	44	44
R-49 (fishing)	n/a[(c)]	43	43

Grey shading indicates threshold does not apply at this noise receptor.
a) Source: Health Canada 2017.
b) The sleep disturbance threshold only applies during the nighttime period.
c) The sleep disturbance threshold only applies at receptors where people may sleep.
$L_{eq,night}$ = energy equivalent sound level for the nighttime period; dBA = A-weighted decibel; RFD = reasonably foreseeable development; n/a = not applicable.

Table 7.3-25 presents an analysis of sleep disturbance associated with noise from the Fission Patterson Lake South Property airstrip in combination with noise from the Project airstrip. Table 7.3-25 presents predicted L_{max} noise levels (i.e., the maximum noise level expected during aircraft takeoff and landing activities at either the Fission Patterson Lake South Property airstrip or the Project airstrip). Also presented are the number of times during a typical nighttime period that L_{max} noise levels are predicted to exceed Health Canada sleep disturbance thresholds as a result of takeoff and landing events at the Fission Patterson Lake South Property airstrip and the Project airstrip. Note the analysis is insensitive to the temporal overlap in take off and landing events; it considers the L_{max} noise level from each takeoff and landing as separate but potentially simultaneous events. Values for all 16 receptors within the RSA are provided, but Health Canada exceedance values are only presented for the eight receptors where sleep disturbance thresholds are applicable (i.e., the eight receptor locations where people may sleep).

The results show that L_{max} noise levels associated with the Fission Patterson Lake South Property airstrip and the Project airstrip are predicted to comply with Health Canada guidance for intermittent noise at each of the eight receptors in the RSA where people may sleep (Table 7.3-25). At each of these receptors, L_{max} values are predicted to exceed the sleep disturbance thresholds of 45 dBA and 60 dBA fewer than 10 times per nighttime period. The results presented for the Application Case (Table 7.3-16) and RFD Case (Table 7.3-25) are identical as the assumed aircraft and noise emissions are identical. Noise levels (L_{max}) associated with takeoff and landing events at the Project airstrip are greater than noise levels associated with takeoff and landing events at the Fission Patterson Lake South Property airstrip for each of the 16 receptors considered in the noise assessment.

Table 7.3-25: Sleep Disturbance Analysis – Intermittent Noise for the Reasonably Foreseeable Development Case

Noise Receptor	Predicted L_{max} from the Fission Patterson Lake South Property Airstrip and the Project Airstrip (dBA)		Number of L_{max} Exceedances of Health Canada Sleep Disturbance Thresholds during Typical Nighttime[(a)]			
	Construction	Operations	Construction		Operations	
			45 dBA[(b)]	60 dBA[(c)]	45 dBA[(b)]	60 dBA[(c)]
R-04 (cabin)	≤40	≤40	0	0	0	0
R-05 (lodge)	46	46	0	0	0	0
R-06 (old cabin)	44	43	0	0	0	0
R-07 (cabin)	42	42	0	0	0	0
R-08 (tourist camp)	42	42	0	0	0	0
R-09 (tourist camp)	49	49	0	0	0	0
R-22 (fishing nets)	71	71	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(d)]
R-26 (plane crash)	49	49	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(d)]
R-30 (historical camp)	73	73	3	1	2	1
R-31 (rough camp)	49	49	0	0	0	0
R-40 (fishing)	≤40	≤40	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(d)]
R-41 (fishing)	54	54	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(d)]
R-42 (fishing)	59	59	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(d)]
R-43 (fishing)	44	44	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(d)]
R-48 (fishing)	65	64	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(d)]
R-49 (fishing)	62	62	n/a[(d)]	n/a[(d)]	n/a[(d)]	n/a[(d)]

Grey shading indicates threshold does not apply at this noise receptor.
a) Source: Health Canada 2017.
b) The L_{max} threshold of 45 dBA applies in cases where people sleep in tents or other structures with very low transmission loss values.
c) The L_{max} threshold of 60 dBA applies in cases where people sleep in a building with partially open windows.
d) Health Canada sleep disturbance thresholds do not apply at this receptor since people do not sleep at this location.
L_{max} = maximum sound level; dBA = A-weighted decibel, ≤ = less than or equal to; n/a = not applicable.

Alberta Energy Regulator Low Frequency Noise Analysis

Table 7.3-26 presents an analysis of LFN for the RFD Case. The LFN analysis was primarily based on the first part of a two-part test from AER Directive 038 (AER 2007), which considered the difference between noise levels expressed in dBC and dBA. The second part of the LFN test, which focused on tonal components, cannot be applied to results from predictive noise models and so the second part of this test was only applied to the measured existing noise levels (Table 7.3-6).

The results indicate that the difference between RFD Case cumulative noise levels expressed in dBA and dBC is predicted to be greater than or equal to 20 at five receptors (i.e., R-05, R-06, R-09, R-26, and R-31) during

Construction of the Project (Table 7.3-26); these are the same five receptors at which the difference between dBA and dBC noise levels was predicted to be greater than or equal to 20 in the Application Case (Table 7.3-17). The difference between RFD Case cumulative noise levels expressed in dBA and dBC is predicted to be less than 20 at all 16 receptors during Operations of the Project; this result is consistent with the Application Case (Table 7.3-17).

Table 7.3-26: Low Frequency Noise Analysis for the Reasonably Foreseeable Development Case

Noise Receptor	Difference between RFD Case Cumulative Noise Levels in dBC and dBA				LFN Threshold[a]	Comment on Clear Tonal Components
	Construction		Operations			
	Daytime	Nighttime	Daytime	Nighttime		
R-04 (cabin)	16	18	17	18	20	No tone in existing noise
R-05 (lodge)	18	**21**	17	18		
R-06 (old cabin)	18	**21**	16	18		
R-07 (cabin)	18	14	17	11		
R-08 (tourist camp)	18	16	18	16		
R-09 (tourist camp)	**20**	**21**	17	18		
R-22 (fishing nets)	11	13	11	13		
R-26 (plane crash)	**20**	**21**	17	18		
R-30 (historical camp)	16	17	16	17		
R-31 (rough camp)	**20**	**21**	17	18		
R-40 (fishing)	18	17	18	18		
R-41 (fishing)	11	12	12	12		
R-42 (fishing)	15	16	14	15		
R-43 (fishing)	9	10	9	11		
R-48 (fishing)	14	15	14	15		
R-49 (fishing)	14	15	14	15		

Bold font used to identify differences that exceed LFN threshold.
a) Source: AER 2007.
dBA = A-weighted decibel; dBC = C-weighted decibel; RFD = reasonably foreseeable development; LFN = low frequency noise.

Equipment and activities associated with the Project and with the Fission Patterson Lake South Property would increase $L_{eq,day}$, $L_{eq,night}$, L_{dn}, and L_{max} noise levels for as long as these sites are active and overlap through time, but noise levels are expected to return to existing conditions once activities at the two projects cease. Cumulative effects from the two projects are likely but uncertain given that the Patterson Lake South Property has not received project approvals. Noise effects for the RFD Case are predicted to be negative, continuous, and reversible. Cumulative effects are expected to be confined to the RSA (i.e., within 10 km of the Project). Noise levels are predicted to be detectable relative to existing conditions but are predicted to remain compliant with thresholds set out in ECCC, Health Canada, and AER guidance documents (Environment Canada 2009; Health Canada 2017; AER 2007).

The duration of cumulative effects for the RFD Case would depend on the temporal overlap of noise-generating activities for the Project and the Fission Patterson Lake South Property (i.e., maximum effects from both projects). Noise effects from the proposed Project would occur during four years of Construction, 24 years of Operations, and the five years of Active Closure Stage (i.e., a total of 33 years). Noise effects from the Fission Patterson Lake South Property would occur during a hypothetical or projected three-year construction period, seven-year operating period (production and processing), and active decommissioning period

(Section 7.3.2.5, Assessment Cases). The anticipated start of construction and duration of active decommissioning at the Fission Patterson Lake South Property were not publicly available at the time this assessment was completed. For the assessment, it was assumed that active decommissioning of the Fission Patterson Lake South Property would have a duration similar to or less than that of the Active Closure Stage for the Project (i.e., 5 years; Section 7.3.2.5). The duration of noise effects for the Fission Patterson Lake South Property was therefore assumed to be 15 years. If noisy activities at the Fission Patterson Lake South Property completely overlap noisy activities associated with the Project, the duration of cumulative noise effects for the RFD Case would be a maximum of 15 years. A decrease in temporal overlap of the two projects would result in a shorter duration of cumulative noise effects. Once active decommissioning ends at either the Fission Patterson Lake South Property or the Project, the remaining noise effects would be limited to one project.

The residual effects of noise in the RFD case on Indigenous land and resource users and other resource users are assessed in Section 16.5.2.3.1, Noise and Section 17.5.2.2, Quality of the Resource Use Experience, respectively.

7.3.6 Residual Effects Classification

Residual effects have been classified for Construction and Operations as activities during these Project phases would be most intense relative to Closure. These residual effects are considered as part of the Application Case. Following the Active Closure Stage, noise emissions from Project activities during the Transitional Monitoring Stage are predicted to be similar to levels measured during existing conditions. Residual effects were also classified for the cumulative noise emissions from the Project and the Fission Patterson Lake South Property. These residual effects were considered as part of the RFD Case.

Residual effects from changes in noise levels for the Application Case and for the RFD Case are summarized in Table 7.3-27 according to direction, magnitude, geographic extent, duration/reversibility, frequency, and probability of occurrence, following the methods described in Section 7.3.2.8. Effective implementation of Project mitigation measures outlined in Section 7.3.4 (Table 7.3-8) is expected to reduce the magnitude of residual effects on receptors. It is also expected that the Fission Patterson Lake South Property would implement appropriate mitigation and adaptive management to avoid and minimize project-specific and cumulative effects.

Table 7.3-27: Classification of Residual Effects on Noise Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case

Measurement Indicator	Criterion	Rating / Effect Size	
		Application Case	RFD Case
Noise levels ($L_{eq,day}$, $L_{eq,night}$, L_{dn}, L_{max})	Direction	▪ Negative	▪ Negative
	Magnitude	▪ Low: changes would be detectable but comply with regulatory thresholds: o margin of compliance with ECCC thresholds: 4 dBA to 48 dBA o margin of compliance with Health Canada %HA threshold: 3.5% to 6.5% o margin of compliance with Health Canada sleep disturbance threshold: 5 dBA to 14 dBA	▪ Low: changes would be detectable but comply with regulatory thresholds: o margin of compliance with ECCC thresholds: 2 dBA to 48 dBA o margin of compliance with Health Canada %HA threshold: 2.5% to 6.5% o margin of compliance with Health Canada sleep disturbance threshold: 3 dBA to 14 dBA
	Geographic extent	▪ Regional: Project noise levels were predicted to attenuate to existing noise levels at distances between 2.1 km and 9.2 km of the maximum disturbance area for the Project	▪ Regional (i.e., within 10 km of the Project)
	Duration	▪ 33 years	▪ Maximum of 15 years, depending on extent of temporal overlap between the Project and the Fission Patterson Lake South Property
	Reversibility	▪ Reversible at the end of Active Closure Stage	▪ Reversible at the end of Active Closure Stage for the Project and/or active decommissioning for the Fission Patterson Lake South Property
	Frequency	▪ Continuous	▪ Continuous
	Probability of occurrence	▪ Certain	▪ Probable for period of temporal overlap between projects

RFD = reasonably foreseeable development; $L_{eq,day}$ = energy equivalent sound level for the daytime period; $L_{eq,night}$ = energy equivalent sound level for the nighttime period; L_{dn} = combined day-night sound level; L_{max} = maximum sound level; dBA = A-weighted decibel; dBC = C-weighted decibel; ECCC = Environment and Climate Change Canada; %HA = percent highly annoyed.

The residual effects classification for the effects of noise on Indigenous and other resource users in the Application Case and RFD Case are discussed in Section 16.6, Residual Effects Classification and Determination of Significance and Section 17.6, Residual Effects Classification and Determination of Significance, respectively.

7.3.7 Prediction Confidence and Uncertainty

Scientific inference is associated with uncertainty, and prediction confidence depends on the level of uncertainty and the way it is addressed. Primary factors affecting confidence in the predictions made in the noise assessment include:

- availability and accuracy of baseline data;
- availability and accuracy of Project design data;
- availability and accuracy of design data for the Fission Patterson Lake South Property;
- accuracy of noise emissions estimates for Project equipment;
- accuracy of noise emissions estimates for equipment at the Fission Patterson Lake South Property;
- selecting the location for noise receptors to reflect public interests and potential concerns;
- level of certainty associated with computer noise modelling, specifically the inability of computer noise modelling to provide high-resolution spectral information required to fully apply the LFN test from AER Directive 038 (AER 2007); and

- applying suitable noise thresholds to determine effects.

Uncertainty was managed by:

- collecting and processing baseline measurements in accordance with AER Directive 038 (AER 2007);
- reviewing Project design data (e.g., site plans, equipment lists, building drawings) to provide the most accurate and precise estimates from noise emission sources;
- reviewing best publicly available design data for the Fission Patterson Lake South Property (Fission 2019) to provide the most accurate and precise estimates from noise emission sources;
- assuming the potential for full temporal overlap of Project activities and activities at the Fission Patterson Lake South Property;
- estimating equipment noise emissions using vendor data, acoustics handbooks, measurements of comparable equipment, and professional experience (Appendix 7B);
- reviewing feedback from engagement and JWG meetings on noise receptor locations (Section 7.3.2.1, Incorporation of Indigenous and Local Knowledge);
- using established technical standards to develop computer noise models (ISO 1996; ECAC 2016); and
- using noise thresholds from credible regulatory bodies to analyze effects (Environment Canada 2009; Health Canada 2017; AER 2007).

Remaining uncertainty was primarily and appropriately addressed by making assumptions that conservatively overestimated rather than underestimated potential effects (i.e., a precautionary assessment). For example, computer noise models assume that each receptor is downwind from each noise source 100% of the time (Appendix 7B). Because downwind conditions enhance noise propagation, this assumption overestimates the magnitude of noise levels under typical or average environmental conditions.

7.3.8 Monitoring, Follow-Up, and Adaptive Management

Monitoring programs are proposed to be used to:

- verify environmental noise levels are consistent with (or less than) model predictions presented in the EIS and thereby confirm the noise emissions, propagation modelling, and other assumptions used in the EIS were reasonable and conservative;
- verify compliance with regulatory noise thresholds considered in the EIS (Environment Canada 2009; Health Canada 2017; AER 2007);
- confirm absence of clear tonal components in Project noise emissions (Section 7.3.5.1), or provide information to inform additional mitigation if necessary; and
- identify unanticipated negative effects.

Follow-up noise monitoring would be conducted in accordance with methods from AER Directive 038 (AER 2007) and would occur once during Construction and once during Operations. During the monitoring program, noise levels would be measured at a minimum of three terrestrial receptors for a period of not less than 24 hours using integrating sound level meters. Monitoring data would be post-processed to obtain representative $L_{eq,day}$, $L_{eq,night}$, and L_{dn} values for each receptor. Representative $L_{eq,day}$, $L_{eq,night}$, and L_{dn} values would be compared to model predictions from the EIS and to regulatory thresholds. If initial noise monitoring during Construction and Operations shows compliance with regulatory thresholds, then additional noise monitoring would not be required unless and until there are substantial changes to noise-emitting activities (e.g., addition of new equipment that was not modelled or assessed in the EIS).

In addition, Environmental Committees (i.e., one per primary Indigenous Group) composed of two NexGen and two Indigenous Group representatives would be established to act in an oversight manner to monitor the environmental performance of the Project and verify the parties are implementing the regulatory and environmental commitments made in respect of the Project.

Indigenous Groups have made recommendations related to mitigating the effects of the Project on the environment, including community-led long-term environmental testing and monitoring during Construction and Operations of the Project (TSD IV: MN-S; TSD V.2: CRDN; YNLRO 2019). NexGen has committed to provide funding for the lifespan of the Project for a full-time independent Indigenous Monitor chosen by each primary Indigenous Group; this Indigenous Monitor would have access to conduct environmental sampling for the Project, subject to the Indigenous Monitor complying with appropriate health and safety and other reasonable site-specific policies. The Indigenous Monitor would be able to report openly and without restriction to the Environmental Committee and Indigenous Group's community members on the performance of the Project. The Indigenous Monitor would also provide regular reports to the Environmental Committee.

7.3.9 Key Findings

Noise effects from the Project were assessed at receptors, which were located based on Indigenous and Local Knowledge and professional judgment. Noise levels were predicted using standardized and accepted models, approaches, and analytical techniques. Noise effects were assessed using guidance and thresholds from ECCC (Environment Canada 2009), Health Canada (2017), and the AER (2007). Noise levels were calculated, and effects were assessed for the Project (i.e., Application Case) and the Project in combination with the Fission Patterson Lake South Property (i.e., RFD Case).

Noise from the Project and from the Fission Patterson Lake South Property is predicted to result in detectable changes from existing conditions. However, cumulative noise levels are predicted to remain compliant with ECCC, Health Canada, and AER thresholds at all receptors considered in this assessment.

Increased noise levels could affect wildlife and Indigenous and other land and resource use. The noise assessment therefore provides information that is used to support the assessments of the following biophysical, cultural, and socio-economic VCs:

- wildlife and wildlife habitat (Section 14);
- heritage resources and Indigenous land and resource use (Section 16); and
- other land and resource use (Section 17).

7.4 Climate Change

7.4.1 Introduction

Section 7.4, Climate Change, of the Environmental Impact Statement (EIS) characterizes the potential residual effects of the Rook I Project (Project) on climate change, which is an attribute of the atmospheric environment. Climate change is a valued component (VC) for the Environmental Assessment (EA); the climate change VC considers the influence of Project greenhouse gas (GHG) emissions on climate change.

Climate change is defined as change in global or regional climate patterns, primarily attributed to increased atmospheric concentrations of GHGs (Government of Canada 2021b). Greenhouse gasses have the potential to affect future climate as they contribute to the greenhouse effect by absorbing infrared radiation in the atmosphere, increasing temperature, and changing weather patterns (Government of Canada 2015). Therefore, assessing GHGs is the most effective method for determining a project's effect on climate change. The Project would emit GHGs throughout all phases, with sources that produce carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). This assessment presents how these contributions may influence provincial and national GHG emissions levels. The climate change VC also estimates the GHG emissions intensity, which is defined as the amount of emissions divided by the pounds of uranium concentrate produced annually.

The Project would support lower carbon emission power generation through supplying uranium for use as fuel the nuclear reactors. Therefore, the downstream effects of the Project are likely to enhance Canada's ability to meet the national emission reduction targets (CNSC 2017). Additionally, the Project may accelerate Canada's transition to a low carbon economy by providing the country with the fuel needed from cleaner energy sources (i.e., nuclear power). This assessment for the climate change VC does not explicitly consider the benefits of the Project in contributing to a low-carbon economy and instead focuses on Project's contribution to the GHG emission levels. Additionally, the effects of a changing climate on the Project are assessed in Section 22, Assessment of Effects of the Environment on the Project. Appendix 6A, Climate Change Road Map, summarizes how climate change was considered in the discipline-specific effects assessments of the EIS (i.e., Section 7 through Section 19).

7.4.1.1 Purpose and Approach to the Assessment

The purpose of Section 7.4 is to provide a detailed and comprehensive assessment of all potential Project-specific effects and cumulative effects from the Project and other previous, existing, and reasonably foreseeable developments (RFDs), if applicable, on climate change. This subsection meets the Terms of Reference for the Project submitted to the Saskatchewan Ministry of Environment (ENV) and the Canadian Nuclear Safety Commission (CNSC) *Generic Guidelines for the Preparation of an Environmental Impact Statement – Pursuant to the Canadian Environmental Assessment Act, 2012* (Appendix 1A, Concordance Tables). The assessment of climate change followed the overall EA approach and methods (Section 6, Environmental Assessment Approach and Methods) and includes the following primary steps:

Step 1 – Define component-specific methods (Section 7.4.2): presents the specific approaches and methods used to measure and assess the effects of the Project on climate change as well as cumulative effects from the Project, other previous and existing projects and activities, and RFDs, if applicable.

Step 2 – Characterize existing conditions (Section 7.4.3): describes and characterizes existing conditions to provide both context and a basis for evaluating potential changes to climate caused by the Project.

Step 3 – Evaluate Project interactions and mitigations (Section 7.4.4): identifies Project components and/or activities with the potential to affect climate change and provides environmental design features and mitigation policies and actions committed to by NexGen to avoid or minimize potential adverse effects. A pathways analysis is used to focus further assessment on key interactions between the Project and climate change by evaluating the different effects pathways to determine if, after incorporation of mitigation, there is still potential to cause residual adverse effects. Primary pathways anticipated to result in residual adverse effects after incorporation of mitigation are carried forward to Step 4 for further analysis. Where potential adverse effects are adequately mitigated and thus not carried forward for further analysis (i.e., mitigation results in a negligible effect or avoids the pathway altogether), the reasons for concluding the assessment at this stage are provided.

Step 4 – Analyze residual effects (Section 7.4.5): evaluates and describes the potential Project effects on climate change that are anticipated to occur through the primary pathways; this evaluation is achieved through a comparison of GHG emission estimates to the existing conditions described by the current provincial and federal GHG emission levels. Comparisons are made to national Energy, Waste, and Industrial Processes and Product Use sectors, as defined in Environment and Climate Change Canada (ECCC; 2021). Comparisons are made only for additional context but not included in the evaluation directly, as provincial and federal GHG emissions levels include all sector-level emissions. The residual effects analysis is presented as an integrated narrative that describes the effects of the Project over time and highlights predicted effects at the point when adverse effects of the Project are expected to be greatest. The analysis of effects on climate change also implicitly considers the cumulative effects of historical, existing, and future projects (i.e., RFDs) through comparison to provincial and federal emissions levels.

Step 5 – Classify residual effects and determine significance (Section 7.4.6): summarizes the results of the residual effects analysis using effects criteria (i.e., direction, magnitude, geographic extent, duration, reversibility, frequency, and probability of occurrence). Significance is determined using the results of the residual effects analysis and classification. Significance is determined for adverse effects only and for the maximum adverse effects of the Project and the cumulative effects from the Project, other previous and existing projects and activities, and RFDs.

Step 6 – Describe uncertainty and define prediction confidence (Section 7.4.7): identifies key uncertainties and explains how these uncertainties have been addressed to achieve a conservative, precautionary assessment. The implications of the approaches used to address uncertainties and the level of confidence in the residual effects analysis are discussed.

Step 7 – Identify monitoring and follow-up (Section 7.4.8): outlines the proposed actions to verify predicted residual effects. The purpose of these actions is to evaluate effectiveness of planned mitigation designs, policies, and practices, and address key sources of uncertainty.

7.4.2 Component Methods

7.4.2.1 Incorporation of Indigenous and Local Knowledge

Indigenous and Local Knowledge included in the assessment of climate change was shared by potentially affected First Nations and Métis Groups (collectively referred to as Indigenous Groups) and local priority area (LPA)[4] community members through the Project engagement process. The overall approach and methods for the incorporation of Indigenous and Local Knowledge into the EA is discussed in detail in Section 3, Indigenous and Local Knowledge. Issues and concerns related to climate change raised by Indigenous Groups and LPA community members, and how these comments were addressed, are summarized in Appendix 2B, Summary of Issues and Concerns Identified by Indigenous Groups, and identified and addressed in this assessment, where applicable.

A key source of Indigenous and Local Knowledge is the Project-specific studies completed by Indigenous Groups, including Traditional Land Use and Occupancy studies, Traditional Knowledge and Use studies, and Indigenous Rights and Knowledge studies (henceforth referred to collectively as Indigenous Knowledge and

[4] The LPA consists of the local communities closest to the Project that would experience most of the Project effects and for which NexGen would prioritize local training, employment, and business opportunities for the Project. These communities are located along, or accessed via, Highways 155 and 955 north of the intersection of Highways 155 and 925.

Traditional Land Use [IKTLU] Studies). The IKTLU Studies that were reviewed and referenced in the EIS as technical support documents (TSDs) are listed below:

- TSD II (BNDN), Birch Narrows Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD III (BRDN), Buffalo River Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD IV (MN-S), Métis Nation – Saskatchewan Northern Region 2 Traditional Land Use & Diet Study for the NexGen Rook I Project;
- TSD V.1 (CRDN), Preliminary Identification of Issues and Concerns Related to the Proposed NexGen Energy Ltd. Rook I Project in the Patterson Lake Area; A Review; Clearwater River Dene Nation; Traditional Land Use and Occupancy Mapping Interviews; 2010 – 2016;
- TSD V.2 (CRDN), Clearwater River Dene Nation Indigenous Rights and Knowledge Survey related to the proposed NexGen Energy Ltd. Rook I Project in the Patterson Lake Area;
- TSD V.3 (CRDN), Socio-economic and Harvest Study; Clearwater River Dene Nation; NexGen Rook 1 Project; and
- TSD VI (YNLR), Provision of Athabasca Denesųłiné Traditional Knowledge, Land Use and Occupancy Information for the NexGen Rook I Project Environmental Assessment.

Another key source of Indigenous and Local Knowledge was information shared by Indigenous Group representatives during Joint Working Group (JWG) meetings. The JWGs represent an agreed-upon primary engagement mechanism as outlined in the Study Agreements signed by each Indigenous Group and NexGen. More details regarding the JWGs can be found in Section 2, Indigenous, Regulatory, and Public Engagement and Section 3, Indigenous and Local Knowledge. There are four JWGs with the Project's primary Indigenous Groups (Section 2.4.1, Identification of Indigenous Groups for Engagement):

- Clearwater River Dene Nation (CRDN) JWG;
- Métis Nation – Saskatchewan (MN-S) JWG representing MN-S Northern Region 2 (NR2);
- Birch Narrows Dene Nation (BNDN) JWG; and
- Buffalo River Dene Nation (BRDN) JWG.

The leadership of each Indigenous Group selected their JWG participants with consideration of group diversity; where possible, members included Elders, youth, different genders, a range of ages, and land users around Patterson Lake.

In addition to the IKTLU Studies and JWGs, Indigenous and Local Knowledge shared during specific engagement activities undertaken through the EA development process was incorporated into the assessment, where appropriate. These engagement activities included, but were not limited to:

- community information sessions held in four locations in 2019 (NexGen 2019);
- site tours;
- comments from the CRDN (2019a) on the Cluff Lake Mine licence renewal;
- other formal and informal meetings;
- workshops with specific groups (e.g., Fur Block N-19 trapper's workshop); and

- environmental and socio-economic baseline data collection.

Comments submitted by Indigenous Groups on the Project Description (CRDN 2019b; MN-S 2019; YNLRO 2019; ACFN 2019; CNSC 2019) were also reviewed for applicable Indigenous and Local Knowledge.

Indigenous and Local Knowledge related to climate change was incorporated into the assessment by viewing the information as complementary and influential alongside scientific information. Where possible, knowledge from each potentially affected Indigenous Group or LPA community member was described separately and cited accordingly. Where information is described for multiple potentially affected Indigenous Groups, they are collectively referred to as "Indigenous Groups" throughout the assessment.

Indigenous and Local Knowledge was included in the climate change assessment in the following ways:

- **Component Methods – Valued components:** Indigenous and Local Knowledge was considered in the selection of the VC of climate change and reflects its ecological and socio-economic/cultural value to Indigenous Groups. Indigenous Groups shared their observations and experiences of climate change, which certain individuals believe has affected their ability to practice traditional and cultural activities (Section 7.4.2.2.1).
- **Project Interactions and Mitigation:** Indigenous and Local Knowledge helped to inform the scoping of Project interactions, pathway analysis, and consideration of mitigation measures (Section 7.4.4). This includes observations and experiences of land users related to the cumulative effects of reduced air quality and climate related effects in the region from industry, including mining activities.
- **Monitoring, Follow-Up, and Management:** Feedback provided by Indigenous Groups during engagement, including recommendations, was considered in the development of monitoring and follow-up activities (Section 7.4.8). In addition, it is planned that ongoing feedback from Indigenous Groups on the effectiveness of mitigations would be considered when updating monitoring and management plans. Independent Indigenous Monitors chosen by each primary Indigenous Group would have opportunities to participate in environmental monitoring programs for the proposed Project.

Specific references to Indigenous and Local Knowledge, and Project comments and concerns related to climate change raised by Indigenous Groups and LPA community members, are included in the applicable subsections of this assessment.

7.4.2.2 Valued Components, Measurement Indicators, and Assessment Endpoints

7.4.2.2.1 Valued Components

Valued components are aspects of the biophysical, cultural, and socio-economic environments that are considered to have scientific, social, cultural, economic, historical, archaeological, or aesthetic importance (Beanlands and Duinker 1983; CNSC 2021). The BNDN and BRDN define VCs as tangible biophysical resources (e.g., particular places and species) and less tangible social, economic, cultural, health, and knowledge-based values (e.g., social cohesion, place names, Indigenous language; TSD II: BNDN; TSD III: BRDN).

Valued components were identified using many factors (Section 6.3.1, Valued Components) such as:

- potential for interaction with the Project and degree of interaction, including presence, abundance, and amount of spatial overlap of a VC with the Project;
- sensitivity of a VC to potential Project effects and level of damage or harm that could be realized should an adverse effect occur;
- ecological and socio-economic/cultural value to Indigenous Groups and local communities, government agencies, and the public;
- recent experience with similar projects in Saskatchewan and other jurisdictions in Canada; and
- avoidance of redundancy with other VCs; for example, if two potential VCs represent the same issues, mitigation actions, and potential effects from the Project, only one was evaluated as part of the assessment.

Selection of the climate change VC was based on the potential of Project GHG emissions to contribute to climate change, the socio-economic and cultural importance of climate change, and the international, federal, and provincial commitments to decrease GHG emissions (Table 7.4-1). Canada is a signatory to the Paris Agreement, which is an international agreement to strengthen the global response to the threat of climate change, building on the United Nations Framework Convention on Climate Change (United Nations 2015). The Paris Agreement established a collective long-term goal to hold the increase in the global average temperature to below 2°C above pre-industrialized levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrialized levels, through a commitment to reduce GHG emissions (United Nations 2015). The Paris Agreement also established a global goal of enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change.

The effects of climate change reflect both ecological and cultural importance for Indigenous Groups. Many Indigenous land users have been experiencing changes in climate and adapting to its effects for years. For example, caribou is considered the lifeblood of the Athabasca Denesųłiné, and they follow the annual migration patterns of the barren-ground caribou throughout their range, which "fluctuates due to natural cycles, and effects due to climate changes, forest fires, development, and other reasons" (TSD VI: YNLR).

According to the CRDN, winter temperatures are "considerably and noticeably warmer now than in the past" (TSD V.2: CRDN). Members of the CRDN have reported that "forest fires are more frequent and tend to be bigger and burn hotter than in earlier times", an observation that was echoed by members of the BNDN (TSD II: BNDN; TSD V.1: CRDN; TSD V.2: CRDN).

Some Indigenous Group members have commented that the effects of climate change have affected their ability to practice traditional and cultural activities. For example, BNDN hunters and harvesters have experienced "shifts in ecology, weather, and natural cycles" which has affected "the ability of BNDN members to hunt and trap at preferred times and in preferred locations" (TSD II: BNDN). The MN-S and BRDN have commented on the effects of climate change on the land and resources in general (TSD III: BRDN; TSD IV: MN-S), and the BRDN noted that climate change has potentially affected waterfowl populations:

> Even here we used to get lots of ducks and they've dwindled down to from 100 to a handful and that's a big decrease, which I notice because back when I used to go hunting for ducks on the prairie I'd be gone . . . [for] half [an] hour and get my five, six ducks and be back. And now I'll be gone walking around all day. So . . . I see a big difference in climate change . . . (TSD III: BRDN)

These comments raised by members of Indigenous Groups reflect the importance of assessing climate change as a VC within the EA.

7.4.2.2.2 Measurement Indicators

Measurement indicators are used to characterize changes to attributes of the environment from the Project, other human developments, and natural factors. The changes in measurement indicators are used to predict overall effects on VCs and assessment endpoints (Section 6.3.2, Assessment Endpoints and Measurement Indicators). The significance of effects from the Project on climate change is evaluated by linking changes in measurement indicators to effects on the assessment endpoints for climate change (Table 7.4-1).

Three measurement indicators were identified and used for the climate change assessment (Table 7.4-1):

- **GHG emissions of CO_2**: the quantity of CO_2 expressed in carbon dioxide equivalent (CO_2e) reflects federal and provincial commitments to GHG emissions and climate change. Emissions of CO_2 are expressed on an annual basis in tonnes of CO_2e per year (t CO_2e/yr) or kilotonnes of CO_2e per year (kt CO_2e/yr).
- **GHG emissions of CH_4**: the quantity of CH_4 expressed in CO_2e reflects federal and provincial commitments to GHG emissions and climate change. Emissions of CH_4 are expressed on an annual basis in t CO_2e/yr or kt CO_2e/yr.
- **GHG emissions of N_2O**: the quantity of N_2O expressed in CO_2e reflects federal and provincial commitments to GHG emissions and climate change. Emissions of N_2O are expressed on an annual basis in t CO_2e/yr or kt CO_2e/yr.

Additional GHGs were screened as measurement indicators for the Project. The Project is not expected to have sources that produce perfluorocarbons, hydrofluorocarbons, or sulphur hexafluoride (e.g., refrigerants). Although electrical equipment would likely contain sulphur hexafluoride for insulation, this gas would be contained in a sealed system and would not be released to the atmosphere.

7.4.2.2.3 Assessment Endpoints

Assessment endpoints are qualitative expressions that represent the key properties of VCs that should be protected; as such, assessment endpoints incorporate the concept of sustainability and function as significance thresholds (Section 6.3.2). The assessment endpoints for climate change relate to the contribution of the Project to provincial and federal GHG emission totals and the ability of Canada to achieve commitments of reduced emissions. These endpoints have been selected for determination of significance, as GHG emissions from the Project could affect the provincial and federal GHG levels, as well as affect their commitments to manage these levels. The Government of Saskatchewan has set targets in the *Saskatchewan Growth Plan* (Government of Saskatchewan 2015b) to reduce GHG emissions from electricity generation by 40% by 2030 from 2005 levels. The Government of Canada set a 30% reduction in total GHG emissions below 2005 levels by 2030 and net-zero emissions by 2050 in the *Pan Canadian Framework on Clean Growth and Climate Change* (Government of Canada 2016). The 2030 reduction target has recently been revised to be a 40% to 45% reduction below 2005 levels (Prime Minister of Canada Justin Trudeau 2021).

Sectoral emissions have been considered only to provide context and have not been included as assessment endpoints for the determination of significance. The compilation and interpretation of the results from analyzing changes in measurement indicators provides lines of evidence that collectively facilitate a determination of whether the assessment endpoints are maintained or achieved (Section 6.3.2).

Table 7.4-1: Valued Component, Rationale, Measurement Indicators, and Assessment Endpoints

VC	Rationale	Measurement Indicators	Assessment Endpoints
Climate change	▪ GHG contribute to climate change ▪ Socio-economic/cultural importance ▪ Federal and provincial plans associated with GHG emissions reductions and climate change	▪ Project GHG emissions of CO_2 ▪ Project GHG emissions of CH_4 ▪ Project GHG emissions of N_2O	▪ Contribution of Project GHG emissions to the provincial and federal totals ▪ Continued ability for Canada to reach climate change commitments in the form of emission reduction targets

GHG = greenhouse gas; CH_4 = methane; CO_2 = carbon dioxide; N_2O = nitrous oxide; VC = valued component.

For the purposes of accounting and reporting, as defined by *The GHG Protocol: A Corporate Accounting and Reporting Standard* (WRI and WBCSD 2013), GHG emissions are typically classified as Scope 1, Scope 2, or Scope 3. These three scopes are generally defined as follows:

- **Scope 1: Direct GHG emissions:** Emissions occurring from sources that are owned or controlled by a proponent (e.g., generators, boilers, vehicles, process and fugitive emissions).
- **Scope 2: Indirect GHG emissions:** Emissions from the generation of purchased electricity, heating, and cooling consumed by the proponent.
- **Scope 3: Other indirect GHG emissions:** Emissions that are a consequence of a proponent's activities but occur from sources not financially or operationally controlled by that proponent (e.g., emissions from waste, the extraction and production of purchased materials, and business travel; ISO 2006).

The estimate of GHG emissions focused on the emissions directly linked to the proposed Project. These emissions are classified as Scope 1, direct GHG emissions (Appendix 7C, Greenhouse Gas Emissions Estimation Methodology Report). The inclusion of Scope 1 emissions is in accordance with the GHG assessment guidance developed by the CNSC (CNSC 2017).

There are no Scope 2 (i.e., indirect) emissions as a result the Project. All electricity, heating, and cooling would be generated on site, and the emissions are categorized as Scope 1 emissions.

Consistent with the federal GHG reporting program for individual projects, Scope 3 emissions have not been considered in this assessment (ECCC 2020a).

7.4.2.3 Spatial Boundaries

Spatial boundaries are not defined for this assessment, as GHG emissions are both regional and global by nature. Boundaries for GHG emissions correlate with the administrative inventory boundaries that currently apply to GHG emissions under the federal GHG policy, regulations, and legislation (ECCC 2020a,b).

7.4.2.4 Temporal Boundaries

The temporal scope of the assessment focuses on the 43-year period from initial Construction to the end of Decommissioning and Reclamation (i.e., Closure) as defined by the following Project phases (Section 6.4.2, Temporal Boundaries):

- **Construction Phase (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. The duration of Construction is expected to be four years.

- **Operations Phase (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. The duration of Operations is expected to be 24 years.
- **Decommissioning and Reclamation Phase (Closure):** includes two stages expected to occur over 15 years:
  - **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 and 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. The duration of the Active Closure Stage is expected to be five years.
  - **Transitional Monitoring Stage:** includes monitoring and reporting activities that occur post-Active Closure Stage that 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 back under Provincial management through the Institutional Control Program. The duration of the Transitional Monitoring Stage is nominally 10 years; however, NexGen acknowledges this duration would be dependent on the achievement of performance criteria.

The main sources of GHG emissions would occur from Project-related equipment and activities during Construction and Operations, including electricity generation, on-site mobile equipment, heating, land use change, stationary combustion, waste incineration, industrial processes, and explosives. Operations is anticipated to have the largest annual emissions and potential for the greatest change to GHG emissions due to the number and size of sources present. The GHG emissions were calculated annually for Construction and Operations.

The level of activities and associated GHG emissions during Closure is expected to be reduced relative to Construction and Operations. As a precautionary approach, GHG emissions calculated for Construction were conservatively applied to Closure for the assessment. The Active Closure Stage would include emissions from electricity generation, on-site mobile equipment, heating, land use change, stationary combustion, waste incineration, industrial processes, and explosives. Explosive and industrial process emissions are not expected to occur during Closure.

7.4.2.5 Assessment Cases

The concept of assessment cases was applied to the climate change assessment to estimate the incremental and cumulative effects from the Project and other developments (Section 6.5, Assessment Cases). The approach incorporated temporal boundaries for analyzing the potential effects from previous, existing, and approved projects and RFDs before, during, and after the anticipated lifespan of the Project. Assessment cases for the Project included a Base Case, Application Case, and RFD Case.

Base Case for climate change is represented by existing conditions. The Base Case describes the existing GHG emission levels without the proposed Project to provide an understanding of the current conditions that may be influenced by the Project. The existing conditions represent the cumulative historical and current GHG emissions that have influenced the observed condition/patterns of climate change (CEA Agency 2018).

Application Case for climate change represents predictions of the combined effects of the previous and existing projects/activities and natural factors contributing to the GHG emission totals in the Base Case plus the GHG emissions from the proposed Project.

Reasonably Foreseeable Development Case for climate change includes the Base Case, Application Case, and RFDs that have not yet been approved. Reasonably foreseeable developments are defined as projects and activities that fit any of the first three, and the last criteria from the list below:

- are currently under regulatory review or have officially entered a formal regulatory application process;
- have been publicly disclosed by other proponents;
- may be induced by the Project;
- have the potential to change the Project or the effects predictions; and
- occur in the administrative inventory boundaries that currently apply to GHG emissions under the federal GHG policy, regulations, and legislation (ECCC 2020a,b).

The effects of historical and existing projects on climate change are already included in the provincial and federal emission levels (Table 7.4-6). The effects of future development in the region would be considered through the appropriate GHG policy, regulations and legislation (ECCC 2020a,b) and the continued ability for Canada to reach climate change commitments in the form of emission reduction targets. Therefore, by definition of the assessment endpoints in Table 7.4-1, a specific RFD Case was not completed, but the Application Case provides the necessary information for the federal government to consider the Project relative to future development.

7.4.2.6 Existing Conditions

Existing conditions for GHG emissions are characterized by the provincial and federal GHG emissions levels using the ECCC *National Inventory Report 1990–2019: Greenhouse Gas Sources and Sinks in Canada* (National Inventory Report 1990–2019; ECCC 2021). These GHG emission levels were used to identify the existing conditions and provide a basis for evaluating potential changes from the Project. To assist in contextualizing the Project, the GHG emissions were also characterized GHG emissions by the Energy, Waste, and Industrial Processes and Product Use sectors (ECCC 2021) at a provincial level. The existing conditions represent the previous and existing projects included in the most recently available provincial and federal emission levels, consistent with federal GHG policy, regulations, and legislation (ECCC 2020a,b).

7.4.2.7 Project Interactions and Mitigations

Interactions (i.e., linkages) between Project components or activities, and the corresponding potential changes to measurement indicators, were identified by a pathway analysis that was then used to inform the residual effects analysis for climate change (Section 6.7, Pathways Analysis). The first part of the analysis was to identify all potential effects pathways for all phases of the Project (Section 6.7.1, Identification of Project Interactions). Each pathway was initially assumed to have a linkage to potential effects on climate change.

Potential pathways from Project activities to climate change were identified using the following:

- review of the Project description (Section 5) and potential effects scoping by the project development, environmental, and socio-economic teams for the Project;
- input from Indigenous, regulatory, and public engagement (Section 2) and Indigenous and Local Knowledge (Section 3);
- scientific knowledge;
- previous experience with mining projects; and
- consideration of potential effects identified from the Terms of Reference (Section 1, Appendix 1A).

Potential adverse effects of the Project were then identified, and practicable mitigation was applied to avoid, minimize, and/or rehabilitate adverse effects on climate change (Section 6.7.2, Identification of Mitigation). Avoidance and minimization are widely recognized as the most important approach for biodiversity conservation (BBOP 2021). Avoidance designs and actions integrated into the Project were developed iteratively between the Project's environmental and project development teams. Minimization techniques and technology were also identified and implemented collaboratively between Project teams.

Each potential effect pathway was evaluated using proposed mitigation to predict whether the pathway had the potential to cause residual adverse effects (Section 6.7.3, Pathway Screening). A screening-level assessment was applied using Indigenous and Local Knowledge, scientific knowledge, logic, experience with similar developments, and an understanding of the effectiveness of mitigation (i.e., level of certainty that mitigation would work) to assign each pathway to one of the following categories:

- **No pathway:** Analysis reveals that the pathway could be removed (i.e., the effect is avoided) by mitigation so that the Project would result in no measurable environmental change relative to existing conditions or guideline values and, therefore, would have no residual effect on climate change.
- **Secondary pathway:** The pathway could result in a measurable but minor environmental change relative to existing conditions or guideline values, but this change would be sufficiently small that it would have a negligible residual effect on climate change. Therefore, the pathway is not expected to contribute to effects of RFDs to cause a significant effect.
- **Primary pathway:** The pathway is likely to result in an environmental change relative to existing conditions or guideline values and could cause a greater than negligible effect on climate change.

Project interactions determined as no pathway or secondary pathways were not carried forward for further assessment (Section 6.7.3). Primary pathways that could result in changes to the environment with one or more associated measurement indicator and have the potential to cause a greater than negligible effect on climate change were carried forward to the residual effects analysis and residual effects classification (Section 7.4.5).

7.4.2.8 Residual Effects Analysis

The residual effects analysis measures and describes the effects of the proposed Project on climate change relative to existing conditions. Residual effects are described for each of the measurement indicators for the primary pathways identified for the climate change VC (Section 7.4.4.3, Primary Pathways). The residual effects analysis was completed for the Application Case (Section 6.8, Residual Effects Analysis).

The residual effects analysis considered the quantity of GHG emissions (i.e., measured the quantitative GHG emissions expected to be generated from the Project). For the climate change VC, most residual effects criteria do not vary due to the long-term to permanent (i.e., duration) and global nature (i.e., beyond regional extent) of GHGs. The effects of GHG releases are invariably adverse, continuous, and irreversible (i.e., lasting well beyond when the contribution of GHGs ceases). Therefore, when considering GHGs, the only applicable residual effects criterion is magnitude.

The cumulative effects assessment is implicitly included in the residual effects analysis by nature of the endpoint assessments (i.e., provincial and federal emission totals). The cumulative effects assessment is presented as a narrative describing the residual cumulative effects from the Project, other previous and existing projects and activities, and RFDs, including a discussion on how the Project would contribute to reaching future provincial and federal GHG targets. The Project has the potential to emit GHGs throughout all Project phases (i.e., Construction, Operations, and Closure) as a result of the various processes and activities including electricity generation, on-site mobile equipment, heating, land use change, stationary combustion, waste incineration, industrial processes, and explosives.

Greenhouse gas emissions and the emissions intensity for the Project were quantified using methods and relevant reference material as outlined in Table 7.4-2. Additional information related to estimation guidelines is presented in Appendix 7C.

Table 7.4-2: Applicable Guidelines for Estimation of Greenhouse Gas Emissions

Reference Document	GHG Reporting Program	Source	Date
Canada's GHG Quantification Requirements, Version 4.0 and the Technical Guidance on Reporting GHG Emissions	GHG Reporting Program	ECCC	December 2020
The GHG Protocol: A Corporate Accounting and Reporting Standard	Multiple programs (e.g., Global Reporting Initiative), ISO 14064	World Business Council for Sustainable Development and World Resources Institute	February 2013 Amendment
Intergovernmental Panel on Climate Change Guidelines for National GHG Inventories	United Nations Framework Convention on Climate Change National GHG Inventories Programme	Intergovernmental Panel on Climate Change	2006

GHG = greenhouse gas; ECCC = Environment and Climate Change Canada; ISO = International Organization for Standardization.

As noted in Section 7.4.2.2.2, Measurement Indicators and Section 7.4.2.2.3 Assessment Endpoints, there are expected to be no Scope 2 emissions for the Project and Scope 3 emissions are not assessed consistent with the federal GHG reporting program for individual projects (ECCC 2020a). The Scope 1 emission sources for each measurement indicator are presented in Table 7.4-3.

Table 7.4-3: Measurement Indicators and Emission Sources

Measurement Indicator	Emitted from the Project	Emission Sources
CO_2	Yes	▪ Product of land use change ▪ Product of fuel combustion from stationary equipment and on-site mobile equipment ▪ Product of waste incineration, as a fraction of fossil carbon in waste burned ▪ Product of blasting and industrial processes (i.e., sulphuric acid production and the acidification of ore material)
CH_4	Yes	▪ Product of fuel combustion from stationary equipment, heating, and on-site mobile equipment ▪ Product of waste incineration
N_2O	Yes	▪ Product of fuel combustion from stationary equipment and on-site mobile equipment ▪ Product of waste incineration

CH_4 = methane; CO_2 = carbon dioxide; N_2O = nitrous oxide.

The emissions of the measurement indicators are expressed in annual tonnes of CO_2e, which is calculated by multiplying the annual emissions of each GHG by its global warming potential. The global warming potential of each gas represents its ability to trap heat in the atmosphere in comparison to CO_2 (Government of Canada 2019). The global warming potentials that were used to calculate the Project GHG emissions are accepted values of 1, 25, and 298 for CO_2, CH_4, and N_2O, respectively (CNSC 2017).

The GHG emission sources are summarized in Table 7.4-4. Additional information on the methods used, including the detailed calculations, are provided in Appendix 7C.

Table 7.4-4: Summary of Rook I Project Greenhouse Gas Emission Sources

Phase	Emission Source	Estimation Method
Construction	**Direct Emissions (Scope 1)**	
	Land use change	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 2*[(a)]
	Electricity generation	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[(b)]
	On-Site mobile equipment	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1[(b)]
	Waste Incineration	*National Inventory Report 1990–2019*, Section A3.6.3.1[(c)]
	Heating	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.2[(b)]
	Explosives	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Energy, Chapter 1*[(a)]
	Stationary combustion	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[(b)]
	Industrial processes[(d)]	*Canada's Greenhouse Gas Quantification Requirements*, Technical Guidance on Reporting Greenhouse Gas Emissions, Section 3.2.1 *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Energy, Chapter 1*[(a)]

Table 7.4-4: Summary of Rook I Project Greenhouse Gas Emission Sources

Phase	Emission Source	Estimation Method
Operations	**Direct Emissions (Scope 1)**	
	Electricity generation	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[b]
	Heating	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.2[b]
	On-Site mobile equipment	Canada's Greenhouse Gas Quantification Requirements, GHGRP, Section 2.A.1[b]
	Waste incineration	*National Inventory Report 1990–2019*, Section A3.6.3.1[c]
	Stationary combustion	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[b]
	Land use change	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 2*[a]
	Industrial processes	*Canada's Greenhouse Gas Quantification Requirements*, Technical Guidance on Reporting Greenhouse Gas Emissions, Section 3.2.1 *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Energy, Chapter 1*[a]
	Explosives	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Energy, Chapter 1*[a]
Closure	**Direct Emissions (Scope 1)**	
	Electricity generation[e]	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[b]
	On-Site mobile equipment	Canada's Greenhouse Gas Quantification Requirements, GHGRP, Section 2.A.1[b]
	Heating[e]	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.2[b]
	Land use change (annual loss of carbon sink only)	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 2*[a]
	Waste incineration[e]	*National Inventory Report 1990–2019*, Section A3.6.3.1[c]
	Stationary combustion[e]	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[b]

a) Source: IPCC 2006.
b) Source: ECCC 2020a.
c) Source: ECCC 2021.
d) Industrial process emissions occur only in Year -1 of Construction.
e) Stationary combustion emissions, heating emissions, electricity generation emissions, and waste incineration emissions are only expected to occur in the Active Closure Stage.
IPCC = Intergovernmental Panel on Climate Change; GHGRP = Greenhouse Gas Reporting Program.

The residual effects analysis used a reasoned narrative to describe anticipated changes to each measurement indicator caused by the Project. This narrative description of anticipated effects is the foundation for the residual effects classification. Residual effects are summarized or classified in tabular form using effects criteria, an approach that is intended to provide structure and comparability across VCs and intermediate components assessed for the Project (Section 6.9.1, Residual Effects Classification). As noted above, magnitude is the only criterion applied to the Climate Change VC. The approach to classify magnitude is provided in Table 7.4-5.

Table 7.4-5: Definitions Applied to Effects Criteria Classifications for the Assessment of Climate Change

Criterion	Rating	Definition
Magnitude	Qualitative narrative or numeric quantification	**Negligible:** effects that are so small that they are neither detectable nor measurable
		Low: 0.1% to 1% of the annual provincial emission levels, or 0.01% to 0.1% of the annual federal emission levels
		Moderate: >1% to <5% of the provincial annual emission levels, or >0.1% to <0.5% of the federal annual emission levels
		High: >5% of the provincial annual emission levels, or >0.5% of the federal annual emission levels

> = greater than; < = less than.

7.4.2.9 Residual Effects Classification and Determination of Significance

The significance of adverse residual effects on climate change was evaluated using the assessment endpoints as a significance threshold, and in general, the determination of significance followed the approach provided in Section 6.9.2, Significance Determination. The classification of residual effects criteria provided the foundation for determining if the threshold for significance (i.e., assessment endpoints) was exceeded. The assessment endpoints for the climate change VC are the following:

- contribution of Project GHG emissions to the provincial and federal totals; and
- continued ability for Canada to reach climate change commitments in the form of emission reduction targets.

The national sector emissions were considered only for providing context and were not used for determination of significance.

Confidence in the significance prediction for climate change was identified and discussed as part of the reasoned narrative.

7.4.2.10 Prediction Confidence and Uncertainty

The purpose of the assessment is to estimate the future GHG emissions released from the proposed Project. As with all future emissions estimates, the estimates made in this assessment embody some degree of uncertainty. The assessment applied a precautionary (i.e., conservative) approach to address uncertainty by identifying the greatest magnitude of potential adverse effects when a range of outcomes were possible. Consequently, uncertainty was addressed in a manner that increased the level of confidence that residual effects were conservatively estimated. The key uncertainties for climate change and the way they were addressed are presented as part of this assessment (Section 7.4.7, Prediction Confidence and Uncertainty).

7.4.2.11 Monitoring, Follow-Up, and Adaptive Management

Monitoring programs are proposed to address the uncertainties associated with the effects predictions and to evaluate the performance of mitigation. In general, monitoring is used to verify the effects predictions. Monitoring is also used to identify any unanticipated effects and to support the implementation of adaptive management to limit these effects. Typically, monitoring includes one or both of the following categories that may be applied during the Project lifespan:

- **Regulatory compliance monitoring:** monitoring activities, procedures, and programs undertaken to confirm the implementation of approved design standards, mitigation and conditions of approval, and NexGen commitments.
- **Follow-up monitoring:** programs designed to test the accuracy of effects predictions, reduce or address uncertainties, determine the effectiveness of mitigation, or provide appropriate feedback to operations for modifying or adopting new mitigation designs, policies, and practices (e.g., implementation of adaptive management). Results from these programs can be used to increase the certainty of effect predictions in future EAs.

Where relevant, conceptual monitoring programs would be proposed to confirm predictions and to address the uncertainties associated with the effects predictions and mitigation, and upon Project approval, would be included in the Integrated Management System.

The implementation of robust, long-term environmental testing and monitoring has also been requested by Indigenous Groups to verify protection of the environment, including community-led monitoring during Construction and Operations of the Project (TSD IV: MN-S; TSD V.2: CRDN; TSD VI: YNLR).

In addition to environmental monitoring programs typically implemented for projects (i.e., as noted above), NexGen is working with local Indigenous Groups to implement independent environmental monitoring. In combination with standard Project monitoring processes, independent Indigenous monitoring would be used to verify Project performance and to determine if mitigations and controls are effective in protecting the receiving environment.

Adaptive management measures may also be proposed to address the uncertainties associated with the effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

7.4.3 Existing Conditions

The existing conditions were characterized using the most recent annual dataset from the federal *National Inventory Report 1990–2019* (ECCC 2021), which includes the GHG emissions from previous and existing human and natural disturbances at the provincial, national sector, and federal scales.

Canada's total annual GHG emissions reported for 2019 were 730 megatonnes of carbon dioxide equivalent (Mt CO_2e). Based on the available emissions reported globally for 2017, Canada represented 1.5% of the total global GHG emissions. Greenhouse gas emissions vary across provinces and territories and depend on the population size, energy sources, and types of industries (ECCC 2021). Saskatchewan's emissions for 2019 were estimated to be 75 Mt CO_2e (ECCC 2021).

Sources within the Project emissions are expected to contribute to sub-sectors within the national Energy, Waste, and Industrial Processes and Product Use sectors, as defined by ECCC (2021). The 2019 emissions in the national sectors and sub-sectors are characterized as follows. The transportation sub-sector emitted

217 Mt CO_2e (37%) and the stationary combustion sub-sector emitted 319 Mt CO_2e (54%) in 2019, contributing to the overall totals for Canada's Energy Sector GHG emissions (ECCC 2021). At the national scale in 2019, the incineration and open burning of waste sub-sector accounted for 0.19 Mt CO_2e (0.7%) of Canada's Waste Sector GHG emissions. For the same year, the chemical industry sub-sector accounted for 6.8 Mt CO_2e (12.6%) of Canada's Industrial Processes and Product Use Sector (ECCC 2021).

The baseline GHG emissions at the provincial level, national sector, and federal level are provided in Table 7.4-6; the emissions levels summarized in Table 7.4-6 include the cumulative effects of existing projects and activities that occur within the spatial assessment boundaries for the climate change VC. Baseline information for Saskatchewan and Canada was obtained from the National Inventory Report 1990 to 2019 (ECCC 2021) for submission to the United Nations Framework Convention on Climate Change. Both provincial and national emissions are provided for the most recent 2019 reporting year.

Table 7.4-6: Baseline Greenhouse Gas Emissions (2019)

Emission Source	Annual GHG Emissions (Mt CO_2e)
Saskatchewan (all sectors)	75
National Energy Sector – stationary combustion sources	319
National Energy Sector – transport	217
National Waste Sector – incineration and open burning of waste	0.19
National Industrial Processes and Product Use Sector – chemical industry	6.8
Canada (all sectors)	730

Source: ECCC 2021.
GHG = greenhouse gas; Mt CO_2e = megatonnes of carbon dioxide equivalent.

7.4.4 Project Interactions and Mitigations

The pathways analysis identified potential adverse effects of the Project on climate change, identified practicable mitigation for these potential effects, and determined whether potential effects could be sufficiently mitigated such that they are not expected to cause a residual adverse effect. As described in Section 7.4.2.7, Project Interactions and Mitigations, the pathways analysis assigned each potential effect as:

- no pathway (i.e., mitigation results in no effect on climate change);
- secondary pathway (i.e., mitigation results in a negligible effect on climate change); or
- primary pathway (i.e., effect that is greater than negligible and carried forward for further assessment).

The pathway analysis is summarized in Table 7.4-7. All Scope 1 Project GHG emissions were included in the primary pathway, and as such, there is only one primary pathway that was carried forward for detailed assessment in Section 7.4.5, Residual Effects Analysis. This effects pathway applies to all Project phases.

The environmental design features and mitigations in Table 7.4-7 represent the list of key actions used to inform the pathway analysis as part of preparing the EIS. In addition to this list of key actions, NexGen would implement the Environmental Protection Program, which would describe the processes required to monitor and characterize GHG emissions from Project facilities and activities. This program would be used to periodically evaluate mitigation performance and identify additional mitigation, where required, and prompt potential adaptive management measures (Section 7.4.8, Monitoring, Follow-Up, and Adaptive Management). Where relevant, adaptive management measures may also be proposed to address uncertainties associated with effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

Potential accidents and malfunctions that have the capability to influence biophysical or human environments are discussed in Section 21, Accidents and Malfunctions.

Table 7.4-7: Potential Effects Pathways for Climate Change

Pathway ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
CC-01	Project components/activities that contribute to GHG emissions during **all Project phases**: ▪ combustion of fossil fuels in mobile vehicles and heavy equipment for the following: o land clearing, site preparation, and construction of facilities and infrastructure o underground shaft development o process plant and underground operations o removal of infrastructure o restoration and revegetation of facilities and infrastructure o site traffic o transportation of personnel and materials to and from the site ▪ combustion of fossil fuels in stationary equipment (e.g., power generation, heating, calciner operation, waste incinerator operation) ▪ explosive detonation ▪ industrial processes (e.g., sulphuric acid production, acidification of ore material) ▪ non-hazardous and hazardous waste incineration	**<u>GHG emissions:</u>** GHG emissions from Project components and activities contribute to climate change	▪ Evaluate opportunities to **reduce fuel combustion requirements** of infrastructure and equipment, to the extent practical, during detailed design ▪ **Primarily use LNG** for power generation ▪ **Recover heat from the LNG powerplant** and use to heat other process and ancillary buildings, to the extent practical ▪ **Optimize haul routes** to reduce fuel consumption and emissions from equipment ▪ **Use excess steam generated from the acid plant** to heat other process buildings, to the extent practical ▪ **Use energy efficient LED lighting** and other similar efficiencies to reduce electrical demand, where practical ▪ **Use and maintain emissions control devices** on combustion-based equipment ▪ Where required, **remove merchantable trees and the majority of the woody debris with soils that are salvaged** (where not planned for use in future reclamation activities), to maintain the carbon stocks and avoid release of carbon through decomposition ▪ **Limit idling of vehicles and equipment** to the extent practical ▪ **Maintain mobile mining equipment and vehicles** and operate the equipment within parameters for engine exhaust system design ▪ Conduct **regular equipment maintenance** ▪ Identify and implement **procurement criteria** that confirm stationary and mobile engines meet applicable performance standards ▪ Implement **energy management strategy** for measuring and evaluating thermal and electrical energy use ▪ Implement **GHG management strategy** to reduce emissions to the extent practical ▪ Implement a Project-specific **Waste Management Program** and a Project-specific **Conventional Waste Management Plan**	Primary pathway

Bolded text represents the key topic of the environmental design features and mitigation.
LED = light-emitting diode; GHG = greenhouse gas; LNG = liquified natural gas.

7.4.4.1 No Pathways

There were no Project-environment interactions that result in no effects pathways for the climate change VC.

7.4.4.2 Secondary Pathways

There were no Project-environment interactions that result in secondary effects pathways for the climate change VC.

7.4.4.3 Primary Pathways

The following Project interaction was predicted to be the primary pathway affecting the climate change VC (Table 7.4-7) and was carried forward for further assessment of residual effects (Section 7.4.5):

CC-01: GHG emissions:

- GHG emissions from Project components and activities contribute to climate change.

In general, Indigenous Groups raised concerns about the cumulative effects of existing industrial air emissions, including from oil and gas activity in Alberta, which contribute to climate change (TSD II: BNDN; TSD III BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; BRDN-JWG 2019a; CRDN-JWG 2021; MN-S-JWG 2019b; MN-S-JWG 2020). The MN-S also expressed concerns related to anticipated changes to the climate over the lifespan of the Project (CNSC 2019). These comments by Indigenous Groups support the assessment of the GHG primary pathway within the residual effects analysis (Section 7.4.5).

7.4.5 Residual Effects Analysis

7.4.5.1 Application Case

7.4.5.1.1 Project Greenhouse Gas Emissions

This subsection presents the estimated direct GHG emissions of the Project. For each emission source, emissions are estimated for the measurement indicators of CO_2, CH_4, and N_2O, when relevant, as well as the total CO_2e emissions.

The direct emissions represent:

- **Electricity generation:** includes the natural gas and diesel combustion from the generators used to produce electricity on site.
- **On-Site mobile equipment:** includes the diesel combustion of surface and underground mobile equipment that would be used for construction activities, mining operations, road maintenance, material movement, and movement of personnel around site.
- **Heating:** includes the natural gas combustion within the mine heaters and building heaters, for underground and surface operations.
- **Land use change emissions:** includes the lost carbon sink annually due to removed vegetation and the one-time total carbon losses in biomass due to disturbances. There are no CH_4 or N_2O emissions associated with land use change.
- **Stationary combustion:** includes the natural gas and diesel combustion from the burner that would heat the calciner (i.e., industrial furnace) to remove impurities from the processed ore and the incinerators.

- **Waste incineration:** includes the emissions released through the domestic and low-level radiological waste as the fraction of fossil carbon.
- **Industrial processes:** includes the sulphuric acid production plant and the acidification of ore material. Industrial process emissions would begin in the final year of the Construction (i.e., Year -1) and do not produce quantifiable CH_4 or N_2O emissions.
- **Explosive emissions:** includes the explosives used for blasting.

As a percentage of the total Project GHG emissions, explosive emissions, waste incineration, and industrial process emissions are below the 5% materiality threshold defined by *The Greenhouse Gas Reporting Protocol: A Corporate Accounting and Reporting Standard*, (WRI and WBCSD 2013) and, as such, are not required to be reported under standard GHG accounting principles. Nevertheless, these emission sources have been included in this assessment for completeness and transparency.

The estimated direct GHG emissions of the Project are presented annually by GHG compound and emission source for Construction, Operations, and Closure in Table 7.4-8 and Table 7.4-9. Table 7.4-8 presents Project direct (Scope 1) emissions of CO_2, CH_4, N_2O, and total CO_2e from electricity generation, on-site mobile equipment, heating, and land use change. Table 7.4-9 presents Project direct (Scope 1) emissions of the same GHGs from stationary combustion, waste incineration, industrial process, and explosives.

For Construction, emissions were estimated annually for Year -4 to Year -1.

For Operations, emissions were estimated annually for Year 1 to Year 10. For Years 11 to 24, the emissions from Year 10 were considered to be reflective of annual operational emissions for these years as there are no anticipated changes to operational emissions over this period compared to Year 10.

For the Active Closure Stage (i.e., Year 25 to Year 29), emissions were calculated as follows:

- Emissions from stationary combustion, heating, electricity generation, waste incineration, on-site mobile equipment, and land use change are included. Explosive and industrial process emissions are not expected to occur during Closure, and therefore have not been included. Due to the unknowns and uncertainty around the specific active closure activities, conservative estimates were used for Active Closure Stage emissions. Annual emissions within this stage were assumed to be equivalent to Year -1 of Construction for each source, with the exception of on-site mobile equipment emissions, which were assumed to be equivalent to Year -3. The annual on-site mobile equipment emissions for the Active Closure Stage were conservatively assumed to be equal to the annual on-site mobile equipment emissions from Year -3 of Construction because Year -3 would have the highest emissions from this source during Construction.
- The annual stationary combustion, heating, electricity generation, waste incineration, and land use change emissions for the Active Closure Stage were assumed to be equal to the annual emissions from the same sources, respectively, from Year -1. These values were considered conservatively representative as they would be the highest within Construction, with the exception of the electricity generation emissions. Year -1 was chosen as the estimate for electricity generation emissions during the Active Closure Stage because it would have the highest annual emissions from the natural gas-powered electricity generation only. While Year -4 would have higher emissions, this is due to the diesel-powered generators that would be used while the natural gas power plant scales up and would not be expected to be representative of the Active Closure Stage.

For the Transitional Monitoring Stage (i.e., Year 30 to Year 39), emissions from on-site mobile equipment (i.e., pickup trucks conducting civil works and site services) and land use change were included. It was assumed the Transitional Monitoring Stage of Closure would only include pickup trucks for conducting civil works and site services. The annual fuel consumption for these pieces of equipment was assumed to equal the total maximum annual fuel consumption of the pickup trucks from Construction (i.e., Year -3).

The total CO_2e emissions by source and the overall annual total emissions of the Project are provided in Table 7.4-10, as well as the relative contribution of each source. Detailed supporting calculations are provided in Appendix 7C.

Table 7.4-8: Rook I Project Direct (Scope 1) Greenhouse Gas Emissions by Compound from Electricity Generation, On-Site Mobile Equipment, Heating and Land Use Change

Phase	Year	Electricity Generation Emissions (t)				On-Site Mobile Equipment Emissions (t)				Heating Emissions (t)				Land Use Change Emissions (t)[d]			
		CO_2	CH_4	N_2O	CO_2e	CO_2	CH_4	N_2O	CO_2e	CO_2	CH_4	N_2O	CO_2e	CO_2	CH_4	N_2O	CO_2e
Construction	Year -4	47,100	1.4	0.4	47,300	4,600	0.1	<0.1	4,600	100	<0.1	<0.1	100	118,100	n/a	n/a	118,100
	Year -3	19,200	4.9	0.5	19,500	15,500	0.4	0.1	15,500	900	<0.1	<0.1	900	2,200	n/a	n/a	2,200
	Year -2	16,900	4.3	0.4	17,200	8,300	0.2	0.1	8,300	4,800	0.1	0.1	4,800	2,200	n/a	n/a	2,200
	Year -1	41,300	10.6	1.1	41,900	7,900	0.2	0.1	7,900	8,800	0.2	0.2	8,900	2,200	n/a	n/a	2,200
Operations	Year 1	47,600	12.2	1.2	48,300	11,200	0.3	0.1	11,200	11,900	0.2	0.2	12,000	2,200	n/a	n/a	2,200
	Year 2	49,100	12.6	1.3	49,800	11,800	0.3	0.1	11,800	11,900	0.2	0.2	12,000	2,200	n/a	n/a	2,200
	Year 3	50,000	12.8	1.3	50,700	11,800	0.3	0.1	11,800	11,800	0.2	0.2	11,900	2,200	n/a	n/a	2,200
	Year 4	49,500	12.7	1.3	50,200	11,600	0.3	0.1	11,700	11,700	0.2	0.2	11,800	2,200	n/a	n/a	2,200
	Year 5	49,100	12.6	1.3	49,800	10,500	0.3	0.1	10,500	11,700	0.2	0.2	11,800	2,200	n/a	n/a	2,200
	Year 6	49,000	12.5	1.3	49,700	10,500	0.3	0.1	10,500	11,700	0.2	0.2	11,800	2,200	n/a	n/a	2,200
	Year 7	48,600	12.5	1.2	49,300	11,000	0.3	0.1	11,100	11,700	0.2	0.2	11,800	2,200	n/a	n/a	2,200
	Year 8	48,100	12.3	1.2	48,800	11,000	0.3	0.1	11,100	11,700	0.2	0.2	11,800	2,200	n/a	n/a	2,200
	Year 9	48,100	12.3	1.2	48,800	11,000	0.3	0.1	11,000	11,700	0.2	0.2	11,800	2,200	n/a	n/a	2,200
	Year 10	47,800	12.2	1.2	48,500	10,500	0.3	0.1	10,500	11,600	0.2	0.2	11,700	2,200	n/a	n/a	2,200
	Years 11-24 (per yr)[a]	47,800	12.2	1.2	48,500	10,500	0.3	0.1	10,500	11,600	0.2	0.2	11,700	2,200	n/a	n/a	2,200
Closure	Years 25-29 (per yr)[b]	41,300	10.6	1.1	41,900	15,500	0.4	0.1	15,500	8,800	0.2	0.2	8,900	2,200	n/a	n/a	2,200
	Years 30-39 (per yr)[c]	n/a	n/a	n/a	n/a	200	<0.1	<0.1	200	n/a	n/a	n/a	n/a	2,200	n/a	n/a	2,200
Total Scope 1 Emissions by Source (t CO_2e)		**1,487,100**	**369.7**	**37.2**	**1,508,300**	**373,700**	**10.1**	**3.2**	**374,000**	**338,400**	**6.1**	**6.1**	**341,400**	**210,500**	**n/a**	**n/a**	**210,500**

Note: Total does not always equate to the sum of the numbers presented in the table due to rounding. The actual totals are based on calculations performed using a greater number of significant figures than those shown in the table. Refer to Appendix 7C for a detailed description of the emission calculations.

a) It is assumed that the emissions from Year 10 are reflective of annual emissions for Years 11 to 24.

b) It is assumed that the stationary combustion, heating, electricity generation, waste incineration, and land use emissions from Year -1 are reflective of annual emissions for Years 25 to 29. It is assumed that the on-site mobile equipment emissions from Year -3 are reflective of annual emissions for Years 25 to 29. Explosive and industrial process emissions are not expected to occur during Closure.

c) The emissions sources during the Transitional Monitoring Stage (Years 30 to 39) include fuel combustion from pickup trucks and land use change. The annual fuel consumption for these equipment were assumed to be equal the total maximum annual fuel consumption of the pickup trucks from Construction. The annual land-use change emissions for Closure were conservatively estimated to be equal to the annual land-use change emissions from the loss of the carbon sink.

d) Land use change emissions only generate CO_2; therefore, the breakdown of CH_4, and N_2O is not applicable. Refer to Appendix 7C for a detailed description of the emission calculations.

CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent; n/a = not applicable, < = less than; t CO_2e = tonnes of carbon dioxide equivalent.

Table 7.4-9: Rook I Project Direct (Scope 1) Greenhouse Gas Emissions by Compound from Stationary Combustion, Waste Incineration, Industrial Process, and Explosive Emissions

Phase	Year	Stationary Combustion Emissions (t)				Waste Incineration Emissions (t)				Industrial Process Emissions (t)[d]				Explosive Emissions (t)[e]			
		CO_2	CH_4	N_2O	CO_2e	CO_2	CH_4	N_2O	CO_2e	CO_2	CH_4	N_2O	CO_2e	CO_2	CH_4	N_2O	CO_2e
Construction	Year -4	0	0	0	0	500	0.1	0.8	700	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3
	Year -3	900	<0.1	<0.1	900	500	0.1	0.8	700	n/a	n/a	n/a	n/a	n/a	n/a	n/a	40
	Year -2	900	<0.1	<0.1	900	500	0.1	0.8	700	n/a	n/a	n/a	n/a	n/a	n/a	n/a	100
	Year -1	900	<0.1	<0.1	900	500	0.1	0.8	700	40	n/a	n/a	40	n/a	n/a	n/a	100
Operations	Year 1	3,000	0.1	<0.1	3,000	900	0.1	1.6	1,300	200	n/a	n/a	200	n/a	n/a	n/a	200
	Year 2	3,200	0.1	<0.1	3,200	900	0.1	1.6	1,300	200	n/a	n/a	200	n/a	n/a	n/a	300
	Year 3	3,200	0.1	<0.1	3,200	900	0.1	1.6	1,300	300	n/a	n/a	300	n/a	n/a	n/a	200
	Year 4	3,200	0.1	<0.1	3,200	900	0.1	1.6	1,300	300	n/a	n/a	300	n/a	n/a	n/a	200
	Year 5	3,200	0.1	<0.1	3,200	900	0.1	1.6	1,300	300	n/a	n/a	300	n/a	n/a	n/a	200
	Year 6	2,100	0.1	<0.1	2,100	900	0.1	1.6	1,300	300	n/a	n/a	300	n/a	n/a	n/a	200
	Year 7	2,200	0.1	<0.1	2,200	900	0.1	1.6	1,300	300	n/a	n/a	300	n/a	n/a	n/a	200
	Year 8	2,300	0.1	<0.1	2,300	900	0.1	1.6	1,300	300	n/a	n/a	300	n/a	n/a	n/a	200
	Year 9	2,100	0.1	<0.1	2,100	900	0.1	1.6	1,300	300	n/a	n/a	300	n/a	n/a	n/a	100
	Year 10	2,200	0.1	<0.1	2,200	900	0.1	1.6	1,300	300	n/a	n/a	300	n/a	n/a	n/a	100
	Years 11-24 (per yr)[a]	2,200	0.1	<0.1	2,200	900	0.1	1.6	1,300	300	n/a	n/a	300	n/a	n/a	n/a	100
Closure	Years 25-29 (per yr)[b]	0	0	0	0	500	0.1	0.8	700	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Years 30-39 (per yr)[c]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Scope 1 Emissions by Source (t CO_2e)		**60,200**	**2.4**	**<0.1**	**60,200**	**26,100**	**3.3**	**45.6**	**37,500**	**7,040**	**n/a**	**n/a**	**7,040**	**n/a**	**n/a**	**n/a**	**3,543**

Note: Total does not always equate to the sum of the numbers presented in the table due to rounding. The actual totals are based on calculations performed using a greater number of significant figures than those shown in the table. Refer to Appendix 7C for a detailed description of the emission calculations.

a) It is assumed that the emissions from Year 10 are reflective of annual emissions for Years 11 to 24.

b) It is assumed that the stationary combustion, heating, electricity generation, waste incineration, and land use emissions from Year -1 are reflective of annual emissions for Years 25 to 29. It is assumed that the on-site mobile equipment emissions from Year -3 are reflective of annual emissions for Years 25 to 29. Explosive and industrial process emissions are not expected to occur during Closure.

c) The emissions sources during the Transitional Monitoring Stage (Years 30 to 39) include fuel combustion from pickup trucks and land use change. The annual fuel consumption for these equipment were assumed to be equal the total maximum annual fuel consumption of the pickup trucks from Construction. The annual land-use change emissions for Closure were conservatively estimated to be equal to the annual land-use change emissions from the loss of the carbon sink.

d) Industrial process emissions only generate CO_2; therefore, the breakdown of CH_4, and N_2O is not applicable. Refer to Appendix 7C for a detailed description of the emission calculations.

e) Explosive emissions are calculated using an emission factor for CO_2e; therefore, the breakdown of emissions by CO_2, CH_4, and N_2O is not applicable. Refer to Appendix 7C for a detailed description of the emission calculations.

CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent; n/a = not applicable, < = less than; t CO_2e = tonnes of carbon dioxide equivalent.

Table 7.4-10: Summary of Annual Rook I Project Total Greenhouse Gas Emissions by Source

Phase	Year	Project Emissions (t CO_2e)								Annual Total Emissions (t CO_2e)
		Electricity Generation	On-Site Mobile Equipment	Heating	Land Use Change	Stationary Combustion	Waste Incineration	Industrial Processes	Explosives	
Construction	**Year -4**	**47,300**	**4,600**	**100**	**118,100**	**0**	**700**	**n/a**	**3**	170,800
	Year -3	19,500	15,500	900	2,200	900	700	n/a	40	39,700
	Year -2	17,200	8,300	4,800	2,200	900	700	n/a	100	34,200
	Year -1	41,900	7,900	8,900	2,200	900	700	40	100	62,640
Operations	Year 1	48,300	11,200	12,000	2,200	3,000	1,300	200	200	78,400
	Year 2	49,800	11,800	12,000	2,200	3,200	1,300	200	300	80,800
	Year 3	**50,700**	**11,800**	**11,900**	**2,200**	**3,200**	**1,300**	**300**	**200**	81,600
	Year 4	50,200	11,700	11,800	2,200	3,200	1,300	300	200	80,900
	Year 5	49,800	10,500	11,800	2,200	3,200	1,300	300	200	79,300
	Year 6	49,700	10,500	11,800	2,200	2,100	1,300	300	200	78,100
	Year 7	49,300	11,100	11,800	2,200	2,200	1,300	300	200	78,400
	Year 8	48,800	11,100	11,800	2,200	2,300	1,300	300	200	78,000
	Year 9	48,800	11,000	11,800	2,200	2,100	1,300	300	100	77,600
	Year 10	48,500	10,500	11,700	2,200	2,200	1,300	300	100	76,800
	Years 11-24 (per year)[(a)]	48,500	10,500	11,700	2,200	2,200	1,300	300	100	76,800
Closure	**Years 25-29 (per yr)[(b)]**	**41,900**	**15,500**	**8,900**	**2,200**	**n/a**	**700**	**n/a**	**n/a**	69,200
	Years 30-39 (per yr)[(c)]	n/a	200	n/a	2,200	n/a	n/a	n/a	n/a	2,400
Total Project Emissions by Source (t CO_2e)		**1,508,300**	**374,000**	**341,400**	**210,500**	**60,200**	**37,500**	**7,040**	**3,500**	**2,542,440**
Percent of Total Project Emissions by Source (%)		59.3	14.7	13.4	8.3	2.4	1.5	0.3	0.1	**100.0**

Bold and shaded values indicate the year with the highest total emissions during each phase. These values will be used in the residual effects analysis to compare the Project emissions to baseline conditions.

a) It is assumed that the emissions from Year 10 are reflective of annual emissions for Years 11 to 24.

b) It is assumed that the stationary combustion, heating, electricity generation, waste incineration, and land use emissions from Year -1 are reflective of annual emissions for Years 25 to 29. It is assumed that the on-site mobile equipment emissions from Year -3 are reflective of annual emissions for Years 25 to 29. Explosive and industrial process emissions are not expected to occur during Closure.

c) The emissions sources during the Transitional Monitoring Stage (Years 30 to 39) include fuel combustion from pickup trucks and land use change. The annual fuel consumption for these equipment were assumed to be equal the total maximum annual fuel consumption of the pickup trucks from Construction. The annual land-use change emissions for Closure were conservatively estimated to be equal to the annual land-use change emissions from the loss of the carbon sink.

CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent; n/a = not applicable; t CO_2e = tonnes of carbon dioxide equivalent.

7.4.5.1.2 Project Emissions Intensity

The emissions intensity measurement consists of the amount of GHG emitted per pound of uranium concentrate produced on an annual basis. The *Proposed CNSC Path Forward for Assessing Total GHG Production from Nuclear Facilities* guidance document (CNSC 2017) proposes using a cradle-to-gate analysis for EAs under the *Canadian Environmental Assessment Act, 2012*. Cradle-to-gate analysis includes the processes in the production chain from extraction of the product until the product is ready to use (i.e., completion of milling). For example, a project for milling would have to include GHG emissions associated with the mining activity that occurs upstream, or prior to the milling process in the production chain. The guidance states that new projects that are upstream to a nuclear power plant would have to include upstream processes in GHG assessment and not the processes that occur downstream, or after the project in the production chain. Using this cradle-to-gate boundary set by the CNSC, the Project emission intensity is representative of the mining and milling stage of the life cycle of nuclear power (CNSC 2017).

In accordance with *The Greenhouse Gas Reporting Protocol: A Corporate Accounting and Reporting Standard* and informed by the Strategic Assessment on Climate Change, the units produced, in pounds of uranium concentrate, and the emissions intensity, in tonnes of CO_2e per pound of uranium concentrate, are reported separately for each year of Operations in Table 7.4-11 (WRI and WBCSD 2013; ECCC 2020b). Both packaged pounds (uranium concentrate packaged after the milling process) and contained pounds triuranium octoxide (U_3O_8) contained within the raw ore before milling) were used in the emissions intensity calculation. The net GHG emissions, calculated in Table 7.4-10 as the annual total emissions, are also provided in Table 7.4-11 for completeness.

The Life Cycle Analysis of Greenhouse Gas Emissions from the Mining and Milling of Uranium in Saskatchewan (Parker 2015) provides an overview of the GHG emissions intensity during the uranium mining and milling phase of the nuclear fuel life cycle for three uranium mine and mill facilities located in northern Saskatchewan. The three mine and mill facilities considered in this study include McArthur River-Key Lake operation mine-mill, Eagle Point-Rabbit Lake operation mine-mill, and McClean Lake operation mine-mill (Parker 2015). The emissions intensity production-weighted average for the three mining and milling operations are calculated as part of a life cycle analysis of the nuclear fuel cycle (Parker 2015).

The Project's GHG emission intensity is based on the amount of GHG emitted per pound of uranium concentrate produced on an annual basis, not on a life-cycle analysis basis. Therefore, the Project GHG emission intensity is not directly comparable to the emission intensities from Parker (2015), as the emissions intensity assessment boundary is different. No other publicly available industry average emission intensity relevant to the Project was available for comparison.

Table 7.4-11: Emissions Intensity by Rook I Project Year

Phase	Year	Units Produced (lb U_3O_8)		Net GHG Emissions (t CO_2e)	Emissions Intensity (t CO_2e/lb U_3O_8)	
		Packaged Pounds	Contained Pounds		Packaged Pounds	Contained Pounds
Operations	Year 1	25,481,226	26,111,530	78,400	0.003	0.003
	Year 2	28,616,288	29,324,142	80,800	0.003	0.003
	Year 3	28,694,297	29,404,080	81,600	0.003	0.003
	Year 4	28,646,178	29,354,771	80,900	0.003	0.003
	Year 5	23,428,657	24,008,189	79,300	0.003	0.003
	Year 6	23,174,670	23,747,919	78,100	0.003	0.003
	Year 7	15,268,636	15,646,322	78,400	0.005	0.005
	Year 8	15,565,533	15,950,563	78,000	0.005	0.005
	Year 9	17,541,204	17,975,104	77,600	0.004	0.004
	Year 10	19,409,393	19,889,504	76,800	0.004	0.004
	Years 11-19[a]	6,097,809	6,248,645	76,800	0.013	0.012
	Years 20-24[a]	5,817,228	5,961,123	76,800	0.013	0.013
Average Annual Emissions Intensity					**0.009**	**0.008**

a) The units produced are consistent for Years 11 to 19 and for Years 20 to 24. It is assumed that the emissions from Year 10 are reflective of annual emissions for Years 11 to 24; therefore, the net GHG emissions for Years 11 to 19 and for Years 20 to 24 are the same as Year 10.
U_3O_8 = triuranium octoxide; GHG = greenhouse gas; t CO_2e/lb U_3O_8 = tonnes of carbon dioxide equivalent per pound of triuranium octoxide; t CO_2e = tonnes of carbon dioxide equivalent; lb U_3O_8 = pounds of triuranium octoxide.

The residual effects of the estimated maximum annual Project GHG emissions from each Project phase on provincial, national sector, and federal levels were assessed through the comparison to the most recent available emission totals for Saskatchewan and Canada. The GHG emissions from Year -4, Year 3, and Year 25 of the Project are highlighted in Table 7.4-12. These years were selected for the comparison as they are estimated to have the greatest emissions during each of Construction, Operations, and Closure, respectively, and serve as a conservative representation of the Project's annual emissions by phase. The annual stationary combustion emissions have been combined with annual heating emissions and annual electricity generation emissions in Table 7.4-12 because these emissions would all be a result of fuel combustion in stationary equipment. There are no federal or provincial baseline emission estimates for explosives and land use change; therefore, these emissions are not calculated as a relative percentage. The annual GHG emissions for Year -4, Year 3, and Year 25 (i.e., representative of the maximum annual emissions for each phase) are compared to the annual GHG emissions for provincial, national sector, and federal emission levels in Table 7.4-13. Table 7.4-13 also presents a comparison of annual GHG emissions from the Project to the Canada's 2030 emissions target, as outlined in *Canada's 2030 Emissions Reduction Plan* (Government of Canada 2022).

Table 7.4-12: Maximum Annual Emissions by Rook I Project Phase

Emission Source	Construction Maximum Annual GHG Emissions – Year -4 (kt CO_2e)	Operations Maximum Annual GHG Emissions – Year 3 (kt CO_2e)	Closure Maximum Annual GHG Emissions – Year 25 (kt CO_2e)
Stationary combustion, heating, and electricity generation	47.40	65.80	50.80
On-Site mobile equipment	4.60	11.80	15.50
Land use change	118	2.20	2.20
Waste incineration	0.70	1.30	0.70
Industrial processes	n/a	0.30	n/a
Annual Project Total	170.80	81.60	69.20

Source: Data for Saskatchewan, National Sector, and Canada GHG emissions were obtained from the National Inventory Report 1990–2019 (ECCC 2021).
GHG = greenhouse gas; kt CO_2e = kilotonnes of carbon dioxide equivalent; n/a = not applicable.

Table 7.4-13: Rook I Project Annual Emissions Compared to Baseline Values by Phase

Emission Source	GHG Emissions (kt CO_2e)	Construction Maximum Annual GHG Emissions (Year -4) as a Relative Percentage of Baseline (%)	Operations Maximum Annual GHG Emissions (Year 3) as a Relative Percentage of Baseline (%)	Closure Maximum Annual GHG Emissions (Year 25) as a Relative Percentage of Baseline (%)
Saskatchewan (2019)	**75,000**	0.23	0.11	0.09
National Energy Sector – stationary combustion sources	319,000	0.01	0.02	0.02
National Energy Sector – transport	217,000	0.00	0.01	0.01
National Waste Sector – incineration and open burning of waste	190	0.37	0.68	0.37
National Industrial Processes and Product Use Sector – chemical industry	68,000	n/a	0.00	n/a
Canada (2019)	**730,000**	**0.02**	**0.01**	**0.01**
Canada (2030)	**503,000**	**0.03**	**0.02**	**0.01**

Source: Data for Saskatchewan, National Sector, and Canada GHG emissions were obtained from the National Inventory Report 1990-2019 (ECCC 2021).
GHG = greenhouse gas; kt CO_2e = kilotonnes of carbon dioxide equivalent; n/a = not applicable.

Emission of GHGs from the Project would have an adverse effect on climate change due to the global and permanent nature of GHG emissions. However, total Project emissions would be less than 0.3% of the provincial annual total emissions and less than 0.02% of the 2019 federal annual total emissions or 0.03% of the 2030 federal annual total emissions target. Given the low contribution of the Project to the federal totals shown in Table 7.4-13, Canada maintains the ability to reach its climate change commitments within the current regulatory framework. Saskatchewan also maintains the ability to reach its climate change commitments as part of *Saskatchewan's Growth Plan,* which commits to reducing carbon emissions in electricity production and advancing the development of zero-emission small modular reactor technology using Saskatchewan uranium (Government of Saskatchewan 2015b). The lower carbon intensity of electricity generated from nuclear sources compared to coal and natural gas sources could support Saskatchewan meeting its commitments.

7.4.5.2 Reasonably Foreseeable Development Case

The Application Case already considers the cumulative effects of historical, existing, and future projects through comparison to provincial and federal emissions levels and the continued ability for Canada to reach climate change commitments in form of emission reduction targets (Table 7.4-6). Therefore, the RFD Case is out of scope and is already included in the Application Case that provides the necessary information for the federal government to consider the Project relative to future development.

7.4.6 Residual Effects Classification and Determination of Significance

Following the methods described in Section 7.4.2.8, Residual Effects Analysis, residual effects on the climate change VC from Project GHG emissions are classified in Table 7.4-14 according to direction, magnitude, geographic extent, duration, reversibility, frequency, and probability of occurrence. Using these residual effects classification criteria, any emission of GHGs from the Project has an adverse effect (i.e., negative direction) on climate change due to the global (i.e., geographic extent) and permanent (i.e., duration) nature of GHG emissions. Any GHG emissions are considered to be irreversible (i.e., reversibility) and continuous (i.e., frequency) due to the natural and anthropogenic drivers of GHG releases, lasting well beyond when the contribution of GHGs ceases. It is certain that the Project would result in GHG emissions during all phases (i.e., probability of occurrence). Based on the effects criteria classifications for the assessment of climate change described in Table 7.4-5, the magnitude of Project GHG emissions is considered low because the total Project emissions would be less than 0.3% of the provincial total emissions and less than 0.02% of the federal total emissions.

Effective implementation of mitigation outlined in Section 7.4.4 is expected to reduce the magnitude of the Project GHG emissions through technology/component selection and the operational practices. Mitigation measures outlined in Section 7.4.4 are incorporated into the Project emissions in Section 7.4.5.1.1, Project Greenhouse Gas Emissions.

Table 7.4-14: Classification of Residual Effects on Climate Change Measurement Indicators for the Application Case

Measurement Indicator	Criterion	Rating / Effect Size
GHG emissions	▪ Direction	▪ Negative
	▪ Magnitude	▪ Low (<0.3% provincial baseline, <0.02% federal baseline)
	▪ Geographic extent	▪ Beyond regional (global)
	▪ Duration	▪ Permanent
	▪ Reversibility	▪ Irreversible
	▪ Frequency	▪ Continuous
	▪ Probability of occurrence	▪ Certain

< = less than; GHG = greenhouse gas.

In relation to the assessment endpoints for the climate change VC, the Project GHG emissions would not be significant in affecting Canada's ability to reach the national emission reduction targets or in affecting Canada's alignment to transition to a low carbon economy. At less than 0.3% of the provincial baseline emissions and less than 0.02% of the federal baseline emissions, the Project would not contribute significantly to the respective totals. Furthermore, due to the low life cycle GHG emissions from nuclear power generation compared to coal and natural gas power generation, the downstream effects of the Project are likely to enhance Canada's ability to meet the national emission reduction targets (CNSC 2017). Additionally, the Project may accelerate Canada's transition to a low carbon economy by providing the country with the fuel needed from cleaner energy sources (i.e., nuclear power).

7.4.7 Prediction Confidence and Uncertainty

Estimating GHG emissions is associated with uncertainty, and prediction confidence depends on the level of uncertainty and the way it is addressed. Primary factors affecting confidence in the predictions made in the climate change VC assessment include:

- availability and accuracy of baseline data;
- availability and accuracy of GHG emission factors for non-traditional emission sources (i.e., explosives);
- level of complexity of GHG emissions in terms of who bears the responsibility for the effects GHG emissions are likely to have on climate change; and
- level of certainty associated with the effectiveness of proposed mitigations, where applicable.

Uncertainty was managed by:

- completing quality assurance and quality control of emissions calculations;
- using the best available method for calculating emissions from each emission source; and
- using the best available emission factor data for calculating emissions.

Remaining uncertainty was primarily addressed by making assumptions that overestimated rather than underestimated potential effects (i.e., a precautionary assessment). When calculating the Project GHG emissions, a worst-case scenario was assumed in which GHG emissions were calculated based on the maximum expected value in any given year (e.g., maximum annual fuel consumption, maximum annual waste incinerated, maximum annual explosive used). This conservative approach yields an estimate of the maximum annual GHG emissions from the Project. Furthermore, Closure emissions include inherent uncertainty due to the limited detail in the active closure activities and the transitional monitoring programs. Conservative assumptions were made while estimating GHG emissions from Closure, as outlined in Section 7.4.5.1.1. In reality, the Project GHG emissions would likely be lower than the calculated maximum annual emissions. Therefore, the level of confidence associated with the effects of Project GHG emissions is considered high.

The Transitional Monitoring Stage emissions were conservatively estimated to be from on-site mobile equipment (i.e., pickup trucks conducting civil works and site services) and land use change.

7.4.8 Monitoring, Follow-Up, and Adaptive Management

This subsection presents a list of the identified monitoring and follow-up required to confirm effects predictions and address uncertainty identified in Section 7.4.6. The Project would result in increased GHG emissions compared to current sector, provincial, and federal totals during all Project phases, despite application of identified mitigation measures. The federal GHG reporting program requires reporting of facilities that produce GHG emissions over the 10 kt threshold; the Project would meet this requirement, should this threshold be exceeded. Specifically, reporting of GHGs would involve:

- quantifying the Project GHG emissions annually; and

- reporting the Project GHG emissions annually to applicable regulatory reporting program, which is Canada's GHG Reporting Program (ECCC 2019).

In addition, Environmental Committees (i.e., one per primary Indigenous Group) composed of two NexGen and two Indigenous Group representatives would be established to act in an oversight manner to monitor the environmental performance of the Project and verify the parties are implementing the regulatory and environmental commitments made in respect of the Project.

Indigenous Groups have made recommendations related to mitigating the effects of the Project on the environment, including community-led long-term environmental testing and monitoring during construction and operation of the Project (TSD IV: MN-S; TSD V.2: CRDN; YNLRO 2019). NexGen has committed to provide funding for the lifespan of the Project for a full-time independent Indigenous Monitor chosen by each primary Indigenous Group; this Indigenous Monitor would have access to conduct environmental sampling for the Project, subject to the Indigenous Monitor complying with appropriate health and safety and other reasonable site-specific policies. The Indigenous Monitor would be able to report openly and without restriction to the Environmental Committee and Indigenous Group's community members on the performance of the Project. The Indigenous Monitor would also provide regular reports to the Environmental Committee.

7.4.9 Key Findings

The Project GHG emissions for Construction, Operations, and Closure were analyzed, and Project GHG emissions were compared to the provincial and federal GHG levels to identify the significance of the Project on the federal and provincial emission reduction targets. The Project would result in increased GHG emissions compared to current sector, provincial, and federal totals during all phases. However, the GHG residual Project effects were assessed to be less than 0.3% of the provincial baseline emissions and less than 0.02% of the federal baseline emissions. The Project would therefore not contribute significantly to the respective totals. The Project GHG emissions would also not be significant in affecting Canada's ability to reach the national emission reduction targets or in affecting Canada's alignment to transition to a low carbon economy. The Project is likely to assist Canada's ability to meet its GHG reduction targets, as the mined materials support the nuclear energy sector, which has a low carbon intensity compared to fossil fuel-based electricity production.

7.5 References

Acts and Regulations

Canadian Environmental Assessment Act, 2012. SC 2012, c 19, s 52. *Repealed*, 2019, c 28, s 9. Available at https://laws-lois.justice.gc.ca/eng/acts/C-15.21/20170622/P1TT3xt3.html.

The Occupational Health and Safety Regulations, 2020. OC579-2020 under the *Saskatchewan Employment Act*, s 3-83 and 9-12. Approved 4 November 2020. Available at https://pubsaskdev.blob.core.windows.net/pubsask-prod/124952/OC579-2020.pdf.

Literature Cited

ACFN (Athabasca Chipewyan First Nation). 2019. NexGen Energy Ltd. Rook 1 Project. July 2019.

AER (Alberta Energy Regulator). 2007. Directive 038: Noise Control.

BBOP (Business and Biodiversity Offset Programme). 2021. Key Concepts: The Mitigation Hierarchy. Washington, D.C. Accessed September 2021. Available at https://www.forest-trends.org/bbop/bbop-key-concepts/mitigation-hierarchy/.

Beanlands G, Duinker P. 1983. An ecological framework for environmental impact assessment in Canada. Halifax Nova Scotia: Institute for Resources and Environmental Studies, Dalhousie University 132 p.

BNDN-JWG (Birch Narrows Dene Nation-Joint Working Group). 2019. Meeting Minutes. Meeting #2. 4 December 2019.

BNDN-JWG. 2020. Meeting Minutes. Meeting #4. 2 March 2020.

BNDN-JWG. 2021a. Meeting Minutes. Meeting #7. 27 January 2021.

BNDN-JWG. 2021b. Meeting Minutes. Meeting #11. 28 May 2021.

BRDN-JWG (Buffalo River Dene Nation-Joint Working Group). 2019a. Meeting Minutes. Meeting #1. 1 November 2019.

BRDN-JWG. 2019b. Meeting Minutes. Meeting #2. 5 December 2019.

BRDN-JWG. 2020a. Meeting Minutes. Meeting #3 and Site Tour. 23 January 2020.

BRDN-JWG. 2020b. Meeting Minutes. Meeting #4. 21 February 2020.

CARB (California Air Resources Board). 2021. Inhalable Particulate Matter and Health (PM2.5 and PM10). Accessed August 2021. Available at https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health.

CCME (Canadian Council of Ministers of the Environment). 2012. Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone. PN 1483. Available at https://ccme.ca/en/res/pn1483_gdad_eng-secured.pdf.

CCME. 2020a. Guidance Document on Achievement Determination for Canadian Ambient Air Quality Standards for Nitrogen Dioxide. PN 1608. Available at https://ccme.ca/en/res/gdadforcaaqsfornitrogendioxide_en1.0.pdf.

CCME. 2020b. Guidance Document on Achievement Determination for Canadian Ambient Air Quality Standards for Sulphur Dioxide. PN 1610. Available at https://ccme.ca/en/res/gdadforcaaqsforsulphurdioxide_en1.0.pdf.

CCME. 2021. Canada's Air. Air Quality Report. Accessed August 2021. Available at https://www.ccme.ca/en/air-quality-report.

CEA Agency (Canadian Environmental Assessment Agency). 2018. Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Interim Technical Guidance. March 2018 Version 2. Available at http://publications.gc.ca/collections/collection_2018/acee-ceaa/En106-204-2018-eng.pdf.

CNSC (Canadian Nuclear Safety Commission). 2017. Proposed CNSC Path Forward for Assessing Total GHG Production from Nuclear Facilities. Internal Document. Draft. E-Doc: 6515289.

CNSC. 2019. Disposition Table of Public and Indigenous Groups' Comments on Project Description – Rook I Project. E-Doc: 6001783. Submitted 12 December 2019. Available at https://iaac-aeic.gc.ca/050/evaluations/proj/80171/contributions/id/35239.

CNSC. 2021 Generic Guidelines for the Preparation of an Environmental Impact Statement – Pursuant to the *Canadian Environmental Assessment Act*, *2012*. Available at https://www.cnsc-ccsn.gc.ca/eng/resources/environmental-protection/ceaa-2012-generic-eis-guidelines/.

CRDN (Clearwater River Dene Nation). 2019a. Comments in Respect License Renewal for Orano Canada Inc. Cluff Lake Project. Canadian Nuclear Safety Commission. CMD 19-H3.12. File 6.01.07.

CRDN. 2019b. Clearwater River Dene Nation Comments on Project Description NexGen Energy Ltd.'s Rook I Project. 31 May 2019.

CRDN-JWG (Clearwater River Dene Nation-Joint Working Group). 2020a. Meeting Minutes. Meeting #1. 31 January 2020.

CRDN-JWG. 2020b. Meeting Minutes. Meeting #3. 10 March 2020.

CRDN-JWG. 2021. Meeting Minutes. Meeting #4. 24 March 2021.

ECAC (European Civil Aviation Conference). 2016. Document 29 – Report on Standard Method of Computing Noise Contours Around Civil Airports.

ECCC (Environment and Climate Change Canada). 2019. Greenhouse gas reporting: facilities. Available at https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/facility-reporting.html.

ECCC. 2020a. Canada's Greenhouse Gas Quantification Requirements, Ver. 4.0. Greenhouse Gas Reporting Program. Available at https://publications.gc.ca/collections/collection_2021/eccc/En81-28-2020-eng.pdf.

ECCC. 2020b. Strategic Assessment of Climate Change. October 2020. Available at https://www.strategicassessmentclimatechange.ca/.

ECCC. 2021. National Inventory Report (NIR) 1990–2019: Greenhouse Gas Sources and Sinks in Canada. Canada's Submission to the United Nations Framework Convention on Climate Change. Available at https://unfccc.int/documents/271493.

ENV (Saskatchewan Ministry of Environment). 2012a. Air Monitoring Guideline for Saskatchewan. March 2012. Accessed August 2021. Available at https://publications.saskatchewan.ca/api/v1/products/71865/formats/80068/download.

ENV. 2012b. Saskatchewan Air Quality Modelling Guideline. Accessed August 2021. Available at https://pubsaskdev.blob.core.windows.net/pubsask-prod/80061/80061-English.pdf.

Environment Canada. 1998. National Ambient Air Quality Objectives for Particulate Matter. Accessed August 2021. Available at https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/air/naaqo-onqaa/particulate_matter_matieres_particulaires/summary-sommaire/98ehd220.pdf.

Environment Canada. 2009. Environmental Code of Practice for Metal Mines.

Fission (Fission Uranium Corp.). 2019. Technical Report on the Pre-feasibility Study on the Patterson Lake South Property Using Underground Mining Methods, Northern Saskatchewan, Canada. NI 43-101 Report. Prepared by Roscoe Postle Associates Inc. for Fission Uranium Corp. November 2019.

Fission. 2021. Fission Project Description. Prepared by Clifton Engineering Group Inc. and Canada North Environmental Services Limited Partnership for Fission Energy Corp. 22 November 2021.

Government of Alberta. 2019. Alberta Ambient Air Quality Objectives and Guidelines Summary. Accessed August 2021. Available at https://open.alberta.ca/dataset/0d2ad470-117e-410f-ba4f-aa352cb02d4d/resource/4ddd8097-6787-43f3-bb4a-908e20f5e8f1/download/aaqo-summary-jan2019.pdf.

Government of Canada. 2015. Greenhouse Effect. Available at https://www.canada.ca/en/environment-climate-change/services/climate-change/causes.html.

Government of Canada. 2016. Pan-Canadian Framework on Clean Growth and Climate Change. Canada's Plan to Address Climate Change and Grow the Economy. Available at https://publications.gc.ca/collections/collection_2017/eccc/En4-294-2016-eng.pdf.

Government of Canada. 2019. Global Warming Potentials. Available at https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/quantification-guidance/global-warming-potentials.html.

Government of Canada. 2021a. Common air pollutants: Carbon monoxide. Accessed August 2021. Available at https://www.canada.ca/en/environment-climate-change/services/air-pollution/pollutants/common-contaminants/carbon-monoxide.html.

Government of Canada. 2021b. Greenhouse Gas Emissions: Drivers and Impacts. Available at https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions-drivers-impacts.html.

Government of Canada. 2022. Canada's 2030 Emissions Reduction Plan – Chapter 3. Available at https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030/plan/chapter-3.html.

Government of Saskatchewan. 2015a. Table 20: Saskatchewan Ambient Air Quality Standards. Accessed August 2021. Available at https://envrbrportal.crm.saskatchewan.ca/Pages/SEQS/Table20-SEQS-SAAQS.pdf.

Government of Saskatchewan. 2015b. Saskatchewan's Growth Plan. Available at https://www.saskatchewan.ca/government/budget-planning-and-reporting/plan-for-growth.

Health Canada. 2017. Guidance for Evaluating Human Health Impacts in Environmental Assessment – Noise.

Health Link BC. 2021. Harmful Noise Levels. Accessed August 2021. Available at https://www.healthlinkbc.ca/health-topics/harmful-noise-levels.

Hegmann G, Cocklin C, Creasey R, Dupuis S, Kennedy A, Kingsley L, Ross W, Spalling H, Stalker D, AXYS Environmental Consulting Ltd. 1999. Cumulative Effects Practitioners Guide. Prepared for: Canadian Environmental Assessment Agency.

IEC (International Electrotechnical Commission). 2003. IEC 61672-1 Electroacoustics – Sound Level Meters – Part 1: Specifications.

IPCC (Intergovernmental Panel on Climate Change). 2006. IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). Published: IGES, Japan. Available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/.

ISO (International Organization for Standardization). 1996. ISO 9613-2 Acoustics – Attenuation of Sound During Propagation Outdoors – Part 2: General Method of Calculation.

ISO. 2006. Greenhouse Gases - Part 1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals, 14064–1.

MN-S (Métis Nation – Saskatchewan). 2019. Comments concerning the NexGen Energy Ltd. Rook I Project Description. Submission to the Canadian Nuclear Safety Commission and Saskatchewan Ministry of Environment re: NexGen Rook I Project. April 2019.

MN-S-JWG (Métis Nation – Saskatchewan-Joint Working Group). 2019a. Meeting Minutes. Meeting #1. 29 October 2019.

MN-S-JWG. 2019b. Meeting Minutes. Meeting #2. 10 December 2019.

MN-S-JWG. 2020. Meeting Minutes. Meeting #4. 27 February 2020.

NexGen (NexGen Energy Ltd.). 2019. Community Information Session. Round One – June 2019. Submitted to Saskatchewan Ministry of Environment - Environmental Assessment Branch. Canadian Nuclear Safety Commission (CNSC). July 2019.

Parker D. 2015. Life Cycle Analysis of Greenhouse Gas Emissions from the Mining and Milling of Uranium in Saskatchewan. Thesis Submitted to the University of Saskatchewan. Available at https://harvest.usask.ca/handle/10388/ETD-2015-06-2120.

Prime Minister of Canada Justin Trudeau. 2021. Prime Minister Trudeau announces increased climate ambition. Accessed April 2021. Available at https://pm.gc.ca/en/news/news-releases/2021/04/22/prime-minister-trudeau-announces-increased-climate-ambition.

United Nations. 2015. Paris Agreement. Available at https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

USEPA (United States Environmental Protection Agency). 1995. AP-42, Fifth Edition Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources. Accessed August 2021. Available at https://19january2017snapshot.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors_.html.

USEPA. 2021. User's Guide for the AMS/EPA Regulatory Model (AERMOD). EPA-454/B-21-001. Available at https://gaftp.epa.gov/Air/aqmg/SCRAM/models/preferred/aermod/aermod_userguide.pdf.

WRI and WBCSD (World Resources Institute and World Business Council for Sustainable Development). 2013. The Greenhouse Gas Reporting Protocol: A Corporate Accounting and Reporting Standard.

YNLRO (Ya'thi Néné Lands and Resources Office). 2019. Comments concerning the NexGen Energy Ltd. Rook I Project Description. Written Submission from the Ya'thi Néné Lands and Resources Office In the Matter of; NexGen Energy Ltd. Rook I Project Description. May 2019.

Appendix 7A Air Dispersion Modelling Report

Abbreviations and Units of Measure

Abbreviation	Definition
ANFO	ammonium nitrate fuel oil
BSFC	brake-specific fuel consumption
CAAQS	Canadian Ambient Air Quality Standards
CAC	criteria air contaminant
CAT	Caterpillar
CCME	Canadian Council of Ministers of the Environment
CEPEI	Canadian Energy Partnership for Environmental Innovation
D&F	dioxins and furans
EA	Environmental Assessment
ENV	Saskatchewan Ministry of Environment
HC	hydrocarbons
LLRW	low-level radioactive waste
MSAPR	Multi-Sector Air Pollution Regulations
NPAG	non-potentially acid generating
PAG	potentially acid generating
PM	particulate matter
PM_{10}	particulate matter with a diameter of 10 microns or less
$PM_{2.5}$	particulate matter with a diameter of 2.5 microns or less
Project	Rook I Project
RFD	reasonably foreseeable development
RSA	regional study area
SAAQS	Saskatchewan Ambient Air Quality Standards
SAG	semi-autogenous grinding
SAQMG	Saskatchewan Air Quality Modelling Guideline
TAF	transient adjustment factor
TSP	total suspended particulates
U_3O_8	triuranium octoxide
USEPA	United States Environmental Protection Agency
VC	valued component
WRF	Weather Research and Forecast

Unit	Definition
°	degree
%	percent
°C	degrees Celsius
µg/m^3	µg/m^3
µg/Rm^3	micrograms per reference cubic metre
µm	micron
Bq/g	becquerels per gram
Bq/m^3	becquerels per cubic metre
Bq/s	becquerels per second
d	day
dsm^3	dry standard cubic metre
dsm^3/s	dry standard cubic metre per second
g	gram
g/GJ	grams per gigajoule
g/hp/h	grams per horsepower per hour
g/m^2/30 d	grams per square metre per 30 days
g/m^2/yr	grams per square metre per year

Unit	Definition
g/m^3	grams per cubic metre
g/s	grams per second
GJ	gigajoule
ha	hectare
hp	horsepower
kg	kilogram
kg/blast	kilograms per blast
kg/h	kilograms per hour
kg/ha	kilograms per hectare
kg/ha/yr	kilograms per hectare per year
kg/m^3	kilograms per cubic metre
kg/VKT	kilograms per vehicle kilometres travelled
kg/t	kilograms per tonne
km	kilometre
km/h	kilometres per hour
L	litre
L/h	litres per hour
Lb	pound
Lb fuel/hp/h	pounds of fuel per horsepower per hour
Lb/MMBtu	pounds per million British thermal unit
Lb/t	pounds per tonne
m	metre
m^2	square metre
m^3	cubic metre
m^3/h	cubic metres per hour
m^3/s	cubic metres per second
mm	millimetre
mg/m^3	milligrams per cubic metre
MMBtu/h	million British thermal units per hour
ppm	parts per million
t	tonne
t/d	tonnes per day
t/ha	tonnes per hectare
t/m^3	tonnes per cubic metre
t/yr	tonnes per year
yr	year

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Attachment 7A-1 Radon Releases Memo

7A1 INTRODUCTION

This technical document supplements Environmental Impact Statement (EIS) Section 7, Air Quality, Noise, and Climate Change of the for the Rook I Project (Project).

The general approach used to evaluate the potential air quality effects of the Project includes the following steps:

- Establish the existing air quality and meteorological conditions in the regional study area (RSA; Annex I, Atmospheric Baseline Report, Section 5.3.2, Regional Air Quality).
- Quantify the air emissions from Project Construction and Operations and other nearby planned industrial developments (e.g., Fission Patterson Lake South Property project) in the Reasonably Foreseeable Development (RFD) Case (Section 7A2, Air Emission Inventory).
- Develop a representative site-specific meteorological dataset for use in the air dispersion modelling assessment (Section 7A3.1, Dispersion Meteorology).
- Use dispersion modelling to predict the concentration and/or deposition rates of indicator compounds released from the Project that would result in highest overall changes to air quality (Section 7A3.2, Dispersion Modelling).
- Use dispersion modelling to predict the concentration and/or deposition rates of the other compounds required as inputs to other disciplines affected by changes in air quality (e.g., soil, water quality, vegetation, wildlife, and human health; Section 7A3.2).
- Compare the predicted indicator compound concentrations to the relevant provincial or federal guidelines and standards (EIS Section 7.2.5, Residual Effects Analysis).

7A2 AIR EMISSION INVENTORY

The overall approach in developing the Project emission inventory was to work closely with the Project design team to define the emission inventory inputs (e.g., fuel consumption, vehicle fleet) and activity rates (e.g., mill throughput, operational hours per day). A conservative approach was taken, in that the inventory was developed for the each most intensive year of Construction and Operations when air emissions are expected to be highest.

Since the Project is currently at the design stage, the Project emission inventory was developed based on input from the design team and the best available information, adopting a conservative approach. It is likely that some Project information will ultimately differ from what was assumed for the purpose of the emission inventory. Given the conservative approach, these differences are not expected to have a meaningful change to the outcome of the assessment, as the assumptions are likely to lead to over-estimates of potential Project effects.

7A2.1 Air Quality Indicators

The assessment of air quality focuses on predicting changes of the concentrations of selected indicator compounds, namely the criteria air contaminants (CACs). These indicator compounds were selected as air quality measurement indicators because they represent compounds that are expected to be emitted from the Project and they are compounds for which relevant ambient air quality criteria exist. These measurement indicator compounds fall into the following three general categories:

- Combustion gases: nitrogen dioxide, sulphur dioxide, and carbon monoxide. Nitrogen dioxide is one of a group of highly reactive gases known as nitrogen oxides, which also includes nitric oxide. The nitrogen dioxide emissions from the sources are generally quantified as nitrogen oxides.
- Particulate matter (PM): total suspended particulates (TSP), which are PM with a diameter of 40 microns or less including PM with a diameter of 10 microns or less (PM_{10}) and PM with a diameter of 2.5 microns or less ($PM_{2.5}$). The deposition of TSP is used to represent the dust deposition or dust fall in the assessment.
- Sulphuric acid: emitted from the Project acid plant.

These compounds are generally referred to as CACs.

Although not specific air quality measurement indicators, additional compounds that were specific to uranium mining and milling operations, which were also used by other valued components (VCs) and intermediate components (e.g., soil, water quality, vegetation, wildlife, human health), were modelled to support those components. The modelling of these compounds also supported the Technical Support Document (TSD) XXI, Environmental Risk Assessment. These compounds include the following:

- Metals: emitted as a fraction of PM from either fugitive sources of mineral dust, or PM associated with combustion emissions.
- Radon: released from mining and milling of uranium ores.
- Radionuclides: emitted from mining and milling of uranium ores.
- Dioxins and furans (D&F): emitted from a domestic waste incinerator and a low-level radioactive waste (LLRW) incinerator.

Table 7A-1 summarizes the air quality measurement indicators and other compounds, of which emission rates were quantified and modelled. The table also lists whether the compounds are emitted from the Project during Construction and/or Operations, where the concentration and/or deposition was modelled, and whether the compounds were assessed in the air quality effects assessment or provided to support other VCs or intermediate components.

Table 7A-1: Air Quality Measurement Indicators and Other Compounds

Air Compounds	Emitted from Project during Construction	Emitted from Project during Operations	Concentration Modelled	Deposition Modelled	Assessed in Air Quality Effects Assessment	Modelling Results Provided to other VCs or intermediate components
Air Quality Measurement Indicators						
Nitrogen dioxide	√	√	√	x	√	√
Sulphur dioxide	√	√	√	x	√	√
Sulphuric acid	x	√	√	x	√	√
Carbon monoxide	√	√	√	x	√	√
$PM_{2.5}$	√	√	√	√	√	√
PM_{10}	√	√	√	√	√	√
TSP	√	√	√	√	√	√
Metals						
Silver (Ag)	√	√	√	√	x	√
Arsenic (As)	√	√	√	√	x	√
Barium (Ba)	√	√	√	√	x	√
Beryllium (Be)	√	√	√	√	x	√
Cadmium (Cd)	√	√	√	√	x	√
Cobalt (Co)	√	√	√	√	x	√
Chromium (Cr)	√	√	√	√	x	√
Copper (Cu)	√	√	√	√	x	√
Mercury (Hg)	√	√	√	√	x	√
Molybdenum (Mo)	√	√	√	√	x	√
Nickel (Ni)	√	√	√	√	x	√
Lead (Pb)	√	√	√	√	x	√
Antimony (Sb)	√	√	√	√	x	√
Selenium (Se)	√	√	√	√	x	√
Tin (Sn)	√	√	√	√	x	√
Thorium (Th)	√	√	√	√	x	√
Uranium (U)	√	√	√	√	x	√
Vanadium (V)	√	√	√	√	x	√
Zinc (Zn)	√	√	√	√	x	√
Cesium (Cs)	√	√	√	√	x	√
Bismuth (Bi)	√	√	√	√	x	√
Calcium (Ca)	√	√	√	√	x	√
Iron (Fe)	√	√	√	√	x	√
Magnesium (Mg)	√	√	√	√	x	√
Manganese (Mn)	√	√	√	√	x	√
Sodium (Na)	√	√	√	√	x	√
Others						
Radon	√	√	√	x	x	√
Radionuclide	√	√	√	√	x	√
D&F	√	√	√	x	x	√

√ = yes; x = no; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; VC = valued component; D&F = dioxins and furans.

Acid deposition occurs when emissions (e.g., sulphur dioxide and nitrogen oxide) from the combustion of fossil fuels and other industrial processes undergo complex chemical reactions in the atmosphere and fall onto land, water, vegetation, or structures as wet deposition (i.e., rain, snow, cloud, fog) or dry deposition (i.e., dry particles, gas). The Saskatchewan air quality modelling guideline (ENV 2012) lists two criteria for acid emissions to determine if a facility's emission would result in acid deposition and required to undertake regional acid deposition. The two criteria are:

- The facility's combined emissions of SO_2, NO_x, and NH_3 are greater than 0.175 tonnes per day (t/d) of H+ equivalent, where:

$$Total\ H+\ equivelent\ \left(\frac{t}{d}\right) = 2 * \frac{SO_2\left(\frac{t}{d}\right)}{64} + 1 * \frac{NO_x\left(\frac{t}{d}\right)}{46} + 1 * \frac{NH_3\left(\frac{t}{d}\right)}{17}$$

- The emissions from the facility are larger than 5% of the baseline emissions in the region.

Preliminary screening results showed that the total H+ equivalent of the Project considering all acidifying emissions (i.e., nitrogen oxides, sulphur dioxide, ammonia, and sulphuric acid) would be approximately one tenth of the 0.175 t/d. As part of NexGen's air quality baseline monitoring program, pH values of rainwater have been monitored at the Project site since September 2018 (Annex I, Atmospheric Baseline Report). The average pH value of the rainwater from September 2018 to October 2020 is 6.36, which is less acidic than clean, unpolluted rain, for which the pH value is approximately 5.6. Due to the relatively low acidity of the rainwater at the Project site, the potential for acid emissions to cause acid deposition issues is likely to be low.

After direct consultation with Saskatchewan Ministry of Environment, given the relatively low emissions of sulphur dioxide, nitrogen oxides, and sulphuric acid, which would result in low potential for contribution to the acid input, the modelling of acid deposition for the Project was not undertaken.

7A2.2 Project Emission Inventory

7A2.2.1 General Project Activities

The assessment provided the model results for Project Construction and Operations. A single maximum year scenario was modelled respectively for Construction and Operations. This maximum year may be a synthesis of different emissions that occur throughout the Project life to arrive at a conservative set of inputs. For example, the maximum emission rates for each source in Construction would not necessarily all occur in the same year of Construction, but they were considered together in the assessment. The emissions during Closure were not quantified, as Closure emissions were not expected to exceed those of Construction or Operations.

For Construction, the second year was determined to be the peak year of construction activities based on the construction mobile equipment usage. For Operations, the maximum emissions for various sources tend to occur in Year 1, Year 2, or Year 3, though some maximum emissions do occur in other years.

Project information that was used in the emission inventory were obtained from the following sources:

- NexGen Energy Rook I Project - Project description (NexGen 2019);
- NexGen Energy Rook I Project – Prefeasibility Study Report (NexGen 2018); and
- provided directly by the Project engineering design team.

7A2.2.2 Emission Sources

Table 7A-2 lists the emission sources at the Project that are assumed to be active during Construction and Operations. The emission types and the emitted compounds are also listed in the table. Generally, there are two types of emission sources from the Project:

- Stack emissions: air emissions released through a stack, chimney, vent, or other functionally equivalent opening.
- Fugitive emissions: emissions that could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.

The fugitive emissions such as drilling and blasting for underground mining operations would be released through the mine vents, therefore, although there are fugitive emissions at sources, they were represented as stack sources in the model. The fugitive emissions from road dust and wind erosion are represented as volume or area sources in the model. Area sources are used to model air emission releases that occur over an area (e.g., stockpiles). Volume sources are used to model air emission releases that occur over a three-dimensional volume. For example, the traffic induced air emission on road was recommended to be modelled as a series of volume sources by USEPA (2012).

Table 7A-2: Summary of Emission Sources

Emission Sources	Specific Activities	Emissions Types	Emitted Compounds	Construction	Operations
Acid plant	Acid plant	Stack	▪ sulphur dioxide ▪ sulphuric acid	x	√
Calciner	Calciner natural gas burner	Stack	▪ CACs	x	√
	Calciner exhaust	Stack	▪ PM ▪ sulphur dioxide ▪ uranium	x	√
	Calciner bin baghouse exhaust	Stack	▪ PM ▪ uranium	x	√
Concrete batch plant	Concrete batching	Fugitive – volume	▪ PM	√	√
Crushing	Underground operations	Fugitive – mine vent	▪ PM	x	√
	Aggregate operations	Fugitive – area	▪ PM ▪ metals	√	√
	SAG and ball mill	Fugitive – stack	▪ PM ▪ radon ▪ radionuclide ▪ metals	x	√
Dozing	Ore storage pad	Fugitive – area	▪ PM ▪ radon ▪ radionuclide ▪ metals	x	√
	Special waste rock stockpile	Fugitive – area	▪ PM ▪ radionuclide ▪ metals	x	√
	NPAG waste rock stockpile	Fugitive – area	▪ PM ▪ radon ▪ radionuclide ▪ metals	√	√
	PAG waste rock stockpile	Fugitive – area	▪ PM ▪ radon ▪ radionuclide ▪ metals	√	√

Table 7A-2: Summary of Emission Sources

Emission Sources	Specific Activities	Emissions Types	Emitted Compounds	Construction	Operations
Drilling	Underground operations	Fugitive – mine vent	▪ PM ▪ radon ▪ radionuclide ▪ metals	√	√
Blasting	Underground operations	Fugitive – mine vent	▪ CACs ▪ radon ▪ radionuclide ▪ metals	√	√
Material handling	Underground material handling	Fugitive – mine vent	▪ PM ▪ radionuclide ▪ metals	√	√
	Headframe drop	Fugitive – volume	▪ PM ▪ radionuclide ▪ metals	√	√
	NPAG stockpile drop	Fugitive – area	▪ PM ▪ radon ▪ radionuclide ▪ metals	√	√
	PAG stockpile drop	Fugitive – area	▪ PM ▪ radon ▪ radionuclide ▪ metals	√	√
	Aggregate handling	Fugitive – area	▪ PM	√	√
	Ore storage stockpile loading and drop	Fugitive – area	▪ PM ▪ radionuclide ▪ metals	x	√
	Special waste stockpile drop	Fugitive – area	▪ PM ▪ radionuclide ▪ metals	x	√
Power plant	Natural gas-fired gensets	Stack	▪ CACs	√	√
Freeze plant generator	Diesel-fired generator	Stack	▪ CACs	√	x
Grading	Surface	Fugitive – volume	▪ PM ▪ metals	√	√
	Underground	Fugitive – volume	▪ PM ▪ metals	√	√
Incinerators	Batch incinerator	Stack	▪ CACs ▪ D&F ▪ metals	√	√
	LLRW incinerator	Stack	▪ CACs ▪ D&F ▪ radon ▪ metals	√	√
Baghouses	Lime silo – reagents	Stack	▪ PM	x	√
	Lime silo – precipitation	Stack	▪ PM	x	√
Mobile equipment	Underground	Fugitive – mine vent	▪ CACs	√	√
	Surface	Fugitive – volume	▪ CACs	√	√
Heaters	Mine heaters	Fugitive – mine vent	▪ CACs	√	√
	Camp heaters	Fugitive – area	▪ CACs	√	√
	Frost fighter heaters	Fugitive – area	▪ CACs	√	x

Table 7A-2: Summary of Emission Sources

Emission Sources	Specific Activities	Emissions Types	Emitted Compounds	Construction	Operations
Road dust	Underground	Fugitive – mine vent	▪ PM ▪ metals	√	√
	Surface	Fugitive – volume	▪ PM ▪ metals	√	√
Wind erosion	Ore storage pad	Fugitive – area	▪ PM ▪ metals	x	√
	Special waste rock stockpile	Fugitive – area	▪ PM ▪ radon ▪ radionuclide ▪ metals	x	√
	NPAG waste rock stockpile	Fugitive – area	▪ PM ▪ radon ▪ radionuclide ▪ metals	√	√
	PAG waste rock stockpile	Fugitive – area	▪ PM ▪ radon ▪ radionuclide ▪ metals	√	√
	Aggregate stockpile	Fugitive – area	▪ PM ▪ metals	√	√
Uranium concentrate handling	Uranium concentrate handling	Stack	▪ PM ▪ uranium	√	√
General construction	General construction	Fugitive – area	▪ PM	√	x

√ = yes; x = no; NPAG = non-potentially acid generating; PAG = potentially acid generating; LLRW = low-level radioactive waste; PM = particulate matter; SAG = semi-autogenous grinding; CAC = criteria air contaminant; D&F = dioxins and furans.

7A2.2.3 Project Emissions Summary

Table 7A-3 compares the maximum annual emissions between Project Construction and Operations. Construction has higher emissions of nitrogen oxides, $PM_{2.5}$, PM_{10}, and TSP due to the use of diesel rather than liquified natural gas as the primary fuel for on-site power generation and more site preparation activities on the surface during Construction.

Table 7A-3: A Comparison of Project Emissions by Phase

Phase	Maximum Annual Emission Rates (t/yr)						
	Nitrogen Oxides	Sulphur Dioxide	Sulphuric Acid	Carbon Monoxide	$PM_{2.5}$	PM_{10}	TSP
Construction	271.17	1.03	n/a	57.27	20.47	75.41	200.72
Operations	175.07	5.03	0.35	141.65	18.08	61.01	180.16

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; n/a = not applicable.

Table 7A-4 and Table 7A-5 present a breakdown of Construction and Operations emissions by source categories, respectively. Below is the high-level discussion of the main contributors of emissions in each phase of the Project.

Nitrogen Oxides

- Construction: power generation by diesel is the largest source (82.9%), followed by liquified natural gas power generation (9.6%) and mine fleet exhaust (6.4%).
- Operations: power generation is the largest source (89.6%) followed by mine fleet exhaust (5.2%).

Sulphur Dioxide

- Construction: incinerator (57.3%) and diesel power generators (36.6%) are the largest sources.
- Operations: acid plant is the largest source (54.0%) followed by LLRW incinerator (29.3%) and batch incinerator (11.8%).

Sulphuric Acid

- Construction: no emissions of sulphuric acid.
- Operations: acid plant is the sole source of sulphuric acid emissions.

Carbon Monoxide

- Construction: power generation by diesel is the largest source (32.7%), followed by liquified natural gas power generation (26.0%) and mine fleet exhaust (18.9%).
- Operations: power generation is the largest source (48.6%), followed by underground blasting (26.9%) and mine heater (15.4%).

$PM_{2.5}$

- Construction: power generation by diesel is the largest source (30.7%), followed by aggregate operations (15.5%), road dust (13.6%), and construction activities (10.2%).
- Operations: power generation is the largest source (25.8%), followed by calciner stacks (18.4%) and road dust (13.1%).

PM_{10}

- Construction: road dust is the largest source (37.0%), followed by construction activities (27.8%) and aggregate operations (10.7%).
- Operations: road dust is the largest source (39.0%), followed by calciner stacks (15.5%) and underground hauling (11.9%).

TSP

- Construction: road dust is the largest source (51.8%), followed by construction activities (20.5%) and aggregate operations (9.8%).
- Operations: road dust is the largest source (51.3%), followed by underground hauling (15.7%) and calciner stacks (9.8%).

Table 7A-4: Rook I Project Construction Emissions By Source Category

Emission Source	Maximum Annual Emission Rates (t/yr)						
	Nitrogen Oxides	Sulphur Dioxide	Sulphuric Acid	Carbon Monoxide	$PM_{2.5}$	PM_{10}	TSP
Acid plant	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Calciner stacks	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Batch plant	n/a	n/a	n/a	n/a	0.87	1.56	5.83
SAG and ball mill	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Aggregate operations	n/a	n/a	n/a	n/a	3.17	8.10	19.62
Dozing	n/a	n/a	n/a	n/a	0.66	1.19	6.28
Material handling	n/a	n/a	n/a	n/a	0.01	0.05	0.09
Small heaters	1.47	0.00	n/a	4.27	0.05	0.18	0.35
UG grading	n/a	n/a	n/a	n/a	n/a	n/a	n/a
UG diesel mine fleet	0.07	0.00	n/a	0.08	0.00	0.00	0.00
UG hauling	n/a	n/a	n/a	n/a	n/a	n/a	n/a
UG material handling	n/a	n/a	n/a	n/a	0.01	0.04	0.08
UG drilling	n/a	n/a	n/a	n/a	0.00	0.00	0.01
UG blasting	0.24	0.01	n/a	6.72	0.00	0.01	0.01
Power plant	26.08	0.00	n/a	14.92	0.78	0.78	0.78
Road dust	n/a	n/a	n/a	n/a	2.79	27.92	103.95
Grading	n/a	n/a	n/a	n/a	0.19	2.14	6.12
Incinerator	1.00	0.59	n/a	0.16	0.35	0.46	0.70
LLRW incinerator	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Lime silos	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mine fleet	17.25	0.05	n/a	10.82	1.68	1.73	1.73
Mine heater	0.20	0.00	n/a	1.58	0.01	0.01	0.01
Wind erosion	n/a	n/a	n/a	n/a	1.52	3.80	7.61
Uranium concentrate handling	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Construction activity	n/a	n/a	n/a	n/a	2.10	20.95	41.08
Construction gensets	224.85	0.38	n/a	18.73	6.28	6.50	6.50
Total	**271.17**	**1.03**	**n/a**	**57.27**	**20.47**	**75.41**	**200.72**

UG = underground; LLRW = low-level radioactive waste; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; SAG = semi-autogenous grinding; n/a = not applicable.

Table 7A-5: Rook I Project Operations Emissions by Source Category

Emission Source	Maximum Annual Emission Rates (t/yr)						
	Nitrogen Oxides	Sulphur Dioxide	Sulphuric Acid	Carbon Monoxide	$PM_{2.5}$	PM_{10}	TSP
Acid plant	n/a	2.71	0.35	n/a	n/a	n/a	n/a
Calciner stacks	0.13	0.06	n/a	10.50	3.32	9.44	17.70
Batch plant	n/a	n/a	n/a	n/a	0.01	0.02	0.08
SAG and ball mill	n/a	n/a	n/a	n/a	0.33	1.12	2.19
Aggregate operations	n/a	n/a	n/a	n/a	0.23	0.41	1.48
Dozing	n/a	n/a	n/a	n/a	0.99	1.78	9.42
Material handling	n/a	n/a	n/a	n/a	0.48	1.65	3.23
Small heaters	0.26	0.00	n/a	0.17	0.01	0.01	0.01

Table 7A-5: Rook I Project Operations Emissions by Source Category

Emission Source	Maximum Annual Emission Rates (t/yr)						
	Nitrogen Oxides	Sulphur Dioxide	Sulphuric Acid	Carbon Monoxide	$PM_{2.5}$	PM_{10}	TSP
UG grading	n/a	n/a	n/a	n/a	0.03	0.47	0.95
UG diesel mine fleet	1.87	0.02	n/a	0.18	0.01	0.10	0.10
UG hauling	n/a	n/a	n/a	n/a	0.73	7.25	28.22
UG material handling	n/a	n/a	n/a	n/a	0.01	0.04	0.08
UG drilling	n/a	n/a	n/a	n/a	0.40	0.40	0.50
UG blasting	0.24	0.02	n/a	49.77	0.02	0.26	0.50
Power plant	156.92	0.02	n/a	89.81	4.67	4.67	4.67
Road dust	n/a	n/a	n/a	n/a	2.38	23.77	92.38
Grading	n/a	n/a	n/a	n/a	0.19	2.20	6.29
Incinerator	1.00	0.59	n/a	0.16	0.35	0.46	0.70
LLRW incinerator	1.86	1.47	n/a	0.24	0.85	1.09	1.64
Lime silos	n/a	n/a	n/a	n/a	0.17	0.17	0.17
Mine fleet	9.14	0.05	n/a	5.35	0.95	0.98	0.98
Mine heater	3.64	0.08	n/a	28.51	0.14	0.14	0.14
Wind erosion	n/a	n/a	n/a	n/a	1.61	4.04	8.07
Uranium concentrate handling	n/a	n/a	n/a	n/a	0.20	0.56	0.66
Construction activity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Construction gensets	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total	**175.07**	**5.03**	**0.35**	**184.70**	**18.08**	**61.01**	**180.16**

UG = underground; LLRW = low-level radioactive waste; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; SAG = semi-autogenous grinding; n/a = not applicable.

7A2.2.4 Emission Estimation by Source Category

7A2.2.4.1 Acid Plant

The emission rates of sulphur dioxide and sulphuric acid were estimated by using the vendor-guaranteed concentrations in exhaust air from the acid plant and the volumetric flow rate of the exhaust air.

The concentration of sulphur dioxide from the acid plant was set at 344 mm per normal cubic metre, and the concentration of sulphuric acid was set at 45 m, per normal cubic metre. The vendor has set a performance guarantee with these levels as the maximum concentration of the exhaust air. The flow rate of the exhaust is 900 normal cubic metres per hour.

The calculated emission rates are presented in Table 7A-6**.** The acid plant throughput for acid produced is 300 t/d. The sulphur dioxide and sulphuric acid emissions were converted into 0.025 kg/t of acid produced and 0.0032 kg/t of acid produced, respectively. These emission rates are well below the United States Environmental Protection Agency (USEPA) guidance (USEPA 2015), which are 2 kg/t for sulphur dioxide and 0.075 kg/t for sulphuric acid. The emission rates have been converted to grams per second for presentation as these are the units used directly by the dispersion model.

Table 7A-6: Acid Plant Stack Emissions

Source	Sulphur Dioxide (g/s)	Sulphuric Acid (g/s)
Acid plant stack	8.6×10^{-02}	1.13×10^{-02}

7A2.2.4.2 Calciner

The calciner is an indirect fired drum heater that heats products (i.e., uranium concentrate) to 840°C. The system is composed of a natural gas burner and a small ventilating air stream passing through the calciner so that no gases are concentrated in the calciner. The calciner will not run during Construction.

7A2.2.4.2.1 Calciner Natural Gas Burner

The natural gas burner has combustion products that indirectly heat the calciner before passing through a heat recovery unit. Combustion air is pulled through the calciner shell and exits the stack. The nitrogen oxides, carbon monoxide, and PM emissions from the calciner natural gas burner were estimated from published emission factors and the maximum natural gas consumption of the burner. The sulphur dioxide emissions were estimated using a mass balance method. The following assumptions were made regarding the emission estimates:

- The highest natural gas consumption is in Operations Year 3 at 83,957 gigajoules (GJ) provided by Project engineering design team.
- Nitrogen oxides emission factor is 16 grams per gigajoule (g/GJ), the limit set for a heater of this size in the Multi-Sector Air Pollutants Regulations (MSAPR; Sulphur in Diesel Fuel Regulations). It is noted that the MSAPR is not applicable to the calciner. The MSAPR nitrogen oxides emission factor (i.e., 0.033 lb/MMBtu) applied in this assessment is similar to the Canadian Energy Partnership for Environmental Innovation (CEPEI)'s emission factor for a low nitrogen oxides burners with flue gas recirculation (i.e., 0.031 lb/MMBtu) (CEPEI 2021).
- Sulphur dioxide emissions are based on a mass balance for non-odorized gas set at 0.6 mg/m^3 (CEPEI 2021).
- Carbon monoxide emission factor is set at 125 g/GJ, the maximum allowable by the Canadian Council of Ministers of the Environment (CCME) national guideline for commercial/industrial boilers and heaters (CCME 1998).
- CEPEI's default $PM_{2.5}$ emissions factor for gas-fired boilers and process heaters (0.637 g/GJ) was used to estimate the PM emission rates assuming natural gas combustion exhausted PM from the calciner would be sized less than 2.5 µm (CEPEI 2021).
- It is assumed that the calciner natural gas burner will be operating consistently during all hours throughout the year, therefore the emission rates for all averaging periods are identical.

Calciner burner emissions are presented in Table 7A-7 for nitrogen oxides, sulphur dioxide, carbon monoxide, $PM_{2.5}$, PM_{10}, and TSP.

Table 7A-7: Calciner Natural Gas Burner Emissions

Source	Nitrogen Oxides (g/s)	Sulphur Dioxide (g/s)	Carbon Monoxide (g/s)	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
Calciner burner	4.26×10^{-02}	8.85×10^{-05}	3.33×10^{-01}	1.70×10^{-03}	1.70×10^{-03}	1.70×10^{-03}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.2.2 Calciner Exhaust

The exhaust from the calciner is passed through the Calcine Dust Control Venturi Scrubber. The scrubber uses barren strip and water to mitigate dust and gas. The emissions from the calciner exhaust were estimated based on the engineering estimate of material lost from the calciner and a stack test conducted at a similar uranium milling facility. The following information was used in the emission estimate from calciner exhaust:

- The Project process flow diagram indicates 2 kg/h of material is lost in the calciner; the material is presumed to be entirely emitted as TSP to the atmosphere.
- Due to the lack of information of other air pollutants from the calciner exhaust, testing results from a stack test conducted in 2008 for a similar uranium milling facility in Saskatchewan at the McClean Lake Mine were used to estimate the sulphur dioxide emissions from the PM emission rates (AREVA 2014). The McClean Lake mine stack test measured 1.67 g/s of PM (i.e., TSP) and 5.1×10^{-03} g/s of sulphur dioxide. The ratio of stack tested sulphur dioxide to PM (3.054×10^{-03}) was applied to the particulate emission of the Project (2 kg/h) to estimate the sulphur dioxide emissions.
- In the absence of specific emission factors for $PM_{2.5}$ and PM_{10}, the generalized particle size distribution reference provided in Appendix B.2 of USEPA AP-42 for calcining and other heat reaction processes (Category 5; USEPA 1996a) was used to estimate the emission rates of PM_{10}, and $PM_{2.5}$ from TSP. The cumulative percentages of $PM_{2.5}$ and PM_{10} in TSP are 18% and 53%, respectively.

Calciner emissions are presented in Table 7A-8 for sulphur dioxide, $PM_{2.5}$, PM_{10}, and TSP.

Table 7A-8: Calciner Exhaust Stack Emissions

Source	Sulphur Dioxide (g/s)	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
Calciner stack	1.70×10^{-03}	1.00×10^{-01}	2.94×10^{-01}	5.56×10^{-01}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.2.3 Calciner Bin Baghouse Exhaust

The calcined material will be stored in the calciner bin prior to packaging. The PM emissions from the calciner bin baghouse exhaust were estimated using a published PM concentration in the exhaust air and the volumetric flow rate of the exhaust air. The following assumptions were made to estimate the emissions from the baghouse exhaust:

- The PM concentrations of the baghouse exhaust is 0.020 g/m^3 (MECC 2018).
- The diameter and velocity of the baghouse exhaust stack are 0.15 m and 10 m/s respectively, based on professional judgment. Thus, the volumetric flow rate is 0.18 m^3/s.
- The PM emitted from the baghouse is assumed to be less than 2.5 µm.

Table 7A-9 presents the emission rates for the calcine bin baghouse based on the above assumptions.

Table 7A-9: Calciner Bin Baghouse Emissions

Source	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
Calciner bin baghouse	3.65×10^{-03}	3.65×10^{-03}	3.65×10^{-03}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.3 Concrete Batch Plant

The PM emissions from the concrete batch plant were estimated from published emission factors and the material (i.e., aggregate, cement) throughput. In the absence of specific information regarding concrete batch plant emissions, the following assumptions are made:

- The batch plant will primarily produce structural concrete during Construction, and shotcrete during Operations. The peak volume of aggregate per year is 350,000 m^3. It is expected in second year of Construction. During Operations, the maximum production volume is 5,000 m^3 per year.
- The same volume of concrete was assumed to be mixed as the amount of aggregate used in the mix, which is a conservative assumption due to the higher density of concrete than aggregates.
- The cement used in the concrete production was assumed to be 14% of the concrete produced by mass. This is in accordance with USEPA AP-42 Section 11.12 Concrete Batching (USEPA 2006a).
- The emission factors listed in Table 11.12-1 in USEPA AP-42 Section 11.12 Concrete Batching (USEPA 2006a) were used. Industry standard operational dust controls are assumed for the batch plant, such as a drop chute and in-plant filtration system. The controlled emission factors for cement unloading and truck loading were used in the emission inventory.
- Since the emission factors are only listed for TSP and PM_{10} in the USEPA AP-42 emission factor document, the generalized size distribution for ground materials (Category 3) found in Appendix B.2 of EPA AP-42 (USEPA 1996a) was used to estimate the $PM_{2.5}$ fraction. For these reasons, the $PM_{2.5}$ subset of TSP is assumed to be 15%.

Estimated emission rates from the batch plant are presented in Table 7A-10 and Table 7A-11.

Table 7A-10: Concrete Batch Plant Emission Factors

Source	Emission Rate (g/s)		
	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
Cement unloading	7.50×10^{-05}	1.7×10^{-04}	5.00×10^{-04}
Truck loading	7.00×10^{-03}	1.31×10^{-02}	4.90×10^{-02}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Table 7A-11: Concrete Batch Plant Emission Rates

Source	Emission Rate (g/s)		
	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
Batch plant during Construction	2.77×10^{-02}	4.96×10^{-02}	1.85×10^{-01}
Batch plant during Operations	3.96×10^{-04}	7.08×10^{-04}	2.64×10^{-03}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.4 Crushing

Aggregate crushing processes will occur during Construction. Crushing will also occur in two processes during Operations; the grinding circuit in the semi-autogenous grinding (SAG) mill and in the ball mill and aggregate crushing processes.

Emission factors from USEPA AP-42 Chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing (USEPA 2004a) and Environment and Climate Change Canada's pits and quarries National Pollutant Release Inventory reporting guide (ECCC 2021) were used. Controlled and uncontrolled emission factors were provided for the following processes:

- primary crushing;
- secondary crushing;
- tertiary crushing;
- fines crushing;
- screening;
- fines screening; and
- conveyor transfer point.

Controlled emission factors are applicable when processing of material, either naturally wet with a moisture content above 1.5% or moistened to 1.5% and above with wet suppression techniques. The $PM_{2.5}$ emission factors for uncontrolled fine crushing, uncontrolled screening, controlled and uncontrolled fines screening, and uncontrolled conveyor transfer points are not available. The Category 3 PM size distribution found in EPA AP-42 Appendix B.2 (USEPA 1996a) was applied to calculate the $PM_{2.5}$ emission factors from TSP emission factors, (i.e., $PM_{2.5}$ emission factors are 15% of the TSP emission factors).

Because ore and waste rock are assumed to be at or above 5% moisture in the underground mine environment, the controlled emission factors were used. It is conservatively assumed that the aggregate was dry (i.e., less than 1.5% moisture); therefore, emissions are considered as uncontrolled, with respect to emission factors.

The emission factors are listed in Table 7A-12.

Table 7A-12: Emission Factors for Crushing Processes

Crushing Processes	$PM_{2.5}$ Emission Factors (kg/t)[(a)]		PM_{10} Emission Factors (kg/t)[(a)]		TSP Emission Factors (kg/t)[(a)]	
	Uncontrolled	Controlled	Uncontrolled	Controlled	Uncontrolled	Controlled
Primary crushing	0.0006	0.0006	0.0012	0.00027	0.0027	0.0006
Secondary crushing						
Tertiary crushing						
Fines crushing	0.002925	0.002925	0.0075	0.0006	0.0195	0.0015
Screening	0.001875	0.001875	0.0043	0.00037	0.0125	0.0011
Fines screening	0.0225	0.0225	0.036	0.0011	0.15	0.0018
Conveyor transfer point	0.000225	0.000225	0.00055	0.000023	0.0015	0.00007

a) Of material processed.
PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less;
TSP = total suspended particulates.

7A2.2.4.5 Semi-autogenous Grinding and Ball Mill

The SAG mill will receive ore from a variable speed feeder belt at a daily rate of 1,300 t/d. The discharge from the SAG mill will feed the ball mill. The exhaust from the mills would be released by a stack similar to the McClean Lake mill stack, which uses a similar process. The stack testing results for PM from the McClean Lake mill were pro-rated based on relative production ratios to obtain the PM emissions from the SAG and ball mills at the Project. The McClean Lake mill stack testing results showed that the PM emission rate was 3.61×10^{-03} g/s when the ore processing rate was 677 t/d.

The emissions estimates from the Project needed to be modified beyond a straight proration based on production because there is a wet scrubber installed in the McClean Lake mill, which provides a 90% removal efficiency for TSP. The current design of the Project indicates no wet scrubber. Without a wet scrubber, the SAG and ball mills will have PM emissions ten times those of the directly pro-rated emissions from ore processing rates calculated by scaling the emissions from the McLean Lake mill. The size distribution from the Category 3 chart from the USEPA AP-42 Appendix B.2 (USEPA 1996a) was used to calculate the emission rates of PM_{10} (51% of TSP) and $PM_{2.5}$ (15% of TSP).

7A2.2.4.6 Aggregate Operations

The aggregate throughput is estimated based on the batch plant needs. Assuming a density of 1,500 kg/m^3 for aggregate, and an annual maximum estimated concrete production rate of 35,000 m^3 during Construction and 5,000 m^3 during Operations, the annual maximum tonnage of aggregate required is 525,000 t and 7,500 t for Construction and Operations, respectively.

It is assumed that aggregate operations go through a complete suite of open-air primary, secondary, tertiary crushing, fines crushing, screening, fines screening, and three conveyances between the processes. The throughput tonnage was applied for each step.

7A2.2.4.7 Crushing Summary

Crushing emission rates are presented in Table 7A-13.

Table 7A-13: Crushing Emission Rates

Process	Phase	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
SAG and ball mills	Operations	1.04×10^{-02}	3.54×10^{-02}	6.93×10^{-02}
Aggregate	Construction	9.48×10^{-02}	2.37×10^{-01}	5.83×10^{-01}
Aggregate	Operations	7.08×10^{-03}	1.26×10^{-02}	4.63×10^{-02}

SAG = semi-autogenous grinding; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.8 Dozing

During Operations, dozing will be performed by a Caterpillar (CAT) D8 or similar at the waste rock stockpiles, and at the ore stockpiles. Six dozing hours per day were assumed, including two hours per day at each of the non-potentially acid generating (NPAG) and potentially acid generating (PAG) piles, and one hour each per day at the ore and special piles.

Dozing emission factors documented in the USEPA AP-42 Chapter 11.9 Western Surface Coal Mining (USEPA 1998) for bulldozing overburden were used. The emission factors were estimated with the following equations:

$$EF_{TSP} = \frac{2.6s^{1.2}}{M^{1.3}}$$

$$EF_{PM_{15}} = \frac{0.45s^{1.5}}{M^{1.4}}$$

$$EF_{PM_{10}} = 0.75EF_{PM_{15}}$$

$$EF_{PM_{2.5}} = 0.105EF_{TSP}$$

Where: EF_{TSP} = dozing emission factor of TSP in kilograms per hour (kg/h)

s = material silt *content* (%), which was assumed to be 5% from similar mines

M = material moisture content (%), which was assumed to be 3% from similar mines

$EF_{PM_{15}}$ = dozing emission factor of PM with mean aerodynamic diameter less than 15 μm in kg/h

$EF_{PM_{10}}$ = dozing emission factor of PM_{10} in kg/h

$EF_{PM_{2.5}}$ = dozing emission factor of $PM_{2.5}$ in kg/h

During Construction, dozing will be performed by CAT D8 and D9 class equipment in the general mine and mill terraces. Dozing is included in the general construction emissions discussed in Section 7A2.2.4.21, and so is only included conservatively as a source on the waste rock piles during Construction.

The dozing emission factors are summarized in Table 7A-14.

Table 7A-14: Dozing Emission Factors

Parameters	Emission Factor (kg/h)
$PM_{2.5}$	0.452
PM_{10}	0.811
TSP	4.300

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

The dozing emissions are summarized in Table 7A-15. The emission area source for the piles and pad in the model combines the dozing emissions below with material handling emissions.

Table 7A-15: Dozing Emission Rates

Source	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
Dozing during Operations ore storage pad	5.23×10^{-03}	9.38×10^{-03}	4.98×10^{-02}
Dozing during Operations special waste stockpile	5.23×10^{-03}	9.38×10^{-03}	4.98×10^{-02}
Dozing PAG waste rock stockpile	1.05×10^{-02}	1.88×10^{-02}	9.95×10^{-02}
Dozing NPAG waste rock stockpile	1.05×10^{-02}	1.88×10^{-02}	9.95×10^{-02}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; NPAG = non-potentially acid generating; PAG = potentially acid generating.

7A2.2.4.9 Grading

At the Project, road grading will occur on the surface and underground. The emission factors from USEPA AP-42 Chapter 11.9 Western Surface Coal Mining (USEPA 1998) were used to determine grading emission rates. It is noted that grading emission factors from AP-42 Chapter 11.9 tend to be conservative, as they are based on coal mining studies. The emission factors were calculated as:

$$EF_{TSP} = 0.0034\, S^{2.5}$$

$$EF_{PM_{15}} = 0.0056\, S^{2.0}$$

$$EF_{PM_{10}} = 0.60\, EF_{PM_{15}}$$

$$EF_{PM_{2.5}} = 0.031\, EF_{TSP}$$

Where: EF_{TSP} = grading emission factor of TSP in kilograms per vehicle kilometres travelled (kg/VKT)

S = mean vehicle speed in km/h

$EF_{PM_{15}}$ = grading emission factor of PM with mean aerodynamic diameter less than 15 µm in kg/VKT

$EF_{PM_{10}}$ = grading emission factor of PM_{10} in kg/VKT

$EF_{PM_{2.5}}$ = grading emission factor of $PM_{2.5}$ in kg/VKT

Mean surface grader speed assumed third gear of the 140M class motor grader (8 km/h). For underground grading, an HBM Nobas BG 110-M grader in 1st gear (4 km/h) is assumed for underground grading speeds. The maximum grader operation hours are listed in Table 7A-16.

Table 7A-16: Grading Operation Information

Source	Days per Year	Hours per Day	Maximum Annual Gross Operating Hours	Mean Grader Speed (km/h)
Surface	360	6	2,160	8
Underground	365	6	2,190	4

The emission factors for surface and underground grading were listed in Table 7A-17.

Table 7A-17: Grading Emission Factors

Parameters	Emission Factor (kg/VKT)	
	Surface	Underground
$PM_{2.5}$	0.019	0.003
PM_{10}	0.215	0.090
TSP	0.615	0.109

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less;
TSP = total suspended particulates; kg/VKT = kilograms per vehicle kilometres travelled.

Other considerations of grading emissions include:

- Surface grading during Operations will be allocated per unit length to the site access road from the gate house to the mine terrace laydown, and haul routes from the mine terrace to the ore storage pad, special waste rock stockpile, the NPAG waste rock stockpile, and the PAG waste rock stockpile. Smaller roads will not experience large amounts of traffic or grading and are not included in the grading distribution.
- Surface grading during Construction is potentially double counted under the general construction source. However, to allow for conservatism, it is assumed that grading on roads (not the construction area grading) is the same for Operations, with no grading on the special waste pile route (which does not exist yet). Construction underground grading emissions are assumed not to occur in second year of Construction, with minimal underground workings.
- Grading emissions are naturally mitigated over the winter period; variable emission coefficients have been applied in the model to set grading emissions to nil during winter months of November through March.

Grading emissions are presented in Table 7A-18.

Table 7A-18: Grading Emission Rates

Parameter	$PM_{2.5}$ (g/s)		PM_{10} (g/s)		TSP (g/s)	
	Hourly	Daily/Annual	Hourly	Daily/Annual	Hourly	Daily/Annual
Construction grading	4.24×10^{-02}	1.06×10^{-02}	4.78×10^{-01}	1.19×10^{-01}	$1.37 \times 10^{+00}$	3.42×10^{-01}
Operations grading	4.24×10^{-02}	1.06×10^{-02}	4.78×10^{-01}	1.19×10^{-01}	$1.37 \times 10^{+00}$	3.42×10^{-01}
Underground grading	3.75×10^{-03}	9.37×10^{-04}	5.97×10^{-02}	1.49×10^{-02}	1.21×10^{-01}	3.02×10^{-02}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less;
TSP = total suspended particulates.

7A2.2.4.10 Materials Handling, Loading, and Drops

Materials handling, loading, and drops will occur on the surface and underground. The truck loading emission factors from USEPA AP-42 Chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing (USEPA 2004a) were used. Fragmented stone emission factors were used for bulk material handling such as waste rock, and crushed stone factors were used for more heavily processed material such as ore. The emission factor is available for PM_{10} only. The PM_{10}/TSP and $PM_{2.5}$/TSP ratios obtained from AP-42 Appendix B.2 for category 3 (USEPA 1996a) are 0.51 and 0.15, respectively. The loading and drops emission factors are summarized in Table 7A-19. The material throughputs were provided by the Project engineering design team.

Table 7A-19: Loading and Drops Emission Factors

Parameters	Emission Factor (kg/tonne)	
	Fragmented Stone	Crushed Stone
Applicability	Waste rock	Ore, aggregate, special
$PM_{2.5}$	2.35×10^{-06}	1.47×10^{-05}
PM_{10}	8.00×10^{-06}	5.00×10^{-05}
TSP	1.57×10^{-05}	9.80×10^{-05}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Three underground drop points are considered: underground loader to grizzly, belt to transfer car, and transfer car to skip. The maximum daily rate of 4,452 t/d was assumed to occur at each point. The drop emission factor for fragmented stone was applied at the underground drop points. The total for underground handling emissions are presented in Table 7A-20.

Surface loading and drops during Construction occur at: headframe drop to haul truck, haul truck drop to waste rock stockpiles, and the aggregate area. The maximum waste rock throughput for haul truck to each of the waste rock stockpiles (i.e., NPAG waste stockpile and PAG waste stockpile) is 2,226 t/d. The material handling throughput for the aggregate area is the aggregate throughput required by the concrete batch plant (i.e., 1,438 t/d). The dropping emission factor for fragmented stone was applied to the dropping activity for haul truck and the emission factor for crushed stone was applied to the dropping activity in the aggregate area. The surface dropping emissions during Construction are presented in Table 7A-21.

Surface loading and drops during Operations occur at: headframe drop to haul truck, haul truck drop to waste rock stockpiles, haul truck to ore storage stockpile, haul truck to special waste stockpile, loader to mill chute, and the aggregate area. Special waste haul rate is estimated at 80 t/d, and each waste rock stockpile rate is estimated to be evenly split at 1,685 t/d. The ore maximum daily throughput is assumed to be 1,300 t. Spent gypsum is to be piped as paste to underground, therefore, it will not be included in materials handling emissions estimates. The surface dropping during Operations are presented in Table 7A-22.

Table 7A-20: Underground Materials Handling Emissions

Source	Material Throughput (t/d)	$PM_{2.5}$ Emission Rate (g/s)	PM_{10} Emission Rate (g/s)	TSP Emission Rate (g/s)
Loader to grizzly	4,452	1.21×10^{-04}	4.12×10^{-04}	8.08×10^{-04}
Belt to transfer car	4,452	1.21×10^{-04}	4.12×10^{-04}	8.08×10^{-04}
Transfer car to skip	4,452	1.21×10^{-04}	4.12×10^{-04}	8.08×10^{-04}
Total		**3.64×10^{-04}**	**1.24×10^{-03}**	**2.42×10^{-03}**

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Table 7A-21: Construction Surface Materials Handling Emissions

Source	Material Throughput (t/d)	$PM_{2.5}$ Emission Rate (g/s)	PM_{10} Emission Rate (g/s)	TSP Emission Rate (g/s)
Headframe drop	4,452	2.15×10^{-04}	7.30×10^{-04}	1.43×10^{-03}
NPAG stockpile drop	2,226	1.07×10^{-04}	3.65×10^{-04}	7.16×10^{-04}
PAG stockpile drop	2,226	1.07×10^{-04}	3.65×10^{-04}	7.16×10^{-04}
Aggregate handling	1,438	2.18×10^{-03}	7.40×10^{-03}	1.45×10^{-02}
Total		**6.30×10^{-03}**	**2.14×10^{-02}**	**4.20×10^{-02}**

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; NPAG = non-potentially acid generating; PAG = potentially acid generating.

Table 7A-22: Operations Surface Materials Handling Emissions

Source	Material Throughput (t/d)	$PM_{2.5}$ Emission Rate (g/s)	PM_{10} Emission Rate (g/s)	TSP Emission Rate (g/s)
Headframe drop	3,370	2.20×10^{-03}	7.49×10^{-03}	1.47×10^{-02}
NPAG stockpile drop	1,685	1.10×10^{-03}	3.74×10^{-03}	7.34×10^{-03}
PAG stockpile drop	1,685	1.10×10^{-03}	3.74×10^{-03}	7.34×10^{-03}
Ore storage stockpile	1,300	5.31×10^{-03}	1.81×10^{-02}	3.54×10^{-02}
Special waste stockpile	80	3.27×10^{-04}	1.11×10^{-03}	2.18×10^{-03}
Loader to mill chute	1,300	5.31×10^{-03}	1.81×10^{-02}	3.54×10^{-02}
Aggregate handling	21	6.99×10^{-04}	2.38×10^{-03}	4.66×10^{-03}
Total		**1.54×10^{-02}**	**5.25×10^{-02}**	**1.03×10^{-01}**

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; NPAG = non-potentially acid generating; PAG = potentially acid generating.

7A2.2.4.11 Drilling and Blasting

Drilling and blasting will occur underground during Construction and Operations. The current blasting plan provided by the Project engineering design team includes blasting for the production shaft, the exhaust shaft, shaft stations, lateral development, and production. The production blast includes transverse production, longitudinal production, and the underground tailings management facility (UGTMF). During Construction, the blasting will be completed for the production shaft, the exhaust shaft, shaft stations, and lateral development, while the lateral development blasts and production blasts will occur during Operations.

The total annual length of the production shaft, exhaust shaft, lateral development, and the volume of the shaft stations are summarized in Table 7A-23. Assuming a horizontal blasting area of 25 m^2 and a rock density of 2.7 t/m^3, the tonnage of rock blasted for production shaft, exhaust shafts, and shaft stations, and lateral development were estimated and summarized in Table 7A-24. Also summarized in Table 7A-24 is the annual tonnage of material moved for production blasting.

The average blasts per day for each type of blast and the total blasting days for the years during both Construction and Operations are listed in Table 7A-25. Explosives used for the blasting include emulsion, ammonium nitrate fuel oil (ANFO), Geldyne, and Xactex. The explosive usages per round for different types of blasting are summarized in Table 7A-26. The material moved per round of blasting and the blasting area are also listed in Table 7A-26. The production blasting area was calculated from the material moved, rock density, and the depth per round (e.g., 3.8 m). The blasting information was used to calculate the drilling and blasting emissions using applicable emission factors.

Table 7A-23: Blasting Information

Blasting Type	Construction				Operations										
	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
Production shaft (m)	0	367	270	0	0	0	0	0	0	0	0	0	0	0	0
Exhaust shaft (m)	22	465	33	0	0	0	0	0	0	0	0	0	0	0	0
Shaft stations (m^3)	0	900	9,400	0	0	0	0	0	0	0	0	0	0	0	0
Lateral development (m)	0	2,623	6,808	8,456	7,031	6,563	4,224	2,186	1,371	1,372	517	155	0	0	2,623

Table 7A-24: Annual Materials Moved by Blasting

Blasting Type	Construction				Operations										
	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
Production shaft (t)	0	3,398	2,620	0	0	0	0	0	0	0	0	0	0	0	0
Exhaust shaft (t)	204	4,306	306	0	0	0	0	0	0	0	0	0	0	0	0
Shaft stations (t)	0	333	3,481	0	0	0	0	0	0	0	0	0	0	0	0
Production – transverse (t)	0	0	0	0	134,430	264,696	288,198	266,251	250,000	276,912	327,826	309,137	312,512	286,333	108,351
Production – longitudinal (t)	0	0	0	0	49,835	134,410	67,101	93,848	96,607	175,743	123,907	142,584	104,459	25,679	71,911
Production – UGTMF (t)	0	0	0	405,517	332,241	817,030	788,880	766,622	800,437	743,039	762,991	731,227	676,278	696,770	430,355
Total (t)	**204**	**8,037**	**6,407**	**405,517**	**516,506**	**1,216,136**	**1,144,179**	**1,126,721**	**1,147,044**	**1,195,694**	**1,214,724**	**1,182,948**	**1,093,249**	**1,008,782**	**610,617**

UGTMF = underground tailings management facility.

Table 7A-25: Average Blasts Per Day and Blasting Days

Blasting Type	Construction				Operations										
	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
Production shaft (blast)	0.57	0.61	0	0	0	0	0	0	0	0	0	0	0	0	0
Exhaust shaft (blast)	0.71	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shaft stations (blast)	0.0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lateral development (blast)	0	0.1	2.4	4.1	4.2	4.4	3.9	3.1	1.8	2.3	0.7	0.4	0.3	0.4	0.3
Production – transverse (blast)	0	0	0	0.0	0.2	0.3	0.4	0.3	0.3	0.4	0.4	0.6	0.6	0.5	0.2
Production – longitudinal (blast)	0	0	0	0.0	0.1	0.3	0.2	0.2	0.2	0.4	0.3	0.8	0.6	0.1	0.4
Production – UGTMF (blast)	0	0	0.0	0.2	0.1	0.3	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4	0.2
Blasting days	200	200	355	355	355	355	355	355	355	355	355	200	200	200	200

UGTMF = underground tailings management facility.

Table 7A-26: Explosive Usages Per Round of Blasting

<table>
<tr><th>Blasting Type</th><th>Type of Explosive</th><th>Explosive Usage Per Round (kg)</th><th>Material Moved Per Round (t)</th><th>Blasting Surface (m^2)</th></tr>
<tr><td>Shafts</td><td>Emulsion</td><td>439.49</td><td rowspan="4">352</td><td>25</td></tr>
<tr><td rowspan="3">Lateral development</td><td>ANFO</td><td>306.35</td><td rowspan="3">25</td></tr>
<tr><td>Geldyne</td><td>103.51</td></tr>
<tr><td>Xactex</td><td>29.64</td></tr>
<tr><td>Production – transverse</td><td>Emulsion</td><td>2,434</td><td>2,210</td><td>215</td></tr>
<tr><td>Production – longitudinal</td><td>Emulsion</td><td>1,682</td><td>1,172</td><td>114</td></tr>
<tr><td>Production – UGTMF</td><td>Emulsion</td><td>3,261</td><td>9,108</td><td>888</td></tr>
</table>

UGTMF = underground tailings management facility; ANFO = ammonium nitrate fuel oil.

Drilling

Due to the lack of detailed information on the drilling plan (i.e., number of boring holes per blast) at the current stage of the Project, the drilling emissions were estimated based on an intermediate complexity method outlined in an emission inventory guidance for mineral handling and processing industries (MDAQMD 2000). The method assumes a wet drilling operation. No other controls were applied. The drilling emission factors are listed in Table 7A-27.

Table 7A-27: Drilling Emission Factors

Parameters	Emission Factor[a]	
	lb/ton	kg/t
$PM_{2.5}$	0.0008	0.0004
PM_{10}	0.0008	0.0004
TSP	0.001	0.0005

a) Per tonne of material blasted.
PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

The maximum annual drilling emissions during Construction and Operations were used and listed in Table 7A-28. The drilling activities were assumed to happen on all days of the year.

Table 7A-28: Drilling Emission Rates

Phase	Emissions (g/s)		
	$PM_{2.5}$	PM_{10}	TSP
Construction	8.13×10^{-05}	8.13×10^{-05}	1.02×10^{-04}
Operations	1.54×10^{-02}	1.54×10^{-02}	1.93×10^{-02}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Blasting

Blasting emissions are composed of combustion by-products resulting from chemical reactions undertaken during explosion and dust generated from the blast.

Emissions from explosives are based on explosive detonations from Australia National Pollutant Inventory (Australian Government 2016). The emission factors are summarized in Table 7A-29. The sulphur dioxide emissions from ANFO are based on 8% diesel containing 15 parts per million (ppm) of sulphur in diesel. The sulphur dioxide emissions from emulsion are assumed to be the same as ANFO.

Table 7A-29: Emission Factors for Explosives Used

Explosive	Nitrogen Oxides (kg/t)	Sulphur Dioxide (kg/t)	Carbon Monoxide (kg/t)
ANFO (branded <152 mm)	3.8	0.0024	21
Dynamite (gelatin)	26	1	52
Emulsion	0.2	0.0024	17

< = less than; ANFO = ammonium nitrate fuel oil.

The PM emissions from blasting were estimated based on the emission factors in USEPA AP-42 Chapter 11.9: Western Surface Coal Mining (USEPA 1998). The emission factors are based on the blasting surface area and can be calculated as:

$$EF_{TSP} = 0.00022\ A^{1.5}$$

$$EF_{PM_{10}} = 0.52\ EF_{TSP}$$

$$EF_{PM_{2.5}} = 0.03\ EF_{TSP}$$

Where: EF_{TSP} = emission factor for TSP in kilograms per blast (kg/blast)

A = blasting surface area in m^2

$EF_{PM_{10}}$ = emission factor for PM_{10} in kg/blast

$EF_{PM_{2.5}}$ = emission factor for $PM_{2.5}$ in kg/blast

The blasting emissions were estimated for three different averaging periods (i.e., 1-hour, 24-hour, and annual). It is assumed that only one round of blasts can happen in any given hour, thus, the hourly emissions during Construction are the maximum emissions from shaft blasts and lateral development and the hourly emission during Operations are the maximum emissions from lateral development and the three types of production blasts. The hourly gas emissions are summarized in Table 7A-30. The hourly PM emissions are summarized in Table 7A-31.

Table 7A-30: Hourly Gas Emissions from Explosive per Blast

Blast Types	Explosive	Explosive Used (kg)	Carbon Monoxide (kg/blast)	Nitrogen Oxides (kg/blast)	Sulphur Dioxide (kg/blast)	Carbon Monoxide (g/s)	Nitrogen Oxides (g/s)	Sulphur Dioxide (g/s)
Shafts	Emulsion	439	7.47	0.09	0.00	2.08	0.02	0.00
Lateral Development								
Total ANFO per round	ANFO	306	6.43	1.16	0.00	1.79	0.32	0.00
Total Geldyne per round	Dynamite	104	5.38	2.69	0.10	1.50	0.75	0.03
Total Xactex per round	Dynamite	30	1.54	0.77	0.03	0.43	0.21	0.01
Production								
Transverse	Emulsion	2,210	0.70	0.36	0.02	0.19	0.10	0.01
Longitudinal	Emulsion	1,172	0.27	0.14	0.01	0.07	0.04	0.00
UGTMF	Emulsion	9,108	5.82	3.03	0.17	1.62	0.84	0.05
Construction hourly emission						**3.71**	**1.28**	**0.04**
Operations hourly emission						**3.71**	**1.28**	**0.04**

kg/blast = kilograms per blast; UGTMF = underground tailings management facility; ANFO = ammonium nitrate fuel oil.

Table 7A-31: Hourly Particulate Matter Emissions per Blast

Blast Types	Area (m^2/blast)	TSP (kg/blast)	PM_{10} (kg/blast)	$PM_{2.5}$ (kg/blast)	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)
Shafts							
Production shaft	25	0.028	0.014	0.001	0.008	0.004	0.000
Exhaust shaft	25	0.028	0.014	0.001	0.008	0.004	0.000
Shaft stations	25	0.028	0.014	0.001	0.008	0.004	0.000
Lateral development	25	0.028	0.014	0.001	0.008	0.004	0.000
Production							
Transverse	215	0.696	0.362	0.021	0.193	0.100	0.006
Longitudinal	114	0.268	0.140	0.008	0.075	0.039	0.002
UGTMF	888	5.819	3.026	0.175	1.616	0.841	0.048
Construction hourly emission					**0.008**	**0.004**	**0.000**
Operations hourly emission					**1.616**	**0.841**	**0.048**

m^2/blast = square metres per blast; kg/blast = kilograms per blast; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; UGTMF = underground tailings management facility.

For daily and annual emission rates, the annual explosive use, blasting days, and the average blast per day were used. It was assumed that daily emission rates are equivalent to annual emission rates.

The daily and annual emission rates are summarized in Table 7A-32.

Table 7A-32: Daily and Annual Air Emissions

Pollutant	Construction	Operations
	Daily (g/s)	Daily (g/s)
Nitrogen oxides	7.60×10^{-03}	7.60×10^{-03}
Sulphur dioxide	1.81×10^{-04}	6.66×10^{-04}
Carbon monoxide	2.13×10^{-01}	6.47×10^{-01}
$PM_{2.5}$	9.32×10^{-06}	4.79×10^{-04}
PM_{10}	1.62×10^{-04}	8.30×10^{-03}
TSP	3.11×10^{-04}	1.60×10^{-02}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Other Considerations

Other considerations regarding drilling and blasting emissions include:

- For the one-hour emission rates, underground blasting cannot occur at the same time as other underground activities (grading, hauling, materials handling, drilling, and vehicle exhaust) as all other activities are expected to be suspended for safety reasons. To account for this, the higher of blasting emissions and the other underground activities are used for the one-hour mine vent emission rates. The 24-hour and annual emission rates include all activities.
- Blasting is a short duration release of emissions and is conservatively averaged over one hour to fit AERMOD modelling inputs.

7A2.2.4.12 Power Plant

Nine natural gas-fired Jenbacher J620 gensets power the site in an 8+1 configuration during Operations, and a single genset in the modelled year of Construction. The following assumptions were used to calculate emissions from the J620 gensets:

- The nitrogen oxides emissions were estimated from the nitrogen oxides concentration (500 mg/m^3) in the exhaust air and the exhaust flow rate (14,827 m^3/h) provided by the genset specification.
- Environment and Climate Change Canada's natural gas combustion emissions calculator produced by CEPEI was used to estimate emissions of carbon monoxide, sulphur dioxide, and PM. The more conservative CEPEI recommended 99% confidence upper prediction limit for $PM_{2.5}$ was used (CEPEI 2021).
- It is assumed the PM emitted from natural gas fuel combustion are less than 2.5 µm in size, thus, the emission factors for PM_{10} and TSP are equivalent to the $PM_{2.5}$ emission factor.
- The liquified natural gas used to fuel the power plant was assumed to be non-odorized. Thus, the sulphur content was assumed at 0.6 mg/m^3 per CEPEI (2021).
- The fuel consumption of 811 nominal cubic metres per hour was used to calculate the maximum emissions when gensets are operating at 100% capacity.
- The hourly emission rates considered all eight units running at 90% load simultaneously in a one-hour period during Operations, and one unit during Construction. The load percentage is based on the design rate as compared to the peak load rate.
- The 24-hour emission rates assume all running units at 70% load, per standard prime condition operation recommendations.
- The annual emission rate is based on annual fuel burn. Based on the power plant annual natural gas consumption, the number of gensets (i.e., eight during Operations), and the hourly fuel consumption at 100% load (i.e., 811 nominal cubic metres per hour), the eight gensets in the power plant are estimated to run at an annual nominal capacity of 30% during Operations Year 3 and 40% during the first year of Construction. During Construction, the fourth year burns the most natural gas; however, the first year consumes the most diesel for the freeze plant (Section 7A2.2.4.13). Therefore, to be conservative, the first year of Construction was chosen to model the natural gas and diesel combustion emissions, while the second-year emissions were modelled for other sources.

The emission factors used in the CEPEI emission calculators are listed in Table 7A-33.

Table 7A-33: Power Plant Emission Factors

Parameter	Emission Factor (Lb/MMBtu)
Sulphur dioxide	7.71×10^{-05}
Carbon monoxide	3.17×10^{-01}
$PM_{2.5}$	1.65×10^{-02}

Lb/MMBtu = pounds per million British thermal unit; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less.

The fuel consumptions and load factors during Construction and Operations are summarized in Table 7A-34.

Table 7A-34: Fuel Consumptions and Load Factors

Parameter	Construction			Operations		
	Hourly[(a)]	Daily[(a)]	Annual[(b)] (Year-4)	Hourly[(a)]	Daily[(a)]	Annual[(c)] (Year 3)
Fuel consumption (m^3)	730	13,625	2,546,777	730	13,625	15,318,535
Load factor	90%	70%	40%	90%	70%	30%

a) Hourly and daily fuel consumption and load factor for one genset.
b) Annual fuel consumption in Year -4 with one genset operating.
c) Annual fuel consumption in Year 3 with eight gensets operating.

The power plant emission rates are summarized in Table 7A-35 for individual gensets.

Table 7A-35: Genset Emission Rates

Contaminant	Construction (g/s)			Operations (g/s)		
	Hourly	Daily	Annual	Hourly	Daily	Annual
Nitrogen oxides	$1.86 \times 10^{+00}$	$1.44 \times 10^{+00}$	8.27×10^{-01}	$1.86 \times 10^{+00}$	$1.44 \times 10^{+00}$	6.22×10^{-01}
Sulphur dioxide	2.58×10^{-04}	2.00×10^{-04}	1.21×10^{-04}	2.58×10^{-04}	2.00×10^{-04}	8.65×10^{-05}
Carbon monoxide	$1.06 \times 10^{+00}$	8.24×10^{-01}	4.73×10^{-01}	$1.06 \times 10^{+00}$	8.24×10^{-01}	3.56×10^{-01}
$PM_{2.5}$	5.52×10^{-02}	4.29×10^{-02}	2.46×10^{-02}	5.52×10^{-02}	4.29×10^{-02}	1.85×10^{-02}

$PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.13 Freeze Plant Generator

During first year of Construction, 14,904,100 L of diesel will be consumed, primarily for the freeze plant diesel generator power supply.

The following assumptions were made for the emission estimation for the freeze plant generator:

- CAT3516B 1,400-kW diesel generators are assumed to be the power source. The CAT engine specifications are used for emission factors of nitrogen oxides, carbon monoxide, and PM (Table 7A-36).
- It is assumed that all PM emissions are smaller than 10 µm (PM_{10}) and 97% of PM emissions are smaller than 2.5 µm ($PM_{2.5}$; USEPA 2010a).
- The sulphur dioxide emissions were estimated by a mass balance method with the following assumptions:
  - Sulphur content of diesel was assumed to be 15 ppm.
  - The density of diesel was assumed to be 847 kg/m^3.
- Emissions are assumed to be continuous.

Tier 4 rated equipment have substantially lower emissions; however, it is not known if Tier 4 equipment would be available for Construction.

Table 7A-36: Freeze Plant Generator Emission Factors

Parameter	Emission Factor (g/hp/h)
Nitrogen oxides	3.12
Carbon monoxide	0.26
PM	0.09

g/hp/h = grams per horsepower per hour; PM= particulate matter; HC = hydrocarbons.

The emissions are presented in Table 7A-37.

Table 7A-37: Freeze Plant Power Emission Rates

Contaminant	Freeze Plant Power Emission Rate (g/s)
Nitrogen oxides	$7.13 \times 10^{+00}$
Sulphur dioxide	1.20×10^{-02}
Carbon monoxide	5.02×10^{-01}
$PM_{2.5}$	1.99×10^{-01}
PM_{10}	2.06×10^{-01}
TSP	2.06×10^{-01}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.14 Incinerators

The Project will have a batch waste incinerator for camp waste and a LLRW incinerator. The following assumptions were made to estimate incinerator emissions:

- Waste load per day is assumed at 1 t/d for the batch waste incinerator and 2.5 t/d for the LLRW incinerator based on information provided by Project engineering design team. It is assumed that both incinerators will be in use during Operations and that only the batch waste incinerator will be in use during Construction. The incinerators are assumed to run for 10 hours per day, 365 days per year.
- The annual diesel consumption for each incinerator is assumed to be 175,200 L based on information provided by Project engineering design team.
- The emission factors for diesel combustion in the incinerators were taken from the USEPA AP-42 Chapter 1.3 Fuel Oil Combustion (USEPA 1999).
- The PM emission factor used diesel combustion is the sum of the USEPA emission factors for filterable PM and condensable PM. The cumulative particulate size distribution for uncontrolled industrial boilers firing distillate oil was used (USEPA 1999). The ratios of PM_{10} and $PM_{2.5}$ in total particulate matter are 0.5 and 0.12, respectively.
- The CAC emission factors for waste combustion were taken from USEPA AP-42 Chapter 2.1 Refuse Combustion (USEPA 1996b) for modular starved-air combustors. The cumulative particulate size distribution of the refuse incineration taken from Appendix B-1 of the USEPA AP-42 (USEPA 1996a) was used. The ratios of PM_{10} and $PM_{2.5}$ in total PM are 0.671 and 0.54, respectively.

The emission factors for the incinerators are listed in Table 7A-38.

Table 7A-38: Incinerators Emission Factors

Parameter	Emission Factor of Waste Combustion (kg/t)[(a)]	Emission Factor of Diesel Combustion (Lb/10^3 gal)
Nitrogen oxides	1.58	20
Sulphur dioxide	1.61	n/a
Carbon monoxide	0.15	5
$PM_{2.5}$	0.929	0.396
PM_{10}	1.15	1.65

a) Per tonnes of waste.
Lb/10^3 gal = pounds per thousand gallons; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; n/a = not applicable.

Incinerator emission rates are presented in Table 7A-39. The 1-hour and 24-hour rates vary, as the incinerators will run for 10 hours per day. This daily rate is also conservatively assumed to occur annually (i.e., no days of downtime).

Table 7A-39: Incinerator Emission Rates

Pollutant	Batch Incinerator Emission Rates (g/s)			LLRW Incinerator Emission Rates (g/s)		
	Annual	24-hour	1-hour	Annual	24-hour	1-hour
Nitrogen oxides	3.16×10^{-02}	3.16×10^{-02}	7.58×10^{-02}	5.90×10^{-02}	5.90×10^{-02}	1.42×10^{-01}
Sulphur dioxide	1.88×10^{-02}	1.88×10^{-02}	4.51×10^{-02}	4.67×10^{-02}	4.67×10^{-02}	1.12×10^{-01}
Carbon monoxide	5.06×10^{-03}	5.06×10^{-03}	1.21×10^{-02}	7.67×10^{-03}	7.67×10^{-03}	1.84×10^{-02}
$PM_{2.5}$	1.10×10^{-02}	1.10×10^{-02}	2.64×10^{-02}	2.71×10^{-02}	2.71×10^{-02}	6.51×10^{-02}
PM_{10}	1.45×10^{-02}	1.45×10^{-02}	3.47×10^{-02}	3.45×10^{-02}	3.45×10^{-02}	8.28×10^{-02}
TSP	2.21×10^{-02}	2.21×10^{-02}	5.30×10^{-02}	5.20×10^{-02}	5.20×10^{-02}	1.25×10^{-01}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; LLRW = low-level radioactive waste.

7A2.2.4.15 Lime Silo Baghouse

The Project will have two lime silos with identical backwash type bin vent filters. The filters require a source of air during truck unloading for cleaning, otherwise they do not emit between unloading. The following assumptions were made for emissions from the lime silo storage:

- Each lime silo will have a maximum discharge rate of 3,500 kg/h and a fill rate of 17,000 kg/h. They will each require an average of 3.4 trucks per day to maintain reserve levels at maximum usage. Each truck unloading event is expected to take 1.5 hours.
- The truck unloading uses a pneumatic lime transfer blower operating at 822.3 m^3/h at 82 kilopascal gauge, which converts to 0.266 m^3/s of air requiring filtration.
- Ontario modelling guidance for baghouses (MECC 2018) was used to estimate the particulate emission rate. A factor of 10 mg/m^3 was used for the lime silos. This is considered a conservative value per the guidance.
- The lime silos are not used during Construction.

Lime silo baghouse emission rates are presented in Table 7A-40. The rate is assumed to apply for all time ranges.

Table 7A-40: Lime Silo Baghouse Emissions

Source	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
Lime silo – reagents	2.66×10^{-03}	2.66×10^{-03}	2.66×10^{-03}
Lime silo – precipitation	2.66×10^{-03}	2.66×10^{-03}	2.66×10^{-03}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.16 Mine Fleet Exhaust

The USEPA NONROAD emission model (USEPA 2010a,b,c) was used to estimate the mine fleet nitrogen oxides, sulphur dioxide, $PM_{2.5}$, and PM_{10} exhaust emissions. The NONROAD emission model was developed by the USEPA to assist state and local regulatory agencies in the development of accurate emission inventories for off-road diesel engines such as those installed on haul trucks, excavators, dozers, and graders at the Project. The NONROAD model estimates emission rates for off-road diesel engines was based on the following equation:

$$Vehicle\ Emissions = Pop \times Power \times LF \times A \times EF_{adj}$$

Where *Pop* = number of vehicles

Power = average horsepower (hp)

LF = load factor

A = operating hours (h)

EF_{adj} = emission factor after adjustment to account for transient operation and deterioration (grams per horsepower per hour [g/hp/h])

The NONROAD model includes several key elements. First, an inventory of steady-state emission factors is developed for off-road diesel engines with various horsepower ranges. The emission factors represent the emissions from new engines under steady-state operation. These emission factors are called zero-hour, steady-state emission factors. Second, the NONROAD model includes load factors accounting for the fact that the engines do not operate constantly at their maximum rated horsepower in real-world applications. Lastly, the NONROAD model incorporates the emission profile for engines during transient operating conditions (i.e., variations in load demand and engine speeds) and takes into consideration the deterioration of engine performance over time.

In addition to the NONROAD model methodology, the following assumptions were made to support the mine fleet exhaust emission calculations:

- It is not possible to track the age of individual engines annually at an early stage of the mine planning and design process. Therefore, all engines were conservatively assumed to be at the end of their respective engine lives, and the highest engine deterioration engine factor value was used in the NONROAD model emission calculations.
- The mobile equipment exhaust emissions were estimated for surface and underground activities during both Construction and Operations.
- All years of mine Construction and Operations were evaluated. The modelled emissions for Construction and Operations represent the highest expected emissions (i.e., second year during Construction and Year 3 during Operations).
- Diesel is assumed to be 15 ppm sulphur ultra-low sulphur diesel.

- All surface equipment is assumed to have an appropriate engine Tier rating based on the class of equipment at the potential Project start date, unless the specific model equipment specifications indicate otherwise.
- All heavy equipment underground is assumed to be Tier 4 with diesel particulate filters. The filters are estimated to have an 85% efficiency in reducing PM emissions and 70% efficiency in reducing HC and carbon monoxide emissions.
- All combustion-based particulate is considered to be in the PM_{10} size fraction or smaller, and 97% of PM_{10} is considered $PM_{2.5}$. Hourly, daily, and annual emission rates are calculated, with more conservative assumptions for the shorter time scales.
- Not all equipment would operate simultaneously. Therefore a 50% usage rate is applied to the non-allocated surface equipment hourly emissions estimates, which is likely conservative.

For nitrogen oxides, carbon monoxide, and hydrocarbon (HC), the exhaust emission factor for a given diesel equipment type is calculated as:

$$EF_{adj} = EF_{ss} \times TAF \times DF$$

Where: EF_{ss} = zero-hour, steady-state emission factor (g/hp/h)

TAF = transient adjustment factor

DF = deterioration factor

The PM emissions are dependent on the sulphur content of the fuel the engine is burning. The equation used for PM is as follows:

$$EF_{adj} = EF_{ss} \times TAF \times DF \times S_{PMadj}$$

Where: S_{PMadj} = adjustment to PM emission factor to account for variations in fuel sulphur content

TAF = transient adjustment factor

DF = deterioration factor

The sulphur adjustment for PM emissions (S_{PMadj}) is calculated with the following equation:

$$S_{PMadj} = BSFC \times 453.6 \times 7.0 \times soxcnv \times 0.01 \times (soxbas - soxdsl)$$

Where: *BSFC* = in-use adjusted brake-specific fuel consumption (pounds of fuel per horsepower per hour [Lb fuel/hp/h])

453.6 = conversion from pounds to grams

7.0 = grams PM sulphate / grams PM sulphur

soxcnv = grams PM sulphur / grams fuel sulphur consumed

0.01 = conversion from percent to fraction

soxbas = default certification fuel sulphur weight percent

soxdsl = episodic fuel sulphur weight percent

The in-use adjusted brake-specific fuel consumption (BSFC) is calculated as:

$$BSFC = BSFC_{ss} \times TAF_{BSFC}$$

Where: $BSFC_{ss}$ = zero-hour, steady-state BSFC

TAF_{BSFC} = transient adjustment factor for BSFC

The sulphur dioxide emission factors are calculated as follows:

$$SO_2 = (BSFC \times 453.6 \times (1 - soxcnv - HC) \times 0.01 \times soxdsl \times 2$$

Where: *BSFC* = the in-use adjusted fuel consumption in Lb fuel/hp/hr

453.6 = the conversion factor from pounds to grams

soxcnv = fraction of fuel sulphur converted to direct PM

HC = in-use adjusted hydrocarbon emissions in g/hp

0.01 = conversion factor from weight percent to weight fraction

soxdsl = episodic weight percent of sulphur in nonroad diesel fuel

2 = the grams of sulphur dioxide formed from a gram of sulphur

Table 7A-41: Fractions of Emissions of Hauler and Grader for Road Segments

Road	Length (km)	Hauler Fraction	Grader Fraction
HAUL1	0.38	0.22	0.08
HAUL2	0.14	0.08	0.03
HAUL3	0.46	0.27	0.09
HAUL4	0.71	0.42	0.14
Access road	3.34	n/a	0.66

n/a = not applicable.

The vehicle information including vehicle type, fuel type, horsepower, engine tier, gross operating hours, the NONROAD model emission factors, load factors, TAFs and deterioration factors, and the NONROAD estimated emission rates for surface vehicles during Construction are summarized in Table 7A-42 to Table 7A-44. Table 7A-45 to Table 7A-47 list the NONROAD information and emission rates for underground vehicles during Construction. The NONROAD information and emission rates for surface vehicles and underground vehicles during Operations are summarized in Table 7A-48 to Table 7A-50 and Table 7A-51 to Table 7A-53, respectively.

Table 7A-42: Surface Vehicles Information during Construction

Vehicle Name	Fuel Type	Quantity	Horsepower	Engine Tier	Operating Hours Per Day	Operating Hours during Year-3	Non-road Equipment Type	Load Factor	BSFCs (Lb fuel/hp/h)	BSFC TAF	Fraction of Sulphur Converted to PM	Default Fuel Sulphur Level (SOXBAS; ppmw)
CAT 725 Articulated Truck	Diesel	6	309	Tier 3	12	4,320	Backhoe	0.21	0.3670	1.180	0.0225	2,000
CAT 140M Motor Grader	Diesel	2	183	Tier 3	7.5	4,728	Crawler	0.59	0.3670	1.010	0.0225	2,000
CAT 345D L	Diesel	2	380	Tier 3	12	4,320	Excavator	0.59	0.3670	1.010	0.0225	2,000
CAT 314D LCR	Diesel	1	97	Tier 3	12	4,320	Excavator	0.59	0.4080	1.010	0.0225	2,000
CAT 311 LRR	Diesel	1	80	Tier 3	6	2,160	Excavator	0.59	0.4080	1.010	0.0225	2,000
CAT 242B Series 3 Skid Steer	Diesel	3	74	Tier 4	4	3,720	SSLoader	0.21	0.4080	1.000	0.0225	15
CAT 623G Wheel Tractor Scraper	Diesel	3	330	Tier 3	6	2,160	Crawler	0.59	0.3670	1.010	0.0225	2,000
CAT D9T Dozer	Diesel	2	464	Tier 3	6	1,080	Crawler	0.59	0.3670	1.010	0.0225	2,000
CAT D8T Dozer	Diesel	2	310	Tier 4	6	2,160	Crawler	0.59	0.3670	1.000	0.0225	15
CAT Series 2 Soil Compactor	Diesel	2	253	Tier 3	6	2,160	None	0.43	0.3670	1.000	0.0225	2,000
CAT CS64 Soil Compactor	Diesel	2	156	Tier 3	6	2,160	None	0.43	0.3670	1.000	0.0225	2,000
CAT CP64 Soil Compactor	Diesel	2	145	Tier 3	6	2,160	None	0.43	0.3670	1.000	0.0225	2,000
CAT PS150C	Diesel	1	100	Tier 2	6	2,160	None	0.43	0.4080	1.000	0.0225	2,000
CAT 928Hz Wheel Loader	Diesel	2	149	Tier 3	4.5	3,240	RTLoader	0.59	0.3670	1.010	0.0225	2,000
CAT AP600D Asphalt Paver	Diesel	0	174	Tier 3	0	720	Crawler	0.59	0.3670	1.010	0.0225	2,000
Volvo VHD84FT200	Diesel	2	365	Tier 3	6	2,160	None	0.43	0.3670	1.000	0.0225	2,000
Concord Pumps 52 m Pumper	Diesel	1	460	Tier 3	6	720	None	0.43	0.3670	1.000	0.0225	2,000
CAT 80 KVA genset	Diesel	6	142	Tier 4	13.5	18,720	Genset	0.43	0.3670	1.000	0.0225	15
Greaves Power	Diesel	6	142	Tier 4	17	24,000	Genset	0.43	0.3670	1.000	0.0225	15
Commander 500 Portable Welder	Diesel	9	56	Tier 2	3.2	3,240	ArcWelder	0.21	0.4080	1.180	0.0225	2,000
Manitowoc 18000	Diesel	1	600	Tier 3	3	360	None	0.43	0.3670	1.000	0.0225	2,000
Manitowoc 2250	Diesel	1	500	Tier 3	3	720	None	0.43	0.3670	1.000	0.0225	2,000
Manitowoc 999	Diesel	1	400	Tier 3	3	1,080	None	0.43	0.3670	1.000	0.0225	2,000
Manitowoc 777	Diesel	1	260	Tier 3	3	1,080	None	0.43	0.3670	1.000	0.0225	2,000
Manitowoc RT9103	Diesel	1	300	Tier 4	3	1,080	None	0.43	0.3670	1.000	0.0225	15
Manitowoc RT700	Diesel	4	240	Tier 3	3	1,080	None	0.43	0.3670	1.000	0.0225	2,000
Manitowoc RT540	Diesel	6	160	Tier 4	3	1,080	None	0.43	0.3670	1.000	0.0225	15
Manitowoc 7755	Diesel	2	130	Tier 3	3	1,080	None	0.43	0.3670	1.000	0.0225	2,000
Shuttlelift 5540	Diesel	1	85	Tier 3	3	1,080	None	0.43	0.4080	1.000	0.0225	2,000
Manitowoc Grove YB4400 Series	Diesel	1	85	Tier 3	3	1,080	None	0.43	0.4080	1.000	0.0225	2,000
Terex T340-1	Diesel	2	300	Tier 3	3	720	None	0.43	0.3670	1.000	0.0225	2,000

Table 7A-42: Surface Vehicles Information during Construction

Vehicle Name	Fuel Type	Quantity	Horsepower	Engine Tier	Operating Hours Per Day	Operating Hours during Year-3	Non-road Equipment Type	Load Factor	BSFCs (Lb fuel/hp/h)	BSFC TAF	Fraction of Sulphur Converted to PM	Default Fuel Sulphur Level (SOXBAS; ppmw)
CAT 450E Backhoe Loader	Diesel	1	124	Tier 3	3	360	Backhoe	0.21	0.3670	1.180	0.0225	2,000
Volvo VHD64B300 Dump	Diesel	4	425	Tier 4	3	1,440	Backhoe	0.21	0.3670	1.000	0.0225	15
Volvo VHD64B300 Trailer	Diesel	3	425	Tier 4	3	1,440	Backhoe	0.21	0.3670	1.000	0.0225	15
Sterling LT9500	Diesel	2	450	Tier 3	3	2,160	Backhoe	0.21	0.3670	1.180	0.0225	2,000
Chicago Pneumat–c - CPS 375	Diesel	4	111	Tier 3	3	1,080	None	0.43	0.3670	1.000	0.0225	2,000
CAT TL943	Diesel	7	99	Tier 3	3.8	3,960	RTLoader	0.59	0.4080	1.010	0.0225	2,000
CAT TH255C	Diesel	1	84	Tier 4	3	720	RTLoader	0.59	0.4080	1.000	0.0225	15
CAT TL1055D	Diesel	3	125	Tier 4	3	1,440	RTLoader	0.59	0.3670	1.000	0.0225	15
JLG 1250AJP Lift	Diesel	4	87	Tier 4	3	1,440	Backhoe	0.21	0.4080	1.000	0.0225	15
JLG RT Series 3394	Diesel	6	82	Tier 3	3	2,520	Backhoe	0.21	0.4080	1.180	0.0225	2,000
JLG 600 Series	Diesel	8	82	Tier 3	3	1,944	Backhoe	0.21	0.4080	1.180	0.0225	2,000
Ford F350	Diesel	7	400	Tier 4	2.8	3,924	None	0.43	0.3670	1.000	0.0225	15
Ford F150	Diesel	10	385	Tier 4	2.9	3,924	None	0.43	0.3670	1.000	0.0225	15
RT12 Ditch Digger	Diesel	1	16	Tier 4	3	720	None	0.43	0.4080	1.000	0.0225	15
RT45 Ditch Digger	Diesel	1	49	Tier 4	3	360	None	0.43	0.4080	1.000	0.0225	15
Fuel Truck	Diesel	1	400	Tier 3	3	720	None	0.43	0.3670	1.000	0.0225	2,000

CAT = Caterpillar; PM = particulate matter; Lb fuel/hp/h = pounds of fuel per horsepower per hour; ppmw = parts per million by weight; SOXBAS = default certification fuel sulphur weight percent; BFSC = brake-specific fuel consumption; TAF = transient adjustment factor.

Table 7A-43: Surface Vehicles Emission Factors, Transient Factors, and Deterioration Factors during Construction

Vehicle Name	Nitrogen Oxides Steady-State Emission Factor (g/hp/h)	Nitrogen Oxides Transient Factor	Nitrogen Oxides Deterioration Factor	HC Steady-State Emission Factor (g/hp/h)	HC Transient Factor	HC Deterioration Factor	Carbon Monoxide Steady-State Emission Factor (g/hp/h)	Carbon Monoxide Transient Factor	Carbon Monoxide Deterioration Factor	PM Steady-State Emission Factor (g/hp/h)	PM Transient Factor	PM Deterioration Factor	Sulphur Adjustment Factor (g/hp/h)
CAT 725 Articulated Truck	2.5000	1.21	1.008	0.1669	2.29	1.027	0.8425	2.57	1.151	0.1500	2.37	1.473	0.0613
CAT 140M Motor Grader	2.5000	1.04	1.008	0.1836	1.05	1.027	0.7475	1.53	1.151	0.1500	1.47	1.473	0.0525
CAT 345D L	2.5000	1.04	1.008	0.1669	1.05	1.027	0.8425	1.53	1.151	0.1500	1.47	1.473	0.0525
CAT 314D LCR	3.0000	1.04	1.008	0.1836	1.05	1.027	2.3655	1.53	1.151	0.2000	1.47	1.473	0.0584
CAT 311 LRR	3.0000	1.04	1.008	0.1836	1.05	1.027	2.3655	1.53	1.151	0.2000	1.47	1.473	0.0584
CAT 242B Series 3 Skid Steer	3.0000	1.00	1.008	0.1314	1.00	1.027	0.2370	1.00	1.151	0.0184	1.00	1.473	0.0000
CAT 623G Wheel Tractor Scraper	2.5000	1.04	1.008	0.1669	1.05	1.027	0.8425	1.53	1.151	0.1500	1.47	1.473	0.0525
CAT D9T Dozer	2.5000	1.04	1.008	0.1669	1.05	1.027	0.8425	1.53	1.151	0.1500	1.47	1.473	0.0525
CAT D8T Dozer	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
CAT Series 2 Soil Compactor	2.5000	1.00	1.008	0.1836	1.00	1.027	0.7475	1.00	1.151	0.1500	1.00	1.473	0.0520
CAT CS64 Soil Compactor	2.5000	1.00	1.008	0.1836	1.00	1.027	0.8667	1.00	1.151	0.2200	1.00	1.473	0.0520
CAT CP64 Soil Compactor	2.5000	1.00	1.008	0.1836	1.00	1.027	0.8667	1.00	1.151	0.2200	1.00	1.473	0.0520
CAT PS150C	4.7000	1.00	1.009	0.3672	1.00	1.034	2.3655	1.00	1.101	0.2400	1.00	1.473	0.0578
CAT 928Hz Wheel Loader	2.5000	1.04	1.008	0.1836	1.05	1.027	0.8667	1.53	1.151	0.2200	1.47	1.473	0.0525
CAT AP600D Asphalt Paver	2.5000	1.04	1.008	0.1836	1.05	1.027	0.8667	1.53	1.151	0.2200	1.47	1.473	0.0525
Volvo VHD84FT200	2.5000	1.00	1.008	0.1669	1.00	1.027	0.8425	1.00	1.151	0.1500	1.00	1.473	0.0520
Concord Pumps 52 m Pumper	2.5000	1.00	1.008	0.1669	1.00	1.027	0.8425	1.00	1.151	0.1500	1.00	1.473	0.0520
CAT 80 KVA genset	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Greaves Power	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Commander 500 Portable Welder	4.7000	1.10	1.009	0.3672	2.29	1.034	2.3655	2.57	1.101	0.2400	1.97	1.473	0.0682
Manitowoc 18000	2.5000	1.00	1.008	0.1669	1.00	1.027	0.8425	1.00	1.151	0.1500	1.00	1.473	0.0520
Manitowoc 2250	2.5000	1.00	1.008	0.1669	1.00	1.027	0.8425	1.00	1.151	0.1500	1.00	1.473	0.0520
Manitowoc 999	2.5000	1.00	1.008	0.1669	1.00	1.027	0.8425	1.00	1.151	0.1500	1.00	1.473	0.0520
Manitowoc 777	2.5000	1.00	1.008	0.1836	1.00	1.027	0.7475	1.00	1.151	0.1500	1.00	1.473	0.0520
Manitowoc RT9103	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0750	1.00	1.151	0.0092	1.00	1.473	0.0000
Manitowoc RT700	2.5000	1.00	1.008	0.1836	1.00	1.027	0.7475	1.00	1.151	0.1500	1.00	1.473	0.0520
Manitowoc RT540	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Manitowoc 7755	2.5000	1.00	1.008	0.1836	1.00	1.027	0.8667	1.00	1.151	0.2200	1.00	1.473	0.0520

Table 7A-43: Surface Vehicles Emission Factors, Transient Factors, and Deterioration Factors during Construction

Vehicle Name	Nitrogen Oxides Steady-State Emission Factor (g/hp/h)	Nitrogen Oxides Transient Factor	Nitrogen Oxides Deterioration Factor	HC Steady-State Emission Factor (g/hp/h)	HC Transient Factor	HC Deterioration Factor	Carbon Monoxide Steady-State Emission Factor (g/hp/h)	Carbon Monoxide Transient Factor	Carbon Monoxide Deterioration Factor	PM Steady-State Emission Factor (g/hp/h)	PM Transient Factor	PM Deterioration Factor	Sulphur Adjustment Factor (g/hp/h)
Shuttlelift 5540	3.0000	1.00	1.008	0.1836	1.00	1.027	2.3655	1.00	1.151	0.2000	1.00	1.473	0.0578
Manitowoc Grove YB4400 Series	3.0000	1.00	1.008	0.1836	1.00	1.027	2.3655	1.00	1.151	0.2000	1.00	1.473	0.0578
Terex T340-1	2.5000	1.00	1.008	0.1836	1.00	1.027	0.7475	1.00	1.151	0.1500	1.00	1.473	0.0520
CAT 450E Backhoe Loader	2.5000	1.21	1.008	0.1836	2.29	1.027	0.8667	2.57	1.151	0.2200	2.37	1.473	0.0613
Volvo VHD64B300 Dump	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
Volvo VHD64B300 Trailer	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
Sterling LT9500	2.5000	1.21	1.008	0.1669	2.29	1.027	0.8425	2.57	1.151	0.1500	2.37	1.473	0.0613
Chicago Pneumat–c – CPS 375	2.5000	1.00	1.008	0.1836	1.00	1.027	0.8667	1.00	1.151	0.2200	1.00	1.473	0.0520
CAT TL943	3.0000	1.04	1.008	0.1836	1.05	1.027	2.3655	1.53	1.151	0.2000	1.47	1.473	0.0584
CAT TH255C	0.2760	1.00	1.008	0.1314	1.00	1.027	0.2370	1.00	1.151	0.0092	1.00	1.473	0.0000
CAT TL1055D	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
JLG 1250AJP Lift	0.2760	1.00	1.008	0.1314	1.00	1.027	0.2370	1.00	1.151	0.0092	1.00	1.473	0.0000
JLG RT Series 3394	3.0000	1.21	1.008	0.1836	2.29	1.027	2.3655	2.57	1.151	0.2000	2.37	1.473	0.0682
JLG 600 Series	3.0000	1.21	1.008	0.1836	2.29	1.027	2.3655	2.57	1.151	0.2000	2.37	1.473	0.0682
Ford F350	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
Ford F150	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
RT12 Ditch Digger	4.4399	1.00	1.008	0.4380	1.00	1.027	2.1610	1.00	1.151	0.2800	1.00	1.473	0.0000
RT45 Ditch Digger	3.0000	1.00	1.008	0.1314	1.00	1.027	0.1530	1.00	1.151	0.0184	1.00	1.473	0.0000
Fuel Truck	2.5000	1.00	1.008	0.1669	1.00	1.027	0.8425	1.00	1.151	0.1500	1.00	1.473	0.0520

PM = particulate matter; HC = hydrocarbons; g/hp/h = grams per horsepower per hour; CAT = Caterpillar.

Table 7A-44: Surface Vehicles Emission Rates during Construction

Vehicle Name	Nitrogen Oxides Emission Rate (g/s)			Sulphur Dioxide Emission Rate (g/s)			Carbon Monoxide Emission Rate (g/s)			$PM_{2.5}$ Emission Rate (g/s)			PM_{10} Emission Rate (g/s)		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
CAT 725 Articulated Truck	3.298×10^{-01}	1.649×10^{-01}	2.710×10^{-02}	6.217×10^{-04}	3.109×10^{-04}	5.110×10^{-05}	2.695×10^{-01}	1.348×10^{-01}	2.215×10^{-02}	4.850×10^{-02}	2.425×10^{-02}	3.986×10^{-03}	5.000×10^{-02}	2.500×10^{-02}	4.110×10^{-03}
CAT 140M Motor Grader	1.572×10^{-01}	4.913×10^{-02}	4.242×10^{-02}	2.954×10^{-04}	9.231×10^{-05}	7.972×10^{-05}	7.896×10^{-02}	2.468×10^{-02}	2.131×10^{-02}	1.584×10^{-02}	4.951×10^{-03}	4.276×10^{-03}	1.633×10^{-02}	5.104×10^{-03}	4.408×10^{-03}
CAT 345D L	3.264×10^{-01}	1.632×10^{-01}	8.049×10^{-02}	6.135×10^{-04}	3.067×10^{-04}	1.513×10^{-04}	1.848×10^{-01}	9.240×10^{-02}	4.557×10^{-02}	3.290×10^{-02}	1.645×10^{-02}	8.112×10^{-03}	3.392×10^{-02}	1.696×10^{-02}	8.363×10^{-03}
CAT 314D LCR	5.000×10^{-02}	2.500×10^{-02}	2.466×10^{-02}	8.705×10^{-05}	4.352×10^{-05}	4.293×10^{-05}	6.622×10^{-02}	3.311×10^{-02}	3.266×10^{-02}	5.778×10^{-03}	2.889×10^{-03}	2.849×10^{-03}	5.957×10^{-03}	2.978×10^{-03}	2.938×10^{-03}
CAT 311 LRR	4.123×10^{-02}	1.031×10^{-02}	1.017×10^{-02}	7.179×10^{-05}	1.795×10^{-05}	1.770×10^{-05}	5.462×10^{-02}	1.365×10^{-02}	1.347×10^{-02}	4.765×10^{-03}	1.191×10^{-03}	1.175×10^{-03}	4.913×10^{-03}	1.228×10^{-03}	1.211×10^{-03}
CAT 242B Series 3 Skid Steer	3.916×10^{-02}	6.527×10^{-03}	5.543×10^{-03}	7.023×10^{-05}	1.171×10^{-05}	9.941×10^{-06}	3.533×10^{-03}	5.888×10^{-04}	5.000×10^{-04}	3.405×10^{-04}	5.674×10^{-05}	4.819×10^{-05}	3.510×10^{-04}	5.850×10^{-05}	4.968×10^{-05}
CAT 623G Wheel Tractor Scraper	4.252×10^{-01}	1.063×10^{-01}	3.495×10^{-02}	7.991×10^{-04}	1.998×10^{-04}	6.568×10^{-05}	2.407×10^{-01}	6.018×10^{-02}	1.979×10^{-02}	4.286×10^{-02}	1.071×10^{-02}	3.522×10^{-03}	4.418×10^{-02}	1.105×10^{-02}	3.631×10^{-03}
CAT D9T Dozer	3.986×10^{-01}	9.965×10^{-02}	2.457×10^{-02}	7.491×10^{-04}	1.873×10^{-04}	4.618×10^{-05}	2.256×10^{-01}	5.641×10^{-02}	1.391×10^{-02}	4.017×10^{-02}	1.004×10^{-02}	2.476×10^{-03}	4.141×10^{-02}	1.035×10^{-02}	2.553×10^{-03}
CAT D8T Dozer	2.827×10^{-02}	7.067×10^{-03}	3.485×10^{-03}	4.956×10^{-04}	1.239×10^{-04}	6.111×10^{-05}	9.824×10^{-03}	2.456×10^{-03}	1.211×10^{-03}	1.336×10^{-03}	3.339×10^{-04}	1.647×10^{-04}	1.377×10^{-03}	3.442×10^{-04}	1.698×10^{-04}
CAT Series 2 Soil Compactor	1.523×10^{-01}	3.808×10^{-02}	1.878×10^{-02}	2.947×10^{-04}	7.368×10^{-05}	3.633×10^{-05}	5.200×10^{-02}	1.300×10^{-02}	6.411×10^{-03}	9.906×10^{-03}	2.477×10^{-03}	1.221×10^{-03}	1.021×10^{-02}	2.553×10^{-03}	1.259×10^{-03}
CAT CS64 Soil Compactor	9.391×10^{-02}	2.348×10^{-02}	1.158×10^{-02}	1.817×10^{-04}	4.543×10^{-05}	2.240×10^{-05}	3.718×10^{-02}	9.294×10^{-03}	4.583×10^{-03}	9.835×10^{-03}	2.459×10^{-03}	1.213×10^{-03}	1.014×10^{-02}	2.535×10^{-03}	1.250×10^{-03}
CAT CP64 Soil Compactor	8.729×10^{-02}	2.182×10^{-02}	1.076×10^{-02}	1.689×10^{-04}	4.223×10^{-05}	2.082×10^{-05}	3.455×10^{-02}	8.639×10^{-03}	4.260×10^{-03}	9.142×10^{-03}	2.285×10^{-03}	1.127×10^{-03}	9.425×10^{-03}	2.356×10^{-03}	1.162×10^{-03}
CAT PS150C	5.664×10^{-02}	1.416×10^{-02}	1.397×10^{-02}	6.469×10^{-05}	1.617×10^{-05}	1.595×10^{-05}	3.111×10^{-02}	7.777×10^{-03}	7.671×10^{-03}	3.426×10^{-03}	8.566×10^{-04}	8.449×10^{-04}	3.532×10^{-03}	8.831×10^{-04}	8.710×10^{-04}
CAT 928Hz Wheel Loader	1.280×10^{-01}	2.400×10^{-02}	2.367×10^{-02}	2.405×10^{-04}	4.510×10^{-05}	4.448×10^{-05}	7.454×10^{-02}	1.398×10^{-02}	1.379×10^{-02}	2.008×10^{-02}	3.765×10^{-03}	3.714×10^{-03}	2.070×10^{-02}	3.882×10^{-03}	3.828×10^{-03}
CAT AP600D Asphalt Paver	$0.000 \times 10^{+00}$	$0.000 \times 10^{+00}$	6.143×10^{-03}	$0.000 \times 10^{+00}$	$0.000 \times 10^{+00}$	1.154×10^{-05}	$0.000 \times 10^{+00}$	$0.000 \times 10^{+00}$	3.577×10^{-03}	$0.000 \times 10^{+00}$	$0.000 \times 10^{+00}$	9.637×10^{-04}	$0.000 \times 10^{+00}$	$0.000 \times 10^{+00}$	9.935×10^{-04}
Volvo VHD84FT200	2.197×10^{-01}	5.493×10^{-02}	2.709×10^{-02}	4.252×10^{-04}	1.063×10^{-04}	5.243×10^{-05}	8.455×10^{-02}	2.114×10^{-02}	1.042×10^{-02}	1.429×10^{-02}	3.573×10^{-03}	1.762×10^{-03}	1.473×10^{-02}	3.683×10^{-03}	1.816×10^{-03}
Concord Pumps 52 m Pumper	1.385×10^{-01}	3.462×10^{-02}	1.138×10^{-02}	2.680×10^{-04}	6.699×10^{-05}	2.202×10^{-05}	5.328×10^{-02}	1.332×10^{-02}	4.379×10^{-03}	9.006×10^{-03}	2.251×10^{-03}	7.402×10^{-04}	9.284×10^{-03}	2.321×10^{-03}	7.631×10^{-04}
CAT 80 KVA genset	2.831×10^{-02}	1.593×10^{-02}	1.008×10^{-02}	4.964×10^{-04}	2.792×10^{-04}	1.768×10^{-04}	1.019×10^{-02}	5.732×10^{-03}	3.630×10^{-03}	1.338×10^{-03}	7.525×10^{-04}	4.765×10^{-04}	1.379×10^{-03}	7.757×10^{-04}	4.912×10^{-04}
Greaves Power	2.831×10^{-02}	2.005×10^{-02}	1.293×10^{-02}	4.964×10^{-04}	3.516×10^{-04}	2.267×10^{-04}	1.019×10^{-02}	7.218×10^{-03}	4.653×10^{-03}	1.338×10^{-03}	9.476×10^{-04}	6.108×10^{-04}	1.379×10^{-03}	9.769×10^{-04}	6.297×10^{-04}
Commander 500 Portable Welder	1.534×10^{-01}	2.059×10^{-02}	6.303×10^{-03}	1.875×10^{-04}	2.518×10^{-05}	7.706×10^{-06}	1.968×10^{-01}	2.642×10^{-02}	8.087×10^{-03}	1.792×10^{-02}	2.405×10^{-03}	7.363×10^{-04}	1.847×10^{-02}	2.480×10^{-03}	7.591×10^{-04}
Manitowoc 18000	1.806×10^{-01}	2.258×10^{-02}	7.422×10^{-03}	3.495×10^{-04}	4.369×10^{-05}	1.436×10^{-05}	6.950×10^{-02}	8.687×10^{-03}	2.856×10^{-03}	1.175×10^{-02}	1.468×10^{-03}	4.827×10^{-04}	1.211×10^{-02}	1.514×10^{-03}	4.977×10^{-04}
Manitowoc 2250	1.505×10^{-01}	1.881×10^{-02}	1.237×10^{-02}	2.913×10^{-04}	3.641×10^{-05}	2.394×10^{-05}	5.791×10^{-02}	7.239×10^{-03}	4.760×10^{-03}	9.789×10^{-03}	1.224×10^{-03}	8.046×10^{-04}	1.009×10^{-02}	1.261×10^{-03}	8.294×10^{-04}
Manitowoc 999	1.204×10^{-01}	1.505×10^{-02}	1.484×10^{-02}	2.330×10^{-04}	2.913×10^{-05}	2.873×10^{-05}	4.633×10^{-02}	5.791×10^{-03}	5.712×10^{-03}	7.831×10^{-03}	9.789×10^{-04}	9.655×10^{-04}	8.073×10^{-03}	1.009×10^{-03}	9.953×10^{-04}
Manitowoc 777	7.826×10^{-02}	9.783×10^{-03}	9.648×10^{-03}	1.514×10^{-04}	1.893×10^{-05}	1.867×10^{-05}	2.672×10^{-02}	3.340×10^{-03}	3.294×10^{-03}	5.090×10^{-03}	6.363×10^{-04}	6.276×10^{-04}	5.248×10^{-03}	6.559×10^{-04}	6.470×10^{-04}
Manitowoc RT9103	9.969×10^{-03}	1.246×10^{-03}	1.229×10^{-03}	1.748×10^{-04}	2.185×10^{-05}	2.155×10^{-05}	3.093×10^{-03}	3.867×10^{-04}	3.814×10^{-04}	4.710×10^{-04}	5.888×10^{-05}	5.807×10^{-05}	4.856×10^{-04}	6.070×10^{-05}	5.987×10^{-05}
Manitowoc RT700	2.890×10^{-01}	3.612×10^{-02}	8.906×10^{-03}	5.591×10^{-04}	6.989×10^{-05}	1.723×10^{-05}	9.866×10^{-02}	1.233×10^{-02}	3.041×10^{-03}	1.879×10^{-02}	2.349×10^{-03}	5.793×10^{-04}	1.938×10^{-02}	2.422×10^{-03}	5.972×10^{-04}

Table 7A-44: Surface Vehicles Emission Rates during Construction

Vehicle Name	Nitrogen Oxides Emission Rate (g/s)			Sulphur Dioxide Emission Rate (g/s)			Carbon Monoxide Emission Rate (g/s)			$PM_{2.5}$ Emission Rate (g/s)			PM_{10} Emission Rate (g/s)		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
Manitowoc RT540	3.190×10^{-02}	3.988×10^{-03}	6.555×10^{-04}	5.593×10^{-04}	6.992×10^{-05}	1.149×10^{-05}	1.148×10^{-02}	1.435×10^{-03}	2.359×10^{-04}	1.507×10^{-03}	1.884×10^{-04}	3.097×10^{-05}	1.554×10^{-03}	1.942×10^{-04}	3.193×10^{-05}
Manitowoc 7755	7.826×10^{-02}	9.783×10^{-03}	4.824×10^{-03}	1.514×10^{-04}	1.893×10^{-05}	9.335×10^{-06}	3.098×10^{-02}	3.873×10^{-03}	1.910×10^{-03}	8.196×10^{-03}	1.025×10^{-03}	5.052×10^{-04}	8.450×10^{-03}	1.056×10^{-03}	5.209×10^{-04}
Shuttlelift 5540	3.070×10^{-02}	3.838×10^{-03}	3.785×10^{-03}	5.504×10^{-05}	6.881×10^{-06}	6.786×10^{-06}	2.764×10^{-02}	3.455×10^{-03}	3.408×10^{-03}	2.332×10^{-03}	2.915×10^{-04}	2.875×10^{-04}	2.404×10^{-03}	3.005×10^{-04}	2.964×10^{-04}
Manitowoc Grove YB4400 Series	3.070×10^{-02}	3.838×10^{-03}	3.785×10^{-03}	5.504×10^{-05}	6.881×10^{-06}	6.786×10^{-06}	2.764×10^{-02}	3.455×10^{-03}	3.408×10^{-03}	2.332×10^{-03}	2.915×10^{-04}	2.875×10^{-04}	2.404×10^{-03}	3.005×10^{-04}	2.964×10^{-04}
Terex T340-1	1.806×10^{-01}	2.258×10^{-02}	7.422×10^{-03}	3.495×10^{-04}	4.368×10^{-05}	1.436×10^{-05}	6.166×10^{-02}	7.708×10^{-03}	2.534×10^{-03}	1.175×10^{-02}	1.468×10^{-03}	4.827×10^{-04}	1.211×10^{-02}	1.514×10^{-03}	4.977×10^{-04}
CAT 450E Backhoe Loader	2.206×10^{-02}	2.757×10^{-03}	9.064×10^{-04}	4.158×10^{-05}	5.197×10^{-06}	1.709×10^{-06}	1.854×10^{-02}	2.318×10^{-03}	7.621×10^{-04}	4.958×10^{-03}	6.198×10^{-04}	2.038×10^{-04}	5.112×10^{-03}	6.390×10^{-04}	2.101×10^{-04}
Volvo VHD64B300 Dump	2.759×10^{-02}	3.449×10^{-03}	1.134×10^{-03}	4.837×10^{-04}	6.047×10^{-05}	1.988×10^{-05}	9.588×10^{-03}	1.198×10^{-03}	3.940×10^{-04}	1.304×10^{-03}	1.629×10^{-04}	5.357×10^{-05}	1.344×10^{-03}	1.680×10^{-04}	5.523×10^{-05}
Volvo VHD64B300 Trailer	2.069×10^{-02}	2.586×10^{-03}	1.134×10^{-03}	3.628×10^{-04}	4.535×10^{-05}	1.988×10^{-05}	7.191×10^{-03}	8.989×10^{-04}	3.940×10^{-04}	9.777×10^{-04}	1.222×10^{-04}	5.357×10^{-05}	1.008×10^{-03}	1.260×10^{-04}	5.523×10^{-05}
Sterling LT9500	1.601×10^{-01}	2.001×10^{-02}	1.974×10^{-02}	3.018×10^{-04}	3.773×10^{-05}	3.721×10^{-05}	1.308×10^{-01}	1.635×10^{-02}	1.613×10^{-02}	2.354×10^{-02}	2.943×10^{-03}	2.903×10^{-03}	2.427×10^{-02}	3.034×10^{-03}	2.992×10^{-03}
Chicago Pneumatic – CPS 375	1.336×10^{-01}	1.671×10^{-02}	4.119×10^{-03}	2.586×10^{-04}	3.233×10^{-05}	7.971×10^{-06}	5.290×10^{-02}	6.613×10^{-03}	1.631×10^{-03}	1.400×10^{-02}	1.750×10^{-03}	4.314×10^{-04}	1.443×10^{-02}	1.804×10^{-03}	4.447×10^{-04}
CAT TL943	3.572×10^{-01}	5.741×10^{-02}	2.307×10^{-02}	6.219×10^{-04}	9.995×10^{-05}	4.016×10^{-05}	4.731×10^{-01}	7.604×10^{-02}	3.055×10^{-02}	4.128×10^{-02}	6.634×10^{-03}	2.666×10^{-03}	4.256×10^{-02}	6.839×10^{-03}	2.748×10^{-03}
CAT TH255C	3.830×10^{-03}	4.787×10^{-04}	3.148×10^{-04}	7.466×10^{-05}	9.333×10^{-06}	6.136×10^{-06}	3.755×10^{-03}	4.694×10^{-04}	3.087×10^{-04}	1.810×10^{-04}	2.262×10^{-05}	1.487×10^{-05}	1.866×10^{-04}	2.332×10^{-05}	1.533×10^{-05}
CAT TL1055D	1.710×10^{-02}	2.137×10^{-03}	9.369×10^{-04}	2.998×10^{-04}	3.747×10^{-05}	1.643×10^{-05}	6.154×10^{-03}	7.693×10^{-04}	3.372×10^{-04}	8.079×10^{-04}	1.010×10^{-04}	4.427×10^{-05}	8.329×10^{-04}	1.041×10^{-04}	4.564×10^{-05}
JLG 1250AJP Lift	5.648×10^{-03}	7.060×10^{-04}	2.321×10^{-04}	1.101×10^{-04}	1.376×10^{-05}	4.524×10^{-06}	5.538×10^{-03}	6.922×10^{-04}	2.276×10^{-04}	2.668×10^{-04}	3.336×10^{-05}	1.097×10^{-05}	2.751×10^{-04}	3.439×10^{-05}	1.131×10^{-05}
JLG RT Series 3394	1.050×10^{-01}	1.313×10^{-02}	5.035×10^{-03}	1.834×10^{-04}	2.293×10^{-05}	8.795×10^{-06}	2.008×10^{-01}	2.510×10^{-02}	9.628×10^{-03}	1.754×10^{-02}	2.192×10^{-03}	8.409×10^{-04}	1.808×10^{-02}	2.260×10^{-03}	8.669×10^{-04}
JLG 600 Series	1.400×10^{-01}	1.750×10^{-02}	3.884×10^{-03}	2.446×10^{-04}	3.057×10^{-05}	6.784×10^{-06}	2.678×10^{-01}	3.347×10^{-02}	7.428×10^{-03}	2.339×10^{-02}	2.923×10^{-03}	6.487×10^{-04}	2.411×10^{-02}	3.014×10^{-03}	6.688×10^{-04}
Ford F350	9.305×10^{-02}	1.108×10^{-02}	5.954×10^{-03}	1.631×10^{-03}	1.942×10^{-04}	1.044×10^{-04}	3.234×10^{-02}	3.849×10^{-03}	2.069×10^{-03}	4.396×10^{-03}	5.234×10^{-04}	2.813×10^{-04}	4.532×10^{-03}	5.396×10^{-04}	2.900×10^{-04}
Ford F150	1.279×10^{-01}	1.546×10^{-02}	5.731×10^{-03}	2.243×10^{-03}	2.710×10^{-04}	1.005×10^{-04}	4.446×10^{-02}	5.372×10^{-03}	1.992×10^{-03}	6.045×10^{-03}	7.304×10^{-04}	2.708×10^{-04}	6.232×10^{-03}	7.530×10^{-04}	2.792×10^{-04}
RT12 Ditch Digger	8.553×10^{-03}	1.069×10^{-03}	7.030×10^{-04}	1.035×10^{-05}	1.293×10^{-06}	8.504×10^{-07}	4.754×10^{-03}	5.942×10^{-04}	3.907×10^{-04}	7.646×10^{-04}	9.557×10^{-05}	6.284×10^{-05}	7.882×10^{-04}	9.853×10^{-05}	6.479×10^{-05}
RT45 Ditch Digger	1.770×10^{-02}	2.212×10^{-03}	7.273×10^{-04}	3.174×10^{-05}	3.968×10^{-06}	1.304×10^{-06}	1.031×10^{-03}	1.288×10^{-04}	4.236×10^{-05}	1.539×10^{-04}	1.923×10^{-05}	6.323×10^{-06}	1.586×10^{-04}	1.983×10^{-05}	6.519×10^{-06}
Fuel Truck	1.204×10^{-01}	1.505×10^{-02}	9.896×10^{-03}	2.330×10^{-04}	2.913×10^{-05}	1.915×10^{-05}	4.633×10^{-02}	5.791×10^{-03}	3.808×10^{-03}	7.831×10^{-03}	9.789×10^{-04}	6.436×10^{-04}	8.073×10^{-03}	1.009×10^{-03}	6.636×10^{-04}
Total	**$5.149 \times 10^{+00}$**	**$1.195 \times 10^{+00}$**	**5.474×10^{-01}**	**1.417×10^{-02}**	**3.301×10^{-03}**	**1.610×10^{-03}**	**$3.388 \times 10^{+00}$**	**7.702×10^{-01}**	**3.434×10^{-01}**	**5.012×10^{-01}**	**1.207×10^{-01}**	**5.328×10^{-02}**	**5.167×10^{-01}**	**1.244×10^{-01}**	**5.493×10^{-02}**

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; CAT = Caterpillar.

Table 7A-45: Underground Vehicles Information during Construction

Vehicle Name	Fuel Type	Quantity	Horsepower	Engine Tier	Operating Hours Per Day	Operating Hours	Non-road Equipment Type	Load Factor	BSFCs (Lb fuel/hp/h)	BSFC TAF	Fraction of Sulphur Converted to PM	Default Fuel Sulphur Level (SOXBAS; ppmw)
Two Boom Jumbo	Diesel	3	160	Tier 4	2	540	Backhoe	0.21	0.3670	1.000	0.0225	15
Rock Bolter	Diesel	4	147	Tier 4	2	540	Backhoe	0.21	0.3670	1.000	0.0225	15
LHDs	Diesel	8	353	Tier 4	10	2,700	Backhoe	0.21	0.3670	1.000	0.0225	15
Scissorlift	Diesel	3	147	Tier 4	4	1,080	Backhoe	0.21	0.3670	1.000	0.0225	15

Lb fuel/hp/h = pounds of fuel per horsepower per hour; PM = particulate matter; SOXBAS = default certification fuel sulphur weight percent; BSFC = brake-specific fuel consumption; TAF = transient adjustment factor; ppmw = parts per million in weight; LHDs = load haul dumps.

Table 7A-46: Underground Vehicles Emission Factors, Transient Factors, and Deterioration Factors during Construction

Vehicle Name	Nitrogen Oxides Steady-State Emission Factor (g/hp/h)	Nitrogen Oxides Transient Factor	Nitrogen Oxides Deterioration Factor	HC Steady-State Emission Factor (g/hp/h)	HC Transient Factor	HC Deterioration Factor	Carbon Monoxide Steady-State Emission Factor (g/hp/h)	Carbon Monoxide Transient Factor	Carbon Monoxide Deterioration Factor	PM Steady-State Emission Factor (g/hp/h)	PM Transient Factor	PM Deterioration Factor	Sulphur Adjustment Factor (g/hp/h)
Two Boom Jumbo	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Rock Bolter	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
LHDs	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
Scissorlift	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000

g/hp/h = grams per horsepower per hour; HC = hydrocarbons; PM = particulate matter.

Table 7A-47: Underground Vehicles Emission Rates during Construction

Vehicle Name	Nitrogen Oxides Emission Rate (g/s)			Sulphur Dioxide Emission Rate (g/s)			Carbon Monoxide Emission Rate (g/s)			$PM_{2.5}$ Emission Rate (g/s)			PM_{10} Emission Rate (g/s)		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
Two Boom Jumbo	7.790×10^{-03}	6.492×10^{-04}	1.601×10^{-04}	4.917×10^{-04}	9.834×10^{-04}	8.850×10^{-05}	3.028×10^{-03}	6.056×10^{-03}	2.759×10^{-03}	5.521×10^{-05}	4.601×10^{-06}	1.134×10^{-06}	5.692×10^{-05}	4.743×10^{-06}	1.170×10^{-06}
Rock Bolter	9.543×10^{-03}	7.952×10^{-04}	1.471×10^{-04}	6.023×10^{-04}	1.205×10^{-03}	8.131×10^{-05}	3.709×10^{-03}	7.419×10^{-03}	2.759×10^{-03}	6.763×10^{-05}	5.636×10^{-06}	1.042×10^{-06}	6.972×10^{-05}	5.810×10^{-06}	1.074×10^{-06}
LHDs	4.583×10^{-02}	1.910×10^{-02}	1.766×10^{-03}	2.893×10^{-03}	2.893×10^{-02}	9.763×10^{-04}	1.720×10^{-02}	1.720×10^{-01}	2.664×10^{-03}	3.248×10^{-04}	1.353×10^{-04}	1.251×10^{-05}	3.349×10^{-04}	1.395×10^{-04}	1.290×10^{-05}
Scissorlift	7.157×10^{-03}	1.193×10^{-03}	2.941×10^{-04}	4.517×10^{-04}	1.807×10^{-03}	1.626×10^{-04}	2.782×10^{-03}	1.113×10^{-02}	2.759×10^{-03}	5.072×10^{-05}	8.454×10^{-06}	2.085×10^{-06}	5.229×10^{-05}	8.715×10^{-06}	2.149×10^{-06}
Total	**7.032×10^{-02}**	**2.173×10^{-02}**	**2.367×10^{-03}**	**4.439×10^{-03}**	**3.292×10^{-02}**	**1.309×10^{-03}**	**2.672×10^{-02}**	**1.966×10^{-01}**	**7.848×10^{-02}**	**4.984×10^{-04}**	**1.540×10^{-04}**	**1.678×10^{-05}**	**5.138×10^{-04}**	**1.588×10^{-04}**	**1.729×10^{-05}**

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less.

Table 7A-48: Surface Vehicles Information during Operations

Vehicle Name	Fuel Type	Quantity	Horsepower	Engine Tier	Operating Hours Per Day	Operating Hours during Year -3	Non-road Equipment Type*	Load Factor	BSFCs (Lb fuel/hp/h)	BSFC TAF	Fraction of Sulphur Converted to PM	Default Fuel Sulphur Level (SOXBAS; ppmw)	Vehicle Type
CAT 725 Articulated Truck	Diesel	2	309	Tier 3	12	7,200	Backhoe	0.21	0.3670	1.180	0.0225	2,000	Haul
CAT 980 Wheel Loader	Diesel	2	400	Tier 3	12	5,760	Backhoe	0.21	0.3670	1.180	0.0225	2,000	Loader
CAT 140M Motor Grader	Diesel	1	183	Tier 3	12	2,160	Crawler	0.59	0.3670	1.010	0.0225	2,000	Grader
CAT 345D L	Diesel	1	380	Tier 3	6	1,080	Excavator	0.59	0.3670	1.010	0.0225	2,000	Other
Kubota Forklift	Diesel	4	46	Tier 3	12	3,600	RTLoader	0.59	0.4080	1.010	0.0225	2,000	Other
Boom Truck	Diesel	1	400	Tier 3	12	2,160	Crawler	0.59	0.3670	1.010	0.0225	2,000	Other
Fire Truck	Diesel	1	425	Tier 3	12	45	None	0.43	0.3670	1.000	0.0225	2,000	Other
JLG 1250AJP	Diesel	1	87	Tier 4	12	180	Backhoe	0.21	0.4080	1.000	0.0225	15	Other
CAT TL943	Diesel	2	99	Tier 3	12	360	RTLoader	0.59	0.4080	1.010	0.0225	2,000	Other
Bus (transport to/from airstrip & mine)	Diesel	2	250	Tier 3	12	720	None	0.43	0.3670	1.000	0.0225	2,000	Other
Ford F350	Diesel	1	400	Tier 4	12	450	None	0.43	0.3670	1.000	0.0225	15	Other
Volvo VHD64B300	Diesel	1	425	Tier 4	6	720	Backhoe	0.21	0.3670	1.000	0.0225	15	Other
Volvo VHD64B300	Diesel	1	425	Tier 4	12	1,440	Backhoe	0.21	0.3670	1.000	0.0225	15	Other
Volvo VHD64B300	Diesel	2	425	Tier 4	12	900	Backhoe	0.21	0.3670	1.000	0.0225	15	Other
Concrete/shotcrete haulage trucks	Diesel	2	400	Tier 3	12	900	Backhoe	0.21	0.3670	1.180	0.0225	2,000	Other
Manitowoc RT700	Diesel	1	240	Tier 3	12	720	None	0.43	0.3670	1.000	0.0225	2,000	Other

Table 7A-48: Surface Vehicles Information during Operations

Vehicle Name	Fuel Type	Quantity	Horsepower	Engine Tier	Operating Hours Per Day	Operating Hours during Year -3	Non-road Equipment Type*	Load Factor	BSFCs (Lb fuel/hp/h)	BSFC TAF	Fraction of Sulphur Converted to PM	Default Fuel Sulphur Level (SOXBAS; ppmw)	Vehicle Type
Ford F150	Diesel	10	385	Tier 4	12	36,000	None	0.43	0.3670	1.000	0.0225	15	Other
Ambulance	Diesel	1	385	Tier 4	12	45	None	0.43	0.3670	1.000	0.0225	15	Other
CAT D8 Dozer	Diesel	1	310	Tier 4	12	2,160	Crawler	0.59	0.3670	1.000	0.0225	15	Dozer
De-icing Unit	Diesel	1	45	Tier 3	6	360	None	0.43	0.4080	1.000	0.0225	2,000	Other
Mobile Rockbreaker	Diesel	1	380	Tier 3	12	1,440	None	0.43	0.3670	1.000	0.0225	2,000	Ore

Lb fuel/hp/h = pounds of fuel per horsepower per hour; CAT = Caterpillar; BSFC = brake-specific fuel consumption; TAF = transient adjustment factor; S = sulphur; PM = particulate matter; SOXBAS = default certification fuel sulphur weight percent; ppmw = parts per million by weight.

Table 7A-49: Surface Vehicles Emission Factors, Transient Factors, and Deterioration Factors during Operations

Vehicle Name	Nitrogen Oxides Steady-State Emission Factor (g/hp/h)	Nitrogen Oxides Transient Factor	Nitrogen Oxides Deterioration Factor	HC Steady-State Emission Factor (g/hp/h)	HC Transient Factor	HC Deterioration Factor	Carbon Monoxide Steady-State Emission Factor (g/hp/h)	Carbon Monoxide Transient Factor	Carbon Monoxide Deterioration Factor	PM Steady-State Emission Factor (g/hp/h)	PM Transient Factor	PM Deterioration Factor	Sulphur Adjustment Factor (g/hp/h)
CAT 725 Articulated Truck	2.5000	1.21	1.008	0.1669	2.29	1.027	0.8425	2.57	1.151	0.1500	2.37	1.473	0.0613
CAT 980 Wheel Loader	2.5000	1.21	1.008	0.1669	2.29	1.027	0.8425	2.57	1.151	0.1500	2.37	1.473	0.0613
CAT 140M Motor Grader	2.5000	1.04	1.008	0.1836	1.05	1.027	0.7475	1.53	1.151	0.1500	1.47	1.473	0.0525
CAT 345D L	2.5000	1.04	1.008	0.1669	1.05	1.027	0.8425	1.53	1.151	0.1500	1.47	1.473	0.0525
Kubota Forklift	4.7279	1.04	1.008	0.2789	1.05	1.027	1.5323	1.53	1.151	0.3389	1.47	1.473	0.0584
Boom Truck	2.5000	1.04	1.008	0.1669	1.05	1.027	0.8425	1.53	1.151	0.1500	1.47	1.473	0.0525
Fire Truck	2.5000	1.00	1.008	0.1669	1.00	1.027	0.8425	1.00	1.151	0.1500	1.00	1.473	0.0520
JLG 1250AJP	0.2760	1.00	1.008	0.1314	1.00	1.027	0.2370	1.00	1.151	0.0092	1.00	1.473	0.0000
CAT TL943	3.0000	1.04	1.008	0.1836	1.05	1.027	2.3655	1.53	1.151	0.2000	1.47	1.473	0.0584
Bus (transport to/from airstrip and mine)	2.5000	1.00	1.008	0.1836	1.00	1.027	0.7475	1.00	1.151	0.1500	1.00	1.473	0.0520
Ford F350	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
Volvo VHD64B300	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
Volvo VHD64B300	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
Volvo VHD64B300	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000

Table 7A-49: Surface Vehicles Emission Factors, Transient Factors, and Deterioration Factors during Operations

Vehicle Name	Nitrogen Oxides Steady-State Emission Factor (g/hp/h)	Nitrogen Oxides Transient Factor	Nitrogen Oxides Deterioration Factor	HC Steady-State Emission Factor (g/hp/h)	HC Transient Factor	HC Deterioration Factor	Carbon Monoxide Steady-State Emission Factor (g/hp/h)	Carbon Monoxide Transient Factor	Carbon Monoxide Deterioration Factor	PM Steady-State Emission Factor (g/hp/h)	PM Transient Factor	PM Deterioration Factor	Sulphur Adjustment Factor (g/hp/h)
Concrete/shotcrete haulage trucks	2.5000	1.21	1.008	0.1669	2.29	1.027	0.8425	2.57	1.151	0.1500	2.37	1.473	0.0613
Manitowoc RT700	2.5000	1.00	1.008	0.1836	1.00	1.027	0.7475	1.00	1.151	0.1500	1.00	1.473	0.0520
Ford F150	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
Ambulance	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
CAT D8 Dozer	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
De-icing Unit	4.7279	1.00	1.008	0.2789	1.00	1.027	1.5323	1.00	1.151	0.3389	1.00	1.473	0.0578
Mobile Rockbreaker	2.5000	1.00	1.008	0.1669	1.00	1.027	0.8425	1.00	1.151	0.1500	1.00	1.473	0.0520

PM = particulate matter; HC = hydrocarbons; g/hp/h = grams per horsepower per hour; CAT = Caterpillar.

Table 7A-50: Surface Vehicles Emissions during Operations

Vehicle Name	Nitrogen Oxides Emission Rate (g/s)			Sulphur Dioxide Emission Rate (g/s)			Carbon Monoxide Emission Rate (g/s)			$PM_{2.5}$ Emission Rate (g/s)			PM_{10} Emission Rate (g/s)		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
CAT 725 articulated truck	1.099×10^{-01}	4.580×10^{-02}	4.517×10^{-02}	2.072×10^{-04}	8.635×10^{-05}	8.517×10^{-05}	8.984×10^{-02}	3.743×10^{-02}	3.692×10^{-02}	1.617×10^{-02}	6.736×10^{-03}	6.644×10^{-03}	1.667×10^{-02}	6.944×10^{-03}	6.849×10^{-03}
CAT 980 wheel loader	1.423×10^{-01}	4.743×10^{-02}	4.678×10^{-02}	2.683×10^{-04}	8.943×10^{-05}	8.820×10^{-05}	1.163×10^{-01}	3.877×10^{-02}	3.824×10^{-02}	2.093×10^{-02}	6.976×10^{-03}	6.880×10^{-03}	2.157×10^{-02}	7.192×10^{-03}	7.093×10^{-03}
CAT 140M motor grader	7.860×10^{-02}	1.965×10^{-02}	1.938×10^{-02}	1.477×10^{-04}	3.693×10^{-05}	3.642×10^{-05}	3.948×10^{-02}	9.870×10^{-03}	9.735×10^{-03}	7.922×10^{-03}	1.980×10^{-03}	1.953×10^{-03}	8.167×10^{-03}	2.042×10^{-03}	2.014×10^{-03}
CAT 345D L	1.632×10^{-01}	4.080×10^{-02}	2.012×10^{-02}	3.067×10^{-04}	7.668×10^{-05}	3.782×10^{-05}	9.240×10^{-02}	2.310×10^{-02}	1.139×10^{-02}	1.645×10^{-02}	4.112×10^{-03}	2.028×10^{-03}	1.696×10^{-02}	4.240×10^{-03}	2.091×10^{-03}
Kubota forklift	1.495×10^{-01}	1.557×10^{-02}	1.536×10^{-02}	1.650×10^{-04}	1.719×10^{-05}	1.695×10^{-05}	8.137×10^{-02}	8.476×10^{-03}	8.360×10^{-03}	1.976×10^{-02}	2.058×10^{-03}	2.030×10^{-03}	2.037×10^{-02}	2.122×10^{-03}	2.093×10^{-03}
Boom truck	1.718×10^{-01}	4.295×10^{-02}	4.236×10^{-02}	3.229×10^{-04}	8.072×10^{-05}	7.962×10^{-05}	9.726×10^{-02}	2.432×10^{-02}	2.398×10^{-02}	1.732×10^{-02}	4.329×10^{-03}	4.270×10^{-03}	1.785×10^{-02}	4.463×10^{-03}	4.402×10^{-03}
Fire truck	1.599×10^{-02}	6.663×10^{-04}	6.571×10^{-04}	3.095×10^{-05}	1.289×10^{-06}	1.272×10^{-06}	6.153×10^{-03}	2.564×10^{-04}	2.529×10^{-04}	1.040×10^{-03}	4.334×10^{-05}	4.274×10^{-05}	1.072×10^{-03}	4.468×10^{-05}	4.406×10^{-05}
JLG 1250AJP	7.060×10^{-04}	2.941×10^{-05}	2.901×10^{-05}	1.376×10^{-05}	5.734×10^{-07}	5.655×10^{-07}	6.922×10^{-04}	2.884×10^{-05}	2.845×10^{-05}	3.336×10^{-05}	1.390×10^{-06}	1.371×10^{-06}	3.439×10^{-05}	1.433×10^{-06}	1.413×10^{-06}
CAT TL943	5.103×10^{-02}	2.126×10^{-03}	2.097×10^{-03}	8.884×10^{-05}	3.702×10^{-06}	3.651×10^{-06}	6.759×10^{-02}	2.816×10^{-03}	2.778×10^{-03}	5.897×10^{-03}	2.457×10^{-04}	2.423×10^{-04}	6.080×10^{-03}	2.533×10^{-04}	2.498×10^{-04}
Bus (transport to/from airstrip and mine)	1.505×10^{-01}	6.271×10^{-03}	6.185×10^{-03}	2.912×10^{-04}	1.213×10^{-05}	1.197×10^{-05}	5.138×10^{-02}	2.141×10^{-03}	2.112×10^{-03}	9.789×10^{-03}	4.079×10^{-04}	4.023×10^{-04}	1.009×10^{-02}	4.205×10^{-04}	4.147×10^{-04}

Table 7A-50: Surface Vehicles Emissions during Operations

Vehicle Name	Nitrogen Oxides Emission Rate (g/s)			Sulphur Dioxide Emission Rate (g/s)			Carbon Monoxide Emission Rate (g/s)			$PM_{2.5}$ Emission Rate (g/s)			PM_{10} Emission Rate (g/s)		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
Ford F350	1.329×10^{-02}	6.923×10^{-04}	6.828×10^{-04}	2.331×10^{-04}	1.214×10^{-05}	1.197×10^{-05}	4.619×10^{-03}	2.406×10^{-04}	2.373×10^{-04}	6.280×10^{-04}	3.271×10^{-05}	3.226×10^{-05}	6.475×10^{-04}	3.372×10^{-05}	3.326×10^{-05}
Volvo VHD64B300	6.897×10^{-03}	1.150×10^{-03}	5.669×10^{-04}	1.209×10^{-04}	2.016×10^{-05}	9.939×10^{-06}	2.397×10^{-03}	3.995×10^{-04}	1.970×10^{-04}	3.259×10^{-04}	5.431×10^{-05}	2.679×10^{-05}	3.360×10^{-04}	5.599×10^{-05}	2.761×10^{-05}
Volvo VHD64B300	6.897×10^{-03}	1.150×10^{-03}	5.669×10^{-04}	1.209×10^{-04}	2.016×10^{-05}	9.939×10^{-06}	2.397×10^{-03}	3.995×10^{-04}	1.970×10^{-04}	3.259×10^{-04}	5.431×10^{-05}	2.679×10^{-05}	3.360×10^{-04}	5.599×10^{-05}	2.761×10^{-05}
Volvo VHD64B300	1.379×10^{-02}	2.299×10^{-03}	5.669×10^{-04}	2.419×10^{-04}	4.031×10^{-05}	9.939×10^{-06}	4.794×10^{-03}	7.990×10^{-04}	1.970×10^{-04}	6.518×10^{-04}	1.086×10^{-04}	2.679×10^{-05}	6.719×10^{-04}	1.120×10^{-04}	2.761×10^{-05}
Concrete/shotcrete haulage trucks	1.423×10^{-01}	7.411×10^{-03}	7.310×10^{-03}	2.683×10^{-04}	1.397×10^{-05}	1.378×10^{-05}	1.163×10^{-01}	6.057×10^{-03}	5.974×10^{-03}	2.093×10^{-02}	1.090×10^{-03}	1.075×10^{-03}	2.157×10^{-02}	1.124×10^{-03}	1.108×10^{-03}
Manitowoc RT700	7.224×10^{-02}	6.020×10^{-03}	5.938×10^{-03}	1.398×10^{-04}	1.165×10^{-05}	1.149×10^{-05}	2.466×10^{-02}	2.055×10^{-03}	2.027×10^{-03}	4.699×10^{-03}	3.916×10^{-04}	3.862×10^{-04}	4.844×10^{-03}	4.037×10^{-04}	3.981×10^{-04}
Ford F150	1.279×10^{-01}	5.331×10^{-02}	5.258×10^{-02}	2.243×10^{-03}	9.346×10^{-04}	9.218×10^{-04}	4.446×10^{-02}	1.853×10^{-02}	1.827×10^{-02}	6.045×10^{-03}	2.519×10^{-03}	2.484×10^{-03}	6.232×10^{-03}	2.597×10^{-03}	2.561×10^{-03}
Ambulance	1.599×10^{-03}	6.663×10^{-05}	6.572×10^{-05}	2.804×10^{-05}	1.168×10^{-06}	1.152×10^{-06}	5.558×10^{-04}	2.316×10^{-05}	2.284×10^{-05}	7.556×10^{-05}	3.148×10^{-06}	3.105×10^{-06}	7.790×10^{-05}	3.246×10^{-06}	3.201×10^{-06}
CAT D8 dozer	1.413×10^{-02}	3.534×10^{-03}	3.485×10^{-03}	2.478×10^{-04}	6.196×10^{-05}	6.111×10^{-05}	4.912×10^{-03}	1.228×10^{-03}	1.211×10^{-03}	6.678×10^{-04}	1.670×10^{-04}	1.647×10^{-04}	6.885×10^{-04}	1.721×10^{-04}	1.698×10^{-04}
De-icing unit	2.562×10^{-02}	2.135×10^{-03}	1.053×10^{-03}	2.913×10^{-05}	2.427×10^{-06}	1.197×10^{-06}	9.480×10^{-03}	7.900×10^{-04}	3.896×10^{-04}	2.301×10^{-03}	1.918×10^{-04}	9.458×10^{-05}	2.373×10^{-03}	1.977×10^{-04}	9.750×10^{-05}
Mobile Rockbreaker	1.144×10^{-01}	1.906×10^{-02}	1.880×10^{-02}	2.214×10^{-04}	3.689×10^{-05}	3.639×10^{-05}	4.401×10^{-02}	7.336×10^{-03}	7.235×10^{-03}	7.439×10^{-03}	1.240×10^{-03}	1.223×10^{-03}	7.670×10^{-03}	1.278×10^{-03}	1.261×10^{-03}
Total	**$1.573 \times 10^{+00}$**	**3.181×10^{-01}**	**2.898×10^{-01}**	**5.737×10^{-03}**	**1.560×10^{-03}**	**1.450×10^{-03}**	**9.011×10^{-01}**	**1.851×10^{-01}**	**1.698×10^{-01}**	**1.594×10^{-01}**	**3.274×10^{-02}**	**3.004×10^{-02}**	**1.643×10^{-01}**	**3.375×10^{-02}**	**3.097×10^{-02}**

CAT = Caterpillar; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less.

Table 7A-51: Underground Vehicles Information during Operations

Vehicle Name	Fuel Type	Quantity	Horsepower	Engine Tier	Operating Hours per Day	Operating Hours during Year -3	Non-road Equipment Type*	Load Factor	BSFCs (Lb fuel/hp/h)	BSFC TAF	Fraction of Sulphur Converted to PM	Default Fuel Sulphur Level (SOXBAS; ppmw)
Two Boom Jumbo	Diesel	3	160	Tier 4	2	2,190	Backhoe	0.21	0.3670	1.000	0.0225	15
Rock Bolter	Diesel	4	147	Tier 4	2	2,920	Backhoe	0.21	0.3670	1.000	0.0225	15
LHDs	Diesel	8	353	Tier 4	10	29,200	Backhoe	0.21	0.3670	1.000	0.0225	15
Scissorlift	Diesel	3	147	Tier 4	4	4,380	Backhoe	0.21	0.3670	1.000	0.0225	15
Production drill	Diesel	4	163	Tier 4	2	2,920	Backhoe	0.21	0.3670	1.000	0.0225	15
Block Holer	Diesel	1	163	Tier 4	0.5	182.5	Backhoe	0.21	0.3670	1.000	0.0225	15
Cable Bolt Jumbos	Diesel	2	115	Tier 4	2	1,460	Backhoe	0.21	0.3670	1.000	0.0225	15
ANFO trucks	Diesel	2	138	Tier 4	4	2,920	Backhoe	0.21	0.3670	1.000	0.0225	15
LH–s - utility	Diesel	1	165	Tier 4	6	2,190	Backhoe	0.21	0.3670	1.000	0.0225	15
Fuel delivery truck	Diesel	1	147	Tier 4	4	1,460	Crawler	0.59	0.3670	1.000	0.0225	15
Boom truck	Diesel	1	147	Tier 4	8	2,920	Backhoe	0.21	0.3670	1.000	0.0225	15

Table 7A-51: Underground Vehicles Information during Operations

Vehicle Name	Fuel Type	Quantity	Horsepower	Engine Tier	Operating Hours per Day	Operating Hours during Year -3	Non-road Equipment Type*	Load Factor	BSFCs (Lb fuel/hp/h)	BSFC TAF	Fraction of Sulphur Converted to PM	Default Fuel Sulphur Level (SOXBAS; ppmw)
Transmixer	Diesel	3	147	Tier 4	4	4,380	Backhoe	0.21	0.3670	1.000	0.0225	15
Shotcrete sprayer	Diesel	2	147	Tier 4	3	2,190	Backhoe	0.21	0.3670	1.000	0.0225	15
Personnel transport vehicles	Diesel	1	99	Tier 4	2	730	None	0.43	0.4080	1.000	0.0225	15
Scissorlift - Construction	Diesel	1	147	Tier 4	2	730	Backhoe	0.21	0.3670	1.000	0.0225	15
Supervisor/Engineer trucks	Diesel	5	99	Tier 4	5	9,125	None	0.43	0.4080	1.000	0.0225	15
Underground grader	Diesel	1	193	Tier 4	6	2,190	Crawler	0.59	0.3670	1.000	0.0225	15
Leaders basket truck with backhoe	Diesel	3	99	Tier 4	6	6,570	Backhoe	0.21	0.4080	1.000	0.0225	15
Mechanic truck	Diesel	1	99	Tier 4	6	2,190	None	0.43	0.4080	1.000	0.0225	15
UG forklifts	Diesel	2	46	Tier 4	10	7,300	RTLoader	0.59	0.4080	1.000	0.0225	15
40 T UG haulage trucks	Diesel	1	503	Tier 4	12	4,380	Backhoe	0.21	0.3670	1.000	0.0225	15

PM = particulate matter; ANFO = ammonium nitrate fuel oil; TAF = transient adjustment factor; BSFC = brake-specific fuel consumption; ppmw = parts per million by weight; Lb fuel hp/h = pounds of fuel per horsepower per hour; SOXBAS = default certification fuel sulphur weight percent; UG =underground.

Table 7A-52: Underground Vehicles Emission Factors, Transient Factors, and Deterioration Factors during Operations

Vehicle Name	Nitrogen Oxides Steady-State Emission Factor (g/hp/h)	Nitrogen Oxides Transient Factor	Nitrogen Oxides Deterioration Factor	HC Steady-State Emission Factor (g/hp/h)	HC Transient Factor	HC Deterioration Factor	Carbon Monoxide Steady-State Emission Factor (g/hp/h)	Carbon Monoxide Transient Factor	Carbon Monoxide Deterioration Factor	PM Steady-State Emission Factor (g/hp/h)	PM Transient Factor	PM Deterioration Factor	Sulphur Adjustment Factor (g/hp/h)
Two Boom Jumbo	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Rock Bolter	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
LHDs	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000
Scissorlift	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Production drill	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Block Holer	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Cable Bolt Jumbos	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
ANFO trucks	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
LH–s - utility	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Fuel delivery truck	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000

Table 7A-52: Underground Vehicles Emission Factors, Transient Factors, and Deterioration Factors during Operations

Vehicle Name	Nitrogen Oxides Steady-State Emission Factor (g/hp/h)	Nitrogen Oxides Transient Factor	Nitrogen Oxides Deterioration Factor	HC Steady-State Emission Factor (g/hp/h)	HC Transient Factor	HC Deterioration Factor	Carbon Monoxide Steady-State Emission Factor (g/hp/h)	Carbon Monoxide Transient Factor	Carbon Monoxide Deterioration Factor	PM Steady-State Emission Factor (g/hp/h)	PM Transient Factor	PM Deterioration Factor	Sulphur Adjustment Factor (g/hp/h)
Boom truck	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Transmixer	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Shotcrete sprayer	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Personnel transport vehicles	0.2760	1.00	1.008	0.1314	1.00	1.027	0.2370	1.00	1.151	0.0092	1.00	1.473	0.0000
Scissorlift - Construction	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0870	1.00	1.151	0.0092	1.00	1.473	0.0000
Supervisors/ Engineers trucks	0.2760	1.00	1.008	0.1314	1.00	1.027	0.2370	1.00	1.151	0.0092	1.00	1.473	0.0000
Underground grader	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0750	1.00	1.151	0.0092	1.00	1.473	0.0000
Leaders basket truck with backhoe	0.2760	1.00	1.008	0.1314	1.00	1.027	0.2370	1.00	1.151	0.0092	1.00	1.473	0.0000
Mechanics truck	0.2760	1.00	1.008	0.1314	1.00	1.027	0.2370	1.00	1.151	0.0092	1.00	1.473	0.0000
UG forklifts	3.0000	1.00	1.008	0.1314	1.00	1.027	0.1530	1.00	1.151	0.0184	1.00	1.473	0.0000
40 T UG haulage trucks	0.2760	1.00	1.008	0.1314	1.00	1.027	0.0840	1.00	1.151	0.0092	1.00	1.473	0.0000

PM = particulate matter; HC = hydrocarbons; ANFO = ammonium nitrate fuel oil; g/hp/h = grams per horsepower per hour; UG = underground.

Table 7A-53: Underground Vehicles Emission Rates during Operations

Vehicle Name	Nitrogen Oxides Emission Rate (g/s)			Sulphur Dioxide Emission Rate (g/s)			Carbon Monoxide Emission Rate (g/s)			$PM_{2.5}$ Emission Rate (g/s)			PM_{10} Emission Rate (g/s)		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
Two Boom Jumbo	7.790×10^{-03}	6.492×10^{-04}	6.492×10^{-04}	1.366×10^{-04}	1.138×10^{-05}	1.138×10^{-05}	8.412×10^{-04}	7.010×10^{-05}	7.010×10^{-05}	5.521×10^{-05}	4.601×10^{-06}	4.601×10^{-06}	5.692×10^{-05}	4.743×10^{-06}	4.743×10^{-06}
Rock Bolter	9.543×10^{-03}	7.952×10^{-04}	7.952×10^{-04}	1.673×10^{-04}	1.394×10^{-05}	1.394×10^{-05}	1.030×10^{-03}	8.587×10^{-05}	8.587×10^{-05}	6.763×10^{-05}	5.636×10^{-06}	5.636×10^{-06}	6.972×10^{-05}	5.810×10^{-06}	5.810×10^{-06}
LHDs	4.583×10^{-02}	1.910×10^{-02}	1.910×10^{-02}	8.035×10^{-04}	3.348×10^{-04}	3.348×10^{-04}	4.778×10^{-03}	1.991×10^{-03}	1.991×10^{-03}	3.248×10^{-04}	1.353×10^{-04}	1.353×10^{-04}	3.349×10^{-04}	1.395×10^{-04}	1.395×10^{-04}
Scissorlift	7.157×10^{-03}	1.193×10^{-03}	1.193×10^{-03}	1.255×10^{-04}	2.091×10^{-05}	2.091×10^{-05}	7.728×10^{-04}	1.288×10^{-04}	1.288×10^{-04}	5.072×10^{-05}	8.454×10^{-06}	8.454×10^{-06}	5.229×10^{-05}	8.715×10^{-06}	8.715×10^{-06}
Production drill	1.058×10^{-02}	8.818×10^{-04}	8.818×10^{-04}	1.855×10^{-04}	1.546×10^{-05}	1.546×10^{-05}	1.143×10^{-03}	9.521×10^{-05}	9.521×10^{-05}	7.499×10^{-05}	6.249×10^{-06}	6.249×10^{-06}	7.731×10^{-05}	6.443×10^{-06}	6.443×10^{-06}
Block Holer	1.323×10^{-03}	5.511×10^{-05}	5.511×10^{-05}	2.319×10^{-05}	9.663×10^{-07}	9.663×10^{-07}	1.428×10^{-04}	5.951×10^{-06}	5.951×10^{-06}	9.374×10^{-06}	3.906×10^{-07}	3.906×10^{-07}	9.664×10^{-06}	4.027×10^{-07}	4.027×10^{-07}
Cable Bolt Jumbos	3.733×10^{-03}	3.111×10^{-04}	3.111×10^{-04}	6.544×10^{-05}	5.454×10^{-06}	5.454×10^{-06}	4.031×10^{-04}	3.359×10^{-05}	3.359×10^{-05}	2.645×10^{-05}	2.205×10^{-06}	2.205×10^{-06}	2.727×10^{-05}	2.273×10^{-06}	2.273×10^{-06}
ANFO trucks	4.479×10^{-03}	7.465×10^{-04}	7.465×10^{-04}	7.853×10^{-05}	1.309×10^{-05}	1.309×10^{-05}	4.837×10^{-04}	8.061×10^{-05}	8.061×10^{-05}	3.175×10^{-05}	5.291×10^{-06}	5.291×10^{-06}	3.273×10^{-05}	5.455×10^{-06}	5.455×10^{-06}
LH–s - utility	2.678×10^{-03}	6.694×10^{-04}	6.694×10^{-04}	4.695×10^{-05}	1.174×10^{-05}	1.174×10^{-05}	2.891×10^{-04}	7.229×10^{-05}	7.229×10^{-05}	1.898×10^{-05}	4.745×10^{-06}	4.745×10^{-06}	1.957×10^{-05}	4.891×10^{-06}	4.891×10^{-06}

Table 7A-53: Underground Vehicles Emission Rates during Operations

Vehicle Name	Nitrogen Oxides Emission Rate (g/s)			Sulphur Dioxide Emission Rate (g/s)			Carbon Monoxide Emission Rate (g/s)			$PM_{2.5}$ Emission Rate (g/s)			PM_{10} Emission Rate (g/s)		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
Fuel delivery truck	6.702×10^{-03}	1.117×10^{-03}	1.117×10^{-03}	1.175×10^{-04}	1.959×10^{-05}	1.959×10^{-05}	7.237×10^{-04}	1.206×10^{-04}	1.206×10^{-04}	4.750×10^{-05}	7.917×10^{-06}	7.917×10^{-06}	4.897×10^{-05}	8.162×10^{-06}	8.162×10^{-06}
Boom truck	2.386×10^{-03}	7.952×10^{-04}	7.952×10^{-04}	4.183×10^{-05}	1.394×10^{-05}	1.394×10^{-05}	2.576×10^{-04}	8.587×10^{-05}	8.587×10^{-05}	1.691×10^{-05}	5.636×10^{-06}	5.636×10^{-06}	1.743×10^{-05}	5.810×10^{-06}	5.810×10^{-06}
Transmixer	7.157×10^{-03}	1.193×10^{-03}	1.193×10^{-03}	1.255×10^{-04}	2.091×10^{-05}	2.091×10^{-05}	7.728×10^{-04}	1.288×10^{-04}	1.288×10^{-04}	5.072×10^{-05}	8.454×10^{-06}	8.454×10^{-06}	5.229×10^{-05}	8.715×10^{-06}	8.715×10^{-06}
Shotcrete sprayer	4.771×10^{-03}	5.964×10^{-04}	5.964×10^{-04}	8.366×10^{-05}	1.046×10^{-05}	1.046×10^{-05}	5.152×10^{-04}	6.440×10^{-05}	6.440×10^{-05}	3.382×10^{-05}	4.227×10^{-06}	4.227×10^{-06}	3.486×10^{-05}	4.358×10^{-06}	4.358×10^{-06}
Personnel transport vehicles	3.290×10^{-03}	2.742×10^{-04}	2.742×10^{-04}	6.413×10^{-05}	5.344×10^{-06}	5.344×10^{-06}	9.677×10^{-04}	8.064×10^{-05}	8.064×10^{-05}	2.332×10^{-05}	1.943×10^{-06}	1.943×10^{-06}	2.404×10^{-05}	2.003×10^{-06}	2.003×10^{-06}
Scissorlift - construction	2.386×10^{-03}	1.988×10^{-04}	1.988×10^{-04}	4.183×10^{-05}	3.486×10^{-06}	3.486×10^{-06}	2.576×10^{-04}	2.147×10^{-05}	2.147×10^{-05}	1.691×10^{-05}	1.409×10^{-06}	1.409×10^{-06}	1.743×10^{-05}	1.453×10^{-06}	1.453×10^{-06}
Supervisors/Engineers trucks	1.645×10^{-02}	3.427×10^{-03}	3.427×10^{-03}	3.207×10^{-04}	6.680×10^{-05}	6.680×10^{-05}	4.839×10^{-03}	1.008×10^{-03}	1.008×10^{-03}	1.166×10^{-04}	2.429×10^{-05}	2.429×10^{-05}	1.202×10^{-04}	2.504×10^{-05}	2.504×10^{-05}
Underground grader	8.800×10^{-03}	2.200×10^{-03}	2.200×10^{-03}	1.543×10^{-04}	3.857×10^{-05}	3.857×10^{-05}	8.192×10^{-04}	2.048×10^{-04}	2.048×10^{-04}	6.237×10^{-05}	1.559×10^{-05}	1.559×10^{-05}	6.430×10^{-05}	1.607×10^{-05}	1.607×10^{-05}
Leaders basket truck with backhoe	4.820×10^{-03}	1.205×10^{-03}	1.205×10^{-03}	9.396×10^{-05}	2.349×10^{-05}	2.349×10^{-05}	1.418×10^{-03}	3.545×10^{-04}	3.545×10^{-04}	3.416×10^{-05}	8.540×10^{-06}	8.540×10^{-06}	3.522×10^{-05}	8.804×10^{-06}	8.804×10^{-06}
Mechanics truck	3.290×10^{-03}	8.225×10^{-04}	8.225×10^{-04}	6.413×10^{-05}	1.603×10^{-05}	1.603×10^{-05}	9.677×10^{-04}	2.419×10^{-04}	2.419×10^{-04}	2.332×10^{-05}	5.829×10^{-06}	5.829×10^{-06}	2.404×10^{-05}	6.009×10^{-06}	6.009×10^{-06}
UG forklifts	4.560×10^{-02}	1.900×10^{-02}	1.900×10^{-02}	8.177×10^{-05}	3.407×10^{-05}	3.407×10^{-05}	7.966×10^{-04}	3.319×10^{-04}	3.319×10^{-04}	5.946×10^{-05}	2.477×10^{-05}	2.477×10^{-05}	6.130×10^{-05}	2.554×10^{-05}	2.554×10^{-05}
40 T UG haulage trucks	8.163×10^{-03}	4.082×10^{-03}	4.082×10^{-03}	1.431×10^{-04}	7.156×10^{-05}	7.156×10^{-05}	8.511×10^{-04}	4.255×10^{-04}	4.255×10^{-04}	5.785×10^{-05}	2.893×10^{-05}	2.893×10^{-05}	5.964×10^{-05}	2.982×10^{-05}	2.982×10^{-05}
Total	**2.069×10^{-01}**	**5.931×10^{-02}**	**5.931×10^{-02}**	**2.965×10^{-03}**	**7.520×10^{-04}**	**7.520×10^{-04}**	**2.307×10^{-02}**	**5.632×10^{-03}**	**5.632×10^{-03}**	**1.203×10^{-03}**	**3.104×10^{-04}**	**3.104×10^{-04}**	**1.240×10^{-03}**	**3.200×10^{-04}**	**3.200×10^{-04}**

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; ANFO = ammonium nitrate fuel oil; UG = underground.

The underground emissions were assumed to be all emitted through the mine vents. The Construction surface emissions were assumed to be released from the mining area. The Operations surface emissions were assigned according to the vehicle type:

- The emissions from haulers were assigned to the four modelled haul road sections based on the length of each haul road (Table 7A-41).
- The grader emissions were assigned to the four haul road sections and access road based on the road lengths (Table 7A-41).
- One quarter of loader emissions were assigned to the aggregate storage pile while three quarters of loader emissions were assigned to the ore storage pile.
- Dozing emissions were assigned to special storage pile, ore storage pile, NPAG storage pile, and PAG storage pile with fractions of 0.17, 0.17, 0.33, and 0.33, respectively.
- Emissions of mobile breaker were assumed to be released from ore storage pile.
- The remaining fleet emissions were assumed to be emitted from the mining area.

Table 7A-54 and Table 7A-55 summarize the surface and underground vehicle emission rates during Construction. Operations surface and underground vehicle emission rates are summarized in Table 7A-56 and Table 7A-57.

Table 7A-54: Surface Vehicle Emission Rates during Construction

Pollutant	Hourly (g/s)	Daily (g/s)	Annual (g/s)
Nitrogen oxides	$2.57 \times 10^{+00}$	$1.20 \times 10^{+00}$	5.47×10^{-01}
Sulphur dioxide	7.09×10^{-03}	3.30×10^{-03}	1.61×10^{-03}
Carbon monoxide	$1.69 \times 10^{+00}$	7.70×10^{-01}	3.43×10^{-01}
$PM_{2.5}$	2.51×10^{-01}	1.21×10^{-01}	5.33×10^{-02}
PM_{10}	2.58×10^{-01}	1.24×10^{-01}	5.49×10^{-02}
TSP	2.58×10^{-01}	1.24×10^{-01}	5.49×10^{-02}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Table 7A-55: Summary of Underground Vehicle Emission Rates during Construction

Pollutant	Hourly (g/s)	Daily (g/s)	Annual (g/s)
Nitrogen oxides	7.03×10^{-02}	2.17×10^{-02}	2.37×10^{-03}
Sulphur dioxide	1.23×10^{-03}	3.81×10^{-04}	4.15×10^{-05}
Carbon monoxide	7.42×10^{-03}	2.28×10^{-03}	2.49×10^{-03}
$PM_{2.5}$	4.98×10^{-04}	1.54×10^{-04}	1.68×10^{-05}
PM_{10}	5.14×10^{-04}	1.59×10^{-04}	1.73×10^{-05}
TSP	5.14×10^{-04}	1.59×10^{-04}	1.73×10^{-05}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Table 7A-56: Surface Vehicle Emission Rates during Operations

Pollutant	Hourly (g/s)	Daily (g/s)	Annual (g/s)
Nitrogen oxides	$1.57 \times 10^{+00}$	3.18×10^{-01}	2.90×10^{-01}
Sulphur dioxide	5.74×10^{-03}	1.56×10^{-03}	1.45×10^{-03}
Carbon monoxide	9.01×10^{-01}	1.85×10^{-01}	1.70×10^{-01}
$PM_{2.5}$	1.59×10^{-01}	3.27×10^{-02}	3.00×10^{-02}
PM_{10}	1.64×10^{-01}	3.38×10^{-02}	3.10×10^{-02}
TSP	1.64×10^{-01}	3.38×10^{-02}	3.10×10^{-02}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Table 7A-57: Underground Vehicle Emission Rates during Operations

Pollutant	Hourly (g/s)	Daily (g/s)	Annual (g/s)
Nitrogen oxides	2.07×10^{-01}	5.93×10^{-02}	5.93×10^{-02}
Sulphur dioxide	2.96×10^{-03}	7.52×10^{-04}	7.52×10^{-04}
Carbon monoxide	2.31×10^{-02}	5.63×10^{-03}	5.63×10^{-03}
$PM_{2.5}$	1.20×10^{-03}	3.10×10^{-04}	3.10×10^{-04}
PM_{10}	1.24×10^{-03}	3.20×10^{-04}	3.20×10^{-04}
TSP	1.24×10^{-03}	3.20×10^{-04}	3.20×10^{-04}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.17 Heaters

The heaters at the Project include mine heaters and small heaters during both Construction and Operations and frost fighter during Construction.

The two proposed natural gas-fired mine heaters will be open combustion units. The following assumptions for emissions from the mine heaters were:

- During Construction, a total of 12,578 GJ of natural gas will be consumed in second year.
- During the maximum Operations year, the total fuel consumption is 226,408 GJ.
- Two heaters were each assumed with heat input capacity of 50 million British thermal units per hour (MMBtu/h), for a total of 100 MMBtu/h. Given the low fuel consumption rate during second year, it is assumed that only one heater would be required with respect to emissions calculations.
- Carbon monoxide emission rates (125 g/GJ) are assumed to be at the maximum allowable limit from the CCME national guidelines for commercial/industrial boilers and heaters (CCME 1998).
- Nitrogen oxides emission rates are per the MSAPR guidelines (16 g/GJ).
- Sulphur dioxide emission rates were estimated with an emission factor of 7.71×10^{-05} pounds per million British thermal unit (Lb/MMBtu; e.g., 0.033 g/GJ) (CEPEI 2021).
- The heaters are in the less than 100 MMBtu/h category. The PM emission factors are not default CEPEI values, rather, they are the more conservative CEPEI recommended assessment values of 99% upper prediction limit (CEPEI 2021).

- The worst-case hourly emissions for all compounds were the estimated emission factors and the heat input of 50 MMBtu/h for each heater. The 24-hour and annual emissions were estimated from the annual fuel consumption assuming the heaters will only be operating from October to April.
- The mine heater exhaust will carry through the underground mine and exit via the mine exhaust.

The emission factors are summarized in Table 7A-58.

Table 7A-58: Emission Factors for Mine Heater and Small Heater

Contaminant	Emission Factor (g/GJ)	
	Mine Heater	Small Heater
Nitrogen oxides	16	20.9
Sulphur dioxide	0.033	0.253
Carbon monoxide	125	13.9
$PM_{2.5}$	0.637	0.637
PM_{10}	0.637	0.637
TSP	0.637	0.637

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Mine heater emission rates from October to April are presented in Table 7A-59. Emissions are divided equally between the two exhaust stacks.

Table 7A-59: Mine Heater Emission Rates

Pollutant	Construction 1-hour Emission Rate (g/s)[(a)]	Operations 1-hour Emission Rate (g/s)[(a)]	Construction 24-hour and Annual Emission Rate (g/s)[(a)]	Operations 24-hour and Annual Emission Rate (g/s)[(a)]
Nitrogen oxides	2.34×10^{-01}	4.69×10^{-01}	1.10×10^{-01}	1.98×10^{-01}
Carbon monoxide	$1.83 \times 10^{+00}$	$3.66 \times 10^{+00}$	8.58×10^{-01}	$1.55 \times 10^{+00}$
$PM_{2.5}$	9.33×10^{-03}	1.87×10^{-02}	4.37×10^{-04}	7.87×10^{-03}
PM_{10}	9.33×10^{-03}	1.87×10^{-02}	4.37×10^{-04}	7.87×10^{-03}
TSP	9.33×10^{-03}	1.87×10^{-02}	4.37×10^{-04}	7.87×10^{-03}

a) From October to April. Variable rates will apply based on this unit base.
PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Small space heater natural gas emissions are estimated, such as camp heating, as presented in Table 7A-60. The total annual fuel consumption of 6,200 GJ during Construction and 12,500 GJ for space heating during Operations were assumed. Other small combustion sources that use this fuel category are considered part of this source. The CEPEI calculator is used for all small-scale space heating emissions estimates. The emission factors used are listed in Table 7A-58. The small-scale heaters are applied as a general area source over the mine terrace building footprint. Given the uncertainty in the number and use of small-scale heaters, all emission rates are considered equivalent.

Table 7A-60: Small Heater Emission Rates

Pollutant	Construction Emission Rate (g/s)[(a)]	Operations Emission Rate (g/s)[(a)]
Nitrogen oxides	7.07×10^{-02}	1.43×10^{-02}
Carbon monoxide	4.72×10^{-03}	9.51×10^{-03}
$PM_{2.5}$	2.16×10^{-04}	4.35×10^{-04}
PM_{10}	2.16×10^{-04}	4.35×10^{-04}
TSP	2.16×10^{-04}	4.35×10^{-04}

a) From October to April. Variable rates will apply based on this unit base.
PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less;
TSP = total suspended particulates.

During Construction, frost fighters are included in the surface construction fleet. Given the uncertainty in the number and use of frost fighters, all emission rates are considered equivalent. Frost fighters are considered as 350,000 British thermal units per hour diesel units. The nitrogen oxides and carbon monoxide emission factors were obtained from CCME national guideline for commercial/industrial boilers and heaters. The emission factors of PM for diesel combustion of the frost fighters were taken from the USEPA AP-42 Chapter 1.3 Fuel Oil Combustion (USEPA 1999). The used PM emission factor is the sum of emission factors for filterable PM and condensable PM. The cumulative particulate size distribution for uncontrolled industrial boilers firing distillate oil was used. The ratios of PM_{10} and $PM_{2.5}$ in total particulate matter are 0.5 and 0.12, respectively. The sulphur dioxide emissions were estimated by a mass balance method with the following assumptions:

- Sulphur content of diesel was assumed to be 15 ppm.
- The density of diesel was assumed to be 847 kg/m^3.

The emission factors are listed in Table 7A-61.

Table 7A-61: Frost Fighter Emission Rates

Contaminant	Unit	Emission Factor
Nitrogen oxides	Lb/MMBtu (g/GJ)	0.093 (40)
Carbon monoxide	Lb/MMBtu (g/GJ)	0.291 (125)
$PM_{2.5}$	Lb/10^3 gal	0.396
PM_{10}	Lb/10^3 gal	1.65
TSP	Lb/10^3 gal	3.3

Lb/MMBtu = pounds per million British thermal unit; g/GJ = grams per gigajoule; Lb/10^3 gal = pound per thousand gallons;
PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less;
TSP = total suspended particulates.

The annual operating hours of the frost fighters will be the maximum in second year of Construction, with a total of 78,480 hours. Assuming the fuel consumption of 9.5 L/h and the frost fighters operating half of the hours in a year (i.e., from October to March), the hourly diesel fuel consumptions will be 169.6 L/h. Frost fighter emissions are presented in Table 7A-62. The frost fighters are applied as a general area source over the mine terrace building footprint, included with the small-scale natural gas heaters.

Table 7A-62: Frost Fighter Heating Emission Rates

Pollutant	Construction Emission Rate (g/s)[a]
Nitrogen oxides	7.28×10^{-02}
Sulphur dioxide	4.30×10^{-06}
Carbon monoxide	2.28×10^{-01}
$PM_{2.5}$	2.23×10^{-03}
PM_{10}	9.31×10^{-03}

a) From October to April. Variable rates will apply based on this unit base.
PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.18 Road Dust

7A2.2.4.18.1 Site Transport Traffic

Both underground and surface hauling will occur at the Project, as well as site transport traffic. The road dust emissions for haul road were estimated from the approach in the USEPA AP-42 Chapter 13.2.2 Unpaved Roads (USEPA 2006b). The emission factors for vehicles travelling on unpaved surfaces in industrial sites are estimated from the following equation:

$$EF = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{2.72}\right)^{b}$$

Where: *EF* = unpaved road dust emission factors in kg/VKT

s = silt content in%. A silt content of 5% is assumed for the roads based on samples of the site road material (69). This could be considered conservative for the access road and highway, as a general value of 3.9% silt content for unpaved roads is indicated in studies

W = mean vehicle weight in tonnes

The constants for the above equation and the calculated emission factors are listed in Table 7A-63.

Table 7A-63: Unpaved Road Dust Equation Constants

Constant	$PM_{2.5}$	PM_{10}	TSP
K (kg/VKT)	1.38131	0.42285	0.042285
a	0.7	0.9	0.9
b	0.45	0.45	0.45

kg/VKT = kilograms per vehicle kilometres travelled; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Four haul road segments, one access road segment, and one underground haul road segment were included in the model to represent the unpaved roads on site, including:

- HAUL1 from headworks to ore pad, carrying ore, special, waste NPAG, and PAG.
- HAUL2 from ore pad to special pad, carrying special waste.
- HAUL3 from ore pad to PAG pile, carrying PAG waste.
- HAUL4 from ore pad to NPAG pile, carrying NPAG waste.

- Access road from the gatehouse to the mill terrace laydown is included in the model. The remainder of the access road out to the highway is anticipated to have minimal effects on results and was omitted from the model for computational efficiency.
- Underground hauling is assumed to be over a 300 m distance. During Construction, underground haul lengths are considered to be negligible, therefore underground Construction hauling emissions are not modelled.

It is assumed that the haul trucks weigh 22.3 t when empty and weigh 45.8 t with a payload of 23.6 t. The average haul truck weight is 34.1 t. The mean vehicle weight on the access road was assumed to be 21.5 t and 20.6 t during Construction and Operations, respectively. Underground hauling is assumed to be by LHD Scooptram ST18 with a 17.5 t payload and a mean weight of 60.25 t.

The estimated emission factors are summarized in Table 7A-64.

Table 7A-64: Road Dust Emission Factors

Road	Phase	Average Weight	$PM_{2.5}$ (kg/VKT)	PM_{10} (kg/VKT)	TSP (kg/VKT)
Haul roads	Construction/Operations	34.1	2.33	0.60	0.60
Access road	Construction	21.5	1.90	0.49	0.05
	Operations	20.3	1.86	0.48	0.05
Underground haul road	Operations	60.25	3.02	0.78	0.08

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; kg/VKT = kilograms per vehicle kilometres travelled.

The annual and daily maximum rock haulage during Construction and Operations are summarized in Table 7A-65. The daily trips for each surface haul road were estimated from the daily maximum haulage required and the payload of the haul trucks (e.g., 23.6 t). Daily access road traffic is determined by dividing the weekly and one-time traffic totals into a daily time frame (e.g., weekly traffic divided by 7, annual traffic divided by 365), and adding each of daily, weekly, and one-time prorated traffic totals. A multiplier of 1.25 is applied to account for variation and to provide conservatism in the emissions. The haul roads and access road information and hauling information needed for the unpaved road dust calculation is summarized in Table 7A-66. The maximum daily underground hoist rate during Construction is 2,105 t/d and during Operations is 4,452 t/d. The maximum trips during Construction and Operations are 254.4 and 120.3, respectively.

Table 7A-65: Annual and Daily Maximum Rock Hauling

Rock	Construction		Operation	
	Annual Maximum (t)	Daily Maximum (t)	Annual Maximum (t)	Daily Maximum (t)
Ore	0	0	427,000	1,220
Special	0	0	28,000	80
NPAG	57,500	2,226	615,000	1,685
PAG	57,500	2,226	615,000	1,685
Total	**115,000**	**4,452**	**1,685,000**	**4,670**

PAG = potentially acid generating; NPAG = non-potentially acid generating.

Table 7A-66: Haul Road Information

Haul Road	Modelled Length (km)	Payload (t)	Construction			Operations		
			Daily Haulage (t)	Daily Trips	VKT	Daily Haulage (t)	Daily Trips	VKT
HAUL1	0.38	23.6	4,452	188.7	143	4,670	198.0	150
HAUL2	0.14	23.6	0	0.0	0	80	3.4	1
HAUL3	0.46	23.6	2,226	94.4	87	1,685	71.4	66
HAUL4	0.71	23.6	2,226	94.4	134	1,685	71.4	101
Access road	3.34	n/a	n/a	42.8	286	n/a	50.7	339
Underground haul	0.3	17.5	2,105	120.3	72	4,452	254.4	153

VKT = vehicle kilometres travelled.

Surface dust mitigation assumes chemical application and watering. The chemical application control factor of 80% is applied for the haul roads in the emissions estimation. A combined dust control efficiency from chemical application and watering (e.g., 91%) was applied to the access road. A combined dust control efficiency (e.g., 83.2%) from wet surface (e.g., equivalent to watering more than twice a day) and lower travelling speed was applied to the underground road dust.

The natural mitigation with snow cover and the daily precipitation greater than 0.254 mm was applied to the surface unpaved road dust. The unpaved road dust was assumed to be zero with snow cover. The summer-time precipitation mitigation factor of 45% estimated from days with total precipitation greater than 0.254 mm from April to October (e.g., 97 days) was applied to the road dust emissions for both haul road and access road.

The surface non-winter unpaved road dust emissions are summarized in Table 7A-67.

Table 7A-67: Surface Non-winter Unpaved Road Dust Emissions

Route	Construction			Operations		
	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	TSP (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)
HAUL1	$2.10 \times 10^{+00}$	5.40×10^{-01}	5.40×10^{-02}	$2.20 \times 10^{+00}$	5.66×10^{-01}	5.66×10^{-02}
HAUL2	0	0	0	1.39×10^{-02}	3.57×10^{-03}	3.57×10^{-04}
HAUL3	$1.28 \times 10^{+00}$	3.29×10^{-01}	3.29×10^{-02}	9.69×10^{-01}	2.49×10^{-01}	2.49×10^{-02}
HAUL4	$1.96 \times 10^{+00}$	5.04×10^{-01}	5.04×10^{-02}	$1.48 \times 10^{+00}$	3.81×10^{-01}	3.81×10^{-02}
Access road	3.09×10^{-01}	1.45×10^{-01}	1.45×10^{-02}	3.59×10^{-01}	9.23×10^{-02}	9.23×10^{-03}
Underground haul road	n/a	n/a	n/a	8.95×10^{-01}	2.30×10^{-01}	2.30×10^{-02}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; n/a = not applicable.

7A2.2.4.18.2 Highway Traffic

The road dust from highway traffic was also estimated for the baseline (i.e., highway traffic without Project traffic), Construction, and Operations. Baseline highway traffic is assumed to be light trucks, and all Project highway traffic travelling to and on the access road is conservatively assumed to be class 8 tractor trailers (mean weight of 26.5 t). Highway 955 includes only a 2 km length for the screening model. Highway road dust emissions have no mitigation applied (chemical, watering, or speed control). Trips are considered two-way. The summer-time natural mitigation (e.g., 45%) was applied to the emissions. The highway road dust emission was estimated from the USEPA AP-42 Chapter 13.2.2 unpaved road dust (USEPA 2006b) for vehicles travelling on publicly accessible roads as the following equation:

$$EF = \frac{k\left(\frac{s}{12}\right)^{a}\left(\frac{S}{30}\right)^{d}}{\left(\frac{M}{0.5}\right)^{c}} - C$$

where: *EF* = unpaved road dust emission factors in kilograms per vehicle kilometre travelled (kg/VKT)

s = silt content in%. A silt content of 5% is assumed for the roads based on samples of the site road material. This could be considered conservative for the access road and highway, as a general value of 3.9% silt content for unpaved roads is indicated in studies

S = average vehicle travelling speed (e.g., 80 km/h)

M = moisture content in percent (%). An average value (e.g., 6.5%) from USEPA AP-42 Chapter 13.2.2 was used in this assessment (USEPA 2006b)

The constants for the above equation (e.g., k, a, c, d, and C) and the emission factors are listed in Table 7A-68.

Table 7A-68: Publicly Accessible Road Dust Equation Constants

Constant	$PM_{2.5}$	PM_{10}	TSP
k (Lb/VMT)	0.18	1.8	6.0
a	1	1	1
c	0.2	0.2	0.3
d	0.5	0.5	0.5
C	0.00036	0.00047	0.00047
EF (kg/VKT)	0.02	0.16	0.42

Lb/VMT = pounds per vehicle miles travelled; kg/VKT = kilograms per vehicle kilometres travelled; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

The road dust emissions estimated for the baseline highway traffic, Construction, and Operations are summarized in Table 7A-69.

Table 7A-69: Highway Non-Winter Road Dust Emissions

Phase	Trips per Day	Route Length (km)	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
Baseline	20.0	2.0	4.10×10^{-03}	4.12×10^{-02}	1.06×10^{-01}
Construction	110.6	2.0	2.26×10^{-02}	2.28×10^{-01}	5.88×10^{-01}
Operations	126.4	2.0	2.59×10^{-02}	2.61×10^{-01}	6.72×10^{-01}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.19 Wind Erosion

Five stockpiles are identified that could have considerable wind erosion emissions during Operations: the ore storage pad stockpiles, the special waste rock stockpile, the NPAG waste rock stockpile, the PAG waste rock stockpile, and the aggregate stockpile (uncovered). A covered sand and aggregate storage facility will also exist, but it is assumed to have no wind erosion because it is not exposed to atmosphere.

Wind erosion emissions were calculated from emission factors taken from the generalized National Pollutant Release Inventory guidance for pits and quarries (ECCC 2021). The National Pollutant Release Inventory method is simpler than the commonly used AP-42 13.2.5 method (USEPA 2006c), which requires an accurate threshold friction velocity, fastest mile data, and was developed for coal mines. The equation for a daily calculation of the particulate emission factor (EF) is:

$$EF = 1.12 \times 10^{-4} \times J \times 1.7 \times (s/1.5) \times (I/15)$$

where: *s* = silt content, which is assumed to be 5%

I = the percentage of time with wind about 19.3 km/h

J = the particle size factor (1, 0.5, and 0.2 for TSP, PM_{10}, and $PM_{2.5}$ respectively)

Wind erosion is calculated for each day independently over five years of the modelled meteorological data. The number of hours in each 24-hour period that exceed 19.3 km/h are considered to have wind erosion emissions. Days with precipitation over 0.254 mm and the winter period from November to March are considered to be naturally mitigated and have zero wind erosion emissions. The fraction of hours for each day that could have wind erosion occur are applied equally to all hours of the given day.

The following assumptions were made for wind erosion emissions:

- It is conservatively assumed that the aggregate stockpile, and NPAG and PAG waste rock stockpiles are active during Construction, as underground mine development is started. Potential wind erosion from other surfaces during the construction period is accounted for by the general construction surface area emission factor discussed in Section 7A2.2.4.21.
- Small earthworks piles during Construction are not considered in the model. It is assumed that the general construction surface area emissions will be sufficient with regard to including small areas of stockpile wind erosion.
- Airstrip emissions are not considered. Propeller wash occurs on a time-scale of seconds to a few minutes duration and does not lend itself to be appropriately modelled (model time steps of one hour). Flights are ephemeral events that do not emit dust continuously for long periods (i.e., an hour or greater). Treatment of the runway (chemical, watering, or winter conditions) along with the aforementioned factors will substantially mitigate dust emissions.
- Stockpile heights will vary over time. All stockpiles are assumed to emit at a constant height.
- The ore storage stockpiles are within a walled open-air enclosure area. A mitigation factor of 75% is applied to this pile, per MDAQMD guidance (MDAQMD 2000).
- The small stockpiles (ore, special waste, and aggregate stockpiles) are assumed to have 100% of their surface area being active. This is a conservative assumption. The NPAG and PAG waste rock stockpiles are assumed to have 25% of their surface area being active, as waste rock dumping is normally constrained to a local portion of a stockpile until that area is filled, then the active area moves. This may

also be a conservative assumption; as little as 10% of a surface mining waste rock stockpile may normally be active.

The erosional emission factor in grams per second per square metre is calculated for each day of five years of modelled meteorology. An hourly variable emissions file accounts for each day in the modelling.

The average annual tonnage is presented in Table 7A-70.

Table 7A-70: Wind Erosion Emission Rates

Parameter	Ore Pad	Special Waste Stockpile	NPAG Waste Rock Stockpile	PAG Waste Rock Stockpile	Aggregate Stockpile
Stockpile area (m^2)	9,520	9,057	489,017	240,550	3,600
Active area (%)	100%	100%	25%	25%	100%
Control efficiency (%)	75%	0%	0%	0%	0%
TSP annual average emissions (t/yr)	9.73×10^{-02}	3.70×10^{-01}	$5.00 \times 10^{+00}$	$2.46 \times 10^{+00}$	1.47×10^{-01}
PM_{10} annual average emissions (t/yr)	4.86×10^{-02}	1.85×10^{-01}	$2.50 \times 10^{+00}$	$1.23 \times 10^{+00}$	7.36×10^{-02}
$PM_{2.5}$ annual average emissions (t/yr)	1.95×10^{-02}	7.40×10^{-02}	9.99×10^{-01}	4.92×10^{-01}	2.94×10^{-02}

NPAG = non-potentially acid generating; PAG = potentially acid generating; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.20 Uranium Concentrate Handling Emissions

In the absence of specific information regarding stack emissions from the uranium concentrate packing/handling area and operations, the following are assumptions for uranium concentrate handling emissions during Operations:

- The uranium concentrate handling will be a negative pressure area and is assumed to vent to the atmosphere via a scrubber stack.
- Emission rates are scaled from the McLean Lake stack testing presented in the AREVA Kiggavik FEIS (AREVA 2014). The testing results of PM and uranium from the uranium concentrate packaging area stack was 0.1 kg/h and 2.60×10^{-03} kg/h, respectively. During the testing, the uranium concentrate production was 2,225 kg/h. The maximum uranium concentrate production of the Project will be 1,706 kg/h, thus a ratio of 0.76 will be applied to the McLean Lake stack testing results to obtain the emissions of the Project.
- The cumulative size distribution of mechanically generated PM from processed ores and non-metallic minerals (Category 4) in USEPA AP-42 Appendix B.2 (1996a) was used. The ratios of PM_{10}/TSP and $PM_{2.5}$/TSP are 0.85 and 0.30, respectively.

All uranium concentrate handling time periods are assumed to emit at the same rate (Table 7A-71).

Table 7A-71: Uranium Concentrate Handling Stack Emission Rates

Source	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)	Uranium (g/s)
Uranium concentrate handling stack	6.30×10^{-03}	1.79×10^{-02}	2.10×10^{-02}	5.46×10^{-04}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.4.21 General Construction Emissions

To account for general area construction emissions that are not covered by the above emission inventory during Construction (e.g., various earth moving activities), additional generic construction emissions will be estimated and included in the Project Construction PM emissions.

An emission factor from The WRAP Fugitive Dust Handbook (WRAP 2006) is used to estimate the fugitive PM_{10} emissions from generic construction activity. The PM_{10} emission factor is 0.11 t of dust per acre per month. The $PM_{2.5}/PM_{10}$ ratio for fugitive dust from general construction activities is 0.1 according to the WRAP Fugitive Dust Handbook (WRAP 2006). The PM_{10}/TSP ratio is obtained from the USEPA AP-42 Appendix B.2 (USEPA 1996a). The PM_{10}/TSP ratio of 0.51 for Category 3 mechanically generated dust from aggregate handling was used.

Speed control mitigation of 15 miles per hour (or less than 25 km/h) is assumed at 57% (WRAP 2006) to the general construction source for heavy equipment.

An area source is determined for the mine area, based on the current Project design. The active area could vary year to year, but the main mine terrace area is a reasonable estimate for the active construction area with earthworks activity at a given time. It is likely that this areal surface source emission would peak in Year-3 based on the construction fleet usage and diminish further during Construction as building activities begin to dominate the construction workflow. The construction area used in the emission calculation is 278,433 m^2.

Other considerations of general construction dust emissions include:

- Generic construction PM emissions are assumed to be naturally mitigated and set to zero during the winter months.
- Generic construction emissions are assumed to emit at the same rate for all averaging periods.

The PM emissions from the general construction activities are summarized in Table 7A-72.

Table 7A-72: General Construction Emissions

Source	$PM_{2.5}$ (g/s)	PM_{10} (g/s)	TSP (g/s)
General construction activity	0.11	1.14	2.23

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.2.5 Metal Concentrations

Metals will be emitted as a portion of fugitive dust and combustion emissions at the Project. The following assumptions regarding the metal composition and emissions from Project sources were made:

- Roads and aggregate metals emissions are determined from the aggregate geochemistry profile (detailed below).
- Combustion-related metals emissions are provided by USEPA AP-42 for their specific combustion type. Based on the small fraction of metals emitted by combustion sources in comparison to mechanically generated mineral dust-related sources (e.g., hauling, grading, wind erosion), combustion sources other than the waste incinerators are not carried forward in the metals modelling.
- Fugitive dust emissions from ore and waste rock are determined from geochemistry analysis. Metals concentrations (ppm) are averaged over all geochemistry samples provided.

- Uranium content from triuranium octoxide (U_3O_8) at Operations Year 1, maximum ore grade of 4.07% U_3O_8, or 3.451% uranium. Special waste grade is 0.15% U_3O_8, or 0.127% uranium concentrate. Ore density is 2.51 t/m^3, waste density is 2.42 t/m^3. Waste rock is determined to be at the specified limit of clean waste, or 0.03% U_3O_8 (0.025% uranium concentrate).

Metals concentrations in each rock type are presented in Table 7A-73. The metals species listed only considers those being modelled in the air quality assessment as requested by other assessment disciplines.

Special considerations were given to uranium emissions from the calciner, including the calciner exhaust and bin baghouse exhaust, and LLRW and mercury emissions from the batch waste incinerator and the LLRW incinerator in the following:

- Due to the lack of information of other air pollutants from the calciner exhaust, testing results from a stack test conducted in 2008 for a similar uranium milling facility in Saskatchewan (AREVA 2014), the McClean Lake mine was used to estimate uranium emissions from the PM emission rates. The McClean Lake mine stack test measured 1.67 g/s of PM and 1.92×10^{-03} g/s of uranium. The ratio of stack tested uranium to PM (e.g., 1.115×10^{-03}) was applied to the PM emission of the Project (e.g., 2 kg/h) to estimate the uranium emissions from calciner exhaust air. The ratio of uranium to PM of the calciner bin baghouse was assumed to be the same as the calciner exhaust.
- Mercury emissions are conservatively assumed to emit at the maximum Canada-wide Standard limit provided by the Environment Canada Technical Document for Batch Waste Incineration (Environment Canada 2010), which is 20 µg/m³. A conversion factor is given in AP-42 2.1 Refuse Combustion (USEPA 1996b) to convert a mass per tonne emission factor to a mass per exhaust volume emission factor. The Canada-wide standard was multiplied by 4.03×10^{-6} to obtain a mass per tonne of waste combusted.
- Uranium emissions from the LLRW are difficult to quantify without a detailed understanding of the feed but are assumed to be equal to the emission limit of 10 g/h at an hourly rate, based on emissions from the Canadian Nuclear Safety Commission Blind River LLRW incinerator (Arcadis 2019). No uranium is assumed to be emitted by the batch waste incinerator.

Table 7A-73: Metals Concentrations in Different Types of Rock

Metal	Waste Rock (ppm)	Special Waste Rock (ppm)	Ore (ppm)	Aggregate (ppm)
Silver (Ag)	0.31	0.24	4.40	0.00
Arsenic (As)	2.38	11.10	33.38	2.25
Barium (Ba)	709.02	964.69	2,020.00	28.75
Beryllium (Be)	0.99	2.28	3.80	0.00
Cadmium (Cd)	0.27	0.50	0.50	0.00
Cobalt (Co)	19.14	31.52	61.25	1.00
Chromium (Cr)	87.58	124.66	160.00	186.75
Copper (Cu)	44.43	135.67	646.88	4.50
Mercury (Hg)	0.01	0.02	0.00	0.00
Molybdenum (Mo)	9.09	116.20	526.75	0.00
Nickel (Ni)	51.90	79.37	134.50	6.00
Lead (Pb)	17.94	65.95	1,115.75	2.00
Antimony (Sb)	0.02	0.78	7.00	0.00

Table 7A-73: Metals Concentrations in Different Types of Rock

Metal	Waste Rock (ppm)	Special Waste Rock (ppm)	Ore (ppm)	Aggregate (ppm)
Selenium (Se)	0.44	2.74	12.00	0.00
Tin (Sn)	0.78	3.29	8.00	1.00
Thorium (Th)	23.86	26.27	53.13	0.00
Uranium (U)	254.40	1,272.01	34,513.79	0.00
Vanadium (V)	130.18	299.08	471.38	7.50
Zinc (Zn)	62.34	44.31	17.75	5.25
Cesium (Cs)	0.82	0.30	0.20	0.00
Bismuth (Bi)	0.78	2.00	16.00	0.00
Calcium (Ca)	3,596.11	1,705.40	2,572.89	2,697.96
Iron (Fe)	29,582.08	13,508.66	13,394.10	7,816.14
Magnesium (Mg)	26,053.49	19,754.82	18,709.37	1,387.00
Manganese (Mn)	304.98	114.30	110.64	232.34
Sodium (Na)	4,395.02	1,268.84	1,431.59	2,789.29

ppm = parts per million.

7A2.2.6 Radionuclide Concentrations

Uranium ore is normally in a secular equilibrium with a few exceptions for some very young ore bodies, which do not apply in Saskatchewan. Therefore, radionuclides in the source rock are assumed to be in secular equilibrium. All decay chain progeny (i.e., lead-210, polonium-210, radium-226, and thorium-230) are assumed to be in the same concentration in becquerels per gram (Bq/g). The conversion from uranium concentration to becquerel concentrations is: 1 becquerel per second (Bq/s) is equivalent to 81 ppm uranium. Therefore, the radionuclide concentrations in each type of rock are calculated from the uranium concentrations of the source rock as listed in Table 7A-73. The radionuclide concentrations for each source rock type are presented in Table 7A-74. The radionuclide emissions were then estimated from the TSP emissions from the sources depending on the rock types and the fraction of rock types. For example, SAG and ball mill stack will emit 0.0693 g/s of TSP and the TSP emissions are assumed to be generated from the processing of ore. Thus, the radionuclide emission rate for the SAG and ball mill stack is the product of TSP emission rate and the radionuclide concentration in ore (e.g., 0.0693 g/s x 426.10 Bq/g = 29.5 Bq/s).

Table 7A-74: Radionuclide Concentrations in Rock Types

Radionuclide	Waste	Special	Ore	Aggregate
Uranium (ppm)	254.4	1,272.0	34,513.8	0.00
Lead-210 (Bq/g)	3.1	15.7	426.1	0.00
Polonium-210 (Bq/g)	3.1	15.7	426.1	0.00
Radium-226 (Bq/g)	3.1	15.7	426.1	0.00
Thorium-230 (Bq/g)	3.1	15.7	426.1	0.00

ppm = parts per million; Bq/g = becquerels per gram.

7A2.2.7 Radon Emission

Radon released to the environment from uranium ore mining and processing is an important issue when considering the potential radiation exposure to members of the public who work, live, or recreate near a uranium mine or processing facility. The potential radon emission sources at the Project include underground mining via the mine vents, ore storage pad, special waste stockpile, and the process plant (e.g., SAG and ball mill stack). The radon emissions were estimated for three cases:

- 11-year EA case at an average grade of 2.37% U_3O_8 in ore.
- 24-year EA case at an average grade of 1.37% U_3O_8 in ore.
- Maximum Case at the maximum annual grade of 4.41% U_3O_8 (Year 1).

The detailed radon inventory is outlined in Attachment A. Table 7A-75 is a summary of the estimated radon emissions for the Project.

Table 7A-75: Radon Emission Rates of the Rook I Project

Sources	Radon Emissions (Bq/s)			Modelled Sources
	11 Year EA Case	24 Year EA Case	Maximum Case	
Underground mining	$2.24 \times 10^{+08}$	$1.29 \times 10^{+08}$	$4.16 \times 10^{+08}$	Mine vent
Ore surface	$1.73 \times 10^{+06}$	$1.00 \times 10^{+06}$	$3.22 \times 10^{+06}$	Ore storage pad
Special waste surface	$3.08 \times 10^{+04}$	$1.78 \times 10^{+04}$	$5.74 \times 10^{+04}$	Special waste stockpile
Process plant	$1.50 \times 10^{+06}$	$8.65 \times 10^{+05}$	$2.78 \times 10^{+06}$	SAG and ball mill stack

Bq/s = becquerels per second; EA = Environmental Assessment; SAG = semi-autogenous grinding.

7A2.2.8 Dioxins and Furans Emission

Dioxins and Furans from waste incinerator exhaust are conservatively assumed to emit at the maximum Canada-wide standard limit set by the Environment Canada Technical Document for Batch Waste Incineration (Environment Canada 2010), which is 80 picograms toxic equivalency units (pg TEQ) per dry standard cubic metre (dscm). Estimated volumetric flow rates (e.g., 2.23 dry standard cubic meter per second [dscm/s]) and the Canada-wide standard limit were then used to estimate the D&F emissions.

7A2.2.9 Variable Emissions

Variable emission profiles were applied to mine heaters, general construction activities, road dust, and wind erosion.

The mine heaters and small heaters would only operate during colder months (October to April) and the fuel consumptions would vary by months. Therefore, separate mine heater and small mine heater monthly variable emission profiles were assigned to one-hour averaging period and 24-hour and annual averaging periods. The mine heater and small mine heater monthly variable emission profile for 24-hour and annual averaging periods was created based on the mine heater and small heater monthly fuel consumptions.

For the general construction activities, road dust, and wind erosion, the PM emission rates were assumed to be zero in winter months (October to April) when there is snow cover on the ground.

The monthly variable emission profile for mine heaters, general construction activities, and road dust are summarized in Table 7A-76. Hourly variable emissions files were generated for wind erosion emissions, including PM emissions, and the radionuclide and metal emissions associated with the wind erosion PM, based on the wind speed and precipitation.

Table 7A-76: Variable Emission Profiles

Month	Mine Heaters and Small Heaters		General Construction	Road Dust
	1-hour	24-hour and Annual	All Averaging Periods	All Averaging Periods
January	1	1.53	0	0
February	1	1.22	0	0
March	1	1	0	0
April	1	0.5	0	0
May	0	0	1	1
June	0	0	1	1
July	0	0	1	1
August	0	0	1	1
September	0	0	1	1
October	1	0.37	0	0
November	1	0.99	0	0
December	1	1.39	0	0

7A2.3 Fission Patterson Lake South Property Project Emissions

7A2.3.1 Emission Summary

The Fission Patterson Lake South Property is a reasonably foreseeable development that would be located 5 km southwest of the Project. Both projects would be combined uranium mills and mines. An emission inventory for the operations phase of Fission Patterson Lake South Property was developed based on their prefeasibility study (Fission 2019). Although a number of characteristics between the two projects will be similar, the following key characteristics differ:

- The Project would mill 1,300 t/d of ore, while Fission Patterson Lake South Property would mill 1,000 t/d of ore.
- The Project maximum material movement is 1,444,081 t/yr, while Fission Patterson Lake South Property is estimated at maximum of 733,000 t/yr.
- Fission Patterson Lake South Property peak processing ore grade is estimated to be 2.0% in Year 3, for an hourly average production rate of 778 kg of recovered U_3O_8 per hour with maximum calcining set to 833 kg U_3O_8 per hour (assuming 1,000 t/d ore at 2% grade).
- The Project represents a detailed mill design, while Fission Patterson Lake South Property has a prefeasibility design only.

Due to the level of information available for Fission Patterson Lake South Property, emissions will be assumed as similar to the Project where appropriate. Scaling of emissions is a common assumption for Fission Patterson Lake South Property, based on the unit of scaling (e.g., 1,300 trips per day versus 1,000 trips per day).

Overall, Fission Patterson Lake South Property annual emission rates are presented in Table 7A-77. A breakdown of Fission Patterson Lake South Property annual emissions by source type is presented in Table 7A-78.

Table 7A-77: Fission Patterson Lake South Property Annual Emission Rates

Phase	Nitrogen Oxides (t/yr)	Sulphur Dioxide (t/yr)	Carbon Monoxide (t/yr)	Sulphuric Acid (t/yr)	$PM_{2.5}$ (t/yr)	PM_{10} (t/yr)	TSP (t/yr)
Operations	156.4	5.0	167.28	0.35	14.4	50.0	155.9

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

Table 7A-78: Fission Patterson Lake South Property Annual Emissions by Source Category

Source Type	Nitrogen Oxides (t/yr)	Sulphur Dioxide (t/yr)	Carbon Monoxide (t/yr)	$PM_{2.5}$ (t/yr)	PM_{10} (t/yr)	TSP (t/yr)
Acid plant	0.00	2.71	0.00	0.00	0.00	0.00
Calciner stacks	0.07	0.03	5.13	1.68	4.67	8.70
Batch plant	0.00	0.00	0.00	0.01	0.02	0.08
SAG and ball mill	0.00	0.00	0.00	0.25	0.86	1.68
Aggregate operations	0.00	0.00	0.00	0.23	0.41	1.48
Dozing	0.00	0.00	0.00	0.99	1.78	9.42
Material handling	0.00	0.00	0.00	0.21	0.72	1.42
Small heaters	0.26	0.00	0.17	0.01	0.01	0.01
UG grading	0.00	0.00	0.00	0.03	0.47	0.95
UG diesel mine fleet	5.67	0.03	0.18	0.26	0.36	0.36
UG hauling	0.00	0.00	0.00	1.31	13.14	51.13
UG material handling	0.00	0.00	0.00	0.01	0.02	0.04
UG drilling	0.00	0.00	0.00	0.20	0.20	0.25
UG blasting	11.29	0.02	49.77	0.02	0.26	0.50
Power plant	130.77	0.02	74.85	3.89	3.89	3.89
Road dust	0.00	0.00	0.00	1.59	15.93	62.01
Grading	0.00	0.00	0.00	0.19	2.20	6.29
Incinerator	1.00	0.59	0.16	0.35	0.46	0.70
LLRW incinerator	1.86	1.47	0.24	0.85	1.09	1.64
Lime silos	0.00	0.00	0.00	0.17	0.17	0.17
Mine fleet	12.93	0.05	6.81	1.19	1.10	1.10
Mine heater	3.64	0.08	28.51	0.14	0.14	0.14
Wind erosion	0.00	0.00	0.00	0.71	1.79	3.57
Uranium concentrate handling	0.00	0.00	0.00	0.10	0.28	0.32
Construction area heating	0.00	0.00	0.00	0.00	0.00	0.00
General Construction	0.00	0.00	0.00	0.00	0.00	0.00

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; UG = underground; LLRW = low-level radioactive waste; SAG = semi-autogenous grinding.

7A2.3.2 Emission Estimation

The Fission Patterson Lake South Property emission rates were estimated by one of the following approaches:

- Fission Patterson Lake South Property emission rates were assumed to be identical to the Project emissions.

- Fission Patterson Lake South Property emission rates were scaled from the Project emissions with the ratios of maximum ore milled, uranium concentrate production, maximum materials movement, or power plant capacity.
- Fission Patterson Lake South Property emission rates were estimated with information provided in the prefeasibility study.

Emissions Identical to the Project

Due to the lack of information, the emission rates from the following sources were considered to be identical to the Project:

- acid plant;
- calciner bin baghouse exhaust;
- cement batch plant;
- aggregate crushing;
- dozing;
- grading;
- blasting;
- incinerators;
- lime silo baghouses;
- mine fleet;
- mine heaters; and
- wind erosion.

Emissions Scaled from the Project

The Fission Patterson Lake South Property emission rates of SAG and ball mill crushing were scaled from the Project emissions by ratio of maximum ore milled per day, which is 0.77 calculated from Fission Patterson Lake South Property maximum ore milled of 1,000 t/d and maximum ore milled at the Project of 1,300 t/d.

The emission rates from the following Fission Patterson Lake South Property sources were scaled from the Project emissions by the ratio of uranium concentrate calcined and handled. The ratio is 0.49 based on the uranium concentrate production at Fission Patterson Lake South Property (e.g., 833 kg/h) and at the Project (1,706 kg/h):

- calciner natural gas burner;
- calciner exhaust; and
- uranium concentrate handling.

The emissions of the following Fission Patterson Lake South Property sources were scaled from the Project emissions by the ratio of material moved. The ratio is 0.51 based on the material moved at Fission Patterson Lake South Property (e.g., 733,000 t/yr) and at the Project (e.g., 1,444,081 t/yr):

- drilling;

- material handling; and
- underground road dust.

The Fission Patterson Lake South Property power plant emissions were scaled from the Project emissions with a ratio of capacity of the power plant. The ratio is 0.83 based on Fission Patterson Lake South Property power plant capacity of 20 MW and the Project power plant capacity of 24 MW.

Additional Emissions

Fission Patterson Lake South Property would have five Epiroc MT 431B haul trucks travelling a decline. Additional driving for these five vehicles is added as a separate underground sub-source for vehicle exhaust and road dust emissions. The exhaust emissions from the two Epiroc haul trucks assigned to surface were added on top of the emissions. The additional haul trucks information is presented in Table 7A-79 through Table 7A-82 and summarized as:

- Five Epiroc MT 431B haul trucks:
  - Trucks are 400 HP, powered with Cummins QSM11 engines rated for EPA Tier 3.
  - Trucks are rated for 28.1 metric tonnes per load, the mine will have 75 trips per day (total of 2,100 trips per day).
  - The base weight is 28 t, for a combined weight of 56.1 t.
  - Four trucks are assumed to operate for 12 hours a day, each completing 19 loads, or one per 38 minutes, for an average speed of 9.0 km/h. The fifth truck is assumed to be used as a spare and undergoing maintenance. If used, it will reduce the proportionally usage of the remaining trucks.
- As the road lengths may change, it is assumed all surface trucks travel 1.4 km:
  - Due to loading and unloading, the proportion of time in each length is indeterminate. An approximation is made of 25% in the mine, 25% in the decline, and 50% on the surface. Therefore, of four active trucks, only two are assumed to be underground at any time.

Table 7A-79: Epiroc Truck Travel Distances

Route	Distance (m)	Time (%)
Mine	700	25
Decline	875	25
Special	920	50
Waste	1,380	
Ore	1,200	

Table 7A-80: Decline and Underground Haul Diesel Emission Rates

Pollutant	Annual/Daily (g/s)	Hourly (g/s)
Nitrogen oxides	1.20×10^{-01}	2.41×10^{-01}
PM	8.07×10^{-03}	1.61×10^{-02}
PM_{10}	8.07×10^{-03}	1.61×10^{-02}
$PM_{2.5}$	7.83×10^{-03}	1.57×10^{-02}

Table 7A-80: Decline and Underground Haul Diesel Emission Rates

Pollutant	Annual/Daily (g/s)	Hourly (g/s)
Carbon monoxide	4.63×10^{-02}	9.27×10^{-02}
Sulphur dioxide	2.33×10^{-04}	4.66×10^{-04}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; PM = particulate matter.

Table 7A-81: Additional Surface Haul Diesel Emission Rates

Pollutant	Hourly (g/s)	Annual (g/s)	Daily (g/s)
Nitrogen oxides	2.41×10^{-01}	1.20×10^{-01}	1.20×10^{-01}
PM	1.61×10^{-02}	8.07×10^{-03}	4.04×10^{-03}
PM_{10}	1.61×10^{-02}	8.07×10^{-03}	4.04×10^{-03}
$PM_{2.5}$	1.57×10^{-02}	7.83×10^{-03}	7.83×10^{-03}
Carbon monoxide	9.27×10^{-02}	4.63×10^{-02}	4.63×10^{-02}
Sulphur dioxide	4.66×10^{-04}	2.33×10^{-04}	2.33×10^{-04}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; PM = particulate matter.

An additional underground hauling sub-source is added for the additional decline ramp length, summed at the mine vent. Surface hauling for Fission Patterson Lake South Property is done by larger trucks than the Project, so load capacity reduces the number of trips per day.

Table 7A-82: Hauling Dust Emissions

Phase	Trips per Day	Route Length (km)	$PM_{2.5}$ (g/s)	TSP (g/s)	PM_{10} (g/s)
Decline	75	0.875	2.87×10^{-02}	$1.12 \times 10^{+00}$	2.87×10^{-01}
Surface	75	1.40	8.66×10^{-02}	$3.37 \times 10^{+00}$	8.66×10^{-01}

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates.

7A2.3.3 Metal Concentrations

The metal concentrations in the four types of rock (e.g., waste, special, ore, and aggregate) of the Fission Patterson Lake South Property were assumed to be the same as the Project, except for the uranium concentration in ore. The Fission Patterson Lake South Property U_3O_8 concentration in ore is 2.00%, which is equivalent to 1.696% of uranium or 16,960.1 ppm.

7A2.3.4 Radionuclide Concentrations

The same approach as the Project was used to estimate the radionuclide emissions from Fission Patterson Lake South Property. The Fission Patterson Lake South Property radionuclide concentrations were then summarized in Table 7A-83. The radionuclide emissions were then estimated from the TSP emissions from the sources depending on the rock types and the fraction of rock types.

Table 7A-83: Radionuclide Concentrations in Rock Types

Radionuclide	Waste	Special	Ore	Aggregate
Uranian concentration (ppm)	254.4	1272	16,960.1	0.00
Lead-210 (Bq/g)	3.14	15.70	209.38	0.00
Polonium-210 (Bq/g)	3.14	15.70	209.38	0.00
Radium-226 (Bq/g)	3.14	15.70	209.38	0.00
Thorium-230 (Bq/g)	3.14	15.70	209.38	0.00

ppm = parts per million; Bq/g = becquerel per gram.

7A2.3.5 Radon Emission

Radon emission sources from Fission Patterson Lake South Property were assumed to be similar to the radon sources from the Project. The modelled emission sources include mine vents, ore storage pile, special waste storage pile, SAG, and ball stack (Table 7A-84). The Fission Patterson Lake South Property radon emissions were scaled from the Project emissions based on the following assumptions:

- The maximum U_3O_8 concentration in ore for Fission Patterson Lake South Property is 2% and the maximum U_3O_8 concentration in ore for the Project is 4.41%. A ratio of 0.45 was applied to all radon sources.
- The Fission Patterson Lake South Property mill throughput is 1,000 t/d, while the Project mill throughput is 1,300 t/d. A ratio of 0.77 was applied to emissions from the SAG and ball mill.
- The modelled areas of special waste stockpile and ore storage pad are different between Fission Patterson Lake South Property and the Project. Ratios of 13.8 and 23.15 were applied to the special waste stockpile and ore storage pad, respectively.

Table 7A-84: Radionuclide Concentrations in Rock Types

Sources	Estimated Rate of Radon Release (Bq/s)
	Maximum Case
Mine vents	$3.77 \times 10^{+08}$
Special waste storage pile	$3.59 \times 10^{+05}$
Ore storage pile	$1.95 \times 10^{+06}$
SAG and ball mill	$4.86 \times 10^{+05}$

Bq/s = becquerel per second; SAG = semi-autogenous grinding.

7A2.3.6 Dioxins and Furans Emission

Fission Patterson Lake South Property D&F emissions are assumed to be identical to the emissions of the Project.

7A2.3.7 Variable Emissions

Similar to the Project, variable emission profiles were applied to mine heaters, general construction activities, road dust, and wind erosion of the Fission Patterson Lake South Property. The same variable emission profiles as the Project were applied in the Fission Patterson Lake South Property modelling.

7A3 AIR DISPERSION MODELLING

The air dispersion modelling approach for this assessment follows the requirements outlined in the Saskatchewan Ministry of Environment (ENV) Saskatchewan Air Quality Modelling Guideline (SAQMG; ENV 2012). The American Meteorological Society / Environmental Protection Agency Regulatory Model, commonly known as the AERMOD dispersion model, was used to predict ground level concentrations and aerial deposition rates of the selected compounds. The AERMOD was specially developed to support USEPA regulatory modelling programs, and it has been adopted by ENV as the air dispersion model of choice for air quality studies in Saskatchewan.

The version of AERMOD model used in this air quality assessment is 19191, the most recent version approved by USEPA at the time when the air quality assessment was initiated. The AERMOD system has two input data processors: AERMET and AERMAP. The AERMET is a meteorological data processor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts. The AERMAP is a terrain data preprocessor that incorporates complex terrain using digital elevation data.

7A3.1 Dispersion Meteorology

The ENV has developed five years (2012 to 2016) of preprocessed meteorological datasets in an AERMOD ready format that are available to the public to use when conducting dispersion modelling for a project in Saskatchewan. These meteorological datasets were produced by the Weather Research and Forecast (WRF) model. Saskatchewan was divided into five air dispersion modelling zones, and ENV has provided a dataset for each of the five zones. When the air dispersion modelling for the Project was initiated in 2019, ENV's AERMOD ready five-year meteorological dataset for the Northern Air Dispersion Modelling Zone had not been released yet. Therefore, a Project-specific AERMET dataset was developed for this assessment with meteorological data input provided by the ENV and in accordance with the relevant guidance including the AERSURFACE User's Guide (USEPA 2008) and the AERMOD Implementation Guide (USEPA 2021a). The meteorological data were extracted from ENV 2012 to 2016 WRF model outputs at a grid point near the Project location.

The Project-specific AERMET dataset has been developed with the meteorological input from the same WRF modelling outputs as the ENV regional meteorological (ENV AERMET) dataset but extracted at a grid point closer to the Project location than the ENV dataset closest to the Project. The surface parameters were determined from the land-use data by using the approach outlined in the AERMOD Implementation Guide; therefore, the Project-specific AERMET dataset is expected to approximately represent the meteorological conditions of the Project site. This section summarizes the materials and methods used to develop the Project-specific AERMET dataset, as well as the findings of the evaluation of both datasets.

A comparison between the meteorological dataset developed specifically for the Project, the ENV dataset, and the on-site measures was conducted and presented in this section. Out of the various meteorological datasets ENV has published for the Northern Air Dispersion Modelling Zone, the Project location is closest to the ENV dataset representing 57.91 degrees north in latitude and 108.862 degrees west in longitude, which is approximately 35 km northeast of the Project location.

7A3.1.1 AERMET Inputs

7A3.1.1.1 Meteorological Inputs

A 5-year (2012 to 2016) meteorological dataset, including a surface data file and an upper air data file, were provided by ENV. The dataset was extracted by ENV from WRF modelling outputs. Weather Research and Forecast extraction at the grid 12 km west of the Project location was provided and used as surface and upper air data input for running AERMET to prepare the meteorological data for use in AERMOD modelling.

7A3.1.1.2 Surface Parameters

The input for the AERMET requires surface roughness, albedo, and Bowen ratio parameters. The surface roughness influences the surface shear stress and is an important factor in determining the magnitude of mechanical turbulence and the stability of the boundary layer. The albedo and Bowen ratio are used to estimate the strength of convective turbulence during unstable conditions. Determining appropriate and representative values for these parameters is important for the development of an AERMET dataset capable of constructing realistic planetary boundary layer similarity profiles and adequately characterizing the dispersive capacity of the atmosphere. Therefore, the surface parameters were determined according to the AERMOD Implementation Guide (USEPA 2021a) as follows:

- The surface roughness values were determined based on an inverse-distance weighted geometric mean. Surface roughness was assigned differently for four sectors within a 1-km radius area.
- The albedo values were determined based on a simple unweighted arithmetic mean (i.e., no direction or distance dependency) within a 10-km radius area.
- The Bowen ratio values were determined based on a simple unweighted geometric mean (i.e., no direction or distance dependency) within a 10-km radius area.

The surface parameters, depending upon land-use type and season, were chosen from tabulated values found in Appendix A of the AERSURFACE User's Guide (USEPA 2008). Four wind sectors were defined for the surface roughness: a northeast section (0° to 90°), southeast section (90° to 180°), southwest section (180°to 270°), and a northwest section (270° to 360°). Monthly variation of surface parameters was chosen to appropriately represent local seasonality at the Project location. The months assigned to each season and the description of each season as in the AERSURFCE User's Guide are listed in Table 7A-85.

Table 7A-85: Local Seasonality and Months

Seasonal Category	Season Description	Project Month Assignments
1	Midsummer with lush vegetation	July
2	Autumn with unharvested cropland	August, September
3	Late autumn after frost and harvest, or winter with no snow	October
4	Winter with continuous snow on ground	November through April
5	Transitional spring with partial green coverage or short annuals	May, June

The surface parameters were then determined with the following procedures:

- Land use data were obtained from the Saskatchewan Digital Land Cover database (Government of Saskatchewan 2021).
- Land use data were extracted for an area with both a 1-km radius and a 10-km radius centred at the Project.
- Monthly surface parameters for each land use category were assigned based on Table A-1 to Table A-3 of the AERSURFACE User's Guide (USEPA 2008).
- The surface parameters were then determined according to the AERMOD Implementation Guide (USEPA 2021a).

The monthly surface parameters assigned for the AERMET model are presented in Table 7A-86.

Table 7A-86: Surface Parameters for AERMET

Month	Season	Surface Roughness (m)				Albedo	Bowen Ratio
		NE	SE	SW	NW		
January	4	1.06	0.46	1.17	1.04	0.27	0.22
February	4	1.06	0.46	1.17	1.04	0.27	0.22
March	4	1.06	0.46	1.17	1.04	0.27	0.22
April	4	1.06	0.46	1.17	1.04	0.27	0.22
May	5	1.12	0.94	1.18	1.05	0.12	0.12
Jun	5	1.12	0.94	1.18	1.05	0.12	0.12
July	1	1.12	0.95	1.18	1.05	0.12	0.12
August	2	1.12	0.95	1.18	1.05	0.12	0.12
September	2	1.12	0.95	1.18	1.05	0.12	0.12
October	3	1.11	0.87	1.18	1.05	0.12	0.12
November	4	1.06	0.46	1.17	1.04	0.27	0.22
December	4	1.06	0.46	1.17	1.04	0.27	0.22

NE = northeast; SE = southeast; SW = southwest; NW = northwest.

7A3.1.2 AERMET Model Options

AERMET was executed with version 18081, the most recent version of AERMET when the Project-specific meteorological datasets were developed. The options were kept consistent with respect to the options in the input files provided by ENV. The relevant AERMET options found in the stage 1 and stage 3 input files are presented in Table 7A-87.

Table 7A-87: Model Options for AERMET

Method	AERMET Option Selection
THRESHOLD	0.5
STABLEBL	BULKRN
WIND_DIR	NORAND
ASOS_ADJ	NO_ADJ
UASELECT	SUNRISE

7A3.1.3 AERMET Outputs and Evaluation

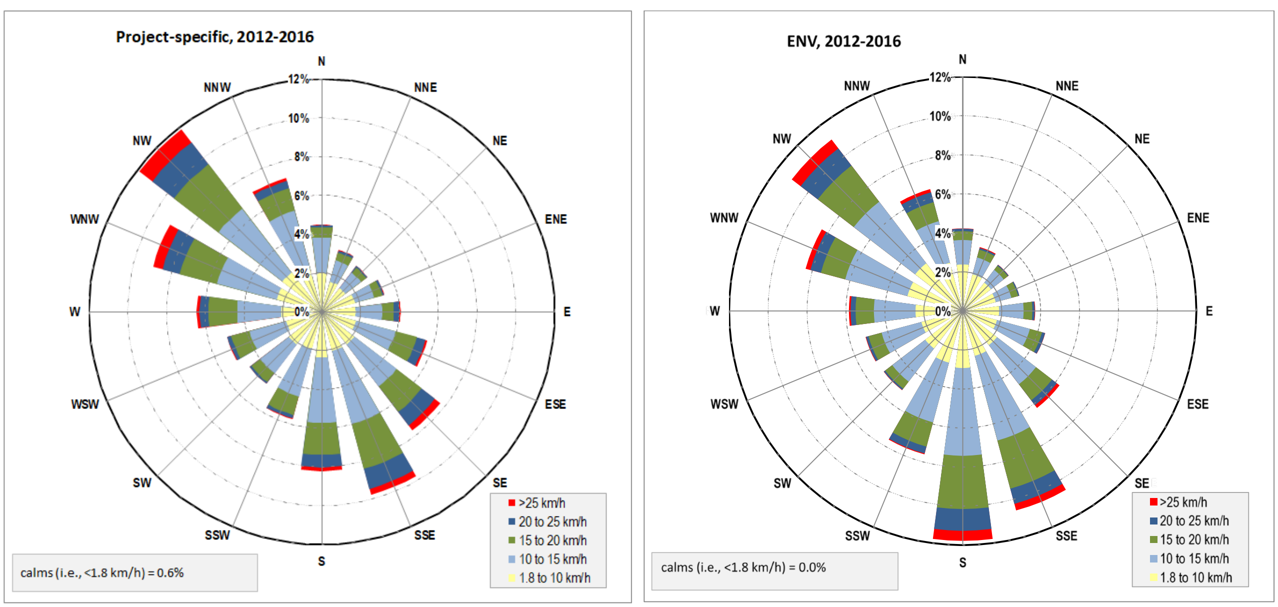
A summary of the AERMET outputs from the Project-specific and the ENV AERMET meteorological datasets are provided in the following subsections. The on-site Project meteorological station has been collecting meteorological data including air temperature, wind speed, and wind direction since November 2015. Therefore, the AERMET derived air temperature and wind data were also compared with the on-site data for the overlapping year of 2016.

7A3.1.3.1 Wind

The dispersion and transport of atmospheric emissions are driven primarily by the wind. A wind rose is often used to illustrate the frequency of wind direction and the magnitude of wind velocity. The lengths of the bars on the wind rose indicate the frequency and speed of wind, while the direction from which the wind blows is illustrated by the orientation of the bar in one of sixteen compass directions.

The AERMET-derived winds for the period from 2012 to 2016 from the Project-specific and the ENV datasets are shown in Figure 7A-1. Both wind roses display similar wind patterns. The annual wind roses indicate that the predominant winds derived from the Project-specific AERMET dataset are from the northwest direction, with subdominant winds from the south-southeast, while the ENV AERMET dataset presents the most dominant winds from the south direction and the subdominant winds from northwest direction. The most frequent hourly wind speeds (70% of the Project-specific AERMET dataset and 75% of the ENV AERMET dataset) are in the range of 3.6 to 15 km/h. Calm conditions, which represent wind speeds under 1.8 km/h or 0.5 m/s, occurred 0.6% of the time in the Project-specific AERMET dataset. It is noted that the ENV AERMET dataset has wind speeds that are all larger than 0.5 m/s.

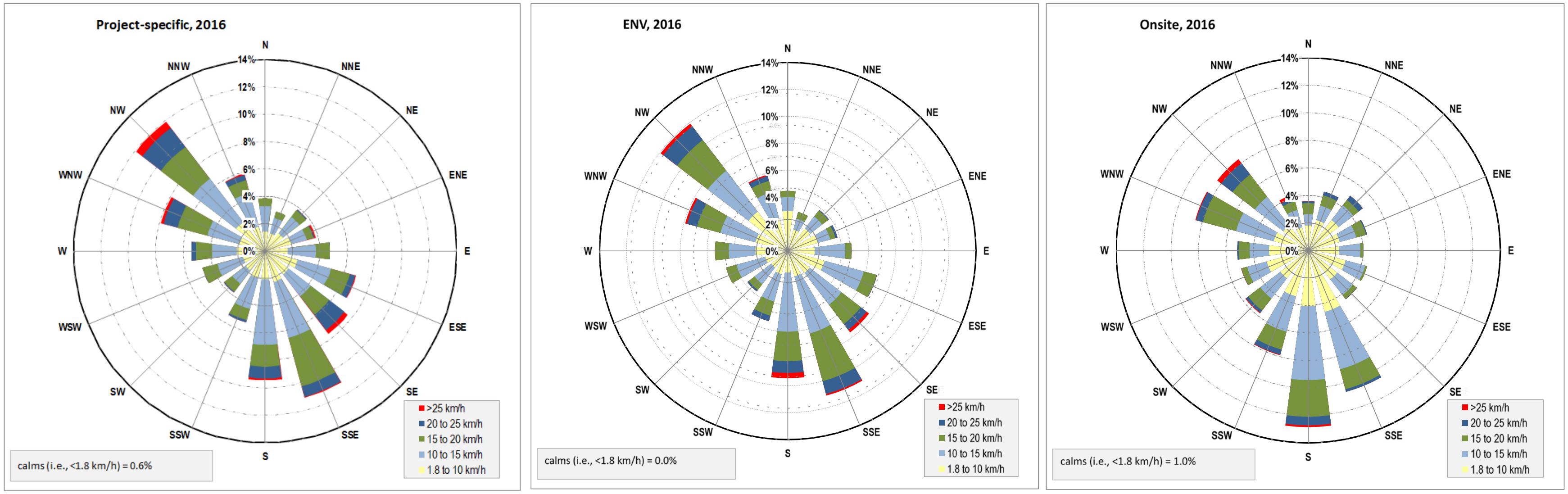
Figure 7A-1: AERMET Wind Roses at the Project Location



<= less than; > = greater than; N = north; NNE = north-northeast; NE = northeast; ENE = east-northeast; E = east; ESE = east-southeast; SE = southeast; SSE = south-southeast; S = south; SSW = south-southwest; SW = southwest; WSW = west-southwest; W = west; WNW = west-northwest; NW = northwest; NNW = north-northwest; ENV = Saskatchewan Ministry of Environment.

Figure 7A-2 presents the annual wind roses derived from the Project-specific AERMET dataset, the ENV AERMET dataset, and the on-site measured wind data in 2016. The comparison between the AERMET wind roses and the on-site wind roses indicate that both AERMET datasets satisfactorily simulated winds at the Project site. The local terrain features that cannot be resolved by the WRF model may have contributed to the differences between on-site measurements and AERMET output.

Figure 7A-2: AERMET-Derived Project Location Wind Roses and On-Site Wind Rose for 2016



<= less than; N = north; NNE = north-northeast; NE = northeast; ENE = east-northeast; E = east; ESE = east-southeast; SE = southeast; SSE = south-southeast; S = south; SSW = south-southwest; SW = southwest; WSW = west-southwest; W = west; WNW = west-northwest; NW = northwest; NNW = north-northwest; ENV = Saskatchewan Ministry of Environment.

7A3.1.3.2 Temperature

Table 7A-88 summarizes the daily average temperatures from the Project-specific AERMET dataset, the ENV AERMET dataset, and the on-site observations in 2016. The daily average temperatures from the Project-specific AERMET dataset ranged from -20.2°C in December to 16.6°C in July in 2016, while the ENV AERMET daily average temperatures ranged from -20.6°C in December to 17.1°C in July in 2016. Both AERMET datasets are similar to the 2016 on-site data.

Table 7A-88: AERMET-Derived Temperature Summary (2016)

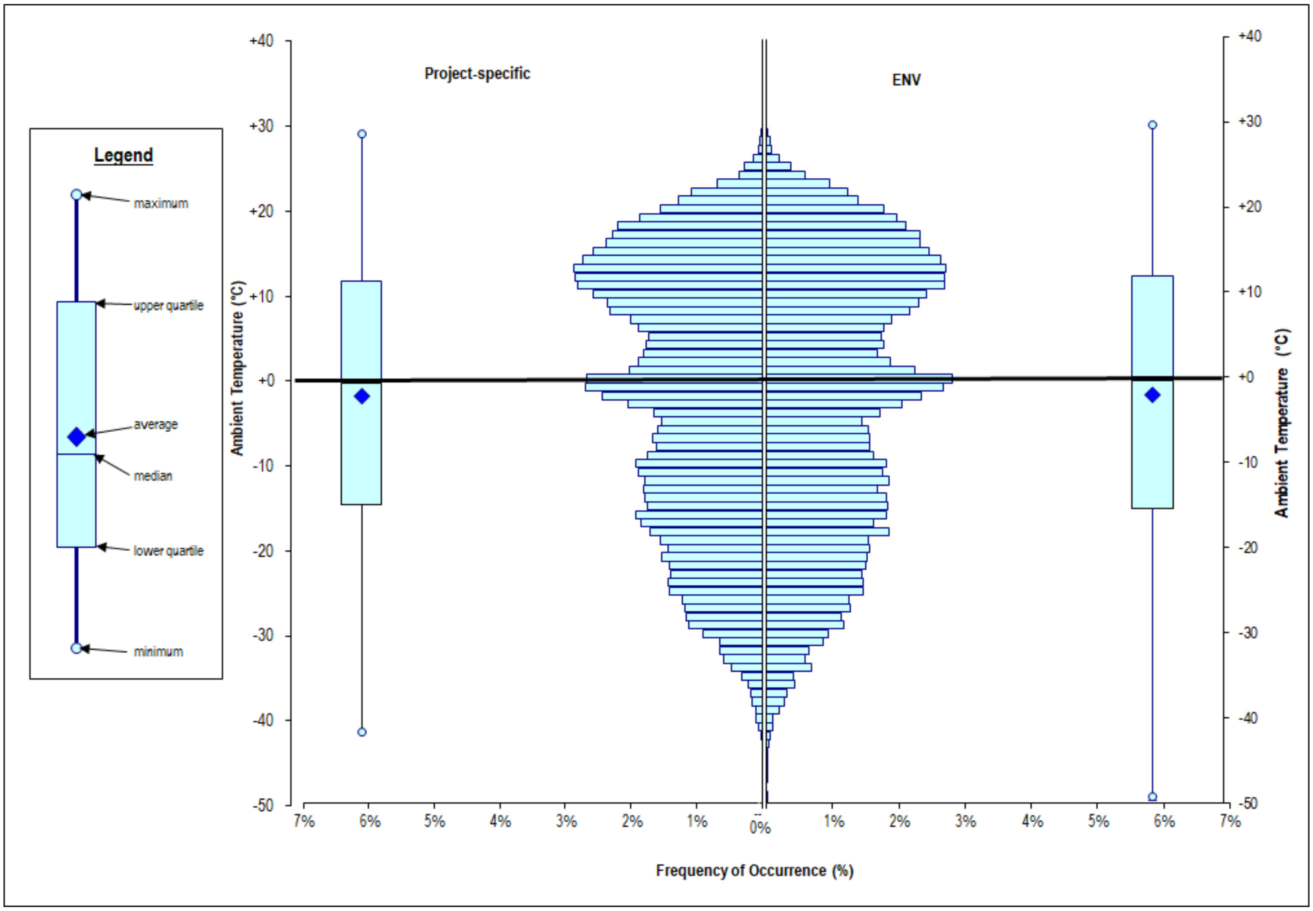
Parameter	Dataset	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Daily average temperature (°C)	Project-specific	-17.5	-18.1	-9.9	-1.8	11.4	14.9	16.6	14.3	8.9	-1.0	-4.2	-20.2	-0.5
	ENV	-18.2	-20.0	-11.1	-3.1	11.6	15.4	17.1	14.3	8.8	-1.3	-4.2	-20.6	-0.9
	On-site	-14.9	-14.3	-6.4	0.2	11.6	15.9	17.6	n/d	n/d	0.0	-2.6	-19.5	n/a
Daily maximum temperature (°C)	Project-specific	-13.4	-11.4	-4.5	2.7	16.7	19.3	20.8	18.7	18.7	0.7	-1.8	-16.9	3.7
	ENV	-13.6	-12.2	-4.8	1.9	17.2	20.0	21.6	19.0	13.4	0.8	-1.8	-17.2	3.7
	On-site	-11.5	-9.2	-1.8	5.8	17.7	21.1	22.5	n/d	n/d	1.5	0.0	-15.8	n/a
Daily minimum temperature (°C)	Project-specific	-21.6	-24.6	-16.5	-7.4	5.1	9.2	11.2	9.2	4.6	-2.9	-6.4	-23.3	-5.2
	ENV	-22.8	-27.6	-18.6	-9.7	4.7	9.4	11.4	8.8	4.1	-3.4	-6.4	-23.8	-6.1
	On-site	-17.7	-19.2	-10.7	-5.7	5.5	10.7	13.0	n/d	n/d	-1.3	-5.2	-22.8	n/a

n/d = no data; n/a = not applicable; ENV = Saskatchewan Ministry of Environment.

The comparison of hourly temperature frequencies from the Project-specific AERMET and ENV AERMET datasets from 2012 to 2016 are shown in Figure 7A-3. Similar distributions of air temperature can be observed. The ENV AERMET dataset predicted more frequent extreme low temperatures than the Project-specific AERMET dataset. The minor differences might have had contributions from the following:

- The ENV AERMET dataset location is 43.5 km northeast of the Project-specific AERMET dataset location.
- The Project-specific AERMET dataset location is in proximity to Patterson Lake, which can slow down the cooling during cold months and warming in warmer months due to its high heat capacity.

Figure 7A-3: Air Temperature Frequencies Derived from Project-Specific and ENV AERMET for 2012 to 2016

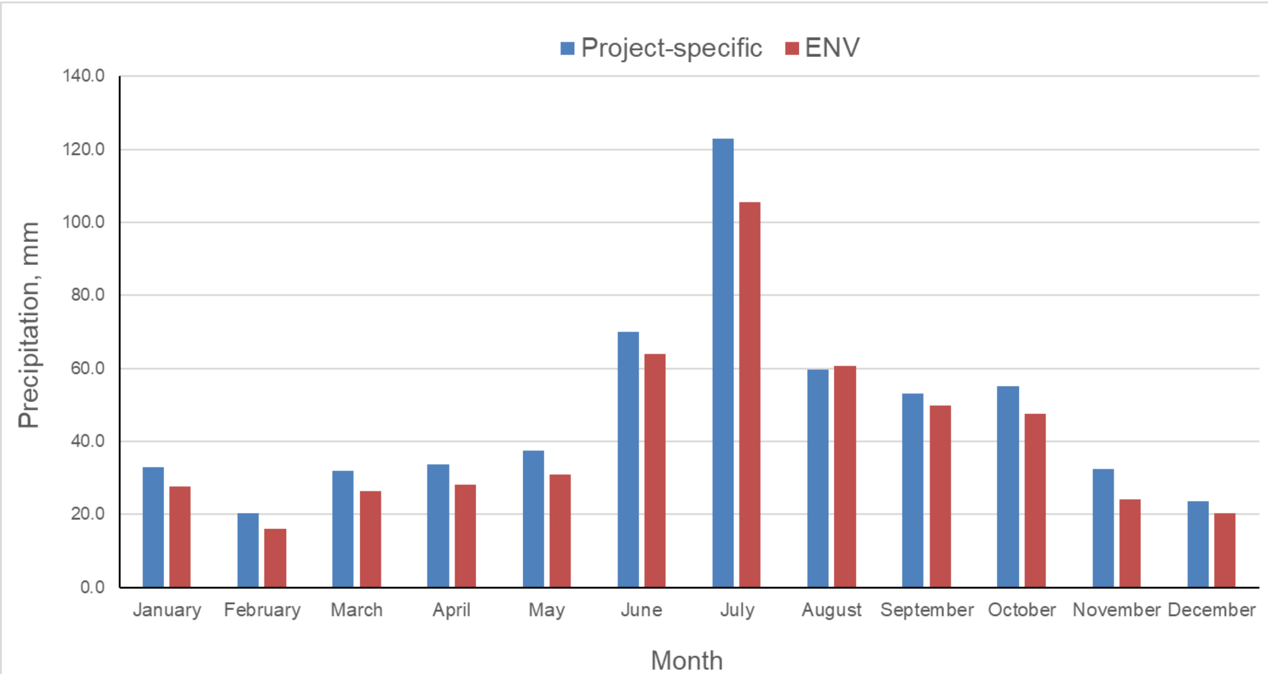


ENV = Saskatchewan Ministry of Environment.

7A3.1.3.3 Precipitation

Figure 7A-4 shows the monthly average precipitation from the Project-specific and ENV AERMET datasets from 2012 to 2016. The two AERMET datasets simulated similar monthly precipitation during the modelling period. The Project-specific AERMET dataset simulated slightly higher annual and monthly precipitation for all months except August than the ENV AERMET dataset, which might have been influenced by the proximity to Patterson Lake. Evaporation from Patterson Lake may have increased the frequency and amount of precipitation at the Project location. Since there are no on-site precipitation data available during the modelling years (i.e., 2012 to 2016), the evaluation against on-site data was not conducted.

Figure 7A-4: Monthly Precipitation from Project-Specific and ENV AERMET for 2012 to 2016



ENV = Saskatchewan Ministry of Environment.

7A3.1.3.4 Stability Class

Atmospheric stability can be viewed as a measure of the atmosphere's capability to disperse air pollutants. The Pasquill-Gifford stability classification scheme is one classification of the atmosphere. The stability classification ranges from Unstable (Stability Classes A, B, and C) to Neutral (Stability Class D) to Stable (Stability Classes E and F). Unstable conditions are primarily associated with daytime heating conditions, which result in enhanced turbulence levels (i.e., enhanced dispersion). Stable conditions are associated primarily with nighttime cooling conditions, which result in suppressed turbulence levels (i.e., more limited dispersion). Neutral conditions are primarily associated with higher wind speeds or overcast conditions.

The stability conditions predicted for the Project site from both datasets are summarized in Table 7A-89 and presented in Figure 7A-5.

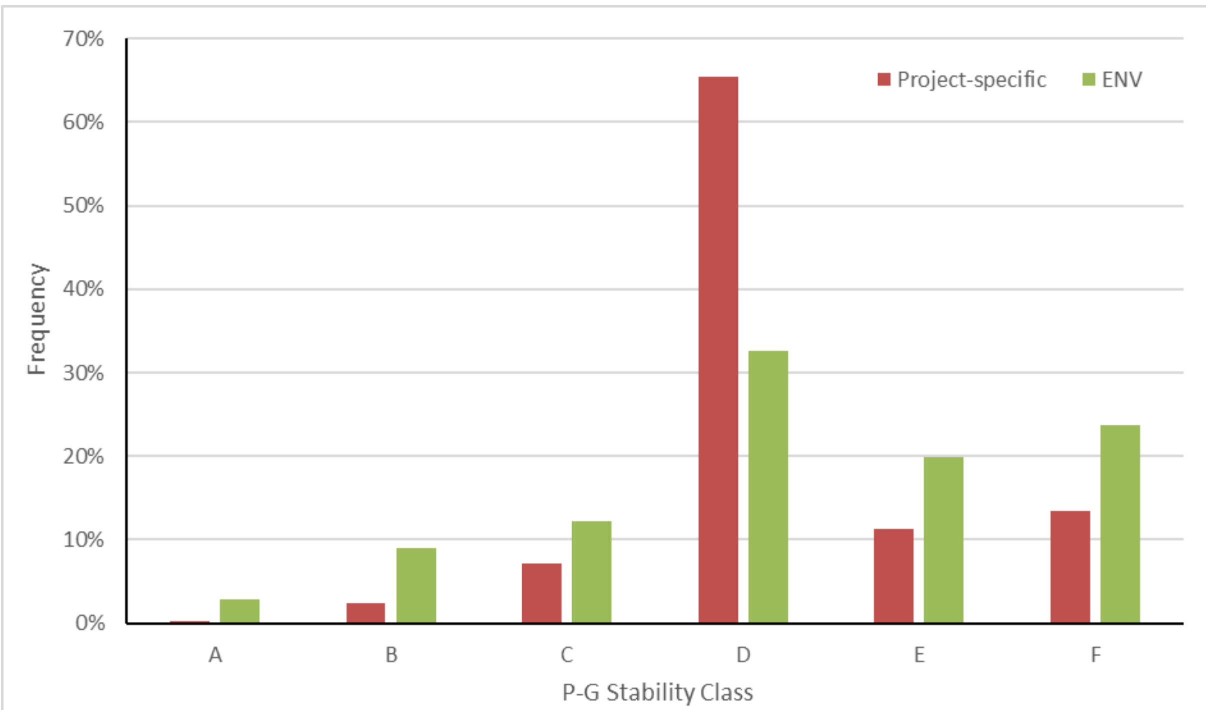
Table 7A-89: AERMET-Derived Stability Class Summary (2012-2016)

AERMET Dataset	Unstable				Neutral	Stable		
	A	B	C	Total Unstable	D	E	F	Total Stable
Project-Specific	0.3%	2.4%	7.2%	9.9%	65.4%	11.3%	13.4%	24.7%
ENV	2.9%	9.0%	12.2%	24.2%	32.6%	19.9%	23.7%	43.5%

ENV = Saskatchewan Ministry of Environment.

The Project-specific AERMET dataset predicts neutral conditions twice as often as those of the ENV AERMET dataset, while predicting less frequent unstable and stable conditions. Note that AERMET calculates and represents atmospheric stability conditions using Monin-Obukhov length. The algorithm built into the AERMOD code (based on Golder Associates Ltd. Nomogram) was used to calculate the Pasquill-Gifford stability class from the Monin-Obukhov length and surface roughness length. Thus, the surface parameters (surface roughness, Bowen ratio, and albedo) all play important roles in the Pasquill-Gifford stability class. As discussed in Section 7A3.1.1.1, the USEPA approach was implemented in determining the surface parameters. The albedo and Bowen ratio were determined by averaging the values over a 10 km radius area centred at the Project. The land use in this area was mainly evergreen forest (41%) and open water (38%). The minimal heating or cooling of the waterbody tends to result in more frequent neutral conditions as simulated by the Project-specific AERMET dataset.

Figure 7A-5: AERMET Derived Stability Classes



ENV = Saskatchewan Ministry of Environment; P-G = Pasquill-Gifford.

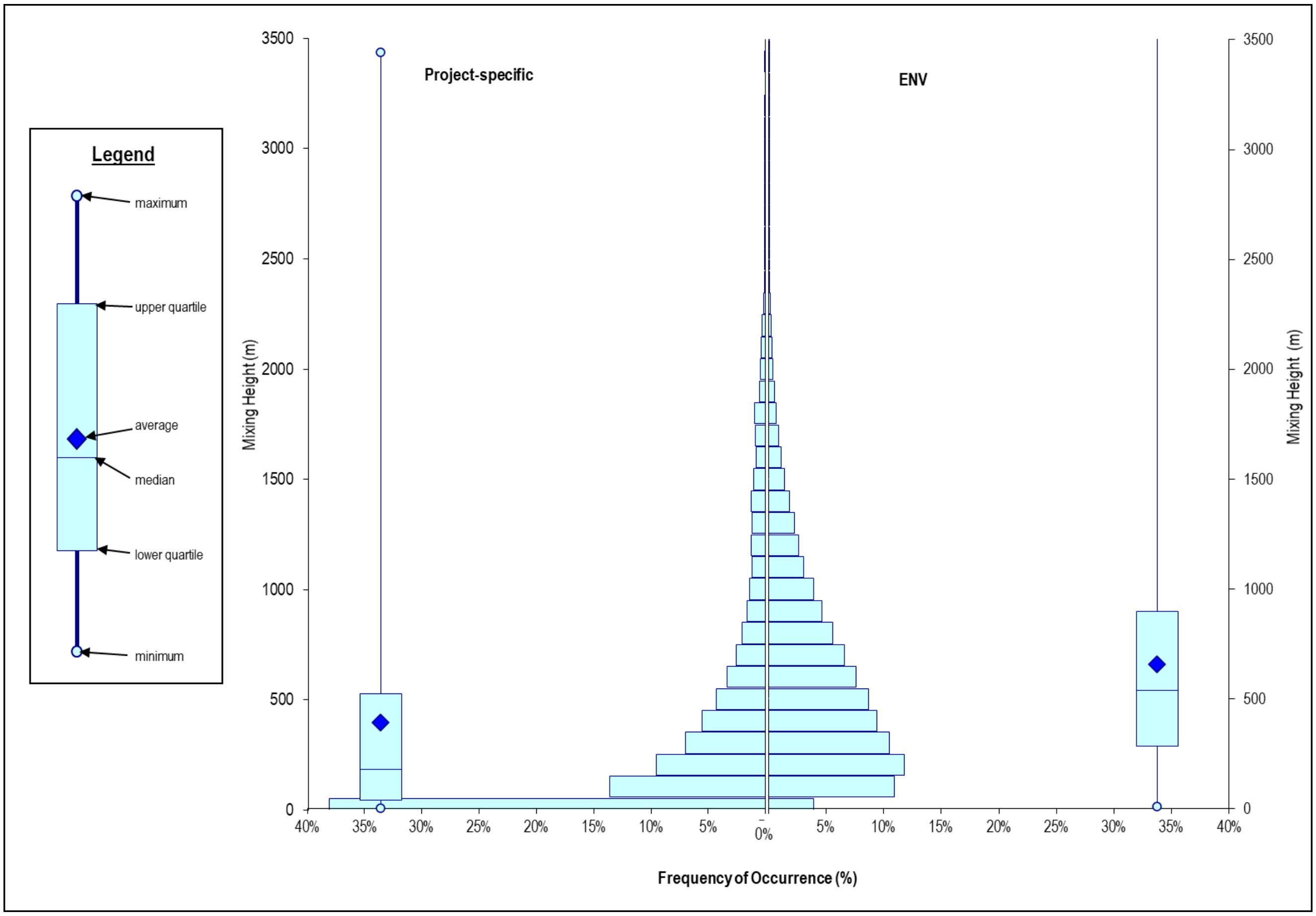
7A3.1.3.5 Mixing Height

Mixing height or boundary layer depth is the depth of the surface layer in which the majority of dispersion will occur. The depth of this well-mixed layer is a function of surface heating (i.e., the convective mixing height) and wind turbulence (i.e., the mechanical mixing height). Low boundary layer depths provide little vertical room for dispersion and can result in elevated concentrations at ground level. Figure 7A-6 provides a comparison of the mechanical mixing heights derived from the Project-specific and the ENV AERMET datasets. The Project-specific AERMET dataset predicts a higher frequency of low mixing height (38% of mixing height less than 100 m) than the ENV AERMET dataset (3.9% of mixing height less than 100 m). There are two factors that may have contributed to the different mixing height predictions:

- The Project-specific AERMET dataset used the mixing heights predicted by the WRF model outputs at the Project location.
- The ENV AERMET dataset calculated the mixing heights within AERMET while using the adj_u* option to adjust the calculation of friction velocity (u*) under low wind and stable boundary conditions.

The frequent low mixing heights of the Project-specific AERMET dataset would likely result in more conservative predictions of ground level concentrations of air pollutants due to limited vertical room for dispersion.

Figure 7A-6: AERMET Derived Mixing Heights



ENV = Saskatchewan Ministry of Environment.

7A3.1.4 Conclusion

A Project-specific AERMET dataset was developed to support this air quality assessment for the Project. A comparison of Project-specific AERMET dataset, ENV AERMET dataset, and on-site data was conducted to show that:

- Similar wind and temperature data were simulated by the two AERMET datasets, and the simulations matched well with on-site data.
- The two AERMET datasets predicted similar precipitation.

- The Project-specific AERMET dataset predicted more frequent neutral atmospheric conditions, which may have been a result of using local land use data, which has more than 38% open water land use category.
- The Project-specific AERMET dataset predicted more frequent mechanical mixing heights of less than 100 m, which would likely result in more conservative ground level predictions.
- In conclusion, the Project-specific AERMET dataset is appropriate for use in the air quality assessment for the Project.

7A3.2 Dispersion Modelling

This section describes the modelling that was completed for the EIS Section 7.2 and to support other intermediate components and VCs. The modelling applied the inputs described above.

7A3.2.1 Assessment Cases

Assessment cases included a Base Case, Application Case, and RFD Case:

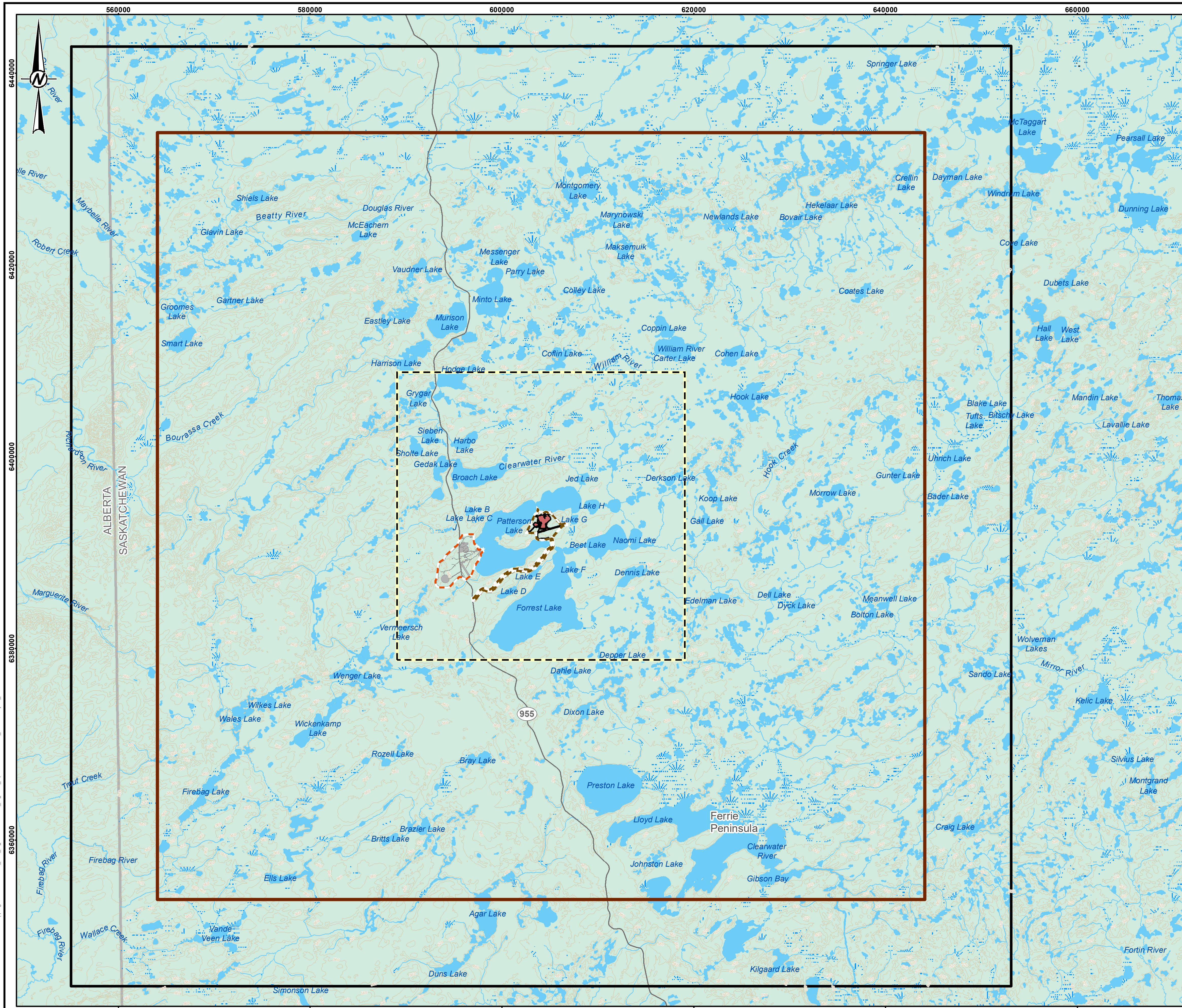
- Base Case is generally represented by existing conditions. The Base Case describes the existing environment in the local study area (LSA) and RSA before application of the Project to provide an understanding of the current conditions that may be influenced by the Project. The Base case concentrations in this assessment were represented by the air quality background concentrations from the baseline study (Annex I, Section 5.3.2).
- Application Case represents predictions of the combined effects of the previous and existing projects/activities and natural factors in the Base Case plus the effects from the Project. The application case modelling was done for the Project during both Construction and Operations.
- The RFD Case includes the Base Case, Application Case, and RFDs that have not yet been approved. The Fission Patterson Lake South Property was included in the RFD Case.

7A3.2.2 Spatial Boundaries

The key spatial boundaries for the air quality assessment are the air dispersion modelling domain, LSA, RSA, and Project footprint. The air dispersion modelling domain is defined as a 100 km by 100 km area centred on the maximum disturbance area for the Project. The LSA is defined as a 30 km by 30 km area centred on the Project; it encompasses all local lakes surrounding the Project (e.g., Patterson Lake, Forrest Lake, Beet Lake, Naomi Lake, Broach Lake, Jed Lake). The RSA is defined as an 80 km by 80 km area also centred on the Project; it encompasses other large waterbodies (e.g.., Preston Lake and Lloyd Lake) that are farther from the Project site.

The Project footprint is defined in the air quality assessment as those areas where public access is restricted. Both the Saskatchewan Ambient Air Quality Standards (SAAQS) and the Canadian Ambient Air Quality Standards (CAAQS) do not apply inside of the Project maximum disturbance boundary, which is not considered natural environment due to the limited public access inside of the Project maximum disturbance boundary.

The air dispersion modelling, LSA, RSA, and Project maximum disturbance boundary are shown in Figure 7A-7.



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- LOCAL ROAD
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- AIR QUALITY LOCAL STUDY
- AIR QUALITY REGIONAL STUDY
- AIR DISPERSION MODELLING DOMAIN

0 12 24

1:400,000 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).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

AIR QUALITY SPATIAL BOUNDARIES

CONSULTANT

wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	SB/ZY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2022-04-26	**FIGURE 7A-7**	
CHECK	ZY	2022-04-26		
REVIEW	CM	2022-04-26		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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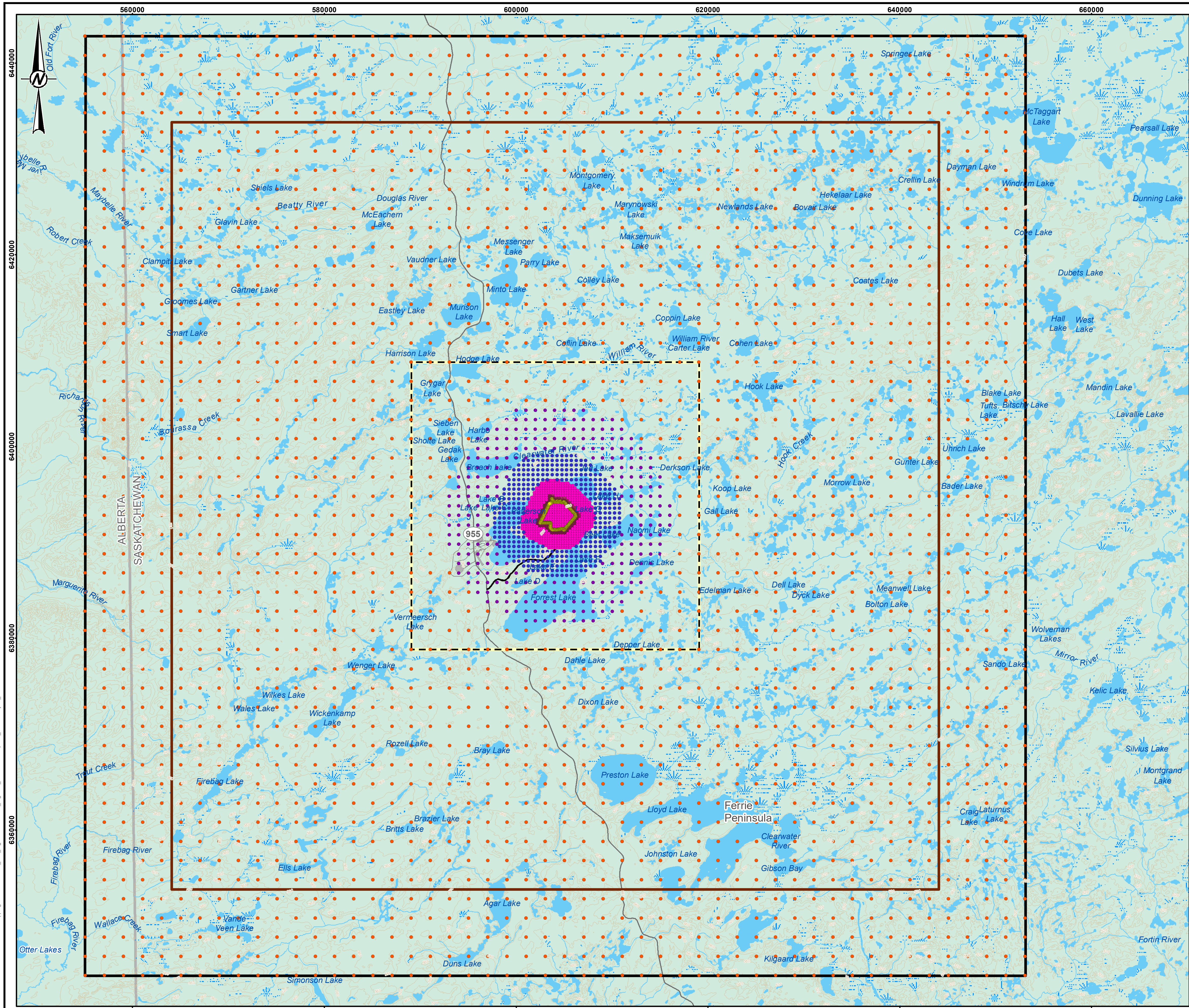
7A3.2.3 Receptors

Ground-level concentrations were predicted by the AERMOD model at selected locations, referred to as receptors, within the air dispersion modelling domain. There are two categories of receptors: gridded receptors and discrete receptors. The gridded receptors are receptors placed in a Cartesian grid pattern at specific spacing between the receptors. The gridded receptors were selected based on requirements in the SAQMG (ENV 2012) as follows:

- The 20-m receptor spacing along the Project maximum disturbance boundary.
- The 50-m receptor spacing within 0.5 km from the Project maximum disturbance boundary.
- The 250-m receptor spacing within 2 km from the Project boundary as well as inside of the Project maximum disturbance boundary.
- The 500-m receptor spacing within 5 km from the Project maximum disturbance boundary.
- The 1,000-m receptor spacing within 10 km from the Project maximum disturbance boundary.
- The 2,000-m receptor spacing beyond 10 km from the Project maximum disturbance boundary to the edge of the RSA.

Figure 7A-8 presents the gridded receptors.



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- LOCAL ROAD
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT

INTERVAL

- 20 m
- 50 m
- 250 m
- 500 m
- 1000 m
- 2000 m
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

0 13 26
1:400,000 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).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
GRIDDED RECEPTORS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	SB/ZY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2022-04-05	**FIGURE 7A-8**	
CHECK	ZY	2022-04-05		
REVIEW	CM	2022-04-05		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25mm 0

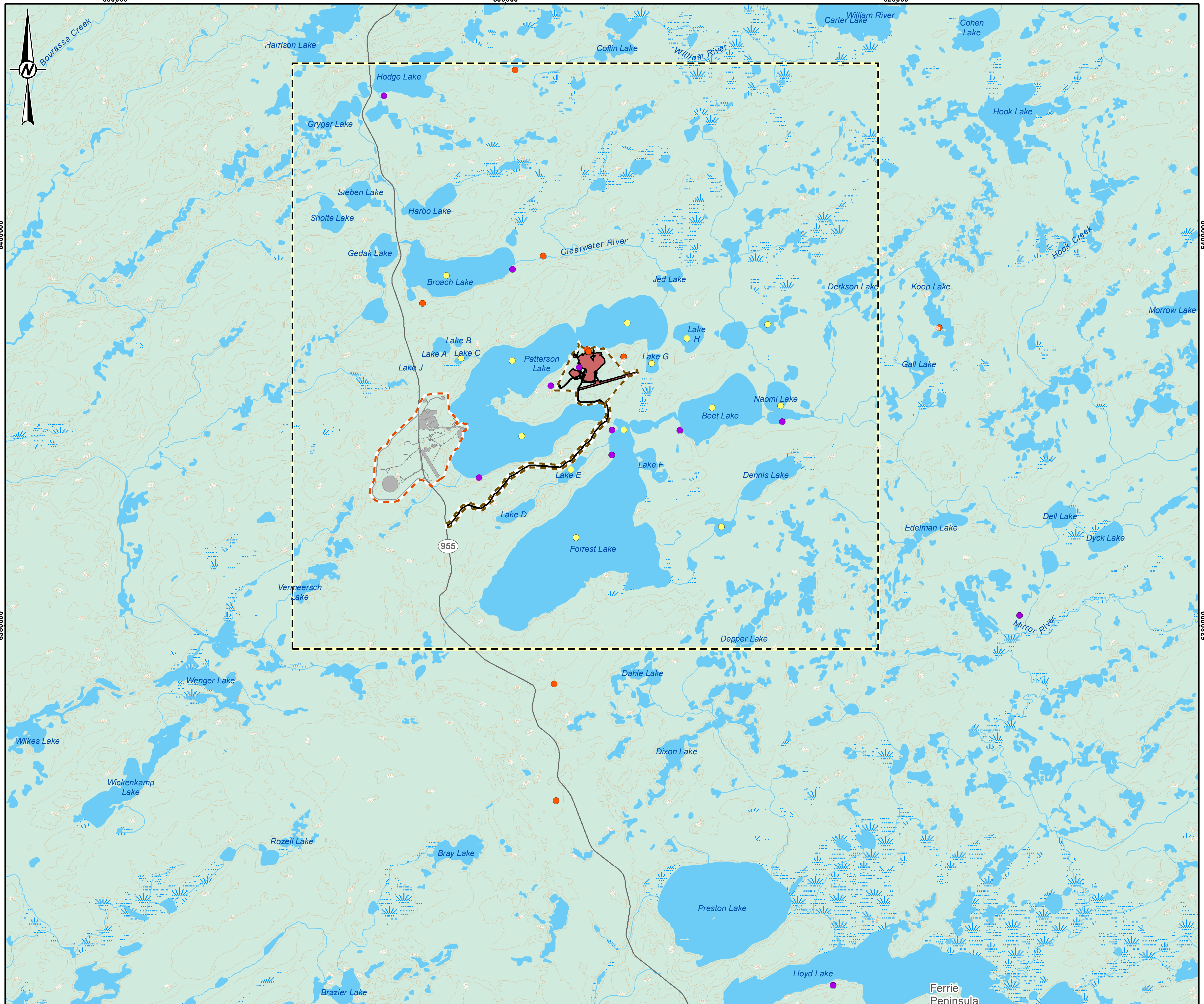
PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\AirAir_EIS_Figures\20144150_Fig7A-8_Gridded-Receptors_RookI-Project_Rev0.mxd PRINTED ON: 2022-04-05 AT: 10:33:37 AM

Discrete receptors are locations of interest based on the needs of the assessment. Because ground-level concentration and deposition predictions were inputs in the analysis of other VCs and intermediate components (e.g., human health, surface water quality, soil, vegetation), specific locations were also included as receptors in the air dispersion modelling. Table 7A-90 and Figure 7A-9 show the discrete receptors included based on the needs of the assessments of other VCs and intermediate compounds.

Table 7A-90: Discrete Receptors

Receptor Name	Receptor Category	Coordinates (m)	
		Easting	Northing
Hodge Lake Reference HH VC	HHRA	593,768	6,407,146
Broach Lake	HHRA	600,359	6,398,266
Camp Worker HH VC	HHRA	603,778	6,393,226
Patterson Lake HH VC	HHRA	598,658	6,387,580
Patterson Lake Eco VC	HHRA	602,320	6,392,289
Forrest Lake	HHRA	605,446	6,388,744
Forrest Lake North Eco VC	HHRA	605,452	6,390,021
Beet Lake HH VC	HHRA	608,931	6,389,997
Naomi Lake	HHRA	614,179	6,390,462
Clearwater River	HHRA	626,340	6,380,517
Lloyd Lake HH VC	HHRA	616,793	6,361,563
Broach Lake	Water quality	596,969	6,397,941
Patterson Lake	Water quality	600,343	6,393,576
Patterson Lake	Water quality	606,230	6,395,494
Lake H	Water quality	609,306	6,394,700
Lake G	Water quality	607,487	6,393,443
Beet Lake	Water quality	610,596	6,391,161
Naomi Lake	Water quality	614,101	6,391,260
Patterson Lake	Water quality	600,839	6,389,706
Forrest Lake	Water quality	603,617	6,384,514
Forrest Lake	Water quality	606,065	6,390,037
Unnamed Lake 2	Water quality	613,440	6,395,428
Lake C	Water quality	597,730	6,393,708
Lake E	Water quality	603,353	6,387,986
Unnamed Lake 1	Water quality	611,059	6,385,076
REF01	Soil and vegetation	601,933	6,398,930
REF02	Soil and vegetation	600,499	6,408,468
REF03	Soil and vegetation	622,227	6,395,264
19REF04	Soil and vegetation	602,495	6,377,007
19REF05	Soil and vegetation	602,591	6,371,032
19REF06	Soil and vegetation	595,754	6,396,514
19EXP02	Soil and vegetation	604,196	6,394,146
19EXP01	Soil and vegetation	604,249	6,394,045
19EXP03	Soil and vegetation	606,046	6,393,766
Preston Lake	Water quality	611,088	6,364,804
Wegner Lake	Water quality	585,088	6,376,804

HHRA = human health risk assessment; VC = valued component; HH = human health.



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- HUMAN HEALTH RISK ASSESSMENT RECEPTORS (HHRA)
- LAKES RECEPTORS
- VEGETATION RECEPTORS
- AIR QUALITY LOCAL STUDY

0 6 12

1:200,000 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).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

DISCRETE RECEPTORS

CONSULTANT

wsp

PROJECT		20144150	PHASE 3101 - 3
DESIGN	SB/ZY	2020-03-13	SCALE AS SHOWN / REV. 0
GIS	NO	2022-04-26	
CHECK	ZY	2022-04-26	**FIGURE 7A-9**
REVIEW	CM	2022-04-26	

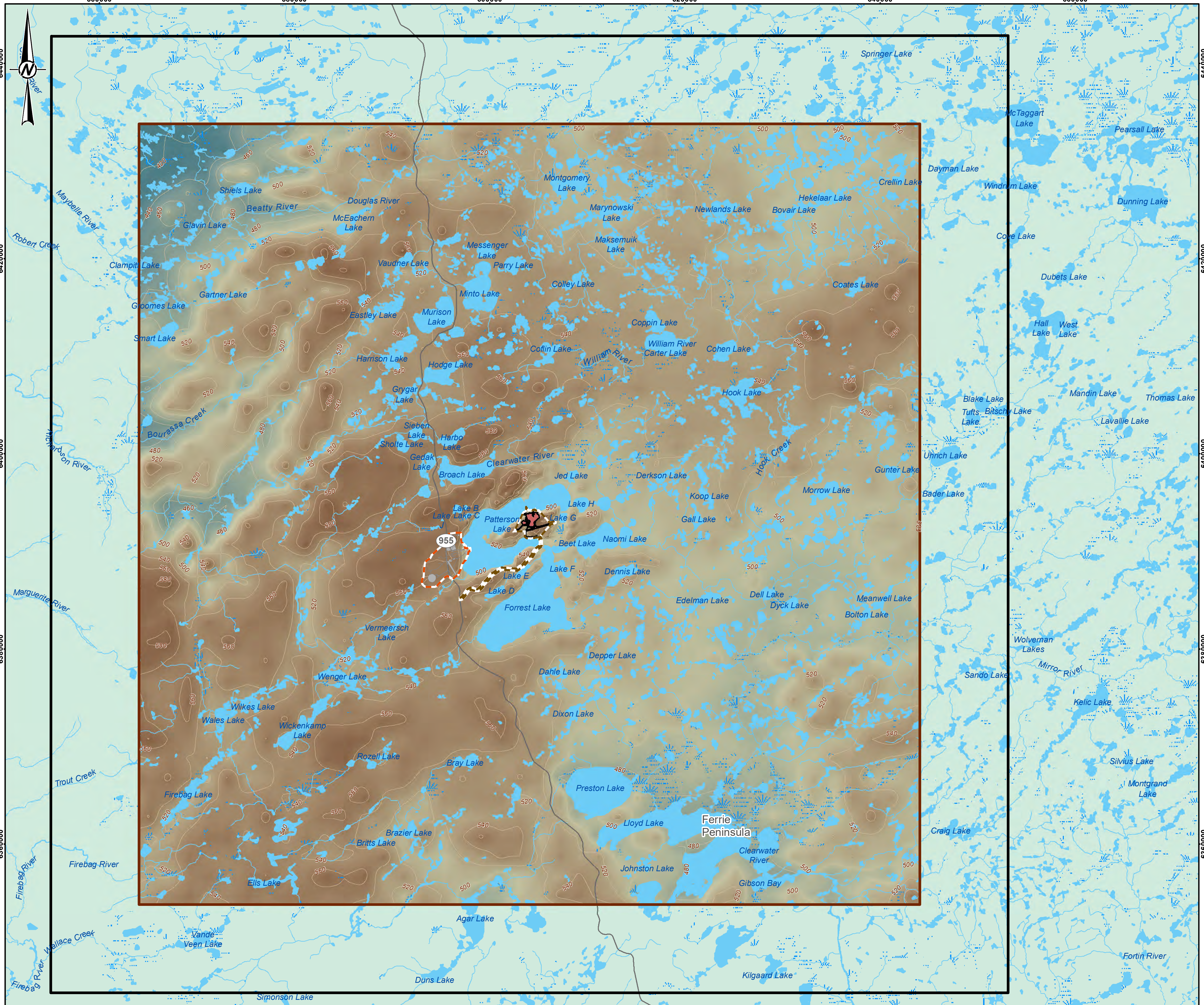
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

7A3.2.4 Terrain

The terrain elevation within the RSA is shown in Figure 7A-10. The terrain features within the RSA are characterized by large waterbodies such as Patterson Lake, Forrest Lake, and Beet Lake surrounding the Project footprint. The terrains are relatively flat, ranging from 403 to 599 m.

The elevation data were used by the AERMOD pre-processor AERMAP to obtain the elevation above sea level for emission sources, buildings, and the receptors.



LEGEND

- LOCAL ROAD
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- AIR QUALITY REGIONAL STUDY
- AIR DISPERSION MODELLING DOMAIN
- TERRAIN ELEVATION CONTOUR 10 m

TERRAIN ELEVATION (m)

High : 599.25

Low : 403.00

0 13 26

1:400,000 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).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

TERRAIN ELEVATION WITHIN REGIONAL STUDY AREA

CONSULTANT

wsp

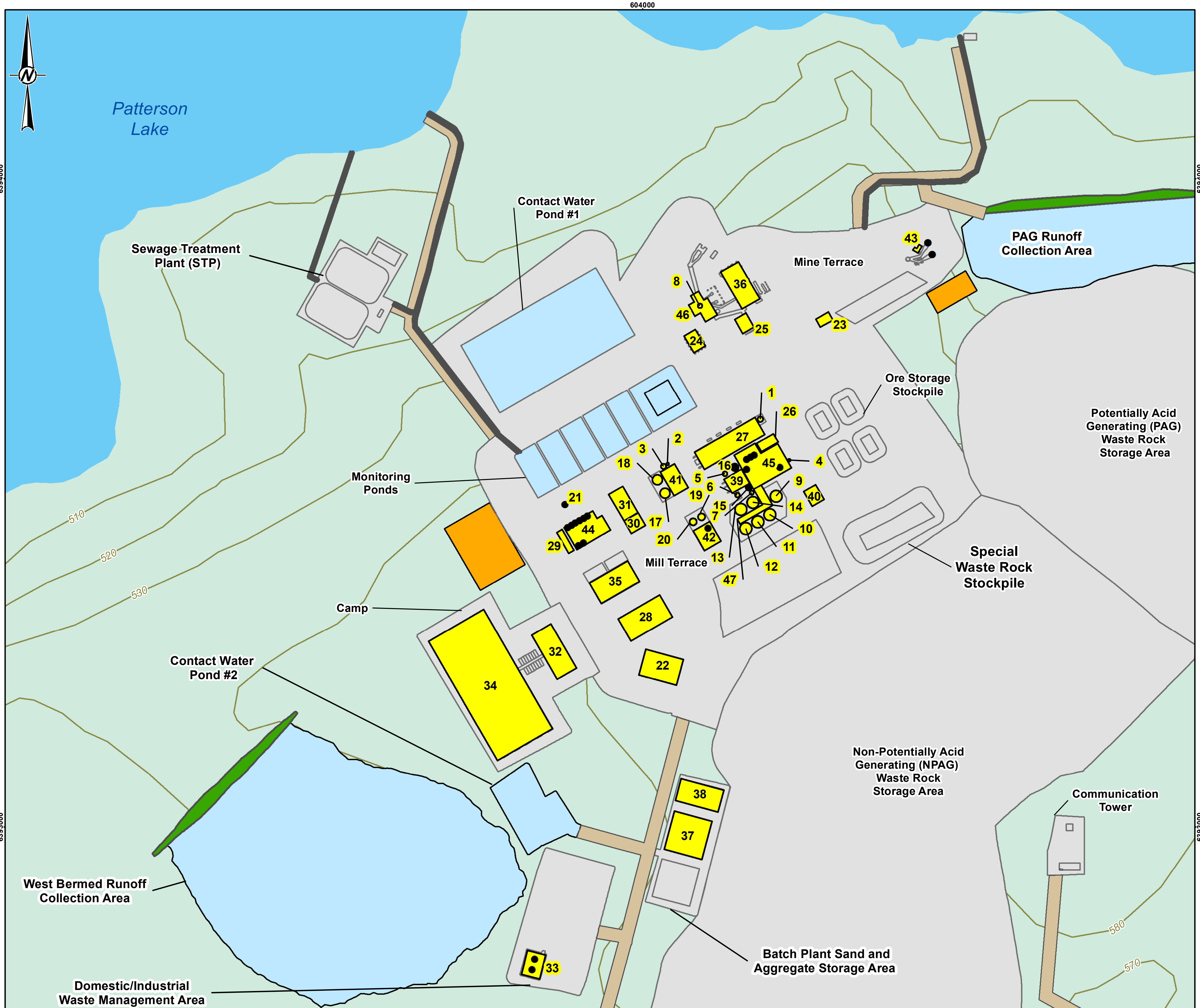
PROJECT		20144150	PHASE	3101 - 3
DESIGN	SB/ZY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2022-04-26		
CHECK	ZY	2022-04-26	FIGURE 7A-10	
REVIEW	CM	2022-04-26		

7A3.2.5 Building Downwash

Buildings or solid structures near short stacks may affect the flow of air and cause eddies to form on the downwind side of a building. According to the SAQMG, the effects of local buildings should be considered when conducting a dispersion modelling assessment. The effects of building downwash on the air dispersion of Project emissions from stacks were considered in this assessment by the use of the Building Profile Input Program. The Building Profile Input Program was run in the Plume Rise Model Enhancement algorithm mode. Figure 7A-11 presents the locations of buildings and stacks at the Project considered in the building downwash analysis. Of all the buildings shown in Figure 7A-11, Table 7A-91 presents the height of the buildings that are expected to result in downwash effects on the Project emission sources. Because the other buildings shown in the figure do not result in downwash effects, they are not included in the table.

Table 7A-91: Height of Buildings Considered in Building Profile Input Program

Building ID	Building Name	Building Height (m)
42	Acid plant	15
39, 45	Mill	26
27	Solvent building	15
41	Effluent plant	15
44	Power plant	8
43	Exhaust plant	8
33	Incinerator building	5



LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- WATERBODY
- WOODED AREA
- INTAKE OR DISCHARGE PIPE
- CONTACT WATER CONTAINMENT BERM
- PROJECT INFRASTRUCTURE
- SITE ROAD
- TOPSOIL STORAGE
- WATER MANAGEMENT POND
- POINT SOURCE CONSIDERED IN THE BUILDING PROFILE INPUT PROGRAM
- BUILDINGS CONSIDERED IN THE BUILDING PROFILE INPUT PROGRAM

0 0.2 0.4
1:6,000 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
ROOK I PROJECT BUILDINGS AND STACKS CONSIDERED IN BUILDING PROFILE INPUT PROGRAM

CONSULTANT
wsp

PROJECT		20144150	PHASE 3101 - 3	
DESIGN	SB/ZY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2022-04-05	**FIGURE 7A-11**	
CHECK	ZY	2022-04-05		
REVIEW	CM	2022-04-05		

7A3.2.6 Nitrogen Oxides to Nitrogen Dioxide Conversion

The nitrogen oxides to nitrogen dioxide conversion method in the AERMOD model selected for this assessment is Ozone Limited Method, one of the three refined nitrogen oxides conversion methods approved by the ENV in the SAQMG (ENV 2012). The Ozone Limited Method is based on the theory that conversion of the nitrogen oxides into nitrogen dioxide in the ambient air is limited by the availability of ozone. Nitrogen oxides is a by-product of fossil fuel combustion. When nitrogen oxide is emitted from a combustion source, it is in the form of both nitric oxide and nitrogen dioxide with the majority of the nitrogen oxides being emitted as nitric oxide. Once released into ambient air, nitric oxide reacts with ozone to form nitrogen dioxide and oxygen based on the reaction below:

$$NO + O_3 \rightarrow NO_2 + O_2$$

The reaction described above is based on the availability of the ozone in the ambient air, and it is thus called Ozone Limited Method. The ENV-recommended ozone levels for a rural setting (i.e., 55 ppb for 1-hour averaging period, 40 ppb for 24-hour averaging period, and 30 ppb for annual averaging period; ENV 2012), were used in the model.

The amount of the nitrogen oxides in the form of nitrogen dioxide in a combustion exhaust gas from a stack is called the in-stack ratio. Depending on the type of the combustion process, the in-stack ratio from a stack exhaust can vary. The most common in-stack ratio used in most jurisdictions is 0.10 or 10%, meaning 10% of the nitrogen oxides emissions in a stack exhaust stream is in the form of nitrogen dioxide and the other 90% of the nitrogen oxides is in the form of nitric oxide and is available to react with ozone to form nitrogen dioxide once released into the ambient air. The in-stack ratios selected for nitrogen oxides emission sources in this assessment are:

- 0.05 for blasting (Attalla et al. 2008) as well as natural gas-fired and diesel-fired power generators (USEPA 2021c); and
- 0.10 for all other sources.

7A3.2.7 Particulate Matter Deposition Parameters

The AERMOD model includes two methods for predicting dry and/or wet deposition of PM emissions. Method 1 is used when the particle size distribution is known or when more than 10% of the total particulate mass has an aerodynamic diameter of 10 µm or larger. Method 2 is used when the particle size distribution is not well known and when a small fraction (less than 10% of the mass) has a diameter of 10 µm or larger (USEPA 2021b). Method 1 was used in this assessment to model the deposition of TSP, PM_{10}, and $PM_{2.5}$. The Method 1 parameters used are listed in Table 7A-92.

Table 7A-92: Particulate Matter Deposition Method 1 Parameters

Parameter	$PM_{2.5}$	PM_{10}		TSP		
Size range	<2.5 µm	<2.5 µm	2.5 to 10 µm	<2.5 µm	2.5 to 10 µm	>10 µm
Mean diameter	0.5	0.5	5	0.5	5	20
Mass fraction	1	Calculated from emission rates of $PM_{2.5}$ and $PM_{2.5-10}$		Calculated from emission rates of $PM_{2.5}$, $PM_{2.5-10}$, and PM_{10}		
Density	1	1	1	1	1	1

PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; < = less than; > = greater than.

7A3.2.8 Emission Sources Representation

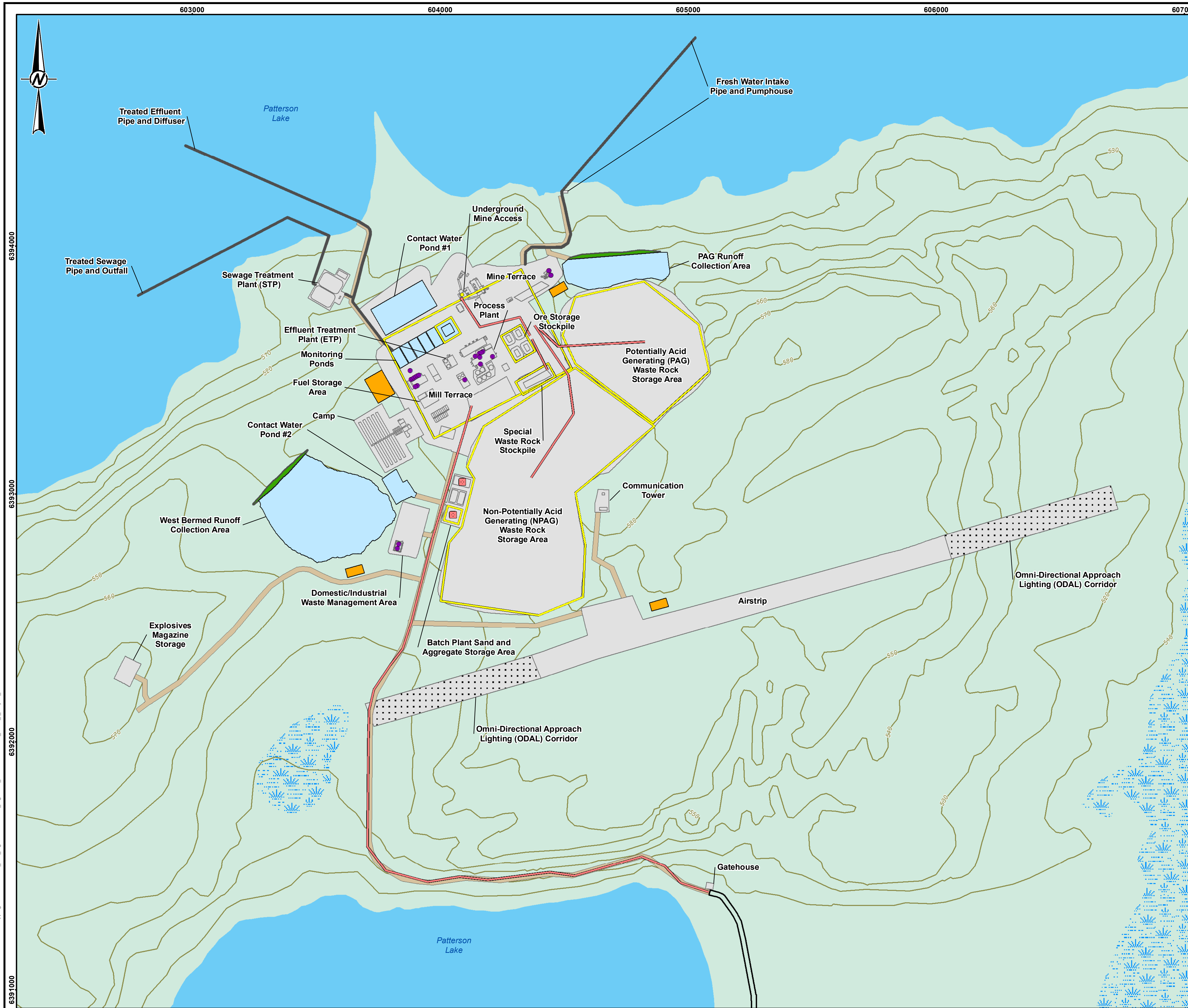
The emission sources were represented in the AERMOD model with various source types, including:

- Point sources representing emissions from stacks and vents, such as SAG and ball mill stack and mine vents.
- Area sources representing emissions from fugitive emissions from a surface, such as ore storage pads.
- Volume sources representing emissions from three-dimension sources such as buildings without vents, like the concrete batch plant. The emissions from the haul road and access road were represented as a series of volume sources placed along the road segments.

The emission sources at the Project and at the Fission Patterson Lake South Property are shown as point sources, area sources, or volume sources in Figure 7A-12 and Figure 7A-13.

The road dust effects from Highway 995 and the access road outside of the Project maximum disturbance area were modelled separately as a 2-km road segment along the northwest to southeast direction, which is perpendicular to the predominant wind direction to account for the worst downwind predictions. A receptor transect was placed in the middle of the 2-km road segment along the northwest to southeast direction with receptors at distances of 20 m, 25 m, 40, m, 50 m, 100 m, 150 m, 200 m, 300 m, 500 m, and 1000 m from the road centre in both the downwind and upwind direction. The road segment was modelled as a series of volume sources. Assuming an average vehicle height of 2.6 m, the volume source parameters are as followed:

- Plume height (e.g., 4.4 m = 1.7 x vehicle height).
- Effective release height (e.g., 2.2 m = ½ x plume height).
- Initial vertical dimension (e.g., 2.05 = plume height / 2.15).



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
- POINT SOURCES
- VOLUME SOURCES
- AREA SOURCES

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

ROOK I PROJECT EMISSION SOURCES

CONS

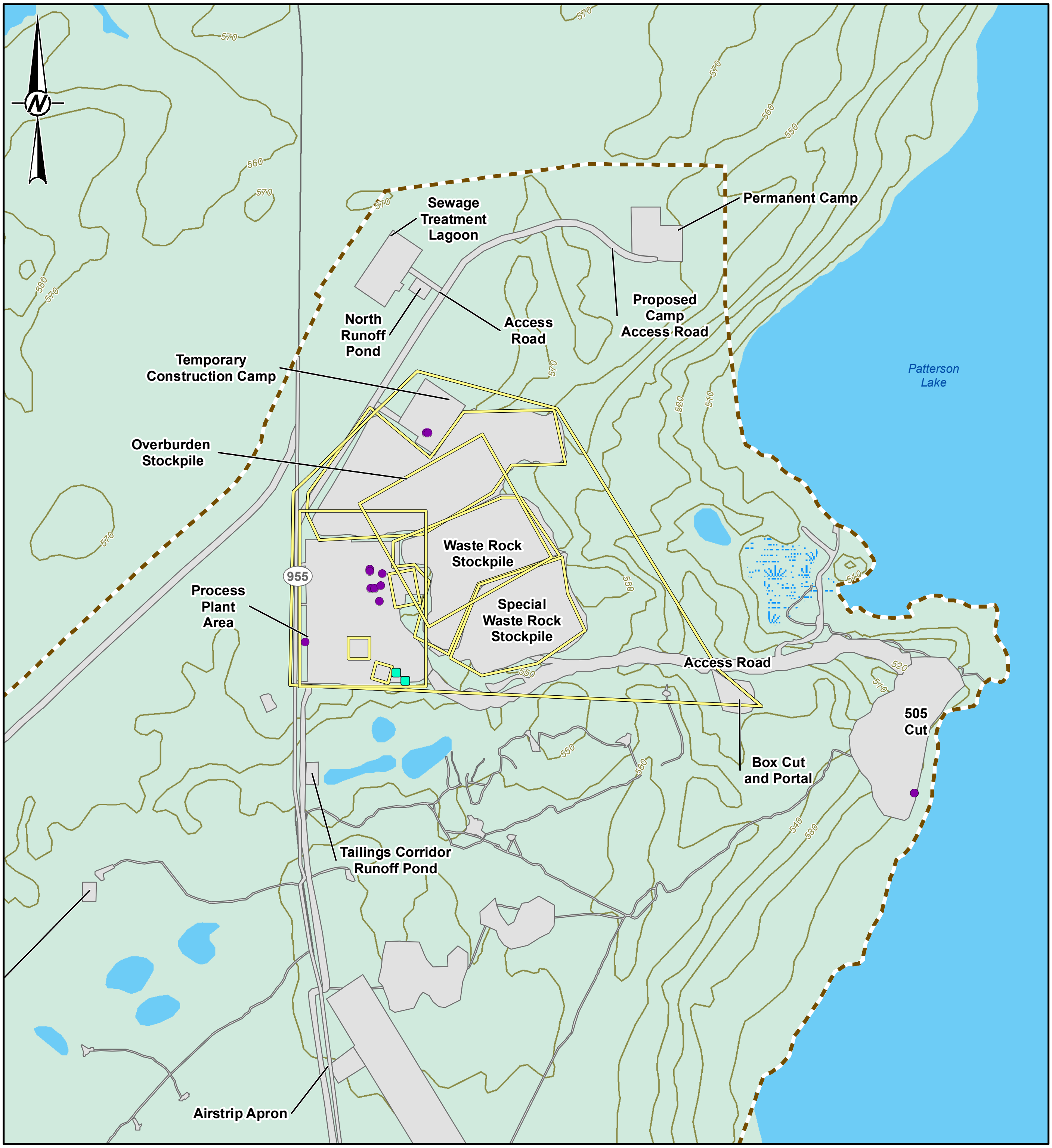
wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	SB/ZY	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2022-04-05		
CHECK	ZY	2022-04-05		
REVIEW	CM	2022-04-05		

FIGURE 7A-12

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm



LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- SECONDARY HIGHWAY
- WATERBODY
- WETLAND
- WOODED
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- POINT SOURCES
- VOLUME SOURCES
- AREA SOURCES

0 0.5 1
1:20,000 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.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
FISSION PATTERSON LAKE SOUTH PROPERTY EMISSION SOURCES

CONSULTANT
wsp

PROJECT		20144150	PHASE 3101 - 3
DESIGN	SB/ZY	2022-04-26	SCALE AS SHOWN REV. 0
GIS	NO	2022-04-26	FIGURE 7A-13
CHECK	ZY	2022-04-26	
REVIEW	CM	2022-04-26	

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\Air\Air_EIS_Figures\20144150_Fig7A-13_Emission-Sources_Patterson-Lake-South-Project-Footprint_Rev0.mxd PRINTED ON: 2022-04-26 AT: 3:07:51 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A 25mm 0

7A3.2.9 Applicable Ambient Air Quality Criteria

The air quality is evaluated based on a comparison of available ambient air quality measurements or model predictions for the CACs against relevant air quality criteria and guidelines that are identified as measurement indicators in Section 7A2.1. A summary of the SAAQS (Government of Saskatchewan 2015) for relevant compounds is provided in Table 7A-93. For sulphuric acid, there are no SAAQS in place; therefore, Alberta Ambient Air Quality Objectives for sulphuric acid are used as substitutes in this assessment.

Table 7A-93: Applicable Ambient Air Quality Standards

Compound	Concentrations (µg/m³)			
	1-hour	8-hour	24-hour	Annual
Nitrogen dioxide	300	n/a	200	45[(a)]
Sulphur dioxide	450	n/a	125	20[(a)]
Sulphuric acid[(b)]	10	5	n/a	n/a
Carbon monoxide	15,000	6,000	n/a	n/a
$PM_{2.5}$	n/a	n/a	28[(c)]	10
PM_{10}	n/a	n/a	50	n/a
TSP	n/a	n/a	100	60[(d)]

Source: Government of Saskatchewan 2015.
a) Arithmetic mean.
b) There are no SAAQS for sulphuric acid; therefore, Alberta Ambient Air Quality Objectives for sulphuric acid are used as surrogates.
c) Average of the annual 98th percentile of the daily 24-hour average concentrations for three consecutive years.
d) Geometric mean.
n/a = not applicable; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; SAAQS = Saskatchewan Ambient Air Quality Standards.

In 2012, the CCME and the Canadian provinces and territories, excluding Quebec, agreed to implement a national Air Quality Management System (CCME 2012). The framework resulted in the development of the CAAQS for $PM_{2.5}$, ozone, nitrogen dioxide, and sulphur dioxide, The CAAQS are human health-based air quality objectives for compound concentrations in ambient air (Table 7A-94). The CAAQS were implemented in a two-phased approach for achievement, namely 2015 and 2020 for $PM_{2.5}$ and ozone (CCME 2012), and 2020 and 2025 for nitrogen dioxide and sulphur dioxide (CCME 2020a,b).

The SAAQS for $PM_{2.5}$ are equivalent to the 2015 CAAQS. The remaining CAAQS are presented here for information only. The CCME has developed guidance documents on achievement determination of CAAQS for $PM_{2.5}$, nitrogen dioxide, and sulphur dioxide (CCME 2012, 2020a,b). Before determining achievement of CAAQS, the transboundary flows and exceptional events need to be identified and the weight of evident approach needs to be used to demonstrate the influence of transboundary flows / exceptional events. Without accounting the transboundary flows / exceptional events, direct comparisons are not made to the CAAQS.

Table 7A-94: Applicable Canadian Ambient Air Quality Objectives

Compound	Averaging Period	Concentration			Unit	Statistic Form
		2015	2020	2025		
Nitrogen dioxide	1-hour	n/d	60	42	ppb	The 3-year average of the annual 98th percentile of the daily maximum 1-hour average concentrations.
		n/d	113	79	µg/m³	
	Annual	n/d	17	12	ppb	The average over a single calendar year of all 1-hour average concentrations.
		n/d	32	22.6	µg/m³	
Sulphur dioxide	1-hour	n/d	70	65	ppb	The 3-year average of the annual 99th percentile of the daily maximum 1-hour average concentrations.
		n/d	183	170	µg/m³	
	Annual	n/d	5	4	ppb	The average over a single calendar year of all 1-hour average concentrations.
		n/d	13	10.5	µg/m³	
$PM_{2.5}$	24-hour	28	27	n/d	µg/m³	The 3-year average of the annual 98th percentile of the daily 24-hour average concentrations.
	Annual	10	8.8	n/d	µg/m³	The average over a single calendar year of all 1-hour average concentrations.

Source: CCME 2021.
n/d = no data; ppb = parts per billion; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less.

7A3.2.10 Applicable Air Emissions Standards and Guidelines

In Canada, various levels of government have established air emissions standards or guidelines as one of the mechanisms to manage the air quality under their jurisdictions. For the Project, there are federal air emission standards or guidelines that may be applicable to the Project. Saskatchewan does not have specific air emission standards or guidelines that are applicable to the Project. The federal air emission standards and guidelines described in this section are not considered measurement indicators. However, they are important in terms of selection of Project mitigations.

7A3.2.10.1 Canadian Council of Ministers of the Environment Emission Guideline for Industrial/Commercial Boilers and Heaters

The federal government introduced MSAPR in 2016, which set nitrogen oxides emission limits from gas-fired boilers, heaters, and stationary spark ignition engines over a specified size and used in specified industry sectors. The MSAPR do not apply to the Project because uranium mines do not fall under any of the regulated industrial sectors referred by the MSAPR. Prior to the introduction of the MSAPR, the CCME had previously established national nitrogen oxides and carbon monoxide emission guidelines for large industrial and commercial boilers and heaters (CCME 1998). The CCME emission guidelines are applicable to the natural gas-fired heaters, such as natural gas-fired mine heaters and calciner burners, at the Project. Table 7A-95 provides a summary of the nitrogen oxides and carbon monoxide emission guidelines applicable to the natural gas-fired heaters at the Project.

Table 7A-95: Canadian Council of Ministers of the Environment National Emission Standards for Natural Gas-Fired Heaters

Capacity		Emission Limit (g/GJ)	
GJ/h	MMBtu/h	Nitrogen Oxides	Carbon Monoxide
10.5-105	0-100	26	125
>105	>100	40	

g/GJ = grams per gigajoule; GJ/h = gigajoules per hour; MMBtu/h = million British thermal units per hour; >= greater than.

7A3.2.10.2 Canadian Off-road Compression-Ignition (Mobile and Stationary) and Large Spark-Ignition Engine Emission Regulations (SOR/2020-258)

The Off-road Compression-Ignition (Mobile and Stationary) and Large Spark-Ignition Engine Emission Regulations were published in the Canada Gazette, Part II, on 23 December 2020, and set performance-based emission standards for air pollutants for new off-road diesel engines and large spark-ignition engines. These regulations use the tier system of classification (i.e., Tier 1 to Tier 4), where each tier corresponds to air emission limits. The regulations do not prohibit the use of equipment with lower tier of emission standards, but rather the regulations require that the manufacturers and importers of equipment meet various tiers of emission standards based on the specified years.

The off-road equipment in the Project's construction, surface, and underground fleet are expected to be a combination of new and used equipment; therefore, the Project's off-road equipment will likely be a combination of Tier 2, Tier 3, and Tier 4 engines under these regulations. The engine tier assumptions used in the development of the Project's emission inventory are further discussed in Section 7A2.2.4.16.

7A3.2.10.3 Canadian Sulphur in Diesel Fuel Regulations (SOR/2002-254)

Sulphur in Diesel Fuel Regulations are federal regulations established to reduce emissions of sulphur dioxide because of the combustion of diesel fuel. The regulations set a limit of 15 mm of sulphur per kg of fuel. All diesel consumed at the Project will meet these regulations.

7A3.2.10.4 Canada-Wide Standards for Dioxins and Furans

In 2001, CCME published Canada-Wide Standards for D&F (CCME 2001), which sets emission performance targets for waste incineration. Under these standards, both municipal solid waste (i.e., including solid non-hazardous wastes regardless of origin) and hazardous waste (i.e., including LLRW) have an emission performance target of a maximum concentration of 80 picograms International Toxic Equivalent per cubic metre in the exhaust gas from a waste incinerator stack. All waste incinerators at the Project will need to meet this standard.

7A3.2.10.5 Canada-Wide Standards for Mercury Emissions

In 2000, CCME published Canada Wide Standards for Mercury Emissions (CCME 2000), which sets emission performance targets for waste incineration. Under these standards, incineration of municipal solid waste and hazardous waste have emission performance targets of maximum concentration of 20 micrograms per reference cubic metre ($\mu g/Rm^3$) and 50 $\mu g/Rm^3$ in the exhaust gas from a waste incinerator stack, respectively.

7A3.2.11 Background Concentrations

The ENV usually requires that air quality assessors use a Saskatchewan provincial government-supplied background air quality values. These values are prescribed based on the provincial zone within which the assessment is being conducted. This provincial background value is designed to account for distant or otherwise un-accounted concentrations of the assessed compounds that are present in the atmosphere. The air quality baseline study included a review of the ENV-prescribed background concentrations for the northern air dispersion modelling zone of Saskatchewan. The data from the air quality monitoring program was used to evaluate and support an update of the government-supplied background air quality concentrations, which were then used in the air quality assessment to characterize existing air quality conditions. The background concentrations used in the air quality assessment are summarized in Table 7A-96. The background concentrations were considered as Base Case of the assessment. The background concentrations were added to the modelling results from both Construction and Operations to form the Application Case modelling results. The background concentrations were added to the modelling results from Project Operations and Fission Patterson Lake South Property to form the RFD Case modelling results.

Table 7A-96: Background Air Compound Concentrations

Compound	Background Concentration for Air Dispersion Modelling (µg/m^3)[(a)]			
	1-Hour	8-Hour	24-Hour	Annual
$PM_{2.5}$	n/a	n/a	6.5	3.1
PM_{10}	n/a	n/a	14.4	n/a
TSP	n/a	n/a	14.4	6.2
Carbon monoxide	527.5 (500 ppb)	527.5 (500 ppb)	n/a	n/a
Nitrogen dioxide	11.3 (6 ppb)	n/a	9.4 (5 ppb)	3.8 (2 ppb)
Sulphur dioxide	0	n/a	0	0

a) 90th percentile value of monitoring data is added to the one-hour and 24-hour predictions and 50th percentile value of the monitoring data is added to the annual predictions per the SAQMG guidance.
n/a = not applicable; ppb = parts per billion; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; TSP = total suspended particulates; SAQMG = Saskatchewan Air Quality Modelling Guideline.

7A3.2.12 Modelling Results

The potential effects of the Project on local and regional air quality are evaluated through air dispersion modelling of identified measurable parameters associated with the Project Construction and Operations. Changes between the background concentration and the predicted maximum ground-level concentrations in the Application Case are used as a representation of the potential effects from the Project.

Hourly concentration predictions were obtained from the dispersion model as either 8,760 or 8,784 hourly predictions for each year in the modelling period (2012 to 2016). When comparing model-predicted maximum concentrations against the SAAQS, the SAQMG (ENV 2012) allows the elimination of some model predictions caused by rare and unusual meteorological conditions. For a refined model such as AERMOD, the SAQMG allows the elimination of these outliers by using the following nth highest concentrations predictions for each receptor location:

- one-hour average: use the ninth highest concentration;
- eight-hour average: use the fifth highest concentration; and
- 24-hour average: use the second highest concentration with the exception of $PM_{2.5}$, which uses three-year average of 98th percentile of 24-hour average concentration.

For all other time averaging periods greater than 24-hours, no modelled concentration may be eliminated. All model predicted concentrations exclude receptors inside of the Project maximum disturbance area, as the SAAQS and the CAAQS do not apply within the Project maximum disturbance area. This recommended approach by the SAQMG described above was followed in the postprocessing of the dispersion model output when comparing the model predictions with the SAAQS.

When comparing the model predicted maximum ground-level concentrations with the CAAQS, the statistical matrix specified in Table 7A-94 was followed. Because some of the CAAQS statistical matrix were based on the average of three years of data, the five-year model output (2012 to 2016) only resulted in three three-year averages (i.e., 2012 to 2014, 2013 to 2015, 2014 to 2016).

The following subsections outline the model predictions of nitrogen dioxide, sulphur dioxide, sulphuric acid, carbon monoxide, $PM_{2.5}$, PM_{10}, and TSP at discrete receptors for Application Case for both Construction and Operations and the RFD case.

7A3.2.12.1 Nitrogen Dioxide

Table 7A-97 lists the predicted maximum one-hour, 24-hour, and annual nitrogen dioxide concentrations at selected receptors for Construction and Operations of the Application Case and RFD Case. The overall maximum concentrations outside of the Project maximum disturbance area are also listed. For one-hour nitrogen dioxide, the maximum concentrations based on CAAQS statistical metrics are listed for all cases and both Construction and Operations.

Table 7A-97: Predicted Maximum Nitrogen Dioxide Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)											
	Application Case – Construction				Application Case – Operations				RFD Case			
	1-Hour	24-Hour	Annual	1-Hour CAAQS	1-Hour	24-Hour	Annual	1-Hour CAAQS	1-Hour	24-Hour	Annual	1-Hour CAAQS
Hodge Lake Reference HH VC	58.4	13.6	3.9	46.9	31.4	11.7	3.8	29.3	34.6	13.6	3.9	31.5
Broach Lake	125.0	19.4	4.1	113.2	54.0	14.8	3.9	48.8	58.6	14.8	4.0	50.2
Camp Worker HH VC	254.5	105.6	14.7	244.1	157.7	91.6	8.5	148.0	157.7	91.6	8.6	148.0
Patterson Lake HH VC	102.1	15.2	3.9	71.7	32.2	11.0	3.8	28.2	108.5	18.2	4.1	76.0
Patterson Lake Eco VC	136.8	28.7	4.5	129.7	82.1	19.6	4.0	84.6	82.2	19.7	4.1	84.6
Forrest Lake	127.6	18.3	4.2	121.6	55.5	14.4	3.9	49.5	59.7	14.5	4.0	54.0
Forrest Lake North Eco VC	131.6	25.2	4.3	127.9	76.5	15.8	4.0	67.0	76.5	15.8	4.1	70.5
Beet Lake HH VC	121.6	21.1	4.1	114.5	40.3	12.3	3.9	39.4	46.6	12.4	3.9	44.3
Naomi Lake	85.7	14.4	3.9	82.9	32.4	11.6	3.8	31.4	34.0	11.6	3.9	33.4
Clearwater River	54.4	13.4	3.9	39.6	26.3	11.2	3.8	22.6	27.2	11.2	3.8	24.2
Lloyd Lake HH VC	28.3	12.1	3.8	25.9	22.5	11.1	3.8	22.3	23.9	11.3	3.8	23.2
Broach Lake	87.3	14.3	4.0	43.7	33.5	12.0	3.8	34.9	50.1	13.4	3.9	49.8
Patterson Lake	135.2	22.5	4.2	128.1	63.9	13.7	3.9	49.7	84.7	13.8	4.0	62.6
Patterson Lake	151.0	24.0	4.5	131.4	112.5	15.2	4.0	74.5	112.7	16.0	4.1	74.6
Lake H	127.0	22.5	4.2	126.7	45.6	12.8	3.9	39.5	52.5	14.7	4.0	39.5
Lake G	146.2	22.9	4.4	131.4	103.9	15.1	4.0	75.9	103.9	15.3	4.1	75.9
Beet Lake	112.5	16.3	4.0	78.8	43.2	12.1	3.9	35.1	45.5	12.2	3.9	43.3
Naomi Lake	102.4	14.6	3.9	44.2	34.5	11.9	3.8	27.7	36.0	11.9	3.9	31.2
Patterson Lake	123.6	19.6	4.0	114.7	36.8	12.0	3.8	35.0	78.2	12.9	4.0	78.2
Forrest Lake	111.7	19.0	4.0	80.0	38.7	12.0	3.8	25.1	43.9	12.0	3.9	31.8
Forrest Lake	129.4	21.3	4.3	129.0	63.6	13.4	4.0	63.6	68.2	14.0	4.0	63.6
Unnamed Lake 2	94.9	15.1	4.0	77.8	32.4	11.6	3.8	29.4	38.8	12.5	3.9	32.7
Lake C	114.3	19.2	4.0	85.2	43.0	12.6	3.8	33.9	84.0	15.3	4.1	76.8
Lake E	124.1	20.4	4.1	124.1	41.9	12.7	3.9	41.9	55.4	12.7	3.9	43.5
Unnamed Lake 1	51.2	13.8	3.9	45.0	32.7	11.8	3.8	28.2	35.3	11.9	3.9	31.3

Table 7A-97: Predicted Maximum Nitrogen Dioxide Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)											
	Application Case – Construction				Application Case – Operations				RFD Case			
	1-Hour	24-Hour	Annual	1-Hour CAAQS	1-Hour	24-Hour	Annual	1-Hour CAAQS	1-Hour	24-Hour	Annual	1-Hour CAAQS
REF01	124.9	24.1	4.2	69.2	45.2	15.5	3.9	40.5	46.7	15.5	4.0	41.6
REF02	75.8	15.8	3.9	38.6	31.5	11.9	3.8	32.0	32.6	12.6	3.9	32.7
REF03	54.3	12.9	3.9	33.0	25.7	10.7	3.8	22.4	27.7	11.9	3.8	24.4
19REF04	74.6	16.3	3.9	48.3	30.5	11.6	3.8	24.9	36.6	12.0	3.8	32.8
19REF05	76.0	15.7	3.9	32.8	27.8	11.0	3.8	22.6	30.4	12.3	3.8	25.2
19REF06	115.1	25.7	4.0	36.5	38.2	11.9	3.8	41.7	58.9	14.2	4.0	44.5
19EXP02	259.4	69.5	9.5	224.2	155.1	41.9	6.3	147.6	155.1	42.3	6.3	147.6
19EXP01	318.9	75.9	10.4	245.9	167.1	48.7	7.0	150.1	167.1	49.0	7.0	150.1
19EXP03	132.9	29.1	5.0	127.7	125.6	28.4	4.3	123.1	125.8	28.5	4.4	124.0
Preston Lake	64.6	12.8	3.9	68.2	24.6	11.0	3.8	21.3	27.9	11.2	3.8	27.9
Wegner Lake	29.6	12.1	3.8	27.5	19.9	10.4	3.8	20.0	24.1	10.7	3.8	23.5
Overall	276.9	79.9	9.7	230.0	167.0	61.9	6.7	153.3	167.0	61.9	6.7	153.3
Applicable Ambient Air Quality Criteria	300	200	45	79.2	300	200	45	79.2	300	200	45	79.2

VC = valued component; HH = human health; CAAQS = Canadian Ambient Air Quality Standards; RFD = reasonably foreseeable development.

7A3.2.12.2 Sulphur Dioxide

Table 7A-98 lists predicted maximum sulphur dioxide concentrations at selected receptors and overall maximum outside of the Project maximum disturbance boundary for all averaging periods for the Application Case and RFD Case. The one-hour sulphur dioxide maximum concentrations based on CAAQS statistical metrics are also listed in the Table.

Table 7A-98: Predicted Maximum Sulphur Dioxide Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)											
	Application Case – Construction				Application Case – Operations				RFD Case			
	1-Hour	24-Hour	Annual	1-Hour CAAQS	1-Hour	24-Hour	Annual	1-Hour CAAQS	1-Hour	24-Hour	Annual	1-Hour CAAQS
Hodge Lake Reference HH VC	0.1	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.6	0.1	0.0	0.6
Broach Lake	0.3	0.0	0.0	0.0	0.6	0.1	0.0	0.8	0.7	0.1	0.0	0.9
Camp Worker HH VC	4.6	1.0	0.1	0.0	17.6	3.8	0.2	18.8	17.6	3.8	0.2	18.9
Patterson Lake HH VC	0.3	0.0	0.0	0.0	0.7	0.1	0.0	0.9	2.2	0.2	0.0	2.7
Patterson Lake Eco VC	0.8	0.1	0.0	0.0	5.4	0.5	0.0	5.8	5.4	0.5	0.0	5.8
Forrest Lake	0.4	0.0	0.0	0.0	0.8	0.1	0.0	1.1	0.8	0.1	0.0	1.2
Forrest Lake North Eco VC	0.5	0.0	0.0	0.0	0.9	0.2	0.0	1.6	0.9	0.2	0.0	1.6
Beet Lake HH VC	0.3	0.0	0.0	0.0	0.5	0.1	0.0	0.7	0.6	0.1	0.0	0.7
Naomi Lake	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.5	0.5	0.1	0.0	0.5
Clearwater River	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.4	0.0	0.0	0.4
Lloyd Lake HH VC	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.4	0.0	0.0	0.4
Broach Lake	0.2	0.0	0.0	0.3	0.5	0.1	0.0	0.5	0.9	0.2	0.0	0.9

Table 7A-98: Predicted Maximum Sulphur Dioxide Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)											
	Application Case – Construction				Application Case – Operations				RFD Case			
	1-Hour	24-Hour	Annual	1-Hour CAAQS	1-Hour	24-Hour	Annual	1-Hour CAAQS	1-Hour	24-Hour	Annual	1-Hour CAAQS
Patterson Lake	0.6	0.1	0.0	0.6	1.1	0.2	0.0	1.7	1.1	0.2	0.0	1.7
Patterson Lake	1.0	0.1	0.0	1.0	1.6	0.2	0.0	2.5	1.6	0.2	0.0	2.5
Lake H	0.4	0.0	0.0	0.4	0.8	0.1	0.0	1.3	1.2	0.1	0.0	1.3
Lake G	0.9	0.1	0.0	0.6	1.8	0.2	0.0	2.3	1.8	0.2	0.0	2.3
Beet Lake	0.3	0.0	0.0	0.3	0.4	0.1	0.0	0.6	0.6	0.1	0.0	0.8
Naomi Lake	0.2	0.0	0.0	0.2	0.4	0.1	0.0	0.6	0.5	0.1	0.0	0.6
Patterson Lake	0.3	0.0	0.0	0.6	1.1	0.1	0.0	1.6	1.4	0.1	0.0	1.9
Forrest Lake	0.3	0.0	0.0	0.2	0.5	0.1	0.0	0.5	0.9	0.1	0.0	0.8
Forrest Lake	0.4	0.0	0.0	0.6	0.7	0.1	0.0	1.1	0.8	0.1	0.0	1.1
Unnamed Lake 2	0.2	0.0	0.0	0.3	0.4	0.1	0.0	0.4	0.6	0.1	0.0	0.7
Lake C	0.3	0.0	0.0	0.4	0.7	0.1	0.0	0.5	1.6	0.2	0.0	1.8
Lake E	0.3	0.0	0.0	0.4	1.1	0.1	0.0	1.8	1.1	0.1	0.0	1.8
Unnamed Lake 1	0.1	0.0	0.0	0.2	0.4	0.0	0.0	0.5	0.5	0.0	0.0	0.5
REF01	0.3	0.1	0.0	0.2	0.5	0.1	0.0	0.6	0.6	0.1	0.0	0.6
REF02	0.2	0.0	0.0	0.2	0.5	0.0	0.0	0.5	0.5	0.1	0.0	0.5
REF03	0.1	0.0	0.0	0.1	0.3	0.0	0.0	0.4	0.4	0.1	0.0	0.5
19REF04	0.2	0.0	0.0	0.2	0.6	0.1	0.0	0.5	0.7	0.1	0.0	0.8
19REF05	0.2	0.0	0.0	0.2	0.5	0.0	0.0	0.5	0.5	0.1	0.0	0.5
19REF06	0.2	0.0	0.0	0.3	0.5	0.0	0.0	0.5	0.9	0.1	0.0	1.1
19EXP02	4.0	0.4	0.0	4.9	4.9	1.0	0.1	6.4	4.9	1.0	0.1	6.4
19EXP01	5.6	0.4	0.0	6.3	5.1	1.2	0.1	5.9	5.1	1.2	0.1	5.9
19EXP03	1.1	0.1	0.0	1.0	4.1	0.5	0.0	4.1	4.1	0.5	0.0	4.2
Preston Lake	0.1	0.0	0.0	0.2	0.3	0.0	0.0	0.4	0.4	0.0	0.0	0.4
Wegner Lake	0.1	0.0	0.0	0.1	0.2	0.0	0.0	0.4	0.4	0.0	0.0	0.5
Overall	4.5	0.7	0.0	5.1	9.4	1.8	0.1	10.4	9.4	1.8	0.1	10.7
Applicable Ambient Air Quality Criteria	450	125	20	170.1	450	125	20	170.1	450	125	20	170.1

VC = valued component; RFD = reasonably foreseeable development; CAAQS = Canadian Ambient Air Quality Standards; HH = human health.

7A3.2.12.3 Sulphuric Acid

Table 7A-99 lists the predicted maximum sulphuric acid concentrations at selected receptors and the overall maximum sulphuric acid concentrations in the RSA.

Table 7A-99: Predicted Sulphuric Acid Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)					
	Application Case – Operations			RFD Case		
	1-Hour	24-Hour	Annual	1-Hour	24-Hour	Annual
Hodge Lake Reference HH VC	0.036	0.005	0.000	0.054	0.009	0.000
Broach Lake	0.072	0.011	0.000	0.085	0.011	0.001
Camp Worker HH VC	2.231	0.490	0.021	2.231	0.490	0.021
Patterson Lake HH VC	0.081	0.008	0.000	0.270	0.028	0.001

Table 7A-99: Predicted Sulphuric Acid Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)					
	Application Case – Operations			RFD Case		
	1-Hour	24-Hour	Annual	1-Hour	24-Hour	Annual
Patterson Lake Eco VC	0.687	0.058	0.002	0.687	0.059	0.003
Forrest Lake	0.101	0.011	0.001	0.106	0.013	0.001
Forrest Lake North Eco VC	0.114	0.021	0.001	0.114	0.021	0.001
Beet Lake HH VC	0.066	0.009	0.000	0.079	0.009	0.001
Naomi Lake	0.034	0.004	0.000	0.052	0.006	0.000
Clearwater River	0.022	0.003	0.000	0.031	0.003	0.000
Lloyd Lake HH VC	0.018	0.003	0.000	0.025	0.004	0.000
Broach Lake	0.045	0.007	0.000	0.113	0.021	0.001
Patterson Lake	0.138	0.022	0.001	0.141	0.022	0.001
Patterson Lake	0.202	0.027	0.001	0.202	0.027	0.002
Lake H	0.105	0.014	0.001	0.121	0.014	0.001
Lake G	0.227	0.022	0.001	0.227	0.022	0.002
Beet Lake	0.055	0.008	0.000	0.071	0.009	0.000
Naomi Lake	0.045	0.005	0.000	0.051	0.005	0.000
Patterson Lake	0.141	0.017	0.001	0.173	0.017	0.001
Forrest Lake	0.050	0.007	0.000	0.114	0.013	0.001
Forrest Lake	0.080	0.015	0.001	0.083	0.015	0.001
Unnamed Lake 2	0.048	0.006	0.000	0.064	0.008	0.000
Lake C	0.083	0.011	0.000	0.200	0.027	0.001
Lake E	0.145	0.015	0.001	0.145	0.015	0.001
Unnamed Lake 1	0.040	0.005	0.000	0.044	0.005	0.000
REF01	0.047	0.007	0.000	0.063	0.010	0.001
REF02	0.036	0.005	0.000	0.052	0.007	0.000
REF03	0.028	0.003	0.000	0.039	0.005	0.000
19REF04	0.046	0.005	0.000	0.061	0.008	0.000
19REF05	0.043	0.005	0.000	0.045	0.006	0.000
19REF06	0.062	0.005	0.000	0.107	0.009	0.001
19EXP02	0.520	0.108	0.011	0.520	0.109	0.011
19EXP01	0.543	0.144	0.014	0.543	0.144	0.014
19EXP03	0.501	0.055	0.003	0.501	0.059	0.003
Preston Lake	0.021	0.002	0.000	0.030	0.004	0.000
Wegner Lake	0.023	0.002	0.000	0.027	0.004	0.000
Overall	1.211	0.228	0.012	1.591	0.253	0.022
Applicable Ambient Air Quality Criteria	10	5	10	5	10	5

VC = valued component; RFD = reasonably foreseeable development; HH = human health.

7A3.2.12.4 Carbon Monoxide

The maximum one-hour and eight-hour carbon monoxide concentrations at selected receptors are listed in Table 7A-100 along with the overall maximum carbon monoxide concentrations within the RSA.

Table 7A-100: Predicted Carbon Monoxide Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)					
	Application Case – Construction		Application Case – Operations		RFD Case	
	1-Hour	8-Hour	1-Hour	8-Hour	1-Hour	8-Hour
Hodge Lake Reference HH VC	586.5	577.9	604.2	581.9	605.3	582.7
Broach Lake	618.9	581.9	615.7	590.1	661.0	595.4
Camp Worker HH VC	864.8	724.6	1060.0	774.9	1,060.0	775.0
Patterson Lake HH VC	603.4	580.6	603.8	579.1	634.5	591.3
Patterson Lake Eco VC	657.9	591.3	671.7	608.1	734.2	609.6
Forrest Lake	665.3	598.7	603.1	584.4	622.4	585.2
Forrest Lake North Eco VC	692.1	609.6	614.2	586.9	614.5	587.8
Beet Lake HH VC	629.3	588.7	604.2	583.5	606.5	583.8
Naomi Lake	605.8	583.0	600.6	580.6	602.1	582.5
Clearwater River	586.6	576.3	589.9	576.8	590.9	578.7
Lloyd Lake HH VC	578.4	574.2	586.0	576.7	590.5	578.6
Broach Lake	597.9	581.4	607.3	583.4	617.3	586.8
Patterson Lake	674.5	601.8	608.5	587.4	622.9	588.6
Patterson Lake	811.6	643.7	651.7	600.6	652.7	603.0
Lake H	654.6	590.4	608.7	587.5	611.7	590.5
Lake G	799.5	615.5	641.6	592.9	641.6	594.9
Beet Lake	638.3	591.9	601.6	581.1	605.1	582.6
Naomi Lake	606.6	582.2	606.4	583.1	607.5	583.5
Patterson Lake	623.3	584.5	602.6	582.0	626.8	588.3
Forrest Lake	641.6	582.2	605.4	578.2	605.6	582.1
Forrest Lake	683.4	595.5	608.0	585.6	616.3	585.7
Unnamed Lake 2	608.8	580.8	606.4	584.5	608.6	586.2
Lake C	635.0	585.1	610.9	583.4	646.9	594.1
Lake E	643.1	588.3	600.6	580.1	618.4	584.8
Unnamed Lake 1	587.2	578.0	599.4	580.7	603.3	583.0
REF01	622.6	584.2	616.2	589.3	617.3	589.3
REF02	590.4	577.6	610.7	582.6	623.6	587.8
REF03	592.1	576.3	596.0	578.1	597.7	580.5
19REF04	593.1	575.4	599.1	580.5	609.4	580.9
19REF05	590.4	576.6	600.3	577.1	610.9	582.9
19REF06	607.7	580.9	606.1	581.5	678.0	598.2
19EXP02	1,488.0	842.4	870.1	710.3	870.2	710.3
19EXP01	1,904.1	915.3	995.7	790.1	995.7	790.1
19EXP03	675.5	604.5	923.8	677.3	923.8	677.3
Preston Lake	581.7	575.7	590.8	576.7	591.1	577.5
Wegner Lake	578.6	574.1	586.0	576.2	594.6	580.2
Overall	1,654.7	831.4	1,255.9	792.5	1,255.9	793.3
Applicable Ambient Air Quality Criteria	15,000	6,000	15,000	6,000	15,000	6,000

VC = valued component; RFD = reasonably foreseeable development; HH = human health.

7A3.2.12.5 $PM_{2.5}$

Table 7A-101 lists the maximum 24-hour and annual $PM_{2.5}$ concentrations at the selected receptors for the Application Case during Construction, Application Case during Operations, and the RFD Case. The overall maximum concentrations of 24-hour and annual $PM_{2.5}$ are also listed in the Table.

Table 7A-101: Predicted $PM_{2.5}$ Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)					
	Application Case – Construction		Application Case – Operations		RFD Case	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	6.6	3.1	6.6	3.1	6.6	3.1
Broach Lake	7.0	3.1	6.7	3.1	6.8	3.1
Camp Worker HH VC	19.5	3.1	10.8	3.8	10.8	3.9
Patterson Lake HH VC	6.8	3.1	6.6	3.1	7.0	3.2
Patterson Lake Eco VC	7.8	3.1	7.2	3.2	7.2	3.2
Forrest Lake	7.1	3.1	6.7	3.1	6.8	3.1
Forrest Lake North Eco VC	7.5	3.1	6.9	3.1	6.9	3.2
Beet Lake HH VC	7.1	3.1	6.7	3.1	6.8	3.1
Naomi Lake	6.7	3.1	6.6	3.1	6.6	3.1
Clearwater River	6.6	3.1	6.5	3.1	6.6	3.1
Lloyd Lake HH VC	6.5	3.1	6.5	3.1	6.5	3.1
Broach Lake	6.7	3.1	6.6	3.1	6.8	3.1
Patterson Lake	7.2	3.2	6.7	3.1	7.0	3.2
Patterson Lake	7.8	3.2	7.1	3.2	7.1	3.2
Lake H	7.1	3.2	6.7	3.1	6.8	3.1
Lake G	7.5	3.2	7.0	3.2	7.1	3.2
Beet Lake	7.0	3.1	6.7	3.1	6.7	3.1
Naomi Lake	6.7	3.1	6.6	3.1	6.6	3.1
Patterson Lake	7.0	3.1	6.7	3.1	7.0	3.2
Forrest Lake	6.7	3.1	6.6	3.1	6.7	3.1
Forrest Lake	7.3	3.2	6.8	3.1	6.9	3.2
Unnamed Lake 2	6.8	3.1	6.6	3.1	6.7	3.1
Lake C	6.8	3.1	6.6	3.1	7.1	3.2
Lake E	7.0	3.1	6.7	3.1	6.8	3.1
Unnamed Lake 1	6.7	3.1	6.6	3.1	6.6	3.1
REF01	6.9	3.1	6.7	3.1	6.7	3.1
REF02	6.6	3.1	6.6	3.1	6.6	3.1
REF03	6.6	3.1	6.5	3.1	6.6	3.1
19REF04	6.6	3.1	6.6	3.1	6.6	3.1
19REF05	6.6	3.1	6.5	3.1	6.6	3.1
19REF06	6.7	3.1	6.6	3.1	6.8	3.1
19EXP02	17.1	4.2	10.3	3.8	10.3	3.8
19EXP01	20.3	4.5	11.6	4.0	11.6	4.0
19EXP03	7.7	3.3	7.5	3.2	7.6	3.2
Preston Lake	6.6	3.1	6.5	3.1	6.5	3.1
Wegner Lake	6.5	3.1	6.5	3.1	6.6	3.1
Overall	16.6	4.1	10.5	3.7	10.6	3.7
Applicable Ambient Air Quality Criteria	28	10	28	10	28	10

HH = human health; VC = valued component; RFD = reasonably foreseeable development; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less.

7A3.2.12.6 PM_{10}

Table 7A-102 lists the maximum 24-hour PM_{10} concentrations predicted at the selected receptors for both Construction and Operations and the RFD Case.

Table 7A-102: Predicted PM_{10} Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)		
	Application Case – Construction	Application Case – Operations	RFD Case
	24-Hour	24-Hour	24-Hour
Hodge Lake Reference HH VC	15.6	14.9	15.2
Broach Lake	18.3	16.5	17.3
Camp Worker HH VC	97.5	60.2	60.3
Patterson Lake HH VC	17.5	15.7	19.3
Patterson Lake Eco VC	29.8	24.2	24.2
Forrest Lake	18.2	16.5	16.6
Forrest Lake North Eco VC	19.9	16.7	16.9
Beet Lake HH VC	18.7	16.0	16.8
Naomi Lake	16.6	15.1	15.3
Clearwater River	14.8	14.6	14.8
Lloyd Lake HH VC	14.6	14.6	14.7
Broach Lake	16.4	15.1	17.4
Patterson Lake	20.8	16.6	19.8
Patterson Lake	32.7	25.5	25.6
Lake H	17.5	16.8	17.2
Lake G	21.6	17.3	17.7
Beet Lake	19.0	15.7	15.9
Naomi Lake	16.2	14.9	15.3
Patterson Lake	19.2	16.9	18.8
Forrest Lake	16.3	15.1	16.3
Forrest Lake	20.2	16.4	16.6
Unnamed Lake 2	15.6	15.0	15.5
Lake C	17.5	15.5	21.5
Lake E	18.9	16.4	17.4
Unnamed Lake 1	15.8	14.9	15.4
REF01	18.7	16.0	16.1
REF02	16.2	15.8	15.9
REF03	15.1	14.7	14.8
19REF04	15.7	15.2	15.3
19REF05	15.3	14.6	15.0
19REF06	16.3	15.1	17.2
19EXP02	130.7	74.6	74.9
19EXP01	203.6	83.6	83.9
19EXP03	25.2	21.4	21.6
Preston Lake	14.8	14.6	14.8
Wegner Lake	14.7	14.6	15.4
Overall	147.0	65.4	65.6
Applicable Ambient Air Quality Criteria	50	50	50

HH = human health; VC = valued component; RFD = reasonably foreseeable development; PM_{10} = particulate matter with a diameter of 10 microns or less.

7A3.2.12.7 Total Suspended Particulates

Table 7A-103 lists the maximum 24-hour and annual TSP concentrations at selected receptors and the overall maximum concentrations within the RSA for both Construction and Operations, and the RFD Case.

Table 7A-103: Predicted Total Suspended Particulates Concentrations at Selected Receptors

Receptor Name	Concentration (µg/m³)					
	Application Case – Construction		Application Case – Operations		RFD Case	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	15.6	6.2	14.9	6.2	15.2	6.2
Broach Lake	18.5	6.3	17.2	6.3	17.3	6.4
Camp Worker HH VC	142.5	15.3	92.8	10.2	92.9	10.3
Patterson Lake HH VC	17.6	6.3	15.9	6.3	20.5	6.6
Patterson Lake Eco VC	36.3	6.8	30.2	6.6	30.2	6.8
Forrest Lake	18.8	6.4	18.2	6.4	18.3	6.5
Forrest Lake North Eco VC	22.8	6.5	19.4	6.5	19.4	6.5
Beet Lake HH VC	19.6	6.4	17.4	6.3	17.8	6.4
Naomi Lake	16.7	6.3	15.4	6.2	15.7	6.3
Clearwater River	14.8	6.2	14.6	6.2	14.8	6.2
Lloyd Lake HH VC	14.6	6.2	14.6	6.2	14.7	6.2
Broach Lake	16.4	6.3	15.3	6.3	18.3	6.4
Patterson Lake	21.8	6.5	18.7	6.4	21.0	6.6
Patterson Lake	34.0	6.9	30.4	6.7	30.9	6.7
Lake H	18.0	6.4	17.3	6.4	18.3	6.4
Lake G	23.2	6.6	19.9	6.5	19.9	6.6
Beet Lake	19.2	6.3	16.3	6.3	16.6	6.3
Naomi Lake	16.4	6.3	15.6	6.2	15.7	6.3
Patterson Lake	19.9	6.4	17.8	6.3	20.8	6.6
Forrest Lake	16.4	6.3	15.8	6.3	17.9	6.4
Forrest Lake	21.2	6.5	17.9	6.4	18.5	6.5
Unnamed Lake 2	15.9	6.3	15.3	6.3	15.9	6.3
Lake C	18.0	6.3	16.3	6.3	23.0	6.8
Lake E	19.1	6.4	17.3	6.3	18.6	6.5
Unnamed Lake 1	15.9	6.2	15.2	6.2	15.8	6.3
REF01	18.9	6.4	16.6	6.3	16.7	6.4
REF02	16.3	6.2	16.0	6.2	16.2	6.3
REF03	15.1	6.2	14.7	6.2	14.9	6.2
19REF04	15.7	6.2	15.2	6.2	15.5	6.3
19REF05	15.3	6.2	14.7	6.2	15.1	6.2
19REF06	16.4	6.3	15.8	6.3	17.8	6.4
19EXP02	185.1	14.3	127.2	11.8	127.7	11.9
19EXP01	247.1	18.1	156.4	14.5	156.4	14.6
19EXP03	33.5	7.1	28.1	7.1	28.3	7.1
Preston Lake	14.8	6.2	14.6	6.2	14.8	6.2
Wegner Lake	14.7	6.2	14.6	6.2	15.4	6.2
Overall	185.3	13.2	109.2	11.2	109.8	11.3
Applicable Ambient Air Quality Criteria	100	60	100	60	100	60

VC = valued component; HH = human health; RFD = reasonably foreseeable development.

7A3.2.13 Additional Modelling Results

This section outlines the results of some supplementary modelling effort (e.g., highway and access road) done to support other intermediate components and valued components. The additional modelling results also include air quality parameters that were not considered as air quality measurement indicators, i.e., dust deposition, metal concentration and deposition, dioxins and furans concentrations, radon and radionuclides concentrations, and radionuclides deposition.

7A3.2.13.1 Highway and Access Road Results

Table 7A-104 lists the predicted maximum 24-hour and annual $PM_{2.5}$ concentrations from highway traffic generated PM emissions during Construction and Operations at various distances from the road centre.

Table 7A-104: Highway Predicted $PM_{2.5}$ Concentrations

Distance from Road Centre (m)	Concentration (µg/m^3)			
	Application Case – Construction		Application Case – Operations	
	24-Hour	Annual	24-Hour	Annual
20	8.2	3.4	8.5	3.4
25	8.1	3.4	8.4	3.4
40	8.2	3.4	8.5	3.4
50	8.1	3.3	8.3	3.3
100	7.5	3.2	7.7	3.2
150	7.3	3.2	7.4	3.2
200	7.1	3.2	7.2	3.2
300	7.0	3.2	7.0	3.2
500	6.8	3.1	6.8	3.1
1,000	6.6	3.1	6.6	3.1
-20	8.3	3.4	8.6	3.4
-25	8.2	3.4	8.5	3.4
-40	8.2	3.4	8.5	3.4
-50	8.0	3.3	8.2	3.4
-100	7.5	3.2	7.7	3.3
-150	7.3	3.2	7.4	3.2
-200	7.1	3.2	7.2	3.2
-300	6.8	3.1	6.9	3.1
-500	6.6	3.1	6.6	3.1
-1,000	6.7	3.1	6.7	3.1

$PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less.

Table 7A-105 lists the predicted maximum 24-hour and annual PM_{10} concentrations from highway traffic during Construction and Operations at various distances from the road centre.

Table 7A-105: Highway Predicted PM_{10} Concentrations

Distance from Road Centre (m)	Application Case 24-hour PM_{10} Concentration (µg/m^3)	
	Construction	Operations
20	45.3	49.7
25	44.2	48.5
40	43.9	48.1
50	39.6	43.3
100	29.4	31.5
150	26.1	27.8
200	24.1	25.5
300	22.0	23.0
500	19.5	20.2
1,000	16.7	17.1
-20	46.3	50.9
-25	45.6	50.1
-40	44.4	48.7
-50	40.4	44.1
-100	32.1	34.6
-150	26.9	28.7
-200	24.1	25.5
-300	20.0	20.9
-500	15.8	16.0
-1,000	17.1	17.5

PM_{10} = particulate matter with a diameter of 10 microns or less.

Table 7A-106 lists the predicted maximum 24-hour and annual TSP concentrations from highway traffic during Construction and Operations at various distances from the road centre.

Table 7A-106: Public Road Predicted Total Suspended Particulates Concentrations

Distance from Road Centre (m)	Concentration (µg/m^3)			
	Application Case – Construction		Application Case – Operations	
	24-Hour	Annual	24-Hour	Annual
20	69.5	10.8	77.4	11.4
25	67.2	10.4	74.8	11.0
40	65.9	10.5	73.3	11.1
50	56.5	9.7	62.6	10.2
100	35.9	8.0	39.0	8.2
150	28.3	7.3	30.3	7.5
200	24.6	7.0	26.0	7.1
300	21.9	6.7	23.0	6.8
500	18.7	6.5	19.3	6.5
1,000	16.2	6.3	16.5	6.3

Table 7A-106: Public Road Predicted Total Suspended Particulates Concentrations

Distance from Road Centre (m)	Concentration (µg/m³)			
	Application Case – Construction		Application Case – Operations	
	24-Hour	Annual	24-Hour	Annual
-20	72.7	11.1	81.1	11.8
-25	70.2	10.8	78.2	11.4
-40	75.6	10.8	84.5	11.4
-50	64.6	10.0	71.9	10.5
-100	42.2	8.3	46.2	8.6
-150	36.2	7.6	39.3	7.8
-200	30.6	7.2	33.0	7.4
-300	21.9	6.8	23.0	6.9
-500	16.9	6.4	17.3	6.5
-1,000	16.5	6.3	16.8	6.3

Table 7A-107, Table 7A-108, and Table 7A-109 list the predicted maximum $PM_{2.5}$, PM_{10}, and TSP concentrations from highway traffic during Construction and Operations at various distances from the road centre.

Table 7A-107: Access Road Predicted $PM_{2.5}$ Concentrations

Distance from Road Centre (m)	$PM_{2.5}$ Concentration (µg/m³)			
	Application Case – Construction		Application Case – Operations	
	24-Hour	Annual	24-Hour	Annual
20	10.8	3.8	11.5	3.9
25	10.6	3.7	11.3	3.8
40	10.8	3.7	11.5	3.8
50	10.5	3.6	11.0	3.7
100	9.1	3.4	9.5	3.5
150	8.5	3.3	8.8	3.4
200	8.1	3.3	8.3	3.3
300	7.7	3.2	7.8	3.2
500	7.2	3.2	7.3	3.2
1,000	6.8	3.1	6.9	3.1
-20	11.0	3.8	11.7	3.9
-25	10.8	3.8	11.4	3.9
-40	10.8	3.8	11.5	3.9
-50	10.3	3.7	10.9	3.8
-100	9.1	3.4	9.5	3.5
-150	8.5	3.3	8.8	3.4
-200	8.0	3.3	8.3	3.3
-300	7.3	3.2	7.4	3.2
-500	6.7	3.1	6.7	3.1
-1,000	6.9	3.1	6.9	3.1

$PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less.

Table 7A-108: Access Road Predicted PM_{10} Concentrations

Distance from Road Centre (m)	Application Case 24-hour PM_{10} Concentration (µg/m^3)	
	Construction	Operations
20	91.6	103.2
25	89.0	100.2
40	88.1	99.1
50	77.6	87.0
100	51.9	57.5
150	43.7	48.0
200	38.6	42.2
300	33.3	36.2
500	27.1	29.0
1,000	20.3	21.1
-20	94.3	106.2
-25	92.4	104.1
-40	89.4	100.6
-50	79.4	89.1
-100	58.7	65.3
-150	45.7	50.4
-200	38.6	42.2
-300	28.5	30.6
-500	17.9	18.4
-1,000	21.2	22.2

PM_{10} = particulate matter with a diameter of 10 microns or less.

Table 7A-109: Access Road Predicted Total Suspended Particulates Concentrations

Distance from Road Centre (m)	Concentration (µg/m^3)			
	Application Case – Construction		Application Case – Operations	
	24-Hour	Annual	24-Hour	Annual
20	222.3	23.4	253.5	26.0
25	213.6	22.0	243.4	24.4
40	208.8	22.3	238.0	24.7
50	173.3	19.5	197.2	21.5
100	95.5	12.8	107.6	13.8
150	66.7	10.4	74.6	11.0
200	52.7	9.2	58.5	9.7
300	42.6	8.2	46.8	8.5
500	30.6	7.3	33.0	7.4
1,000	21.4	6.6	22.4	6.7
-20	234.6	24.8	267.5	27.6
-25	225.0	23.5	256.5	26.1
-40	245.5	23.4	280.1	26.0
-50	204.0	20.5	232.4	22.6
-100	119.4	14.1	135.2	15.3
-150	96.6	11.6	109.0	12.4
-200	75.6	10.1	84.8	10.7

Table 7A-109: Access Road Predicted Total Suspended Particulates Concentrations

Distance from Road Centre (m)	Concentration (µg/m³)			
	Application Case – Construction		Application Case – Operations	
	24-Hour	Annual	24-Hour	Annual
-300	42.8	8.4	47.0	8.8
-500	24.0	7.1	25.4	7.2
-1,000	22.3	6.7	23.5	6.8

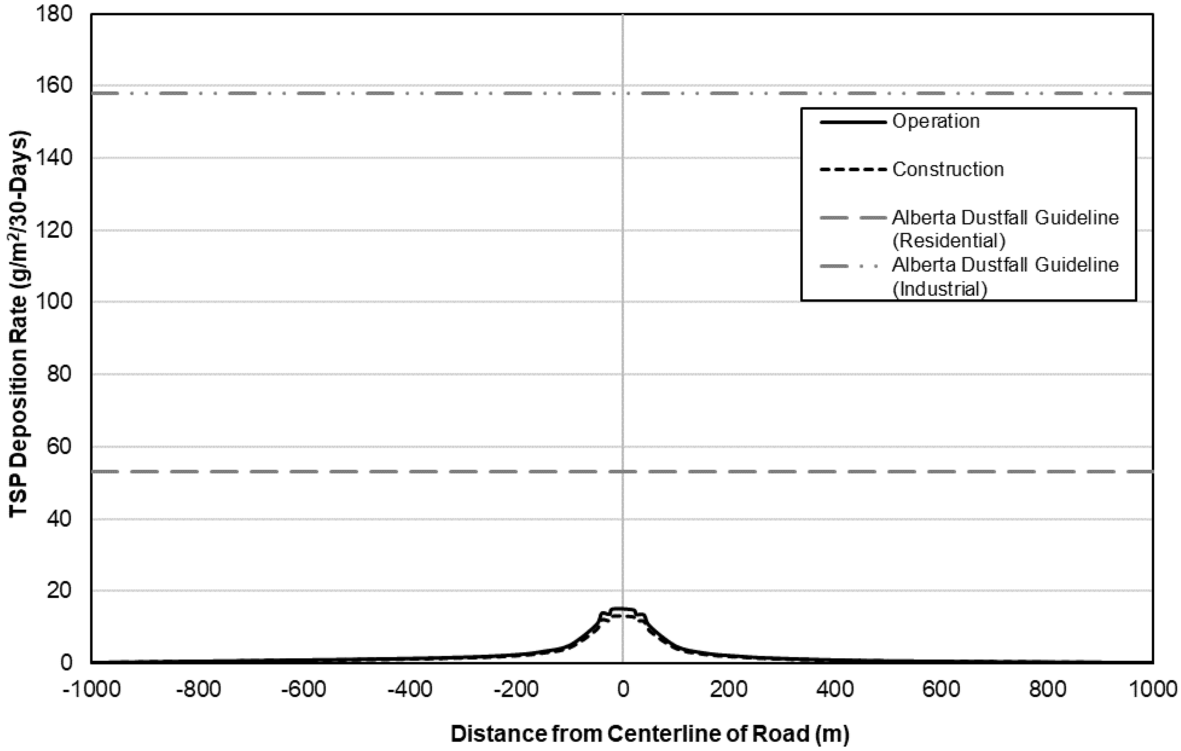
Table 7A-110 lists the predicted maximum monthly and annual TSP deposition rates at various distances from the highway road centre during Construction and Operations. The maximum monthly and annual TSP deposition rates are also shown in Figure 7A-14 and Figure 7A-15, respectively.

Table 7A-110: Highway Predicted Total Suspended Particulates Deposition Rate

Distance from Road Centre (m)	Application Case – Construction		Application Case – Operations	
	g/m²/30 d	g/m²/yr	g/m²/30 d	g/m²/yr
20	12.9	8.3	14.7	9.5
25	11.7	7.5	13.4	8.6
40	11.6	7.6	13.3	8.7
50	9.1	5.9	10.4	6.7
100	4.2	2.7	4.8	3.1
150	2.7	1.8	3.0	2.0
200	2.0	1.3	2.3	1.5
300	1.3	0.8	1.5	0.9
500	0.7	0.4	0.8	0.5
1,000	0.3	0.2	0.3	0.2
-20	13.0	8.5	14.9	9.7
-25	11.8	7.7	13.5	8.8
-40	12.0	7.9	13.8	9.0
-50	9.3	6.1	10.7	7.0
-100	4.4	2.9	5.1	3.3
-150	3.0	1.9	3.4	2.2
-200	2.2	1.4	2.5	1.6
-300	1.6	1.0	1.8	1.1
-500	1.1	0.6	1.2	0.7
-1,000	0.3	0.2	0.4	0.2

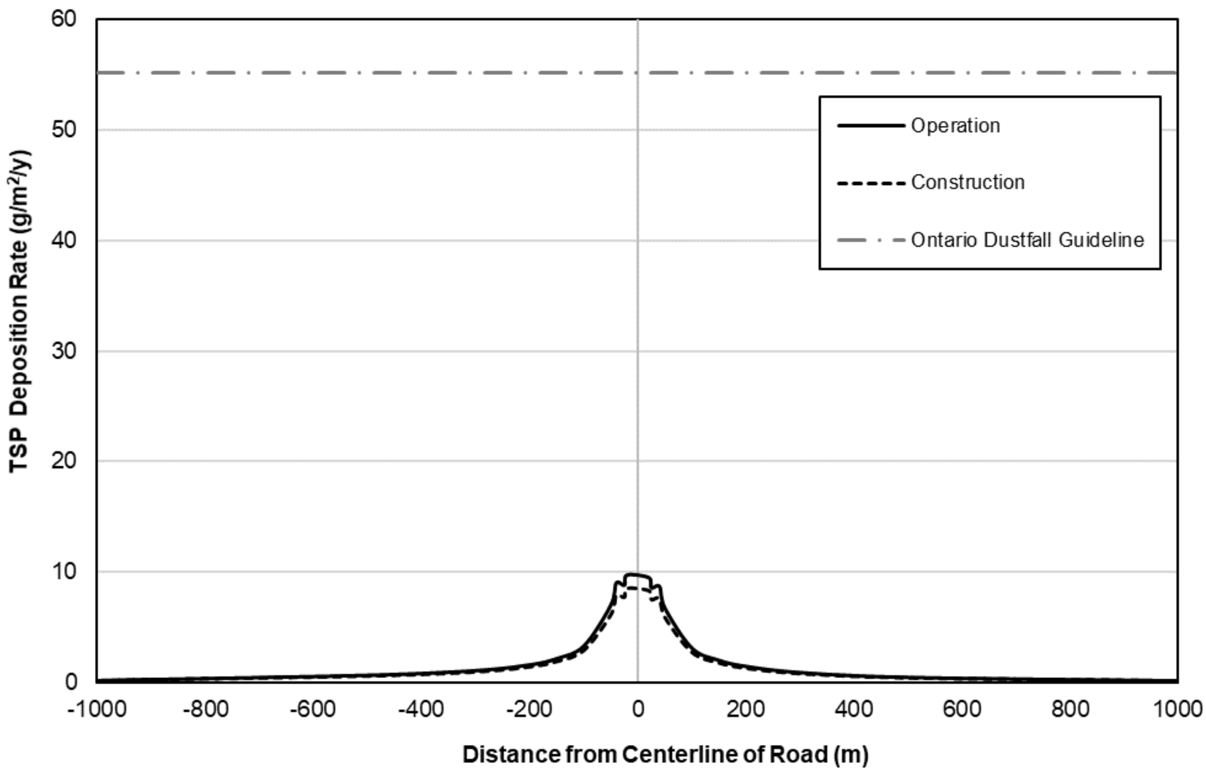
g/m²/30 d = grams per square metre per 30 days.

Figure 7A-14: Highway Predicted Monthly Total Suspended Particulates Deposition Rate



TSP = total suspended particulates.

Figure 7A-15: Highway Predicted Annual Total Suspended Particulates Deposition Rate



TSP = total suspended particulates.

Table 7A-111 lists the maximum monthly and annual TSP deposition rates from access road traffic generated PM emissions at various distances from the road centre during Construction and Operations. The monthly and annual TSP deposition rates from road centre are also shown in Figure 7A-16 and Figure 7A-17, respectively.

Table 7A-111: Access Road Predicted Total Suspended Particulates Deposition Rate

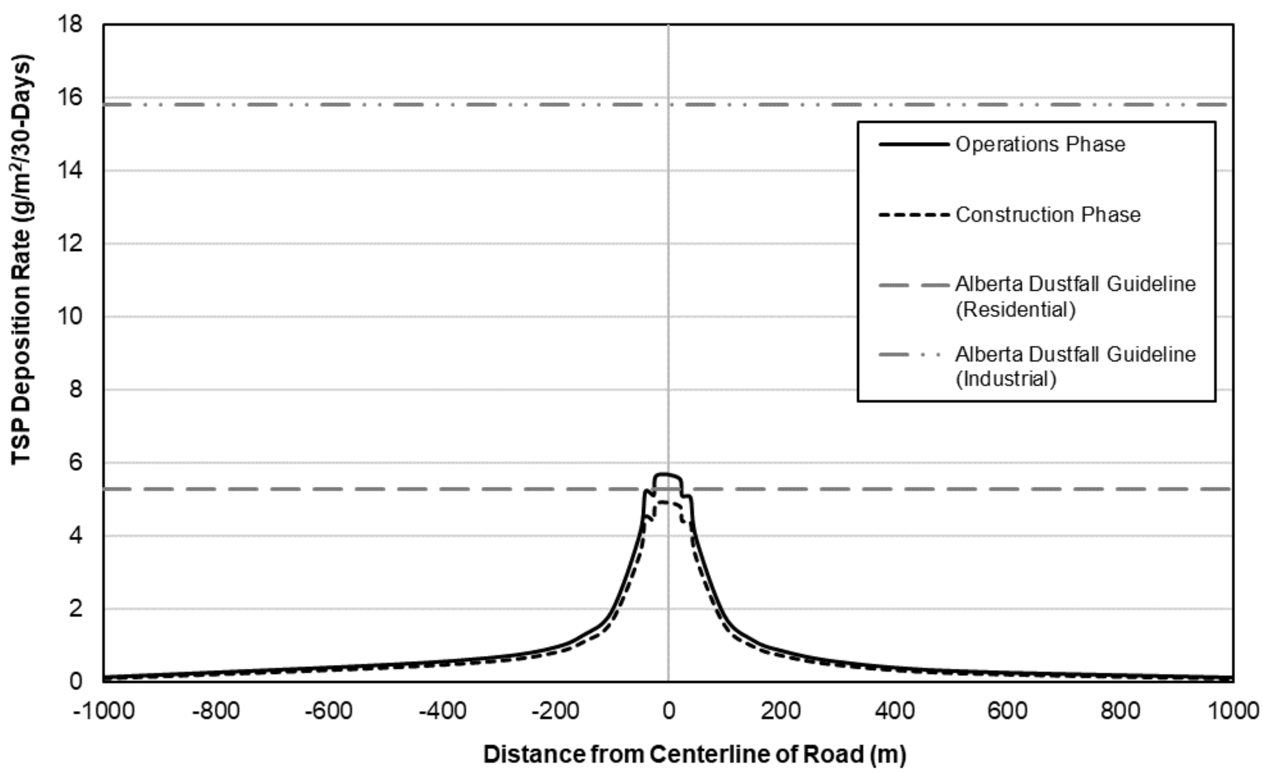
Distance from Road Centre (m)	Application Case – Construction		Application Case – Operations	
	$g/m^2/30$ d	$g/m^2/yr$	$g/m^2/30$ d	$g/m^2/yr$
20	4.85	31.37	5.58	36.07
25	4.43	28.32	5.10	32.56
40	4.39	28.70	5.05	33.00
50	3.42	22.27	3.93	25.60
100	1.58	10.31	1.82	11.86
150	1.00	6.70	1.15	7.71
200	0.75	4.90	0.86	5.63
300	0.49	3.07	0.56	3.52
500	0.27	1.60	0.31	1.84
1,000	0.11	0.58	0.12	0.67
-20	4.92	32.14	5.66	36.96
-25	4.45	29.11	5.11	33.48
-40	4.54	29.78	5.22	34.24
-50	3.52	23.19	4.04	26.66

Table 7A-111: Access Road Predicted Total Suspended Particulates Deposition Rate

Distance from Road Centre (m)	Application Case – Construction		Application Case – Operations	
	g/m²/30 d	g/m²/yr	g/m²/30 d	g/m²/yr
-100	1.67	10.97	1.92	12.62
-150	1.12	7.22	1.28	8.30
-200	0.83	5.36	0.95	6.17
-300	0.60	3.64	0.69	4.18
-500	0.41	2.24	0.47	2.58
-1,000	0.12	0.66	0.13	0.76

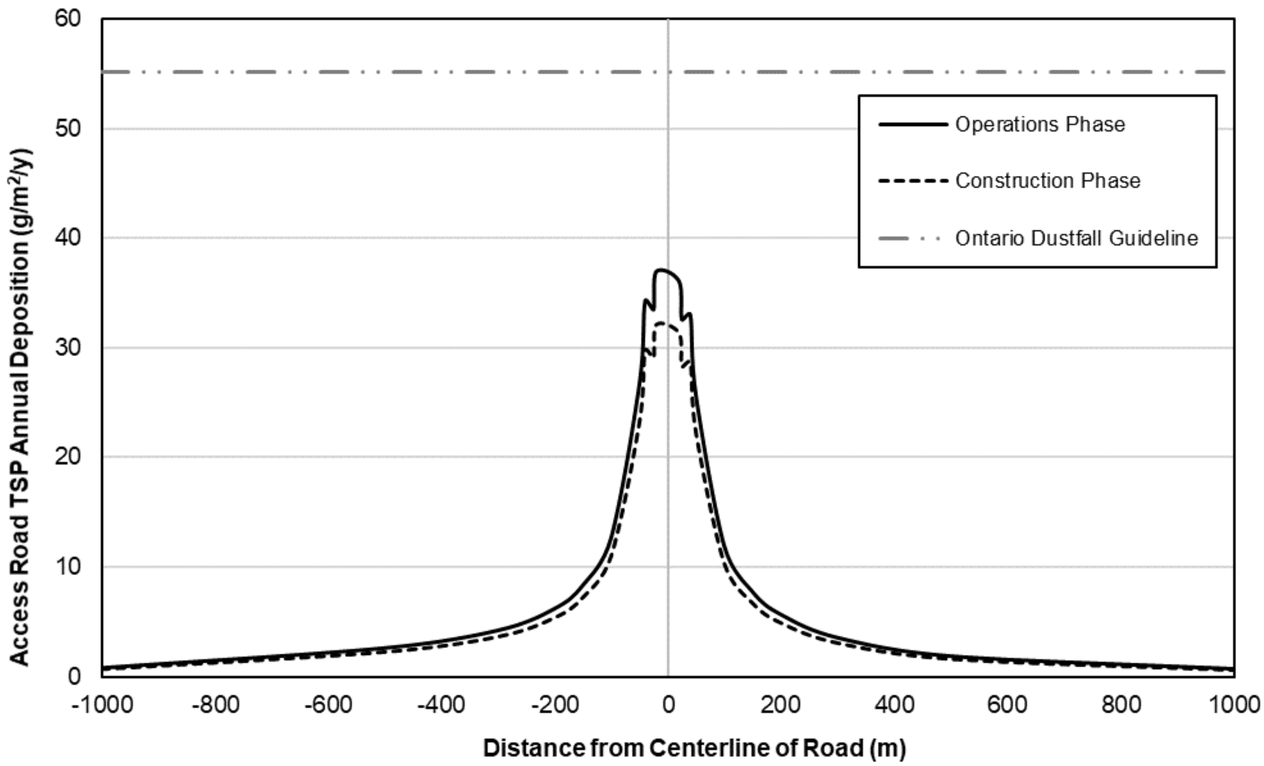
g/m²/30 d = grams per square metre per 30 days.

Figure 7A-16: Access Roads Predicted Monthly Total Suspended Particulates Deposition Rate



TSP = total suspended particulates; g/m²/30 d = grams per square metre per 30 days.

Figure 7A-17: Access Roads Predicted Annual Total Suspended Particulates Deposition Rate



TSP = total suspended particulates; g/m²/30 d = grams per square metre per 30 days.

7A3.2.13.2 Dust Deposition

Maximum monthly and annual dust deposition in the unit of grams per square metre per 30 days (g/m²/30 d) were obtained from the dispersion model. The maximum monthly and annual dust deposition rates at selected receptors are listed in Table 7A-112 and Table 7A-113, respectively. Figure 7A-18 presents the maximum annual dust deposition predictions.

Table 7A-112: Maximum Monthly Total Suspended Particulates Rates at Selected Receptors

Receptor Name	Application Case – Construction	Application Case – Operations	RFD Case
	g/m²/30 d	g/m²/30 d	g/m²/30 d
Hodge Lake Reference HH VC	0.00	0.00	0.00
Broach Lake	0.03	0.03	0.01
Camp Worker HH VC	1.61	1.08	0.45
Patterson Lake HH VC	0.01	0.01	0.06
Patterson Lake Eco VC	0.10	0.09	0.04
Forrest Lake	0.03	0.03	0.02
Forrest Lake North Eco VC	0.05	0.05	0.03
Beet Lake HH VC	0.03	0.03	0.02
Naomi Lake	0.01	0.01	0.01
Clearwater River	0.00	0.00	0.00
Lloyd Lake HH VC	0.00	0.00	0.00

Table 7A-112: Maximum Monthly Total Suspended Particulates Rates at Selected Receptors

Receptor Name	Application Case – Construction	Application Case – Operations	RFD Case
	$g/m^2/30$ d	$g/m^2/30$ d	$g/m^2/30$ d
Broach Lake	0.01	0.01	0.01
Patterson Lake	0.05	0.05	0.03
Patterson Lake	0.08	0.08	0.04
Lake H	0.03	0.03	0.02
Lake G	0.07	0.07	0.04
Beet Lake	0.02	0.02	0.01
Naomi Lake	0.01	0.01	0.01
Patterson Lake	0.02	0.02	0.04
Forrest Lake	0.01	0.01	0.02
Forrest Lake	0.05	0.05	0.03
Unnamed Lake 2	0.01	0.01	0.01
Lake C	0.02	0.02	0.04
Lake E	0.02	0.02	0.02
Unnamed Lake 1	0.01	0.01	0.01
REF01	0.03	0.03	0.02
REF02	0.00	0.00	0.00
REF03	0.00	0.00	0.00
19REF04	0.00	0.00	0.00
19REF05	0.00	0.00	0.00
19REF06	0.01	0.01	0.02
19EXP02	2.10	2.10	1.08
19EXP01	3.11	3.11	1.62
19EXP03	0.23	0.23	0.12
Preston Lake	0.00	0.00	0.00
Wegner Lake	0.00	0.00	0.00
Overall	1.62	1.81	0.95

$g/m^2/30$ d = grams per square metre per 30 days; VC = valued component; HH = human health; RFD = reasonably foreseeable development.

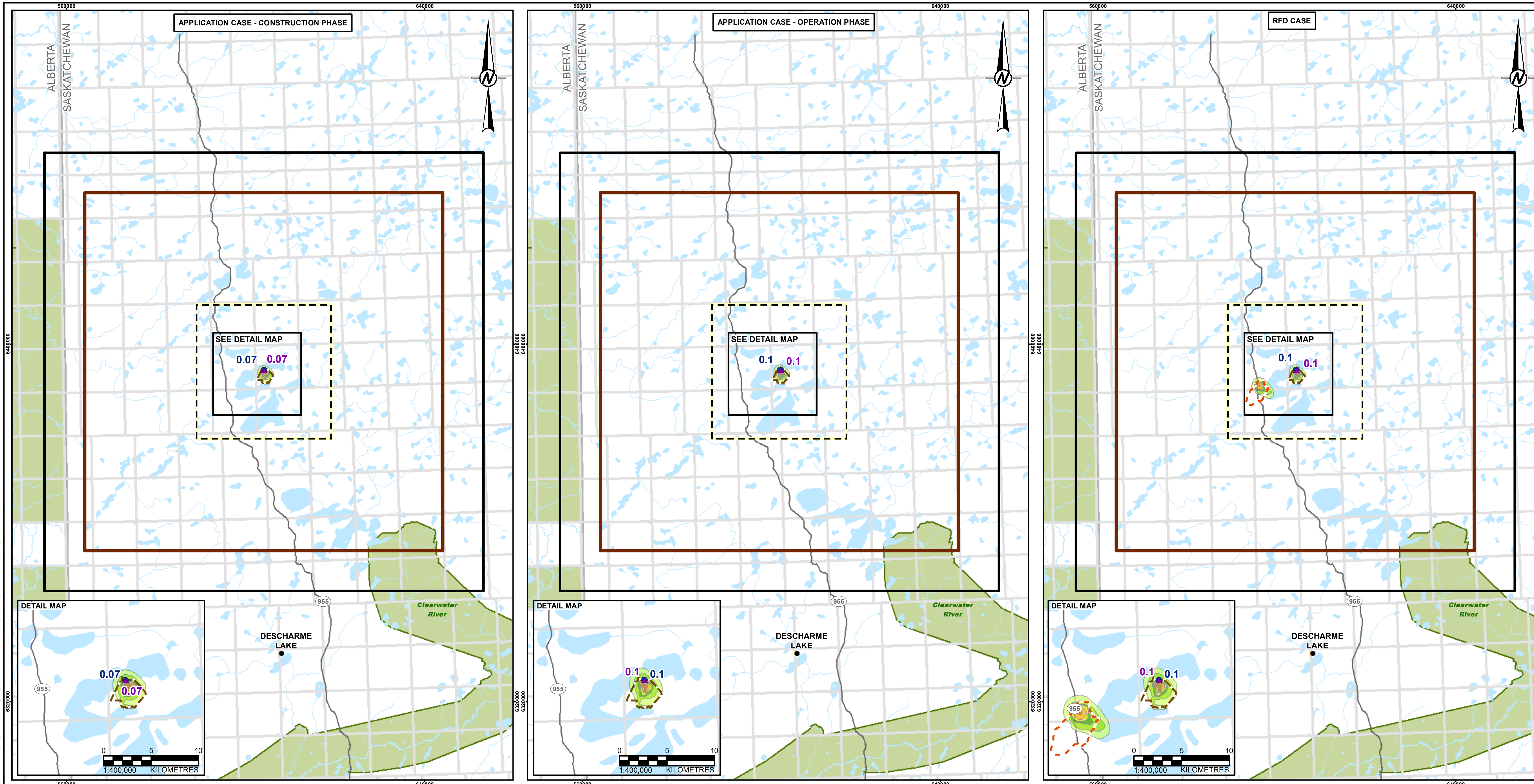
Table 7A-113: Maximum Annual Total Suspended Particulates Deposition Rates at Selected Receptors

Receptor Name	Application Case – Construction		Application Case – Operations		RFD Case	
	kg/ha/yr	$g/m^2/yr$	kg/ha/yr	$g/m^2/yr$	kg/ha/yr	$g/m^2/yr$
Hodge Lake Reference HH VC	0.2	0.0	0.2	0.0	0.4	0.0
Broach Lake	1.3	0.1	1.3	0.1	1.8	0.2
Camp Worker HH VC	87.9	8.8	53.3	5.3	53.8	5.4
Patterson Lake HH VC	0.4	0.0	0.5	0.0	7.8	0.8
Patterson Lake Eco VC	5.1	0.5	4.4	0.4	5.4	0.5
Forrest Lake	1.5	0.2	1.9	0.2	2.7	0.3
Forrest Lake North Eco VC	3.0	0.3	3.4	0.3	4.1	0.4
Beet Lake HH VC	1.4	0.1	1.9	0.2	2.2	0.2
Naomi Lake	0.4	0.0	0.5	0.0	0.6	0.1
Clearwater River	0.1	0.0	0.1	0.0	0.2	0.0

Table 7A-113: Maximum Annual Total Suspended Particulates Deposition Rates at Selected Receptors

Receptor Name	Application Case – Construction		Application Case – Operations		RFD Case	
	kg/ha/yr	g/m²/yr	kg/ha/yr	g/m²/yr	kg/ha/yr	g/m²/yr
Lloyd Lake HH VC	0.0	0.0	0.0	0.0	0.1	0.0
Broach Lake	0.5	0.1	0.6	0.1	1.6	0.2
Patterson Lake	2.0	0.2	2.1	0.2	3.8	0.4
Patterson Lake	3.9	0.4	4.3	0.4	4.7	0.5
Lake H	1.5	0.1	1.8	0.2	2.1	0.2
Lake G	3.9	0.4	4.4	0.4	4.8	0.5
Beet Lake	1.0	0.1	1.2	0.1	1.5	0.2
Naomi Lake	0.4	0.0	0.5	0.0	0.6	0.1
Patterson Lake	1.1	0.1	1.2	0.1	4.3	0.4
Forrest Lake	0.4	0.0	0.5	0.0	2.0	0.2
Forrest Lake	2.9	0.3	3.3	0.3	4.0	0.4
Unnamed Lake 2	0.5	0.0	0.6	0.1	0.7	0.1
Lake C	0.8	0.1	0.8	0.1	4.4	0.4
Lake E	1.0	0.1	1.1	0.1	2.7	0.3
Unnamed Lake 1	0.5	0.0	0.5	0.1	0.7	0.1
REF01	1.3	0.1	1.8	0.2	2.2	0.2
REF02	0.2	0.0	0.2	0.0	0.4	0.0
REF03	0.1	0.0	0.1	0.0	0.2	0.0
19REF04	0.1	0.0	0.1	0.0	0.4	0.0
19REF05	0.1	0.0	0.1	0.0	0.2	0.0
19REF06	0.5	0.0	0.5	0.0	2.0	0.2
19EXP02	103.8	10.4	129.0	12.9	129.6	13.0
19EXP01	148.5	14.8	194.0	19.4	194.4	19.4
19EXP03	13.0	1.3	14.2	1.4	14.7	1.5
Preston Lake	0.1	0.0	0.0	0.0	0.1	0.0
Wegner Lake	0.1	0.0	0.0	0.0	0.1	0.0
Overall	85.9	8.6	113.9	11.4	114.4	11.4

VC = valued component; HH = human health; RFD = reasonably foreseeable development.



LEGEND

- POPULATED PLACE
- SECONDARY HIGHWAY
- WATERCOURSE
- PARK / PROTECTED AREA
- WATERBODY
- FISSION PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- MAXIMUM DISTURBANCE AREA
- PROJECT BOUNDARY MAXIMUM CONCENTRATION [µg/m³]
- OVERALL MAXIMUM CONCENTRATION [µg/m³]
- AIR QUALITY LOCAL STUDY AREA
- AIR QUALITY REGIONAL STUDY AREA
- AIR DISPERSION MODELLING DOMAIN

CONCENTRATION [µg/m³]

- >= 0.46
- >= 0.2 to < 0.46
- >= 0.1 to < 0.2
- >= 0.05 to < 0.1
- >= 0.02 to < 0.05
- >= 0.01 to < 0.02
- < 0.01

0 20 40
1:850,000 KILOMETRES

NOTE(S)
1. MAXIMUM PREDICTION EXCLUDES PREDICTIONS WITHIN DEVELOPMENT AREAS WHERE PUBLIC ACCESS IS RESTRICED
2 ONTARIO DUSTFALL STANDARD [mg/m²/30days] = 60
3. BACKGROUND CONCENTRATION [[mg/m²/30days] = 0

REFERENCE(S)
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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
MAXIMUM ANNUAL TOTAL SUSPENDED PARTICULATES DEPOSITION RATES

CONSULTANT
wsp

PROJECT		20144150	PHASE	3101 - 3
DESIGN	ZY	2020-03-13	SCALE AS SHOWN	REV. 1
GIS	NO	2023-02-24		
CHECK	ZY	2023-02-24	**FIGURE 7A-18**	
REVIEW	CM	2023-02-24		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

7A3.2.13.3 Metal Concentration and Deposition

Table 7A-114 to Table 7A-117 summarize the maximum 24-hour and annual metal concentrations at the selected receptors during Operations.

Table 7A-118 to Table 7A-121 list the maximum 24-hour and annual concentrations at selected receptors for the RFD Case. The overall maximum metal concentrations within the RSA are also listed.

Table 7A-122 to Table 7A-123 list the maximum metal deposition rates at selected receptors during Operations.

Table 7A-124 and Table 7A-125 list the maximum metal deposition rates at selected receptors for the RFD Case.

Table 7A-114: Operations Metal Concentration Predictions (Silver to Cadmium) at Selected Receptors

Receptor Name	Concentration (µg/m³)													
	Silver		Arsenic		Barium		Beryllium		Bismuth		Calcium		Cadmium	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	0	0	0	0	1.40×10^{-04}	1.00×10^{-05}	0	0	0	0	1.54×10^{-03}	7.00×10^{-05}	1.00×10^{-05}	0
Broach Lake	0	0	2.00×10^{-05}	0	1.12×10^{-03}	4.00×10^{-05}	0	0	1.00×10^{-05}	0	7.11×10^{-03}	3.70×10^{-04}	4.00×10^{-05}	0
Camp Worker HH VC	3.00×10^{-05}	0	3.70×10^{-04}	3.00×10^{-05}	1.66×10^{-02}	8.10×10^{-04}	3.00×10^{-05}	0	1.00×10^{-04}	0	2.32×10^{-01}	1.19×10^{-02}	4.60×10^{-04}	5.00×10^{-05}
Patterson Lake HH VC	0	0	1.00×10^{-05}	0	5.20×10^{-04}	2.00×10^{-05}	0	0	0	0	4.22×10^{-03}	1.70×10^{-04}	2.00×10^{-05}	0
Patterson Lake Eco VC	1.00×10^{-05}	0	7.00×10^{-05}	0	4.09×10^{-03}	1.40×10^{-04}	1.00×10^{-05}	0	2.00×10^{-05}	0	4.70×10^{-02}	1.34×10^{-03}	5.00×10^{-05}	0
Forrest Lake	0	0	3.00×10^{-05}	0	2.01×10^{-03}	7.00×10^{-05}	0	0	1.00×10^{-05}	0	1.05×10^{-02}	5.60×10^{-04}	5.00×10^{-05}	0
Forrest Lake North Eco VC	0	0	3.00×10^{-05}	0	2.17×10^{-03}	1.00×10^{-04}	0	0	1.00×10^{-05}	0	1.51×10^{-02}	8.70×10^{-04}	4.00×10^{-05}	0
Beet Lake HH VC	0	0	3.00×10^{-05}	0	2.22×10^{-03}	7.00×10^{-05}	0	0	1.00×10^{-05}	0	1.09×10^{-02}	4.90×10^{-04}	4.00×10^{-05}	0
Naomi Lake	0	0	1.00×10^{-05}	0	5.10×10^{-04}	2.00×10^{-05}	0	0	0	0	2.90×10^{-03}	1.50×10^{-04}	1.00×10^{-05}	0
Clearwater River	0	0	0	0	1.00×10^{-04}	0	0	0	0	0	5.50×10^{-04}	4.00×10^{-05}	0	0
Lloyd Lake HH VC	0	0	0	0	6.00×10^{-05}	0	0	0	0	0	7.50×10^{-04}	3.00×10^{-05}	1.00×10^{-05}	0
Broach Lake	0	0	1.00×10^{-05}	0	5.50×10^{-04}	2.00×10^{-05}	0	0	0	0	3.07×10^{-03}	1.70×10^{-04}	1.00×10^{-05}	0
Patterson Lake	0	0	4.00×10^{-05}	0	1.90×10^{-03}	6.00×10^{-05}	0	0	1.00×10^{-05}	0	1.41×10^{-02}	5.80×10^{-04}	4.00×10^{-05}	0
Patterson Lake	0	0	7.00×10^{-05}	0	2.68×10^{-03}	1.60×10^{-04}	0	0	2.00×10^{-05}	0	4.23×10^{-02}	1.44×10^{-03}	5.00×10^{-05}	0
Lake H	0	0	3.00×10^{-05}	0	2.01×10^{-03}	9.00×10^{-05}	0	0	1.00×10^{-05}	0	1.15×10^{-02}	6.10×10^{-04}	4.00×10^{-05}	0
Lake G	1.00×10^{-05}	0	5.00×10^{-05}	0	3.44×10^{-03}	1.40×10^{-04}	1.00×10^{-05}	0	2.00×10^{-05}	0	1.66×10^{-02}	1.07×10^{-03}	5.00×10^{-05}	0
Hodge Lake Reference HH VC	0	0	0	0	1.40×10^{-04}	1.00×10^{-05}	0	0	0	0	1.54×10^{-03}	7.00×10^{-05}	1.00×10^{-05}	0
Broach Lake	0	0	2.00×10^{-05}	0	1.12×10^{-03}	4.00×10^{-05}	0	0	1.00×10^{-05}	0	7.11×10^{-03}	3.70×10^{-04}	4.00×10^{-05}	0
Camp Worker HH VC	3.00×10^{-05}	0	3.70×10^{-04}	3.00×10^{-05}	1.66×10^{-02}	8.10×10^{-04}	3.00×10^{-05}	0	1.00×10^{-04}	0	2.32×10^{-01}	1.19×10^{-02}	4.60×10^{-04}	5.00×10^{-05}
Patterson Lake HH VC	0	0	1.00×10^{-05}	0	5.20×10^{-04}	2.00×10^{-05}	0	0	0	0	4.22×10^{-03}	1.70×10^{-04}	2.00×10^{-05}	0
Patterson Lake Eco VC	1.00×10^{-05}	0	7.00×10^{-05}	0	4.09×10^{-03}	1.40×10^{-04}	1.00×10^{-05}	0	2.00×10^{-05}	0	4.70×10^{-02}	1.34×10^{-03}	5.00×10^{-05}	0
Forrest Lake	0	0	3.00×10^{-05}	0	2.01×10^{-03}	7.00×10^{-05}	0	0	1.00×10^{-05}	0	1.05×10^{-02}	5.60×10^{-04}	5.00×10^{-05}	0
Forrest Lake North Eco VC	0	0	3.00×10^{-05}	0	2.17×10^{-03}	1.00×10^{-04}	0	0	1.00×10^{-05}	0	1.51×10^{-02}	8.70×10^{-04}	4.00×10^{-05}	0
Beet Lake HH VC	0	0	3.00×10^{-05}	0	2.22×10^{-03}	7.00×10^{-05}	0	0	1.00×10^{-05}	0	1.09×10^{-02}	4.90×10^{-04}	4.00×10^{-05}	0
Unnamed Lake 1	0	0	1.00×10^{-05}	0	4.40×10^{-04}	2.00×10^{-05}	0	0	0	0	2.36×10^{-03}	1.40×10^{-04}	1.00×10^{-05}	0
REF01	0	0	2.00×10^{-05}	0	1.67×10^{-03}	6.00×10^{-05}	0	0	1.00×10^{-05}	0	8.87×10^{-03}	4.50×10^{-04}	3.00×10^{-05}	0
REF02	0	0	1.00×10^{-05}	0	3.20×10^{-04}	1.00×10^{-05}	0	0	0	0	4.40×10^{-03}	1.10×10^{-04}	1.00×10^{-05}	0
REF03	0	0	0	0	1.70×10^{-04}	1.00×10^{-05}	0	0	0	0	1.12×10^{-03}	7.00×10^{-05}	0	0
19REF04	0	0	0	0	2.10×10^{-04}	1.00×10^{-05}	0	0	0	0	2.16×10^{-03}	7.00×10^{-05}	1.00×10^{-05}	0
19REF05	0	0	0	0	1.30×10^{-04}	0	0	0	0	0	1.40×10^{-03}	5.00×10^{-05}	1.00×10^{-05}	0
19REF06	0	0	1.00×10^{-05}	0	8.10×10^{-04}	2.00×10^{-05}	0	0	0	0	4.17×10^{-03}	1.60×10^{-04}	1.00×10^{-05}	0
19EXP02	4.00×10^{-05}	0	4.20×10^{-04}	3.00×10^{-05}	3.37×10^{-02}	1.56×10^{-03}	5.00×10^{-05}	0	1.60×10^{-04}	1.00×10^{-05}	3.13×10^{-01}	1.74×10^{-02}	9.00×10^{-05}	1.00×10^{-05}
19EXP01	6.00×10^{-05}	0	5.40×10^{-04}	4.00×10^{-05}	3.73×10^{-02}	2.29×10^{-03}	6.00×10^{-05}	0	2.20×10^{-04}	1.00×10^{-05}	3.84×10^{-01}	2.51×10^{-02}	8.00×10^{-05}	1.00×10^{-05}

Table 7A-114: Operations Metal Concentration Predictions (Silver to Cadmium) at Selected Receptors

Receptor Name	Concentration (µg/m³)													
	Silver		Arsenic		Barium		Beryllium		Bismuth		Calcium		Cadmium	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
19EXP03	1.00×10^{-05}	0	7.00×10^{-05}	1.00×10^{-05}	4.22×10^{-03}	3.40×10^{-04}	1.00×10^{-05}	0	2.00×10^{-05}	0	3.95×10^{-02}	2.83×10^{-03}	9.00×10^{-05}	0
Preston Lake	0	0	0	0	1.50×10^{-04}	0	0	0	0	0	7.80×10^{-04}	3.00×10^{-05}	0	0
Wegner Lake	0	0	0	0	7.00×10^{-05}	0	0	0	0	0	7.40×10^{-04}	3.00×10^{-05}	0	0
Overall	4.00×10^{-05}	0	6.00×10^{-04}	3.00×10^{-05}	3.26×10^{-02}	1.85×10^{-03}	5.00×10^{-05}	0	1.60×10^{-04}	1.00×10^{-05}	2.78×10^{-01}	1.52×10^{-02}	2.00×10^{-04}	1.00×10^{-05}

VC = valued component; HH = human health.

Table 7A-115: Operations Metal Concentration Predictions (Cobalt to Magnesium) at Selected Receptors

Receptor Name	Concentration (µg/m³)													
	Cobalt		Chromium		Cesium		Copper		Iron		Mercury		Magnesium	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	0	0	9.00×10^{-05}	0	0	0	3.00×10^{-05}	0	7.57×10^{-03}	1.90×10^{-04}	0	0	2.93×10^{-03}	1.30×10^{-04}
Broach Lake	3.00×10^{-05}	0	4.20×10^{-04}	2.00×10^{-05}	0	0	2.90×10^{-04}	1.00×10^{-05}	3.14×10^{-02}	1.18×10^{-03}	0	0	2.49×10^{-02}	8.20×10^{-04}
Camp Worker HH VC	5.10×10^{-04}	2.00×10^{-05}	1.29×10^{-02}	6.30×10^{-04}	0	0	4.60×10^{-03}	1.70×10^{-04}	6.51×10^{-01}	3.55×10^{-02}	6.00×10^{-04}	0	2.90×10^{-01}	1.91×10^{-02}
Patterson Lake HH VC	2.00×10^{-05}	0	2.60×10^{-04}	1.00×10^{-05}	0	0	1.20×10^{-04}	0	1.70×10^{-02}	6.00×10^{-04}	0	0	1.10×10^{-02}	3.90×10^{-04}
Patterson Lake Eco VC	1.20×10^{-04}	0	2.48×10^{-03}	7.00×10^{-05}	0	0	9.20×10^{-04}	3.00×10^{-05}	1.54×10^{-01}	5.04×10^{-03}	0	0	8.38×10^{-02}	3.37×10^{-03}
Forrest Lake	6.00×10^{-05}	0	4.90×10^{-04}	2.00×10^{-05}	0	0	4.10×10^{-04}	2.00×10^{-05}	4.63×10^{-02}	1.97×10^{-03}	0	0	4.07×10^{-02}	1.48×10^{-03}
Forrest Lake North Eco VC	6.00×10^{-05}	0	8.00×10^{-04}	4.00×10^{-05}	0	0	5.20×10^{-04}	2.00×10^{-05}	6.12×10^{-02}	3.00×10^{-03}	0	0	4.78×10^{-02}	2.15×10^{-03}
Beet Lake HH VC	6.00×10^{-05}	0	3.70×10^{-04}	2.00×10^{-05}	0	0	4.90×10^{-04}	2.00×10^{-05}	4.37×10^{-02}	1.86×10^{-03}	0	0	4.35×10^{-02}	1.49×10^{-03}
Naomi Lake	1.00×10^{-05}	0	1.20×10^{-04}	1.00×10^{-05}	0	0	1.00×10^{-04}	0	1.46×10^{-02}	5.50×10^{-04}	0	0	1.39×10^{-02}	4.30×10^{-04}
Clearwater River	0	0	2.00×10^{-05}	0	0	0	3.00×10^{-05}	0	2.08×10^{-03}	1.10×10^{-04}	0	0	1.63×10^{-03}	8.00×10^{-05}
Lloyd Lake HH VC	0	0	1.00×10^{-05}	0	0	0	1.00×10^{-05}	0	1.26×10^{-03}	6.00×10^{-05}	0	0	1.18×10^{-03}	5.00×10^{-05}
Broach Lake	2.00×10^{-05}	0	1.30×10^{-04}	1.00×10^{-05}	0	0	1.20×10^{-04}	0	1.28×10^{-02}	5.60×10^{-04}	0	0	1.04×10^{-02}	3.80×10^{-04}
Patterson Lake	6.00×10^{-05}	0	6.00×10^{-04}	3.00×10^{-05}	0	0	4.80×10^{-04}	1.00×10^{-05}	5.60×10^{-02}	1.99×10^{-03}	0	0	3.84×10^{-02}	1.36×10^{-03}
Patterson Lake	8.00×10^{-05}	0	1.78×10^{-03}	7.00×10^{-05}	0	0	7.00×10^{-04}	3.00×10^{-05}	1.34×10^{-01}	5.38×10^{-03}	0	0	7.32×10^{-02}	3.65×10^{-03}
Lake H	6.00×10^{-05}	0	3.80×10^{-04}	2.00×10^{-05}	0	0	3.30×10^{-04}	2.00×10^{-05}	5.92×10^{-02}	2.46×10^{-03}	0	0	4.65×10^{-02}	1.92×10^{-03}
Lake G	1.00×10^{-04}	0	8.80×10^{-04}	5.00×10^{-05}	0	0	7.60×10^{-04}	3.00×10^{-05}	6.60×10^{-02}	3.87×10^{-03}	0	0	6.66×10^{-02}	2.83×10^{-03}
Beet Lake	4.00×10^{-05}	0	2.60×10^{-04}	1.00×10^{-05}	0	0	2.70×10^{-04}	1.00×10^{-05}	2.98×10^{-02}	1.24×10^{-03}	0	0	2.43×10^{-02}	9.60×10^{-04}
Naomi Lake	3.00×10^{-05}	0	1.10×10^{-04}	1.00×10^{-05}	0	0	1.90×10^{-04}	0	1.84×10^{-02}	5.90×10^{-04}	0	0	1.80×10^{-02}	4.80×10^{-04}
Patterson Lake	4.00×10^{-05}	0	5.70×10^{-04}	2.00×10^{-05}	0	0	2.90×10^{-04}	1.00×10^{-05}	4.18×10^{-02}	1.42×10^{-03}	0	0	2.61×10^{-02}	9.40×10^{-04}
Forrest Lake	2.00×10^{-05}	0	1.80×10^{-04}	1.00×10^{-05}	0	0	1.30×10^{-04}	0	2.05×10^{-02}	6.90×10^{-04}	0	0	1.10×10^{-02}	4.90×10^{-04}
Forrest Lake	7.00×10^{-05}	0	5.60×10^{-04}	3.00×10^{-05}	0	0	4.80×10^{-04}	2.00×10^{-05}	6.03×10^{-02}	2.60×10^{-03}	0	0	4.60×10^{-02}	1.89×10^{-03}
Unnamed Lake 2	2.00×10^{-05}	0	1.40×10^{-04}	1.00×10^{-05}	0	0	1.50×10^{-04}	1.00×10^{-05}	1.46×10^{-02}	8.00×10^{-04}	0	0	1.30×10^{-02}	6.40×10^{-04}

Table 7A-115: Operations Metal Concentration Predictions (Cobalt to Magnesium) at Selected Receptors

Receptor Name	Concentration ($\mu g/m^3$)													
	Cobalt		Chromium		Cesium		Copper		Iron		Mercury		Magnesium	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Lake C	3.00×10^{-05}	0	2.80×10^{-04}	1.00×10^{-05}	0	0	2.40×10^{-04}	1.00×10^{-05}	2.51×10^{-02}	9.10×10^{-04}	0	0	2.50×10^{-02}	6.70×10^{-04}
Lake E	5.00×10^{-05}	0	4.40×10^{-04}	2.00×10^{-05}	0	0	3.70×10^{-04}	1.00×10^{-05}	4.43×10^{-02}	1.71×10^{-03}	0	0	3.61×10^{-02}	1.24×10^{-03}
Unnamed Lake 1	1.00×10^{-05}	0	9.00×10^{-05}	1.00×10^{-05}	0	0	1.10×10^{-04}	0	1.16×10^{-02}	4.60×10^{-04}	0	0	8.23×10^{-03}	3.40×10^{-04}
REF01	5.00×10^{-05}	0	3.90×10^{-04}	2.00×10^{-05}	0	0	3.80×10^{-04}	1.00×10^{-05}	3.85×10^{-02}	1.74×10^{-03}	0	0	3.41×10^{-02}	1.32×10^{-03}
REF02	1.00×10^{-05}	0	2.20×10^{-04}	0	0	0	8.00×10^{-05}	0	1.44×10^{-02}	3.20×10^{-04}	0	0	5.38×10^{-03}	2.30×10^{-04}
REF03	0	0	5.00×10^{-05}	0	0	0	3.00×10^{-05}	0	4.71×10^{-03}	2.10×10^{-04}	0	0	3.30×10^{-03}	1.60×10^{-04}
19REF04	1.00×10^{-05}	0	1.40×10^{-04}	0	0	0	5.00×10^{-05}	0	7.07×10^{-03}	2.10×10^{-04}	0	0	4.10×10^{-03}	1.30×10^{-04}
19REF05	0	0	4.00×10^{-05}	0	0	0	4.00×10^{-05}	0	3.12×10^{-03}	1.10×10^{-04}	0	0	2.03×10^{-03}	9.00×10^{-05}
19REF06	2.00×10^{-05}	0	1.90×10^{-04}	1.00×10^{-05}	0	0	2.00×10^{-04}	0	1.84×10^{-02}	5.70×10^{-04}	0	0	1.37×10^{-02}	4.20×10^{-04}
19EXP02	9.80×10^{-04}	5.00×10^{-05}	1.85×10^{-02}	8.80×10^{-04}	1.00×10^{-05}	0	6.76×10^{-03}	3.60×10^{-04}	9.25×10^{-01}	5.54×10^{-02}	2.00×10^{-04}	0	4.57×10^{-01}	3.12×10^{-02}
19EXP01	1.15×10^{-03}	7.00×10^{-05}	2.50×10^{-02}	1.30×10^{-03}	1.00×10^{-05}	0	9.14×10^{-03}	5.30×10^{-04}	$1.21 \times 10^{+00}$	8.19×10^{-02}	2.00×10^{-04}	0	5.41×10^{-01}	4.52×10^{-02}
19EXP03	1.20×10^{-04}	1.00×10^{-05}	2.18×10^{-03}	1.20×10^{-04}	0	0	8.40×10^{-04}	7.00×10^{-05}	1.62×10^{-01}	1.09×10^{-02}	2.00×10^{-04}	0	1.38×10^{-01}	7.93×10^{-03}
Preston Lake	0	0	3.00×10^{-05}	0	0	0	3.00×10^{-05}	0	3.25×10^{-03}	9.00×10^{-05}	0	0	3.03×10^{-03}	7.00×10^{-05}
Wegner Lake	0	0	3.00×10^{-05}	0	0	0	2.00×10^{-05}	0	2.04×10^{-03}	7.00×10^{-05}	0	0	1.63×10^{-03}	5.00×10^{-05}
Overall	9.60×10^{-04}	6.00×10^{-05}	1.70×10^{-02}	7.80×10^{-04}	2.00×10^{-05}	0	6.94×10^{-03}	4.30×10^{-04}	7.96×10^{-01}	5.54×10^{-02}	2.00×10^{-04}	0	6.11×10^{-01}	3.58×10^{-02}

VC = valued component; HH = human health.

Table 7A-116: Operations Metal Concentration Predictions (Manganese to Antimony) at Selected Receptors

Receptor Name	Concentration ($\mu g/m^3$)														
	Manganese		Molybdenum		Sodium		Nickel in PM_{10}		Nickel in TSP		Lead			Antimony	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	30 d	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	1.10×10^{-04}	0	3.00×10^{-05}	0	1.29×10^{-03}	4.00×10^{-05}	3.00×10^{-05}	0	3.00×10^{-05}	0	5.00×10^{-05}	0	0	0	0
Broach Lake	5.70×10^{-04}	2.00×10^{-05}	2.30×10^{-04}	1.00×10^{-05}	7.09×10^{-03}	2.60×10^{-04}	1.00×10^{-04}	1.00×10^{-05}	6.00×10^{-05}	0	4.70×10^{-04}	4.00×10^{-05}	1.00×10^{-05}	0	0
Camp Worker HH VC	1.58×10^{-02}	7.50×10^{-04}	3.47×10^{-03}	1.20×10^{-04}	1.92×10^{-01}	9.30×10^{-03}	1.42×10^{-03}	1.70×10^{-04}	9.20×10^{-04}	1.20×10^{-04}	7.20×10^{-03}	7.40×10^{-04}	2.50×10^{-04}	4.00×10^{-05}	0
Patterson Lake HH VC	3.50×10^{-04}	1.00×10^{-05}	9.00×10^{-05}	0	4.40×10^{-03}	1.40×10^{-04}	7.00×10^{-05}	0	3.00×10^{-05}	0	1.90×10^{-04}	3.00×10^{-05}	1.00×10^{-05}	0	0
Patterson Lake Eco VC	3.27×10^{-03}	9.00×10^{-05}	6.90×10^{-04}	2.00×10^{-05}	4.04×10^{-02}	1.11×10^{-03}	3.40×10^{-04}	2.00×10^{-05}	1.80×10^{-04}	1.00×10^{-05}	1.42×10^{-03}	1.20×10^{-04}	4.00×10^{-05}	1.00×10^{-05}	0
Forrest Lake	7.20×10^{-04}	3.00×10^{-05}	3.10×10^{-04}	1.00×10^{-05}	9.28×10^{-03}	4.00×10^{-04}	2.00×10^{-04}	1.00×10^{-05}	6.00×10^{-05}	0	6.40×10^{-04}	9.00×10^{-05}	3.00×10^{-05}	0	0
Forrest Lake North Eco VC	1.07×10^{-03}	5.00×10^{-05}	4.00×10^{-04}	2.00×10^{-05}	1.33×10^{-02}	6.50×10^{-04}	2.00×10^{-04}	1.00×10^{-05}	1.00×10^{-04}	1.00×10^{-05}	8.30×10^{-04}	1.30×10^{-04}	4.00×10^{-05}	1.00×10^{-05}	0
Beet Lake HH VC	5.10×10^{-04}	3.00×10^{-05}	3.70×10^{-04}	1.00×10^{-05}	6.56×10^{-03}	3.50×10^{-04}	1.70×10^{-04}	1.00×10^{-05}	4.00×10^{-05}	0	7.80×10^{-04}	7.00×10^{-05}	2.00×10^{-05}	0	0
Naomi Lake	2.20×10^{-04}	1.00×10^{-05}	8.00×10^{-05}	0	2.75×10^{-03}	1.10×10^{-04}	6.00×10^{-05}	0	3.00×10^{-05}	0	1.60×10^{-04}	2.00×10^{-05}	1.00×10^{-05}	0	0
Clearwater River	3.00×10^{-05}	0	2.00×10^{-05}	0	3.70×10^{-04}	2.00×10^{-05}	1.00×10^{-05}	0	1.00×10^{-05}	0	4.00×10^{-05}	0	0	0	0
Lloyd Lake HH VC	1.00×10^{-05}	0	1.00×10^{-05}	0	2.00×10^{-04}	1.00×10^{-05}	2.00×10^{-05}	0	2.00×10^{-05}	0	2.00×10^{-05}	0	0	0	0

Table 7A-116: Operations Metal Concentration Predictions (Manganese to Antimony) at Selected Receptors

Receptor Name	Concentration (µg/m³)														
	Manganese		Molybdenum		Sodium		Nickel in PM_{10}		Nickel in TSP		Lead			Antimony	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	30 d	Annual	24-Hour	Annual
Broach Lake	1.70×10^{-04}	1.00×10^{-05}	9.00×10^{-05}	0	2.31×10^{-03}	1.30×10^{-04}	5.00×10^{-05}	0	2.00×10^{-05}	0	2.00×10^{-04}	3.00×10^{-05}	1.00×10^{-05}	0	0
Patterson Lake	8.20×10^{-04}	3.00×10^{-05}	3.70×10^{-04}	1.00×10^{-05}	1.04×10^{-02}	4.40×10^{-04}	2.20×10^{-04}	1.00×10^{-05}	8.00×10^{-05}	0	7.70×10^{-04}	6.00×10^{-05}	2.00×10^{-05}	0	0
Patterson Lake	3.47×10^{-03}	9.00×10^{-05}	5.10×10^{-04}	2.00×10^{-05}	4.20×10^{-02}	1.19×10^{-03}	2.50×10^{-04}	2.00×10^{-05}	1.90×10^{-04}	1.00×10^{-05}	1.09×10^{-03}	1.00×10^{-04}	5.00×10^{-05}	1.00×10^{-05}	0
Lake H	8.20×10^{-04}	4.00×10^{-05}	2.50×10^{-04}	1.00×10^{-05}	1.15×10^{-02}	4.80×10^{-04}	1.70×10^{-04}	1.00×10^{-05}	6.00×10^{-05}	0	5.30×10^{-04}	6.00×10^{-05}	3.00×10^{-05}	0	0
Lake G	1.16×10^{-03}	6.00×10^{-05}	5.80×10^{-04}	2.00×10^{-05}	1.47×10^{-02}	8.10×10^{-04}	3.10×10^{-04}	1.00×10^{-05}	1.20×10^{-04}	1.00×10^{-05}	1.19×10^{-03}	8.00×10^{-05}	5.00×10^{-05}	1.00×10^{-05}	0
Beet Lake	3.80×10^{-04}	2.00×10^{-05}	2.00×10^{-04}	1.00×10^{-05}	4.90×10^{-03}	2.40×10^{-04}	1.10×10^{-04}	1.00×10^{-05}	4.00×10^{-05}	0	4.10×10^{-04}	6.00×10^{-05}	2.00×10^{-05}	0	0
Naomi Lake	2.10×10^{-04}	1.00×10^{-05}	1.40×10^{-04}	0	2.63×10^{-03}	1.10×10^{-04}	7.00×10^{-05}	0	3.00×10^{-05}	0	2.90×10^{-04}	2.00×10^{-05}	1.00×10^{-05}	0	0
Patterson Lake	7.60×10^{-04}	3.00×10^{-05}	2.20×10^{-04}	1.00×10^{-05}	9.71×10^{-03}	3.20×10^{-04}	1.50×10^{-04}	1.00×10^{-05}	5.00×10^{-05}	0	4.60×10^{-04}	8.00×10^{-05}	1.00×10^{-05}	0	0
Forrest Lake	2.30×10^{-04}	1.00×10^{-05}	1.00×10^{-04}	0	3.19×10^{-03}	1.50×10^{-04}	6.00×10^{-05}	0	4.00×10^{-05}	0	2.10×10^{-04}	2.00×10^{-05}	1.00×10^{-05}	0	0
Forrest Lake	8.50×10^{-04}	4.00×10^{-05}	3.60×10^{-04}	1.00×10^{-05}	1.19×10^{-02}	5.50×10^{-04}	1.70×10^{-04}	1.00×10^{-05}	1.10×10^{-04}	1.00×10^{-05}	7.50×10^{-04}	1.00×10^{-04}	3.00×10^{-05}	0	0
Unnamed Lake 2	2.00×10^{-04}	1.00×10^{-05}	1.10×10^{-04}	0	2.69×10^{-03}	1.60×10^{-04}	6.00×10^{-05}	0	2.00×10^{-05}	0	2.30×10^{-04}	3.00×10^{-05}	1.00×10^{-05}	0	0
Lake C	3.80×10^{-04}	1.00×10^{-05}	1.80×10^{-04}	1.00×10^{-05}	4.85×10^{-03}	1.90×10^{-04}	1.20×10^{-04}	0	4.00×10^{-05}	0	3.70×10^{-04}	3.00×10^{-05}	1.00×10^{-05}	0	0
Lake E	6.30×10^{-04}	3.00×10^{-05}	2.70×10^{-04}	1.00×10^{-05}	8.27×10^{-03}	3.60×10^{-04}	2.10×10^{-04}	1.00×10^{-05}	5.00×10^{-05}	0	5.70×10^{-04}	8.00×10^{-05}	2.00×10^{-05}	0	0
Unnamed Lake 1	1.30×10^{-04}	1.00×10^{-05}	8.00×10^{-05}	0	1.72×10^{-03}	9.00×10^{-05}	4.00×10^{-05}	0	2.00×10^{-05}	0	1.80×10^{-04}	2.00×10^{-05}	1.00×10^{-05}	0	0
REF01	4.60×10^{-04}	3.00×10^{-05}	2.80×10^{-04}	1.00×10^{-05}	6.44×10^{-03}	3.50×10^{-04}	1.30×10^{-04}	1.00×10^{-05}	5.00×10^{-05}	0	5.90×10^{-04}	7.00×10^{-05}	2.00×10^{-05}	0	0
REF02	3.70×10^{-04}	1.00×10^{-05}	6.00×10^{-05}	0	4.45×10^{-03}	7.00×10^{-05}	2.00×10^{-05}	0	2.00×10^{-05}	0	1.10×10^{-04}	1.00×10^{-05}	0	0	0
REF03	7.00×10^{-05}	0	2.00×10^{-05}	0	1.00×10^{-03}	4.00×10^{-05}	2.00×10^{-05}	0	1.00×10^{-05}	0	5.00×10^{-05}	1.00×10^{-05}	0	0	0
19REF04	1.80×10^{-04}	0	3.00×10^{-05}	0	2.21×10^{-03}	5.00×10^{-05}	3.00×10^{-05}	0	3.00×10^{-05}	0	7.00×10^{-05}	0	0	0	0
19REF05	5.00×10^{-05}	0	3.00×10^{-05}	0	6.20×10^{-04}	2.00×10^{-05}	2.00×10^{-05}	0	2.00×10^{-05}	0	6.00×10^{-05}	0	0	0	0
19REF06	2.90×10^{-04}	1.00×10^{-05}	1.50×10^{-04}	0	3.75×10^{-03}	1.30×10^{-04}	6.00×10^{-05}	0	3.00×10^{-05}	0	3.20×10^{-04}	2.00×10^{-05}	1.00×10^{-05}	0	0
19EXP02	2.54×10^{-02}	1.16×10^{-03}	5.46×10^{-03}	2.60×10^{-04}	3.06×10^{-01}	1.44×10^{-02}	2.65×10^{-03}	1.30×10^{-04}	1.57×10^{-03}	7.00×10^{-05}	1.12×10^{-02}	1.27×10^{-03}	5.60×10^{-04}	7.00×10^{-05}	0
19EXP01	3.15×10^{-02}	1.72×10^{-03}	7.42×10^{-03}	3.90×10^{-04}	3.80×10^{-01}	2.13×10^{-02}	3.04×10^{-03}	1.90×10^{-04}	1.89×10^{-03}	1.00×10^{-04}	1.53×10^{-02}	1.70×10^{-03}	8.20×10^{-04}	1.00×10^{-04}	1.00×10^{-05}
19EXP03	3.10×10^{-03}	1.70×10^{-04}	6.40×10^{-04}	5.00×10^{-05}	3.91×10^{-02}	2.24×10^{-03}	4.90×10^{-04}	4.00×10^{-05}	2.70×10^{-04}	2.00×10^{-05}	1.36×10^{-03}	2.50×10^{-04}	1.00×10^{-04}	1.00×10^{-05}	0
Preston Lake	4.00×10^{-05}	0	3.00×10^{-05}	0	5.00×10^{-04}	2.00×10^{-05}	2.00×10^{-05}	0	2.00×10^{-05}	0	5.00×10^{-05}	0	0	0	0
Wegner Lake	4.00×10^{-05}	0	1.00×10^{-05}	0	4.60×10^{-04}	2.00×10^{-05}	1.00×10^{-05}	0	1.00×10^{-05}	0	3.00×10^{-05}	0	0	0	0
Overall	2.13×10^{-02}	1.04×10^{-03}	5.36×10^{-03}	3.20×10^{-04}	2.57×10^{-01}	1.30×10^{-02}	2.52×10^{-03}	1.50×10^{-04}	1.48×10^{-03}	8.00×10^{-05}	1.10×10^{-02}	1.76×10^{-03}	6.70×10^{-04}	7.00×10^{-05}	0

VC = valued component; PM_{10} = particulate matter with a diameter of 10 microns or less; TSP = total suspended particulates; HH = human health.

Table 7A-117: Operations Metal Concentration Predictions (Selenium to Zinc) at Selected Receptors

Receptor Name	Concentration (µg/m³)													
	Selenium		Tin		Thorium		Uranium in PM_{10}		Uranium in TSP		Vanadium		Zinc	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	0	0	0	0	0	0	1.85×10^{-03}	8.00×10^{-05}	1.79×10^{-03}	7.00×10^{-05}	3.00×10^{-05}	0	1.00×10^{-05}	0
Broach Lake	1.00×10^{-05}	0	0	0	3.00×10^{-05}	0	1.45×10^{-02}	4.80×10^{-04}	8.23×10^{-03}	3.00×10^{-04}	2.60×10^{-04}	1.00×10^{-05}	5.00×10^{-05}	0
Camp Worker HH VC	8.00×10^{-05}	0	1.20×10^{-04}	0	4.00×10^{-04}	2.00×10^{-05}	2.30×10^{-01}	9.38×10^{-03}	1.74×10^{-01}	6.10×10^{-03}	3.88×10^{-03}	1.80×10^{-04}	6.40×10^{-04}	5.00×10^{-05}
Patterson Lake HH VC	0	0	0	0	1.00×10^{-05}	0	5.91×10^{-03}	2.10×10^{-04}	4.58×10^{-03}	1.00×10^{-04}	1.10×10^{-04}	0	2.00×10^{-05}	0
Patterson Lake Eco VC	2.00×10^{-05}	0	2.00×10^{-05}	0	1.10×10^{-04}	0	4.46×10^{-02}	1.34×10^{-03}	3.54×10^{-02}	7.50×10^{-04}	9.30×10^{-04}	3.00×10^{-05}	1.90×10^{-04}	1.00×10^{-05}
Forrest Lake	1.00×10^{-05}	0	1.00×10^{-05}	0	6.00×10^{-05}	0	2.07×10^{-02}	8.70×10^{-04}	1.15×10^{-02}	4.00×10^{-04}	4.30×10^{-04}	2.00×10^{-05}	8.00×10^{-05}	0
Forrest Lake North Eco VC	1.00×10^{-05}	0	1.00×10^{-05}	0	6.00×10^{-05}	0	2.65×10^{-02}	1.18×10^{-03}	1.96×10^{-02}	5.80×10^{-04}	4.70×10^{-04}	2.00×10^{-05}	1.00×10^{-04}	0
Beet Lake HH VC	1.00×10^{-05}	0	1.00×10^{-05}	0	6.00×10^{-05}	0	2.43×10^{-02}	7.90×10^{-04}	9.10×10^{-03}	3.20×10^{-04}	4.80×10^{-04}	2.00×10^{-05}	9.00×10^{-05}	0
Naomi Lake	0	0	0	0	2.00×10^{-05}	0	5.34×10^{-03}	2.20×10^{-04}	3.58×10^{-03}	1.30×10^{-04}	1.10×10^{-04}	0	3.00×10^{-05}	0
Clearwater River	0	0	0	0	0	0	1.29×10^{-03}	5.00×10^{-05}	1.28×10^{-03}	5.00×10^{-05}	2.00×10^{-05}	0	0	0
Lloyd Lake HH VC	0	0	0	0	0	0	8.90×10^{-04}	3.00×10^{-05}	8.80×10^{-04}	3.00×10^{-05}	1.00×10^{-05}	0	0	0
Broach Lake	0	0	0	0	2.00×10^{-05}	0	6.52×10^{-03}	2.10×10^{-04}	3.54×10^{-03}	1.10×10^{-04}	1.20×10^{-04}	0	2.00×10^{-05}	0
Patterson Lake	1.00×10^{-05}	0	1.00×10^{-05}	0	5.00×10^{-05}	0	2.54×10^{-02}	7.20×10^{-04}	1.37×10^{-02}	3.50×10^{-04}	4.30×10^{-04}	1.00×10^{-05}	8.00×10^{-05}	0
Patterson Lake	1.00×10^{-05}	0	2.00×10^{-05}	0	8.00×10^{-05}	0	3.29×10^{-02}	1.57×10^{-03}	2.76×10^{-02}	7.60×10^{-04}	6.30×10^{-04}	3.00×10^{-05}	1.70×10^{-04}	1.00×10^{-05}
Lake H	1.00×10^{-05}	0	0	0	6.00×10^{-05}	0	1.78×10^{-02}	9.20×10^{-04}	9.41×10^{-03}	3.40×10^{-04}	3.90×10^{-04}	2.00×10^{-05}	1.00×10^{-04}	0
Lake G	1.00×10^{-05}	0	1.00×10^{-05}	0	1.00×10^{-04}	0	3.60×10^{-02}	1.53×10^{-03}	2.39×10^{-02}	7.70×10^{-04}	7.60×10^{-04}	3.00×10^{-05}	1.30×10^{-04}	1.00×10^{-05}
Beet Lake	0	0	0	0	3.00×10^{-05}	0	1.31×10^{-02}	5.20×10^{-04}	7.24×10^{-03}	2.30×10^{-04}	2.60×10^{-04}	1.00×10^{-05}	5.00×10^{-05}	0
Naomi Lake	0	0	0	0	3.00×10^{-05}	0	9.58×10^{-03}	2.60×10^{-04}	3.53×10^{-03}	1.20×10^{-04}	1.90×10^{-04}	0	4.00×10^{-05}	0
Patterson Lake	1.00×10^{-05}	0	1.00×10^{-05}	0	3.00×10^{-05}	0	1.47×10^{-02}	4.80×10^{-04}	8.46×10^{-03}	1.70×10^{-04}	2.60×10^{-04}	1.00×10^{-05}	6.00×10^{-05}	0
Forrest Lake	0	0	0	0	2.00×10^{-05}	0	6.93×10^{-03}	2.50×10^{-04}	5.53×10^{-03}	1.30×10^{-04}	1.20×10^{-04}	0	3.00×10^{-05}	0
Forrest Lake	1.00×10^{-05}	0	1.00×10^{-05}	0	7.00×10^{-05}	0	2.38×10^{-02}	9.70×10^{-04}	1.48×10^{-02}	4.40×10^{-04}	4.70×10^{-04}	2.00×10^{-05}	1.00×10^{-04}	0
Unnamed Lake 2	0	0	0	0	2.00×10^{-05}	0	7.54×10^{-03}	3.40×10^{-04}	3.34×10^{-03}	1.50×10^{-04}	1.40×10^{-04}	1.00×10^{-05}	3.00×10^{-05}	0
Lake C	0	0	0	0	3.00×10^{-05}	0	1.19×10^{-02}	3.80×10^{-04}	8.73×10^{-03}	1.70×10^{-04}	2.50×10^{-04}	1.00×10^{-05}	5.00×10^{-05}	0
Lake E	1.00×10^{-05}	0	0	0	5.00×10^{-05}	0	1.84×10^{-02}	6.60×10^{-04}	8.39×10^{-03}	2.50×10^{-04}	3.90×10^{-04}	1.00×10^{-05}	8.00×10^{-05}	0
Unnamed Lake 1	0	0	0	0	1.00×10^{-05}	0	5.42×10^{-03}	2.10×10^{-04}	2.63×10^{-03}	1.20×10^{-04}	1.00×10^{-04}	0	2.00×10^{-05}	0
REF01	1.00×10^{-05}	0	0	0	5.00×10^{-05}	0	1.90×10^{-02}	6.50×10^{-04}	3.74×10^{-03}	2.60×10^{-04}	3.60×10^{-04}	1.00×10^{-05}	7.00×10^{-05}	0
REF02	0	0	0	0	1.00×10^{-05}	0	3.53×10^{-03}	1.20×10^{-04}	3.45×10^{-03}	1.10×10^{-04}	7.00×10^{-05}	0	1.00×10^{-05}	0
REF03	0	0	0	0	1.00×10^{-05}	0	1.62×10^{-03}	9.00×10^{-05}	1.43×10^{-03}	7.00×10^{-05}	3.00×10^{-05}	0	1.00×10^{-05}	0
19REF04	0	0	0	0	1.00×10^{-05}	0	2.88×10^{-03}	7.00×10^{-05}	2.81×10^{-03}	6.00×10^{-05}	4.00×10^{-05}	0	1.00×10^{-05}	0
19REF05	0	0	0	0	0	0	1.83×10^{-03}	6.00×10^{-05}	1.76×10^{-03}	5.00×10^{-05}	3.00×10^{-05}	0	0	0
19REF06	0	0	0	0	2.00×10^{-05}	0	1.02×10^{-02}	2.30×10^{-04}	4.65×10^{-03}	1.20×10^{-04}	1.80×10^{-04}	0	3.00×10^{-05}	0
19EXP02	1.30×10^{-04}	1.00×10^{-05}	1.40×10^{-04}	1.00×10^{-05}	8.30×10^{-04}	4.00×10^{-05}	3.46×10^{-01}	1.77×10^{-02}	2.40×10^{-01}	1.01×10^{-02}	7.16×10^{-03}	3.50×10^{-04}	8.80×10^{-04}	7.00×10^{-05}
19EXP01	1.70×10^{-04}	1.00×10^{-05}	1.80×10^{-04}	1.00×10^{-05}	9.00×10^{-04}	6.00×10^{-05}	4.76×10^{-01}	2.60×10^{-02}	3.89×10^{-01}	1.43×10^{-02}	8.81×10^{-03}	5.10×10^{-04}	1.12×10^{-03}	1.00×10^{-04}

Table 7A-117: Operations Metal Concentration Predictions (Selenium to Zinc) at Selected Receptors

Receptor Name	Concentration (µg/m³)													
	Selenium		Tin		Thorium		Uranium in PM_{10}		Uranium in TSP		Vanadium		Zinc	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
19EXP03	1.00×10^{-05}	0	2.00×10^{-05}	0	1.30×10^{-04}	1.00×10^{-05}	4.32×10^{-02}	3.22×10^{-03}	2.23×10^{-02}	1.54×10^{-03}	9.10×10^{-04}	7.00×10^{-05}	3.20×10^{-04}	2.00×10^{-05}
Preston Lake	0	0	0	0	0	0	1.94×10^{-03}	4.00×10^{-05}	1.93×10^{-03}	4.00×10^{-05}	3.00×10^{-05}	0	1.00×10^{-05}	0
Wegner Lake	0	0	0	0	0	0	1.05×10^{-03}	3.00×10^{-05}	9.10×10^{-04}	3.00×10^{-05}	2.00×10^{-05}	0	0	0
Overall	1.20×10^{-04}	1.00×10^{-05}	2.00×10^{-04}	1.00×10^{-05}	9.90×10^{-04}	5.00×10^{-05}	3.48×10^{-01}	2.10×10^{-02}	2.72×10^{-01}	1.17×10^{-02}	7.26×10^{-03}	4.20×10^{-04}	1.46×10^{-03}	8.00×10^{-05}

VC = valued component; PM_{10} = particulate matter with a diameter of 10 microns or less; TSP = total suspended particulates; HH = human heath.

Table 7A-118: Reasonably Foreseeable Development Case Metal Concentration Predictions (Silver to Cadmium) at Selected Receptors

Receptor Name	Concentration (µg/m³)													
	Silver		Arsenic		Barium		Beryllium		Bismuth		Calcium		Cadmium	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	0	0	0	0	2.64×10^{-04}	1.31×10^{-05}	0	0	0	0	2.28×10^{-03}	1.50×10^{-04}	1.12×10^{-05}	0
Broach Lake	0	0	2.03×10^{-05}	0	1.42×10^{-03}	6.60×10^{-05}	0	0	0	0	7.91×10^{-03}	6.28×10^{-04}	3.97×10^{-05}	0
Camp Worker HH VC	2.84×10^{-05}	0	3.72×10^{-04}	2.71×10^{-05}	1.66×10^{-02}	8.50×10^{-04}	2.81×10^{-05}	0	1.04×10^{-04}	0	2.32×10^{-01}	1.22×10^{-02}	4.57×10^{-04}	4.61×10^{-05}
Patterson Lake HH VC	0	0	3.45×10^{-05}	0	3.20×10^{-03}	1.21×10^{-04}	0	0	1.05×10^{-05}	0	1.89×10^{-02}	1.24×10^{-03}	3.87×10^{-05}	0
Patterson Lake Eco VC	0	0	7.30×10^{-05}	0	4.10×10^{-03}	1.88×10^{-04}	0	0	2.14×10^{-05}	0	4.70×10^{-02}	1.93×10^{-03}	5.42×10^{-05}	0
Forrest Lake	0	0	2.79×10^{-05}	0	2.02×10^{-03}	1.08×10^{-04}	0	0	0	0	1.18×10^{-02}	8.36×10^{-04}	5.21×10^{-05}	0
Forrest Lake North Eco VC	0	0	3.41×10^{-05}	0	2.52×10^{-03}	1.40×10^{-04}	0	0	1.25×10^{-05}	0	1.52×10^{-02}	1.13×10^{-03}	4.59×10^{-05}	0
Beet Lake HH VC	0	0	2.85×10^{-05}	0	2.57×10^{-03}	8.99×10^{-05}	0	0	1.29×10^{-05}	0	1.09×10^{-02}	6.61×10^{-04}	4.45×10^{-05}	0
Naomi Lake	0	0	1.28×10^{-05}	0	6.69×10^{-04}	2.91×10^{-05}	0	0	0	0	3.77×10^{-03}	2.43×10^{-04}	1.27×10^{-05}	0
Clearwater River	0	0	0	0	1.30×10^{-04}	0	0	0	0	0	1.45×10^{-03}	7.27×10^{-05}	0	0
Lloyd Lake HH VC	0	0	0	0	8.59×10^{-05}	0	0	0	0	0	9.15×10^{-04}	6.37×10^{-05}	0	0
Broach Lake	0	0	1.88×10^{-05}	0	8.14×10^{-04}	4.97×10^{-05}	0	0	0	0	1.02×10^{-02}	6.22×10^{-04}	2.79×10^{-05}	0
Patterson Lake	0	0	4.18×10^{-05}	0	2.93×10^{-03}	1.47×10^{-04}	0	0	1.23×10^{-05}	0	1.76×10^{-02}	1.32×10^{-03}	6.81×10^{-05}	0
Patterson Lake	0	0	6.97×10^{-05}	0	3.11×10^{-03}	1.83×10^{-04}	0	0	1.70×10^{-05}	0	4.41×10^{-02}	1.63×10^{-03}	4.82×10^{-05}	0
Lake H	0	0	3.12×10^{-05}	0	2.29×10^{-03}	1.03×10^{-04}	0	0	0	0	1.42×10^{-02}	7.58×10^{-04}	4.07×10^{-05}	0
Lake G	0	0	5.46×10^{-05}	0	3.44×10^{-03}	1.58×10^{-04}	0	0	1.81×10^{-05}	0	1.68×10^{-02}	1.25×10^{-03}	4.80×10^{-05}	0
Beet Lake	0	0	1.62×10^{-05}	0	1.22×10^{-03}	5.94×10^{-05}	0	0	0	0	6.03×10^{-03}	4.66×10^{-04}	2.21×10^{-05}	0
Naomi Lake	0	0	1.25×10^{-05}	0	9.39×10^{-04}	3.05×10^{-05}	0	0	0	0	3.70×10^{-03}	2.57×10^{-04}	1.72×10^{-05}	0
Patterson Lake	0	0	4.13×10^{-05}	0	2.22×10^{-03}	1.38×10^{-04}	0	0	0	0	1.86×10^{-02}	1.28×10^{-03}	6.57×10^{-05}	0
Forrest Lake	0	0	2.13×10^{-05}	0	2.15×10^{-03}	7.16×10^{-05}	0	0	0	0	1.27×10^{-02}	5.62×10^{-04}	1.73×10^{-05}	0
Forrest Lake	0	0	3.05×10^{-05}	0	2.31×10^{-03}	1.19×10^{-04}	0	0	1.10×10^{-05}	0	1.25×10^{-02}	9.83×10^{-04}	3.57×10^{-05}	0
Unnamed Lake 2	0	0	0	0	6.84×10^{-04}	3.93×10^{-05}	0	0	0	0	5.27×10^{-03}	3.10×10^{-04}	1.45×10^{-05}	0

Table 7A-118: Reasonably Foreseeable Development Case Metal Concentration Predictions (Silver to Cadmium) at Selected Receptors

Receptor Name	Concentration (µg/m^3)													
	Silver		Arsenic		Barium		Beryllium		Bismuth		Calcium		Cadmium	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Lake C	0	0	3.69×10^{-05}	0	2.13×10^{-03}	1.40×10^{-04}	0	0	1.03×10^{-05}	0	2.74×10^{-02}	1.74×10^{-03}	4.62×10^{-05}	0
Lake E	0	0	3.62×10^{-05}	0	2.45×10^{-03}	1.18×10^{-04}	0	0	0	0	1.47×10^{-02}	8.63×10^{-04}	4.31×10^{-05}	0
Unnamed Lake 1	0	0	0	0	5.29×10^{-04}	2.85×10^{-05}	0	0	0	0	3.65×10^{-03}	2.58×10^{-04}	0	0
REF01	0	0	2.01×10^{-05}	0	1.68×10^{-03}	8.32×10^{-05}	0	0	0	0	8.93×10^{-03}	6.50×10^{-04}	2.85×10^{-05}	0
REF02	0	0	0	0	3.56×10^{-04}	1.92×10^{-05}	0	0	0	0	4.86×10^{-03}	2.19×10^{-04}	1.22×10^{-05}	0
REF03	0	0	0	0	1.90×10^{-04}	1.17×10^{-05}	0	0	0	0	1.85×10^{-03}	1.19×10^{-04}	1.20×10^{-05}	0
19REF04	0	0	0	0	3.04×10^{-04}	1.79×10^{-05}	0	0	0	0	2.77×10^{-03}	1.99×10^{-04}	1.12×10^{-05}	0
19REF05	0	0	0	0	2.24×10^{-04}	1.12×10^{-05}	0	0	0	0	2.32×10^{-03}	1.30×10^{-04}	0	0
19REF06	0	0	1.72×10^{-05}	0	8.96×10^{-04}	6.26×10^{-05}	0	0	0	0	9.27×10^{-03}	6.66×10^{-04}	3.46×10^{-05}	0
19EXP02	4.45×10^{-05}	0	4.19×10^{-04}	2.81×10^{-05}	3.37×10^{-02}	1.60×10^{-03}	5.09×10^{-05}	0	1.64×10^{-04}	0	3.13×10^{-01}	1.76×10^{-02}	9.49×10^{-05}	0
19EXP01	6.06×10^{-05}	0	5.42×10^{-04}	4.11×10^{-05}	3.73×10^{-02}	2.32×10^{-03}	6.27×10^{-05}	0	2.23×10^{-04}	1.23×10^{-05}	3.85×10^{-01}	2.54×10^{-02}	7.87×10^{-05}	0
19EXP03	0	0	7.22×10^{-05}	0	5.21×10^{-03}	3.63×10^{-04}	0	0	2.05×10^{-05}	0	4.39×10^{-02}	3.03×10^{-03}	9.77×10^{-05}	0
Preston Lake	0	0	0	0	1.63×10^{-04}	0	0	0	0	0	9.35×10^{-04}	7.12×10^{-05}	0	0
Wegner Lake	0	0	0	0	2.00×10^{-04}	0	0	0	0	0	2.50×10^{-03}	9.84×10^{-05}	0	0
Overall	4.37×10^{-05}	0	6.05×10^{-04}	3.03×10^{-05}	3.26×10^{-02}	1.89×10^{-03}	5.35×10^{-05}	0	1.61×10^{-04}	1.01×10^{-05}	2.78×10^{-01}	1.55×10^{-02}	2.02×10^{-04}	1.07×10^{-05}

VC = valued component; HH = human health.

Table 7A-119: Reasonably Foreseeable Development Case Metal Concentration Predictions (Cobalt to Magnesium) at Selected Receptors

Receptor Name	Concentration (µg/m^3)													
	Cobalt		Chromium		Cesium		Copper		Iron		Mercury		Magnesium	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	0	0	1.43×10^{-04}	0	0	0	4.74×10^{-05}	0	7.80×10^{-03}	4.70×10^{-04}	0	0	6.98×10^{-03}	3.17×10^{-04}
Broach Lake	4.20×10^{-05}	0	5.23×10^{-04}	2.89×10^{-05}	0	0	3.06×10^{-04}	1.26×10^{-05}	3.94×10^{-02}	2.24×10^{-03}	2.88×10^{-05}	0	2.86×10^{-02}	1.57×10^{-03}
Camp Worker HH VC	5.10×10^{-04}	2.53×10^{-05}	1.29×10^{-02}	6.41×10^{-04}	0	0	4.61×10^{-03}	1.72×10^{-04}	6.51×10^{-01}	3.69×10^{-02}	3.46×10^{-04}	3.43×10^{-05}	2.90×10^{-01}	2.00×10^{-02}
Patterson Lake HH VC	9.06×10^{-05}	0	9.22×10^{-04}	5.71×10^{-05}	0	0	4.74×10^{-04}	2.00×10^{-05}	1.13×10^{-01}	4.63×10^{-03}	1.26×10^{-05}	0	8.99×10^{-02}	3.18×10^{-03}
Patterson Lake Eco VC	1.23×10^{-04}	0	2.49×10^{-03}	8.88×10^{-05}	0	0	9.21×10^{-04}	3.54×10^{-05}	1.54×10^{-01}	6.97×10^{-03}	4.15×10^{-05}	0	8.41×10^{-02}	4.78×10^{-03}
Forrest Lake	5.84×10^{-05}	0	5.08×10^{-04}	3.52×10^{-05}	0	0	4.20×10^{-04}	2.18×10^{-05}	4.81×10^{-02}	3.23×10^{-03}	3.92×10^{-05}	0	4.17×10^{-02}	2.43×10^{-03}
Forrest Lake North Eco VC	7.29×10^{-05}	0	8.03×10^{-04}	5.14×10^{-05}	0	0	5.22×10^{-04}	2.84×10^{-05}	6.91×10^{-02}	4.28×10^{-03}	3.43×10^{-05}	0	5.56×10^{-02}	3.13×10^{-03}
Beet Lake HH VC	7.46×10^{-05}	0	3.82×10^{-04}	2.68×10^{-05}	0	0	5.44×10^{-04}	1.82×10^{-05}	5.45×10^{-02}	2.57×10^{-03}	3.43×10^{-05}	0	5.33×10^{-02}	1.99×10^{-03}
Naomi Lake	1.91×10^{-05}	0	1.81×10^{-04}	0	0	0	1.23×10^{-04}	0	1.76×10^{-02}	8.93×10^{-04}	0	0	1.60×10^{-02}	6.69×10^{-04}
Clearwater River	0	0	6.14×10^{-05}	0	0	0	2.79×10^{-05}	0	5.15×10^{-03}	2.13×10^{-04}	0	0	3.25×10^{-03}	1.54×10^{-04}

Table 7A-119: Reasonably Foreseeable Development Case Metal Concentration Predictions (Cobalt to Magnesium) at Selected Receptors

Receptor Name	Concentration (µg/m³)													
	Cobalt		Chromium		Cesium		Copper		Iron		Mercury		Magnesium	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Lloyd Lake HH VC	0	0	4.65×10^{-05}	0	0	0	1.68×10^{-05}	0	2.82×10^{-03}	1.63×10^{-04}	0	0	2.14×10^{-03}	1.23×10^{-04}
Broach Lake	2.41×10^{-05}	0	6.65×10^{-04}	3.14×10^{-05}	0	0	1.80×10^{-04}	0	3.48×10^{-02}	2.09×10^{-03}	0	0	1.96×10^{-02}	1.22×10^{-03}
Patterson Lake	8.61×10^{-05}	0	1.15×10^{-03}	6.35×10^{-05}	0	0	5.50×10^{-04}	2.72×10^{-05}	6.60×10^{-02}	5.29×10^{-03}	2.81×10^{-05}	0	5.84×10^{-02}	3.63×10^{-03}
Patterson Lake	9.45×10^{-05}	0	1.80×10^{-03}	7.78×10^{-05}	0	0	7.65×10^{-04}	3.55×10^{-05}	1.47×10^{-01}	6.21×10^{-03}	3.65×10^{-05}	0	7.32×10^{-02}	4.28×10^{-03}
Lake H	6.72×10^{-05}	0	4.43×10^{-04}	3.13×10^{-05}	0	0	3.76×10^{-04}	2.08×10^{-05}	6.28×10^{-02}	3.02×10^{-03}	2.94×10^{-05}	0	4.77×10^{-02}	2.31×10^{-03}
Lake G	1.01×10^{-04}	0	9.35×10^{-04}	5.53×10^{-05}	0	0	7.63×10^{-04}	3.34×10^{-05}	7.06×10^{-02}	4.61×10^{-03}	3.63×10^{-05}	0	6.67×10^{-02}	3.39×10^{-03}
Beet Lake	3.57×10^{-05}	0	3.13×10^{-04}	1.96×10^{-05}	0	0	2.70×10^{-04}	1.21×10^{-05}	2.98×10^{-02}	1.74×10^{-03}	1.67×10^{-05}	0	2.43×10^{-02}	1.32×10^{-03}
Naomi Lake	2.73×10^{-05}	0	1.88×10^{-04}	1.01×10^{-05}	0	0	1.98×10^{-04}	0	2.24×10^{-02}	9.12×10^{-04}	1.16×10^{-05}	0	1.97×10^{-02}	6.83×10^{-04}
Patterson Lake	6.58×10^{-05}	0	9.61×10^{-04}	6.02×10^{-05}	0	0	3.83×10^{-04}	2.44×10^{-05}	8.62×10^{-02}	5.15×10^{-03}	3.14×10^{-05}	0	5.98×10^{-02}	3.52×10^{-03}
Forrest Lake	6.06×10^{-05}	0	4.58×10^{-04}	2.30×10^{-05}	0	0	3.14×10^{-04}	1.19×10^{-05}	7.05×10^{-02}	2.48×10^{-03}	0	0	6.03×10^{-02}	1.88×10^{-03}
Forrest Lake	6.52×10^{-05}	0	6.52×10^{-04}	4.24×10^{-05}	0	0	4.80×10^{-04}	2.35×10^{-05}	6.05×10^{-02}	3.76×10^{-03}	2.68×10^{-05}	0	4.62×10^{-02}	2.75×10^{-03}
Unnamed Lake 2	2.01×10^{-05}	0	1.99×10^{-04}	1.25×10^{-05}	0	0	1.56×10^{-04}	0	2.21×10^{-02}	1.17×10^{-03}	0	0	1.54×10^{-02}	8.81×10^{-04}
Lake C	6.81×10^{-05}	0	1.50×10^{-03}	8.89×10^{-05}	0	0	4.32×10^{-04}	2.45×10^{-05}	7.88×10^{-02}	6.20×10^{-03}	2.28×10^{-05}	0	4.97×10^{-02}	3.64×10^{-03}
Lake E	6.88×10^{-05}	0	6.44×10^{-04}	3.74×10^{-05}	0	0	3.87×10^{-04}	2.10×10^{-05}	8.39×10^{-02}	3.88×10^{-03}	3.29×10^{-05}	0	6.42×10^{-02}	2.96×10^{-03}
Unnamed Lake 1	1.53×10^{-05}	0	2.10×10^{-04}	1.07×10^{-05}	0	0	1.09×10^{-04}	0	1.62×10^{-02}	8.93×10^{-04}	0	0	1.36×10^{-02}	6.46×10^{-04}
REF01	4.86×10^{-05}	0	3.98×10^{-04}	2.77×10^{-05}	0	0	3.84×10^{-04}	1.62×10^{-05}	3.86×10^{-02}	2.59×10^{-03}	2.16×10^{-05}	0	3.41×10^{-02}	1.93×10^{-03}
REF02	1.05×10^{-05}	0	2.34×10^{-04}	0	0	0	8.78×10^{-05}	0	1.62×10^{-02}	6.57×10^{-04}	0	0	6.62×10^{-03}	4.51×10^{-04}
REF03	0	0	7.04×10^{-05}	0	0	0	3.63×10^{-05}	0	6.11×10^{-03}	3.76×10^{-04}	0	0	4.20×10^{-03}	2.72×10^{-04}
19REF04	0	0	1.65×10^{-04}	0	0	0	5.90×10^{-05}	0	1.12×10^{-02}	6.83×10^{-04}	0	0	7.14×10^{-03}	4.46×10^{-04}
19REF05	0	0	1.07×10^{-04}	0	0	0	4.88×10^{-05}	0	8.73×10^{-03}	4.16×10^{-04}	0	0	5.54×10^{-03}	2.80×10^{-04}
19REF06	2.63×10^{-05}	0	5.63×10^{-04}	3.00×10^{-05}	0	0	2.12×10^{-04}	1.14×10^{-05}	3.27×10^{-02}	2.34×10^{-03}	0	0	2.46×10^{-02}	1.55×10^{-03}
19EXP02	9.80×10^{-04}	4.76×10^{-05}	1.85×10^{-02}	8.91×10^{-04}	0	0	6.79×10^{-03}	3.67×10^{-04}	9.30×10^{-01}	5.67×10^{-02}	7.20×10^{-05}	0	4.58×10^{-01}	3.21×10^{-02}
19EXP01	1.15×10^{-03}	6.90×10^{-05}	2.50×10^{-02}	1.31×10^{-03}	0	0	9.14×10^{-03}	5.37×10^{-04}	$1.21 \times 10^{+00}$	8.29×10^{-02}	5.92×10^{-05}	0	5.42×10^{-01}	4.60×10^{-02}
19EXP03	1.47×10^{-04}	1.06×10^{-05}	2.22×10^{-03}	1.27×10^{-04}	0	0	8.63×10^{-04}	6.95×10^{-05}	1.65×10^{-01}	1.16×10^{-02}	6.87×10^{-05}	0	1.52×10^{-01}	8.49×10^{-03}
Preston Lake	0	0	5.65×10^{-05}	0	0	0	3.60×10^{-05}	0	3.54×10^{-03}	1.87×10^{-04}	0	0	3.24×10^{-03}	1.35×10^{-04}
Wegner Lake	0	0	1.55×10^{-04}	0	0	0	3.88×10^{-05}	0	8.45×10^{-03}	3.02×10^{-04}	0	0	4.96×10^{-03}	1.96×10^{-04}
Overall	9.67×10^{-04}	5.60×10^{-05}	1.71×10^{-02}	7.91×10^{-04}	1.89×10^{-05}	0	6.94×10^{-03}	4.38×10^{-04}	7.96×10^{-01}	5.64×10^{-02}	1.53×10^{-04}	0	6.48×10^{-01}	3.65×10^{-02}

VC = valued component; HH = human health.

Table 7A-120: Reasonably Foreseeable Development Case Metal Concentration Predictions (Manganese to Antimony) at Selected Receptors

Receptor Name	Concentration (µg/m³)														
	Manganese		Molybdenum		Sodium		Nickel in PM_{10}		Nickel in TSP		Lead			Antimony	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	30 d	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	1.84×10^{-04}	0	3.34×10^{-05}	0	2.25×10^{-03}	1.04×10^{-04}	3.59×10^{-05}	0	3.60×10^{-05}	0	7.01×10^{-05}	0	0	0	0
Broach Lake	6.64×10^{-04}	3.88×10^{-05}	2.30×10^{-04}	0	8.06×10^{-03}	4.97×10^{-04}	8.01×10^{-05}	0	1.18×10^{-04}	0	4.74×10^{-04}	5.09×10^{-05}	1.83×10^{-05}	0	0
Camp Worker HH VC	1.58×10^{-02}	7.69×10^{-04}	3.47×10^{-03}	1.23×10^{-04}	1.92×10^{-01}	9.57×10^{-03}	9.20×10^{-04}	1.19×10^{-04}	1.42×10^{-03}	1.76×10^{-04}	7.21×10^{-03}	7.46×10^{-04}	2.57×10^{-04}	4.48×10^{-05}	0
Patterson Lake HH VC	1.41×10^{-03}	8.11×10^{-05}	2.98×10^{-04}	1.32×10^{-05}	2.00×10^{-02}	1.04×10^{-03}	7.68×10^{-05}	0	2.77×10^{-04}	1.49×10^{-05}	6.27×10^{-04}	6.83×10^{-05}	2.67×10^{-05}	0	0
Patterson Lake Eco VC	3.27×10^{-03}	1.20×10^{-04}	6.95×10^{-04}	2.49×10^{-05}	4.05×10^{-02}	1.52×10^{-03}	1.81×10^{-04}	1.28×10^{-05}	3.41×10^{-04}	2.21×10^{-05}	1.45×10^{-03}	1.33×10^{-04}	5.21×10^{-05}	0	0
Forrest Lake	7.41×10^{-04}	4.98×10^{-05}	3.12×10^{-04}	1.56×10^{-05}	9.60×10^{-03}	6.48×10^{-04}	6.34×10^{-05}	0	2.02×10^{-04}	1.37×10^{-05}	6.54×10^{-04}	1.01×10^{-04}	3.26×10^{-05}	0	0
Forrest Lake North Eco VC	1.07×10^{-03}	7.10×10^{-05}	4.06×10^{-04}	2.03×10^{-05}	1.34×10^{-02}	9.13×10^{-04}	1.00×10^{-04}	0	1.99×10^{-04}	1.72×10^{-05}	8.39×10^{-04}	1.37×10^{-04}	4.25×10^{-05}	0	0
Beet Lake HH VC	5.41×10^{-04}	3.85×10^{-05}	4.03×10^{-04}	1.31×10^{-05}	7.66×10^{-03}	5.03×10^{-04}	4.42×10^{-05}	0	1.80×10^{-04}	1.08×10^{-05}	8.44×10^{-04}	7.32×10^{-05}	2.74×10^{-05}	0	0
Naomi Lake	2.50×10^{-04}	1.38×10^{-05}	8.66×10^{-05}	0	3.17×10^{-03}	1.79×10^{-04}	4.10×10^{-05}	0	7.79×10^{-05}	0	1.83×10^{-04}	2.16×10^{-05}	0	0	0
Clearwater River	9.36×10^{-05}	0	2.16×10^{-05}	0	1.20×10^{-03}	4.49×10^{-05}	1.72×10^{-05}	0	1.73×10^{-05}	0	4.41×10^{-05}	0	0	0	0
Lloyd Lake HH VC	5.83×10^{-05}	0	1.25×10^{-05}	0	7.18×10^{-04}	3.22×10^{-05}	1.97×10^{-05}	0	1.97×10^{-05}	0	2.57×10^{-05}	0	0	0	0
Broach Lake	8.35×10^{-04}	4.09×10^{-05}	1.32×10^{-04}	0	1.02×10^{-02}	5.14×10^{-04}	6.33×10^{-05}	0	1.19×10^{-04}	0	2.75×10^{-04}	3.47×10^{-05}	1.31×10^{-05}	0	0
Patterson Lake	1.41×10^{-03}	8.88×10^{-05}	3.76×10^{-04}	1.87×10^{-05}	1.73×10^{-02}	1.14×10^{-03}	9.48×10^{-05}	0	2.89×10^{-04}	1.87×10^{-05}	7.79×10^{-04}	1.04×10^{-04}	3.91×10^{-05}	0	0
Patterson Lake	3.60×10^{-03}	1.07×10^{-04}	5.52×10^{-04}	2.49×10^{-05}	4.39×10^{-02}	1.36×10^{-03}	1.95×10^{-04}	0	2.83×10^{-04}	1.98×10^{-05}	1.17×10^{-03}	1.07×10^{-04}	5.18×10^{-05}	0	0
Lake H	9.76×10^{-04}	4.58×10^{-05}	2.74×10^{-04}	1.49×10^{-05}	1.27×10^{-02}	5.98×10^{-04}	8.65×10^{-05}	0	2.10×10^{-04}	1.14×10^{-05}	5.71×10^{-04}	6.80×10^{-05}	3.10×10^{-05}	0	0
Lake G	1.18×10^{-03}	7.70×10^{-05}	5.76×10^{-04}	2.43×10^{-05}	1.50×10^{-02}	9.88×10^{-04}	1.34×10^{-04}	0	3.46×10^{-04}	1.74×10^{-05}	1.19×10^{-03}	8.55×10^{-05}	5.07×10^{-05}	0	0
Beet Lake	4.37×10^{-04}	2.73×10^{-05}	1.97×10^{-04}	0	5.51×10^{-03}	3.53×10^{-04}	4.17×10^{-05}	0	1.10×10^{-04}	0	4.11×10^{-04}	5.95×10^{-05}	1.82×10^{-05}	0	0
Naomi Lake	2.48×10^{-04}	1.42×10^{-05}	1.46×10^{-04}	0	3.51×10^{-03}	1.84×10^{-04}	2.77×10^{-05}	0	7.89×10^{-05}	0	3.06×10^{-04}	2.21×10^{-05}	0	0	0
Patterson Lake	1.44×10^{-03}	8.67×10^{-05}	2.39×10^{-04}	1.63×10^{-05}	1.85×10^{-02}	1.12×10^{-03}	6.88×10^{-05}	0	2.84×10^{-04}	1.73×10^{-05}	4.95×10^{-04}	8.80×10^{-05}	3.41×10^{-05}	0	0
Forrest Lake	8.32×10^{-04}	3.65×10^{-05}	1.98×10^{-04}	0	1.15×10^{-02}	4.81×10^{-04}	3.91×10^{-05}	0	1.84×10^{-04}	0	4.17×10^{-04}	5.16×10^{-05}	1.66×10^{-05}	0	0
Forrest Lake	9.07×10^{-04}	5.96×10^{-05}	3.56×10^{-04}	1.66×10^{-05}	1.19×10^{-02}	7.73×10^{-04}	1.07×10^{-04}	0	1.77×10^{-04}	1.52×10^{-05}	7.47×10^{-04}	1.07×10^{-04}	3.49×10^{-05}	0	0
Unnamed Lake 2	2.69×10^{-04}	1.82×10^{-05}	1.13×10^{-04}	0	3.79×10^{-03}	2.36×10^{-04}	3.78×10^{-05}	0	7.52×10^{-05}	0	2.37×10^{-04}	3.28×10^{-05}	1.18×10^{-05}	0	0
Lake C	1.92×10^{-03}	1.21×10^{-04}	3.25×10^{-04}	1.62×10^{-05}	2.35×10^{-02}	1.52×10^{-03}	1.42×10^{-04}	0	2.12×10^{-04}	1.83×10^{-05}	6.78×10^{-04}	7.53×10^{-05}	3.31×10^{-05}	0	0
Lake E	9.11×10^{-04}	5.72×10^{-05}	2.82×10^{-04}	1.43×10^{-05}	1.20×10^{-02}	7.53×10^{-04}	5.70×10^{-05}	0	2.43×10^{-04}	1.35×10^{-05}	5.90×10^{-04}	9.46×10^{-05}	3.01×10^{-05}	0	0
Unnamed Lake 1	2.78×10^{-04}	1.49×10^{-05}	8.51×10^{-05}	0	3.45×10^{-03}	1.92×10^{-04}	2.95×10^{-05}	0	5.25×10^{-05}	0	1.76×10^{-04}	2.71×10^{-05}	0	0	0
REF01	4.78×10^{-04}	4.01×10^{-05}	2.82×10^{-04}	1.15×10^{-05}	6.44×10^{-03}	5.23×10^{-04}	4.98×10^{-05}	0	1.29×10^{-04}	0	5.95×10^{-04}	7.66×10^{-05}	2.41×10^{-05}	0	0
REF02	3.95×10^{-04}	1.12×10^{-05}	6.07×10^{-05}	0	4.83×10^{-03}	1.43×10^{-04}	3.43×10^{-05}	0	3.62×10^{-05}	0	1.25×10^{-04}	1.17×10^{-05}	0	0	0
REF03	9.53×10^{-05}	0	2.70×10^{-05}	0	1.20×10^{-03}	7.83×10^{-05}	3.01×10^{-05}	0	3.03×10^{-05}	0	5.59×10^{-05}	0	0	0	0
19REF04	2.30×10^{-04}	1.21×10^{-05}	4.00×10^{-05}	0	2.87×10^{-03}	1.54×10^{-04}	3.64×10^{-05}	0	4.45×10^{-05}	0	8.33×10^{-05}	1.08×10^{-05}	0	0	0
19REF05	1.56×10^{-04}	0	3.66×10^{-05}	0	2.00×10^{-03}	9.15×10^{-05}	2.60×10^{-05}	0	2.75×10^{-05}	0	7.54×10^{-05}	0	0	0	0
19REF06	7.25×10^{-04}	4.10×10^{-05}	1.62×10^{-04}	0	8.93×10^{-03}	5.24×10^{-04}	5.43×10^{-05}	0	1.13×10^{-04}	0	3.40×10^{-04}	3.57×10^{-05}	1.61×10^{-05}	0	0
19EXP02	2.55×10^{-02}	1.18×10^{-03}	5.46×10^{-03}	2.69×10^{-04}	3.08×10^{-01}	1.46×10^{-02}	1.57×10^{-03}	7.19×10^{-05}	2.65×10^{-03}	1.36×10^{-04}	1.12×10^{-02}	1.28×10^{-03}	5.63×10^{-04}	7.07×10^{-05}	0
19EXP01	3.16×10^{-02}	1.73×10^{-03}	7.42×10^{-03}	3.95×10^{-04}	3.81×10^{-01}	2.15×10^{-02}	1.89×10^{-03}	9.85×10^{-05}	3.05×10^{-03}	1.95×10^{-04}	1.53×10^{-02}	1.70×10^{-03}	8.29×10^{-04}	9.67×10^{-05}	0

Table 7A-120: Reasonably Foreseeable Development Case Metal Concentration Predictions (Manganese to Antimony) at Selected Receptors

Receptor Name	Concentration (µg/m³)														
	Manganese		Molybdenum		Sodium		Nickel in PM_{10}		Nickel in TSP		Lead			Antimony	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	30 d	Annual	24-Hour	Annual
19EXP03	3.15×10^{-03}	1.86×10^{-04}	6.53×10^{-04}	4.89×10^{-05}	3.98×10^{-02}	2.40×10^{-03}	3.58×10^{-04}	2.01×10^{-05}	5.02×10^{-04}	3.85×10^{-05}	1.38×10^{-03}	2.57×10^{-04}	1.01×10^{-04}	0	0
Preston Lake	7.41×10^{-05}	0	2.68×10^{-05}	0	9.24×10^{-04}	3.94×10^{-05}	1.68×10^{-05}	0	1.69×10^{-05}	0	5.68×10^{-05}	0	0	0	0
Wegner Lake	2.04×10^{-04}	0	2.75×10^{-05}	0	2.52×10^{-03}	6.96×10^{-05}	2.92×10^{-05}	0	3.01×10^{-05}	0	4.37×10^{-05}	0	0	0	0
Overall	2.14×10^{-02}	1.06×10^{-03}	5.37×10^{-03}	3.25×10^{-04}	2.59×10^{-01}	1.32×10^{-02}	1.48×10^{-03}	7.88×10^{-05}	2.54×10^{-03}	1.52×10^{-04}	1.10×10^{-02}	1.77×10^{-03}	6.79×10^{-04}	6.99×10^{-05}	0

VC = valued component; PM_{10} = particulate matter with a diameter of 10 microns or less; TSP = total suspended particulates; HH = human health.

Table 7A-121: Reasonably Foreseeable Development Case Metal Concentration Predictions (Selenium to Zinc) at Selected Receptors

Receptor Name	Concentration (µg/m³)													
	Selenium		Tin		Thorium		Uranium in PM_{10}		Uranium in TSP		Vanadium		Zinc	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Hodge Lake Reference HH VC	0	0	0	0	0	0	1.79×10^{-03}	9.13×10^{-05}	1.92×10^{-03}	9.76×10^{-05}	5.53×10^{-05}	0	1.56×10^{-05}	0
Broach Lake	0	0	0	0	3.96×10^{-05}	0	8.66×10^{-03}	3.57×10^{-04}	1.45×10^{-02}	5.48×10^{-04}	3.13×10^{-04}	1.41×10^{-05}	6.45×10^{-05}	0
Camp Worker HH VC	7.98×10^{-05}	0	1.18×10^{-04}	0	4.04×10^{-04}	2.27×10^{-05}	1.75×10^{-01}	6.16×10^{-03}	2.30×10^{-01}	9.47×10^{-03}	3.88×10^{-03}	1.91×10^{-04}	6.41×10^{-04}	4.74×10^{-05}
Patterson Lake HH VC	0	0	0	0	9.78×10^{-05}	0	4.67×10^{-03}	2.82×10^{-04}	9.00×10^{-03}	5.27×10^{-04}	6.48×10^{-04}	2.58×10^{-05}	2.06×10^{-04}	0
Patterson Lake Eco VC	1.60×10^{-05}	0	2.30×10^{-05}	0	1.07×10^{-04}	0	3.54×10^{-02}	8.79×10^{-04}	4.51×10^{-02}	1.51×10^{-03}	9.35×10^{-04}	3.98×10^{-05}	1.90×10^{-04}	1.10×10^{-05}
Forrest Lake	0	0	0	0	5.86×10^{-05}	0	1.15×10^{-02}	4.43×10^{-04}	2.09×10^{-02}	9.82×10^{-04}	4.29×10^{-04}	2.33×10^{-05}	8.04×10^{-05}	0
Forrest Lake North Eco VC	0	0	0	0	7.28×10^{-05}	0	1.96×10^{-02}	6.26×10^{-04}	2.67×10^{-02}	1.29×10^{-03}	5.36×10^{-04}	3.03×10^{-05}	1.18×10^{-04}	0
Beet Lake HH VC	0	0	0	0	7.55×10^{-05}	0	9.10×10^{-03}	3.51×10^{-04}	2.52×10^{-02}	8.45×10^{-04}	5.51×10^{-04}	1.94×10^{-05}	1.08×10^{-04}	0
Naomi Lake	0	0	0	0	2.01×10^{-05}	0	3.94×10^{-03}	1.53×10^{-04}	5.79×10^{-03}	2.56×10^{-04}	1.39×10^{-04}	0	3.42×10^{-05}	0
Clearwater River	0	0	0	0	0	0	1.35×10^{-03}	6.03×10^{-05}	1.33×10^{-03}	6.36×10^{-05}	2.80×10^{-05}	0	0	Clearwater River
Lloyd Lake HH VC	0	0	0	0	0	0	9.42×10^{-04}	4.57×10^{-05}	9.45×10^{-04}	4.47×10^{-05}	1.90×10^{-05}	0	0	Lloyd Lake HH VC
Broach Lake	0	0	0	0	2.22×10^{-05}	0	3.55×10^{-03}	1.99×10^{-04}	7.70×10^{-03}	2.91×10^{-04}	1.81×10^{-04}	1.09×10^{-05}	5.29×10^{-05}	Broach Lake
Patterson Lake	0	0	0	0	8.38×10^{-05}	0	1.37×10^{-02}	4.59×10^{-04}	2.54×10^{-02}	9.81×10^{-04}	6.47×10^{-04}	3.12×10^{-05}	1.19×10^{-04}	Patterson Lake
Patterson Lake	1.28×10^{-05}	0	2.30×10^{-05}	0	7.72×10^{-05}	0	2.79×10^{-02}	7.95×10^{-04}	3.43×10^{-02}	1.64×10^{-03}	7.17×10^{-04}	3.95×10^{-05}	1.70×10^{-04}	Patterson Lake
Lake H	0	0	0	0	6.48×10^{-05}	0	9.41×10^{-03}	3.72×10^{-04}	1.78×10^{-02}	9.66×10^{-04}	5.00×10^{-04}	2.23×10^{-05}	1.01×10^{-04}	Lake H
Lake G	1.35×10^{-05}	0	1.04×10^{-05}	0	9.95×10^{-05}	0	2.44×10^{-02}	8.06×10^{-04}	3.60×10^{-02}	1.60×10^{-03}	7.57×10^{-04}	3.45×10^{-05}	1.31×10^{-04}	Lake G
Beet Lake	0	0	0	0	3.49×10^{-05}	0	7.25×10^{-03}	2.69×10^{-04}	1.31×10^{-02}	5.53×10^{-04}	2.66×10^{-04}	1.28×10^{-05}	5.34×10^{-05}	Beet Lake
Naomi Lake	0	0	0	0	2.72×10^{-05}	0	3.54×10^{-03}	1.51×10^{-04}	9.59×10^{-03}	2.82×10^{-04}	2.02×10^{-04}	0	4.07×10^{-05}	Naomi Lake
Patterson Lake	0	0	0	0	5.90×10^{-05}	0	8.49×10^{-03}	3.11×10^{-04}	1.48×10^{-02}	7.76×10^{-04}	4.90×10^{-04}	2.93×10^{-05}	1.35×10^{-04}	0
Forrest Lake	0	0	0	0	6.66×10^{-05}	0	5.57×10^{-03}	1.88×10^{-04}	7.27×10^{-03}	3.69×10^{-04}	4.32×10^{-04}	1.48×10^{-05}	1.37×10^{-04}	0
Forrest Lake	0	0	0	0	6.58×10^{-05}	0	1.48×10^{-02}	4.82×10^{-04}	2.38×10^{-02}	1.07×10^{-03}	4.74×10^{-04}	2.55×10^{-05}	9.54×10^{-05}	0

Table 7A-121: Reasonably Foreseeable Development Case Metal Concentration Predictions (Selenium to Zinc) at Selected Receptors

Receptor Name	Concentration (µg/m³)													
	Selenium		Tin		Thorium		Uranium in PM_{10}		Uranium in TSP		Vanadium		Zinc	
	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual	24-Hour	Annual
Unnamed Lake 2	0	0	0	0	1.94×10^{-05}	0	3.45×10^{-03}	1.78×10^{-04}	7.56×10^{-03}	3.71×10^{-04}	1.50×10^{-04}	0	3.59×10^{-05}	0
Lake C	0	0	1.01×10^{-05}	0	5.87×10^{-05}	0	9.10×10^{-03}	3.87×10^{-04}	1.20×10^{-02}	6.86×10^{-04}	6.28×10^{-04}	3.06×10^{-05}	1.12×10^{-04}	0
Lake E	0	0	0	0	7.61×10^{-05}	0	8.41×10^{-03}	3.03×10^{-04}	1.86×10^{-02}	8.22×10^{-04}	4.90×10^{-04}	2.48×10^{-05}	1.44×10^{-04}	0
Unnamed Lake 1	0	0	0	0	1.60×10^{-05}	0	2.88×10^{-03}	1.58×10^{-04}	5.43×10^{-03}	2.50×10^{-04}	1.12×10^{-04}	0	2.85×10^{-05}	0
REF01	0	0	0	0	4.90×10^{-05}	0	3.74×10^{-03}	3.04×10^{-04}	1.91×10^{-02}	7.23×10^{-04}	3.58×10^{-04}	1.78×10^{-05}	6.83×10^{-05}	0
REF02	0	0	0	0	1.00×10^{-05}	0	3.58×10^{-03}	1.45×10^{-04}	3.67×10^{-03}	1.55×10^{-04}	7.99×10^{-05}	0	1.65×10^{-05}	0
REF03	0	0	0	0	0	0	1.49×10^{-03}	8.53×10^{-05}	1.73×10^{-03}	1.04×10^{-04}	3.96×10^{-05}	0	0	0
19REF04	0	0	0	0	0	0	2.84×10^{-03}	8.87×10^{-05}	2.91×10^{-03}	1.12×10^{-04}	6.87×10^{-05}	0	1.70×10^{-05}	0
19REF05	0	0	0	0	0	0	2.02×10^{-03}	7.49×10^{-05}	2.09×10^{-03}	7.81×10^{-05}	4.90×10^{-05}	0	1.32×10^{-05}	0
19REF06	0	0	0	0	2.73×10^{-05}	0	5.93×10^{-03}	2.39×10^{-04}	1.05×10^{-02}	3.84×10^{-04}	1.96×10^{-04}	1.34×10^{-05}	5.57×10^{-05}	0
19EXP02	1.26×10^{-04}	0	1.45×10^{-04}	0	8.31×10^{-04}	4.30×10^{-05}	2.40×10^{-01}	1.01×10^{-02}	3.46×10^{-01}	1.79×10^{-02}	7.16×10^{-03}	3.59×10^{-04}	8.77×10^{-04}	7.11×10^{-05}
19EXP01	1.70×10^{-04}	0	1.80×10^{-04}	1.25×10^{-05}	9.03×10^{-04}	6.19×10^{-05}	3.89×10^{-01}	1.44×10^{-02}	4.76×10^{-01}	2.61×10^{-02}	8.81×10^{-03}	5.20×10^{-04}	1.12×10^{-03}	1.02×10^{-04}
19EXP03	1.52×10^{-05}	0	1.79×10^{-05}	0	1.67×10^{-04}	1.04×10^{-05}	2.23×10^{-02}	1.61×10^{-03}	4.35×10^{-02}	3.29×10^{-03}	1.08×10^{-03}	7.82×10^{-05}	3.28×10^{-04}	1.88×10^{-05}
Preston Lake	0	0	0	0	0	0	1.97×10^{-03}	5.41×10^{-05}	1.97×10^{-03}	5.52×10^{-05}	3.49×10^{-05}	0	0	0
Wegner Lake	0	0	0	0	0	0	1.06×10^{-03}	4.80×10^{-05}	1.37×10^{-03}	4.70×10^{-05}	4.24×10^{-05}	0	1.13×10^{-05}	0
Overall	1.23×10^{-04}	0	2.00×10^{-04}	0	9.99×10^{-04}	5.13×10^{-05}	2.72×10^{-01}	1.18×10^{-02}	3.48×10^{-01}	2.11×10^{-02}	7.26×10^{-03}	4.22×10^{-04}	1.56×10^{-03}	7.91×10^{-05}

VC = valued component; PM_{10} = particulate matter with a diameter of 10 microns or less; TSP = total suspended particulates; HH = human health.

Table 7A-122: Operations Metal Deposition Predictions (Silver to Magnesium) at Selected Receptors

Receptor Name	Deposition													
	Silver	Arsenic	Barium	Beryllium	Bismuth	Calcium	Cadmium	Cobalt	Chromium	Cesium	Copper	Iron	Mercury	Magnesium
	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual
	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
Hodge Lake Reference HH VC	0	0	1.00×10^{-04}	0	0	5.00×10^{-04}	0	0	0	0	0	2.20×10^{-03}	0	1.60×10^{-03}
Broach Lake	0	0	5.00×10^{-04}	0	0	3.30×10^{-03}	0	0	2.00×10^{-04}	0	1.00×10^{-04}	1.67×10^{-02}	0	1.22×10^{-02}
Camp Worker HH VC	0	5.00×10^{-04}	1.32×10^{-02}	0	1.00×10^{-04}	1.27×10^{-01}	1.20×10^{-03}	4.00×10^{-04}	8.70×10^{-03}	0	2.30×10^{-03}	5.74×10^{-01}	2.00×10^{-04}	3.55×10^{-01}
Patterson Lake HH VC	0	0	2.00×10^{-04}	0	0	1.20×10^{-03}	0	0	1.00×10^{-04}	0	0	5.40×10^{-03}	0	3.70×10^{-03}
Patterson Lake Eco VC	0	0	1.40×10^{-03}	0	0	1.11×10^{-02}	0	0	7.00×10^{-04}	0	3.00×10^{-04}	4.98×10^{-02}	0	3.24×10^{-02}
Forrest Lake	0	0	9.00×10^{-04}	0	0	4.80×10^{-03}	0	0	3.00×10^{-04}	0	2.00×10^{-04}	2.52×10^{-02}	0	1.91×10^{-02}
Forrest Lake North Eco VC	0	0	1.40×10^{-03}	0	0	8.70×10^{-03}	0	0	5.00×10^{-04}	0	3.00×10^{-04}	4.35×10^{-02}	0	3.15×10^{-02}
Beet Lake HH VC	0	0	1.10×10^{-03}	0	0	5.00×10^{-03}	0	0	3.00×10^{-04}	0	2.00×10^{-04}	2.85×10^{-02}	0	2.33×10^{-02}

Table 7A-122: Operations Metal Deposition Predictions (Silver to Magnesium) at Selected Receptors

Receptor Name	Deposition													
	Silver	Arsenic	Barium	Beryllium	Bismuth	Calcium	Cadmium	Cobalt	Chromium	Cesium	Copper	Iron	Mercury	Magnesium
	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual
	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
Naomi Lake	0	0	2.00×10^{-04}	0	0	1.20×10^{-03}	0	0	1.00×10^{-04}	0	0	5.90×10^{-03}	0	4.30×10^{-03}
Clearwater River	0	0	0	0	0	3.00×10^{-04}	0	0	0	0	0	1.20×10^{-03}	0	8.00×10^{-04}
Lloyd Lake HH VC	0	0	0	0	0	1.00×10^{-04}	0	0	0	0	0	4.00×10^{-04}	0	3.00×10^{-04}
Broach Lake	0	0	2.00×10^{-04}	0	0	1.50×10^{-03}	0	0	1.00×10^{-04}	0	0	7.80×10^{-03}	0	5.80×10^{-03}
Patterson Lake	0	0	9.00×10^{-04}	0	0	5.50×10^{-03}	0	0	3.00×10^{-04}	0	2.00×10^{-04}	2.86×10^{-02}	0	2.10×10^{-02}
Patterson Lake	0	0	1.70×10^{-03}	0	0	1.13×10^{-02}	0	1.00×10^{-04}	6.00×10^{-04}	0	3.00×10^{-04}	5.54×10^{-02}	0	3.92×10^{-02}
Lake H	0	0	9.00×10^{-04}	0	0	4.80×10^{-03}	0	0	3.00×10^{-04}	0	2.00×10^{-04}	2.59×10^{-02}	0	2.02×10^{-02}
Lake G	0	0	2.10×10^{-03}	0	0	1.17×10^{-02}	0	1.00×10^{-04}	6.00×10^{-04}	0	4.00×10^{-04}	6.31×10^{-02}	0	4.82×10^{-02}
Beet Lake	0	0	6.00×10^{-04}	0	0	3.10×10^{-03}	0	0	2.00×10^{-04}	0	1.00×10^{-04}	1.74×10^{-02}	0	1.38×10^{-02}
Naomi Lake	0	0	2.00×10^{-04}	0	0	1.20×10^{-03}	0	0	1.00×10^{-04}	0	0	5.90×10^{-03}	0	4.30×10^{-03}
Patterson Lake	0	0	4.00×10^{-04}	0	0	3.00×10^{-03}	0	0	2.00×10^{-04}	0	1.00×10^{-04}	1.43×10^{-02}	0	1.00×10^{-02}
Forrest Lake	0	0	2.00×10^{-04}	0	0	1.20×10^{-03}	0	0	1.00×10^{-04}	0	0	6.00×10^{-03}	0	4.30×10^{-03}
Forrest Lake	0	0	1.50×10^{-03}	0	0	8.50×10^{-03}	0	0	5.00×10^{-04}	0	3.00×10^{-04}	4.37×10^{-02}	0	3.25×10^{-02}
Unnamed Lake 2	0	0	3.00×10^{-04}	0	0	1.50×10^{-03}	0	0	1.00×10^{-04}	0	1.00×10^{-04}	8.30×10^{-03}	0	6.40×10^{-03}
Lake C	0	0	3.00×10^{-04}	0	0	2.00×10^{-03}	0	0	1.00×10^{-04}	0	1.00×10^{-04}	1.06×10^{-02}	0	7.70×10^{-03}
Lake E	0	0	5.00×10^{-04}	0	0	2.90×10^{-03}	0	0	2.00×10^{-04}	0	1.00×10^{-04}	1.44×10^{-02}	0	1.04×10^{-02}
Unnamed Lake 1	0	0	2.00×10^{-04}	0	0	1.30×10^{-03}	0	0	1.00×10^{-04}	0	0	6.60×10^{-03}	0	4.80×10^{-03}
REF01	0	0	1.00×10^{-03}	0	0	4.70×10^{-03}	0	0	2.00×10^{-04}	0	2.00×10^{-04}	2.73×10^{-02}	0	2.24×10^{-02}
REF02	0	0	1.00×10^{-04}	0	0	6.00×10^{-04}	0	0	0	0	0	3.00×10^{-03}	0	2.10×10^{-03}
REF03	0	0	1.00×10^{-04}	0	0	4.00×10^{-04}	0	0	0	0	0	1.80×10^{-03}	0	1.20×10^{-03}
19REF04	0	0	0	0	0	3.00×10^{-04}	0	0	0	0	0	1.50×10^{-03}	0	9.00×10^{-04}
19REF05	0	0	0	0	0	2.00×10^{-04}	0	0	0	0	0	9.00×10^{-04}	0	5.00×10^{-04}
19REF06	0	0	2.00×10^{-04}	0	0	1.30×10^{-03}	0	0	1.00×10^{-04}	0	0	6.80×10^{-03}	0	5.00×10^{-03}
19EXP02	1.00×10^{-04}	8.00×10^{-04}	6.29×10^{-02}	1.00×10^{-04}	3.00×10^{-04}	3.41×10^{-01}	1.00×10^{-04}	1.80×10^{-03}	1.77×10^{-02}	0	1.31×10^{-02}	$1.78 \times 10^{+00}$	0	$1.36 \times 10^{+00}$
19EXP01	1.00×10^{-04}	1.30×10^{-03}	9.92×10^{-02}	2.00×10^{-04}	5.00×10^{-04}	5.27×10^{-01}	1.00×10^{-04}	2.90×10^{-03}	2.69×10^{-02}	1.00×10^{-04}	2.07×10^{-02}	$2.79 \times 10^{+00}$	0	$2.15 \times 10^{+00}$
19EXP03	0	1.00×10^{-04}	6.10×10^{-03}	0	0	3.80×10^{-02}	0	2.00×10^{-04}	2.00×10^{-03}	0	1.20×10^{-03}	1.95×10^{-01}	0	1.42×10^{-01}
Preston Lake	0	0	0	0	0	1.00×10^{-04}	0	0	0	0	0	6.00×10^{-04}	0	4.00×10^{-04}
Wegner Lake	0	0	0	0	0	1.00×10^{-04}	0	0	0	0	0	5.00×10^{-04}	0	3.00×10^{-04}
Fenceline	1.00×10^{-04}	8.00×10^{-04}	6.60×10^{-02}	1.00×10^{-04}	3.00×10^{-04}	3.23×10^{-01}	2.00×10^{-04}	1.90×10^{-03}	1.57×10^{-02}	0	1.34×10^{-02}	$1.82 \times 10^{+00}$	0	$1.46 \times 10^{+00}$
MPOI	1.00×10^{-04}	8.00×10^{-04}	6.60×10^{-02}	1.00×10^{-04}	3.00×10^{-04}	3.23×10^{-01}	2.00×10^{-04}	1.90×10^{-03}	1.57×10^{-02}	0	1.34×10^{-02}	$1.82 \times 10^{+00}$	0	$1.46 \times 10^{+00}$

Note: Where values are shown as zero (0), assume it is less than 1×10^{-04}.
VC = valued component; HH = human health.

Table 7A-123: Operations Metal Deposition Predictions (Manganese to Zinc) at Selected Receptors

Receptor Name	Deposition														
	Manganese	Molybdenum	Sodium	Nickel in TSP	Nickel in PM_{10}	Lead		Antimony	Selenium	Tin	Thorium	Uranium in TSP	Uranium in PM_{10}	Vanadium	Zinc
	Annual	Annual	Annual	Annual	Annual	Annual	Monthly	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual
	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
Hodge Lake Reference HH VC	0	0	5.00×10^{-04}	0	0	0	0	0	0	0	0	6.00×10^{-04}	2.00×10^{-04}	0	0
Broach Lake	3.00×10^{-04}	1.00×10^{-04}	3.50×10^{-03}	1.00×10^{-04}	0	2.00×10^{-04}	0	0	0	0	0	5.30×10^{-03}	1.00×10^{-03}	1.00×10^{-04}	0
Camp Worker HH VC	1.06×10^{-02}	1.60×10^{-03}	1.34×10^{-01}	3.60×10^{-03}	5.00×10^{-04}	3.40×10^{-03}	7.00×10^{-04}	0	0	1.00×10^{-04}	4.00×10^{-04}	1.42×10^{-01}	1.92×10^{-02}	2.80×10^{-03}	8.00×10^{-04}
Patterson Lake HH VC	1.00×10^{-04}	0	1.20×10^{-03}	0	0	1.00×10^{-04}	0	0	0	0	0	1.70×10^{-03}	2.00×10^{-04}	0	0
Patterson Lake Eco VC	9.00×10^{-04}	2.00×10^{-04}	1.16×10^{-02}	2.00×10^{-04}	0	4.00×10^{-04}	1.00×10^{-04}	0	0	0	0	1.37×10^{-02}	1.20×10^{-03}	3.00×10^{-04}	1.00×10^{-04}
Forrest Lake	4.00×10^{-04}	1.00×10^{-04}	5.00×10^{-03}	1.00×10^{-04}	0	3.00×10^{-04}	1.00×10^{-04}	0	0	0	0	8.90×10^{-03}	1.00×10^{-03}	2.00×10^{-04}	0
Forrest Lake North Eco VC	7.00×10^{-04}	2.00×10^{-04}	9.10×10^{-03}	2.00×10^{-04}	0	4.00×10^{-04}	1.00×10^{-04}	0	0	0	0	1.43×10^{-02}	1.70×10^{-03}	3.00×10^{-04}	1.00×10^{-04}
Beet Lake HH VC	4.00×10^{-04}	2.00×10^{-04}	5.20×10^{-03}	1.00×10^{-04}	0	3.00×10^{-04}	1.00×10^{-04}	0	0	0	0	1.06×10^{-02}	1.30×10^{-03}	2.00×10^{-04}	0
Naomi Lake	1.00×10^{-04}	0	1.20×10^{-03}	0	0	1.00×10^{-04}	0	0	0	0	0	1.80×10^{-03}	3.00×10^{-04}	0	0
Clearwater River	0	0	3.00×10^{-04}	0	0	0	0	0	0	0	0	3.00×10^{-04}	1.00×10^{-04}	0	0
Lloyd Lake HH VC	0	0	1.00×10^{-04}	0	0	0	0	0	0	0	0	1.00×10^{-04}	0	0	0
Broach Lake	1.00×10^{-04}	0	1.60×10^{-03}	0	0	1.00×10^{-04}	0	0	0	0	0	2.00×10^{-03}	4.00×10^{-04}	0	0
Patterson Lake	4.00×10^{-04}	1.00×10^{-04}	5.80×10^{-03}	1.00×10^{-04}	0	3.00×10^{-04}	1.00×10^{-04}	0	0	0	0	8.90×10^{-03}	7.00×10^{-04}	2.00×10^{-04}	0
Patterson Lake	9.00×10^{-04}	2.00×10^{-04}	1.18×10^{-02}	2.00×10^{-04}	0	5.00×10^{-04}	1.00×10^{-04}	0	0	0	0	1.65×10^{-02}	1.20×10^{-03}	4.00×10^{-04}	1.00×10^{-04}
Lake H	4.00×10^{-04}	1.00×10^{-04}	5.00×10^{-03}	1.00×10^{-04}	0	3.00×10^{-04}	1.00×10^{-04}	0	0	0	0	8.60×10^{-03}	6.00×10^{-04}	2.00×10^{-04}	0
Lake G	9.00×10^{-04}	3.00×10^{-04}	1.24×10^{-02}	2.00×10^{-04}	0	6.00×10^{-04}	1.00×10^{-04}	0	0	0	1.00×10^{-04}	1.89×10^{-02}	1.90×10^{-03}	4.00×10^{-04}	1.00×10^{-04}
Beet Lake	3.00×10^{-04}	1.00×10^{-04}	3.30×10^{-03}	1.00×10^{-04}	0	2.00×10^{-04}	0	0	0	0	0	6.00×10^{-03}	7.00×10^{-04}	1.00×10^{-04}	0
Naomi Lake	1.00×10^{-04}	0	1.20×10^{-03}	0	0	1.00×10^{-04}	0	0	0	0	0	1.80×10^{-03}	3.00×10^{-04}	0	0
Patterson Lake	2.00×10^{-04}	1.00×10^{-04}	3.10×10^{-03}	1.00×10^{-04}	0	1.00×10^{-04}	0	0	0	0	0	4.60×10^{-03}	3.00×10^{-04}	1.00×10^{-04}	0
Forrest Lake	1.00×10^{-04}	0	1.30×10^{-03}	0	0	1.00×10^{-04}	0	0	0	0	0	1.90×10^{-03}	2.00×10^{-04}	0	0
Forrest Lake	7.00×10^{-04}	2.00×10^{-04}	8.90×10^{-03}	2.00×10^{-04}	0	5.00×10^{-04}	1.00×10^{-04}	0	0	0	0	1.51×10^{-02}	2.00×10^{-03}	3.00×10^{-04}	1.00×10^{-04}
Unnamed Lake 2	1.00×10^{-04}	0	1.60×10^{-03}	0	0	1.00×10^{-04}	0	0	0	0	0	2.70×10^{-03}	2.00×10^{-04}	1.00×10^{-04}	0
Lake C	2.00×10^{-04}	0	2.20×10^{-03}	0	0	1.00×10^{-04}	0	0	0	0	0	2.90×10^{-03}	3.00×10^{-04}	1.00×10^{-04}	0
Lake E	2.00×10^{-04}	1.00×10^{-04}	3.00×10^{-03}	1.00×10^{-04}	0	1.00×10^{-04}	0	0	0	0	0	4.60×10^{-03}	3.00×10^{-04}	1.00×10^{-04}	0
Unnamed Lake 1	1.00×10^{-04}	0	1.40×10^{-03}	0	0	1.00×10^{-04}	0	0	0	0	0	2.20×10^{-03}	5.00×10^{-04}	0	0
REF01	4.00×10^{-04}	1.00×10^{-04}	5.00×10^{-03}	1.00×10^{-04}	0	3.00×10^{-04}	1.00×10^{-04}	0	0	0	0	9.60×10^{-03}	1.20×10^{-03}	2.00×10^{-04}	0
REF02	0	0	6.00×10^{-04}	0	0	0	0	0	0	0	0	8.00×10^{-04}	3.00×10^{-04}	0	0
REF03	0	0	4.00×10^{-04}	0	0	0	0	0	0	0	0	5.00×10^{-04}	1.00×10^{-04}	0	0
19REF04	0	0	3.00×10^{-04}	0	0	0	0	0	0	0	0	3.00×10^{-04}	1.00×10^{-04}	0	0
19REF05	0	0	2.00×10^{-04}	0	0	0	0	0	0	0	0	2.00×10^{-04}	1.00×10^{-04}	0	0
19REF06	1.00×10^{-04}	0	1.40×10^{-03}	0	0	0	0	0	0	0	0	1.50×10^{-03}	3.00×10^{-04}	0	0

Table 7A-123: Operations Metal Deposition Predictions (Manganese to Zinc) at Selected Receptors

Receptor Name	Deposition														
	Manganese	Molybdenum	Sodium	Nickel in TSP	Nickel in PM_{10}	Lead		Antimony	Selenium	Tin	Thorium	Uranium in TSP	Uranium in PM_{10}	Vanadium	Zinc
	Annual	Annual	Annual	Annual	Annual	Annual	Monthly	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual
	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
19EXP02	2.73×10^{-02}	9.50×10^{-03}	3.55×10^{-01}	4.80×10^{-03}	7.00×10^{-04}	2.00×10^{-02}	3.00×10^{-03}	1.00×10^{-04}	2.00×10^{-04}	2.00×10^{-04}	1.80×10^{-03}	6.27×10^{-01}	9.21×10^{-02}	1.36×10^{-02}	2.90×10^{-03}
19EXP01	4.20×10^{-02}	1.50×10^{-02}	5.49×10^{-01}	7.50×10^{-03}	1.10×10^{-03}	3.16×10^{-02}	4.90×10^{-03}	2.00×10^{-04}	4.00×10^{-04}	4.00×10^{-04}	2.80×10^{-03}	9.80×10^{-01}	1.43×10^{-01}	2.13×10^{-02}	4.60×10^{-03}
19EXP03	3.10×10^{-03}	8.00×10^{-04}	4.00×10^{-02}	5.00×10^{-04}	1.00×10^{-04}	1.70×10^{-03}	3.00×10^{-04}	0	0	0	2.00×10^{-04}	5.41×10^{-02}	5.50×10^{-03}	1.30×10^{-03}	3.00×10^{-04}
Preston Lake	0	0	1.00×10^{-04}	0	0	0	0	0	0	0	0	2.00×10^{-04}	1.00×10^{-04}	0	0
Wegner Lake	0	0	1.00×10^{-04}	0	0	0	0	0	0	0	0	1.00×10^{-04}	0	0	0
Fenceline	2.57×10^{-02}	9.60×10^{-03}	3.40×10^{-01}	4.90×10^{-03}	6.00×10^{-04}	2.03×10^{-02}	2.90×10^{-03}	1.00×10^{-04}	2.00×10^{-04}	2.00×10^{-04}	1.90×10^{-03}	6.23×10^{-01}	7.58×10^{-02}	1.41×10^{-02}	3.10×10^{-03}
MPOI	2.57×10^{-02}	9.60×10^{-03}	3.40×10^{-01}	4.90×10^{-03}	6.00×10^{-04}	2.03×10^{-02}	2.90×10^{-03}	1.00×10^{-04}	2.00×10^{-04}	2.00×10^{-04}	1.90×10^{-03}	6.23×10^{-01}	7.58×10^{-02}	1.41×10^{-02}	3.10×10^{-03}

Note: Where values are shown as zero (0), assume it is less than 1×10^{-04}.
VC = valued component; PM_{10} = particulate matter with a diameter of 10 microns or less; TSP = total suspended particulates; HH = human health.

Table 7A-124: Reasonably Foreseeable Development Case Metal Deposition Predictions (Silver to Magnesium) at Selected Receptors

Receptor Name	Deposition													
	Silver	Arsenic	Barium	Beryllium	Bismuth	Calcium	Cadmium	Cobalt	Chromium	Cesium	Copper	Iron	Mercury	Magnesium
	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual
	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
Hodge Lake Reference HH VC	0	0	1.41×10^{-04}	0	0	1.02×10^{-03}	0	0	0	0	0	5.08×10^{-03}	0	3.61×10^{-03}
Broach Lake	0	0	7.76×10^{-04}	0	0	4.72×10^{-03}	0	0	2.49×10^{-04}	0	1.40×10^{-04}	2.53×10^{-02}	0	1.91×10^{-02}
Camp Worker HH VC	0	5.12×10^{-04}	1.34×10^{-02}	0	0	1.28×10^{-01}	1.16×10^{-03}	3.88×10^{-04}	8.77×10^{-03}	0	2.36×10^{-03}	5.82×10^{-01}	8.68×10^{-04}	3.61×10^{-01}
Patterson Lake HH VC	0	0	3.70×10^{-03}	0	0	2.25×10^{-02}	0	1.05×10^{-04}	1.06×10^{-03}	0	5.65×10^{-04}	1.32×10^{-01}	0	1.02×10^{-01}
Patterson Lake Eco VC	0	0	1.82×10^{-03}	0	0	1.38×10^{-02}	0	0	8.43×10^{-04}	0	3.42×10^{-04}	6.49×10^{-02}	0	4.40×10^{-02}
Forrest Lake	0	0	1.30×10^{-03}	0	0	7.12×10^{-03}	0	0	3.77×10^{-04}	0	2.42×10^{-04}	3.98×10^{-02}	0	3.11×10^{-02}
Forrest Lake North Eco VC	0	0	1.80×10^{-03}	0	0	1.08×10^{-02}	0	0	5.98×10^{-04}	0	3.44×10^{-04}	5.68×10^{-02}	0	4.24×10^{-02}
Beet Lake HH VC	0	0	1.22×10^{-03}	0	0	6.04×10^{-03}	0	0	3.04×10^{-04}	0	2.41×10^{-04}	3.45×10^{-02}	0	2.77×10^{-02}
Naomi Lake	0	0	2.67×10^{-04}	0	0	1.66×10^{-03}	0	0	0	0	0	8.69×10^{-03}	0	6.44×10^{-03}
Clearwater River	0	0	0	0	0	4.04×10^{-04}	0	0	0	0	0	1.96×10^{-03}	0	1.35×10^{-03}
Lloyd Lake HH VC	0	0	0	0	0	3.03×10^{-04}	0	0	0	0	0	1.48×10^{-03}	0	1.01×10^{-03}
Broach Lake	0	0	6.06×10^{-04}	0	0	4.19×10^{-03}	0	0	2.28×10^{-04}	0	1.02×10^{-04}	2.18×10^{-02}	0	1.57×10^{-02}

Table 7A-124: Reasonably Foreseeable Development Case Metal Deposition Predictions (Silver to Magnesium) at Selected Receptors

Receptor Name	Deposition													
	Silver	Arsenic	Barium	Beryllium	Bismuth	Calcium	Cadmium	Cobalt	Chromium	Cesium	Copper	Iron	Mercury	Magnesium
	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual
	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
Patterson Lake	0	0	1.87×10^{-03}	0	0	1.06×10^{-02}	0	0	5.21×10^{-04}	0	3.10×10^{-04}	6.20×10^{-02}	0	4.88×10^{-02}
Patterson Lake	0	0	1.91×10^{-03}	0	0	1.24×10^{-02}	0	0	6.83×10^{-04}	0	3.73×10^{-04}	6.19×10^{-02}	0	4.43×10^{-02}
Lake H	0	0	1.01×10^{-03}	0	0	5.57×10^{-03}	0	0	2.92×10^{-04}	0	1.96×10^{-04}	3.02×10^{-02}	0	2.33×10^{-02}
Lake G	0	0	2.27×10^{-03}	0	0	1.30×10^{-02}	0	0	6.78×10^{-04}	0	4.31×10^{-04}	7.02×10^{-02}	0	5.37×10^{-02}
Beet Lake	0	0	7.34×10^{-04}	0	0	3.99×10^{-03}	0	0	2.07×10^{-04}	0	1.42×10^{-04}	2.18×10^{-02}	0	1.70×10^{-02}
Naomi Lake	0	0	2.65×10^{-04}	0	0	1.66×10^{-03}	0	0	0	0	0	8.67×10^{-03}	0	6.41×10^{-03}
Patterson Lake	0	0	2.11×10^{-03}	0	0	1.23×10^{-02}	0	0	5.94×10^{-04}	0	3.29×10^{-04}	7.22×10^{-02}	0	5.68×10^{-02}
Forrest Lake	0	0	9.64×10^{-04}	0	0	5.50×10^{-03}	0	0	2.57×10^{-04}	0	1.55×10^{-04}	3.26×10^{-02}	0	2.57×10^{-02}
Forrest Lake	0	0	1.81×10^{-03}	0	0	1.04×10^{-02}	0	0	5.68×10^{-04}	0	3.51×10^{-04}	5.50×10^{-02}	0	4.17×10^{-02}
Unnamed Lake 2	0	0	3.44×10^{-04}	0	0	1.99×10^{-03}	0	0	1.04×10^{-04}	0	0	1.06×10^{-02}	0	8.07×10^{-03}
Lake C	0	0	2.00×10^{-03}	0	0	1.25×10^{-02}	0	0	6.29×10^{-04}	0	3.16×10^{-04}	7.07×10^{-02}	0	5.39×10^{-02}
Lake E	0	0	1.29×10^{-03}	0	0	7.53×10^{-03}	0	0	3.78×10^{-04}	0	2.15×10^{-04}	4.30×10^{-02}	0	3.34×10^{-02}
Unnamed Lake 1	0	0	3.08×10^{-04}	0	0	1.88×10^{-03}	0	0	1.02×10^{-04}	0	0	9.78×10^{-03}	0	7.28×10^{-03}
REF01	0	0	1.19×10^{-03}	0	0	5.81×10^{-03}	0	0	2.83×10^{-04}	0	2.29×10^{-04}	3.40×10^{-02}	0	2.77×10^{-02}
REF02	0	0	1.38×10^{-04}	0	0	9.64×10^{-04}	0	0	0	0	0	4.81×10^{-03}	0	3.39×10^{-03}
REF03	0	0	0	0	0	5.83×10^{-04}	0	0	0	0	0	2.89×10^{-03}	0	2.02×10^{-03}
19REF04	0	0	1.41×10^{-04}	0	0	1.12×10^{-03}	0	0	0	0	0	5.51×10^{-03}	0	3.73×10^{-03}
19REF05	0	0	0	0	0	5.09×10^{-04}	0	0	0	0	0	2.51×10^{-03}	0	1.72×10^{-03}
19REF06	0	0	7.53×10^{-04}	0	0	5.45×10^{-03}	0	0	3.03×10^{-04}	0	1.26×10^{-04}	2.76×10^{-02}	0	1.98×10^{-02}
19EXP02	0	8.36×10^{-04}	6.32×10^{-02}	1.04×10^{-04}	3.06×10^{-04}	3.43×10^{-01}	1.08×10^{-04}	1.84×10^{-03}	1.77×10^{-02}	0	1.32×10^{-02}	$1.79 \times 10^{+00}$	0	$1.37 \times 10^{+00}$
19EXP01	1.37×10^{-04}	1.29×10^{-03}	9.95×10^{-02}	1.63×10^{-04}	4.83×10^{-04}	5.29×10^{-01}	1.21×10^{-04}	2.90×10^{-03}	2.70×10^{-02}	0	2.07×10^{-02}	$2.80 \times 10^{+00}$	0	$2.15 \times 10^{+00}$
19EXP03	0	0	6.28×10^{-03}	0	0	3.93×10^{-02}	0	1.82×10^{-04}	2.09×10^{-03}	0	1.20×10^{-03}	2.02×10^{-01}	0	1.48×10^{-01}
Preston Lake	0	0	0	0	0	3.83×10^{-04}	0	0	0	0	0	1.86×10^{-03}	0	1.26×10^{-03}
Wegner Lake	0	0	0	0	0	3.51×10^{-04}	0	0	0	0	0	1.67×10^{-03}	0	1.11×10^{-03}
Unnamed Lake 1	0	0	3.08×10^{-04}	0	0	1.88×10^{-03}	0	0	1.02×10^{-04}	0	0	9.78×10^{-03}	0	7.28×10^{-03}

Note: Where values are shown as zero (0), assume it is less than 1×10^{-04}.
VC = valued component; HH = human health.

Table 7A-125: Reasonably Foreseeable Development Case Metal Deposition Predictions (Manganese to Zinc) at Selected Receptors

Receptor Name	Deposition														
	Manganese	Molybdenum	Sodium	Nickel in TSP	Nickel in PM_{10}	Lead		Antimony	Selenium	Tin	Thorium	Uranium in TSP	Uranium in PM_{10}	Vanadium	Zinc
	Annual	Annual	Annual	Annual	Annual	Annual	Monthly	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual
	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
Hodge Lake Reference HH VC	0	0	1.08 × 10^{-03}	0	0	0	0	0	0	0	0	7.60 × 10^{-04}	2.34 × 10^{-04}	0	0
Broach Lake	3.84 × 10^{-04}	0	5.02 × 10^{-03}	0	0	2.01 × 10^{-04}	0	0	0	0	0	5.85 × 10^{-03}	1.07 × 10^{-03}	1.64 × 10^{-04}	0
Camp Worker HH VC	1.07 × 10^{-02}	1.63 × 10^{-03}	1.36 × 10^{-01}	3.61 × 10^{-03}	4.97 × 10^{-04}	3.43 × 10^{-03}	6.56 × 10^{-04}	0	0	0	3.82 × 10^{-04}	1.43 × 10^{-01}	1.93 × 10^{-02}	2.83 × 10^{-03}	8.58 × 10^{-04}
Patterson Lake HH VC	1.85 × 10^{-03}	3.60 × 10^{-04}	2.47 × 10^{-02}	3.36 × 10^{-04}	0	7.53 × 10^{-04}	1.06 × 10^{-04}	0	0	0	1.12 × 10^{-04}	1.15 × 10^{-02}	1.62 × 10^{-03}	7.58 × 10^{-04}	2.34 × 10^{-04}
Patterson Lake Eco VC	1.14 × 10^{-03}	2.35 × 10^{-04}	1.45 × 10^{-02}	2.48 × 10^{-04}	0	4.96 × 10^{-04}	1.05 × 10^{-04}	0	0	0	0	1.51 × 10^{-02}	1.30 × 10^{-03}	3.87 × 10^{-04}	0
Forrest Lake	5.74 × 10^{-04}	1.69 × 10^{-04}	7.57 × 10^{-03}	1.55 × 10^{-04}	0	3.54 × 10^{-04}	0	0	0	0	0	1.03 × 10^{-02}	1.08 × 10^{-03}	2.74 × 10^{-04}	0
Forrest Lake North Eco VC	8.74 × 10^{-04}	2.41 × 10^{-04}	1.14 × 10^{-02}	2.16 × 10^{-04}	0	5.05 × 10^{-04}	1.17 × 10^{-04}	0	0	0	0	1.54 × 10^{-02}	1.78 × 10^{-03}	3.83 × 10^{-04}	0
Beet Lake HH VC	4.82 × 10^{-04}	1.72 × 10^{-04}	6.39 × 10^{-03}	1.18 × 10^{-04}	0	3.60 × 10^{-04}	0	0	0	0	0	1.10 × 10^{-02}	1.35 × 10^{-03}	2.60 × 10^{-04}	0
Naomi Lake	1.35 × 10^{-04}	0	1.75 × 10^{-03}	0	0	0	0	0	0	0	0	2.04 × 10^{-03}	3.53 × 10^{-04}	0	0
Clearwater River	0	0	4.25 × 10^{-04}	0	0	0	0	0	0	0	0	3.81 × 10^{-04}	1.15 × 10^{-04}	0	0
Lloyd Lake HH VC	0	0	3.21 × 10^{-04}	0	0	0	0	0	0	0	0	2.17 × 10^{-04}	0	0	0
Broach Lake	3.44 × 10^{-04}	0	4.47 × 10^{-03}	0	0	1.42 × 10^{-04}	0	0	0	0	0	3.17 × 10^{-03}	5.90 × 10^{-04}	1.29 × 10^{-04}	0
Patterson Lake	8.64 × 10^{-04}	2.11 × 10^{-04}	1.15 × 10^{-02}	1.99 × 10^{-04}	0	4.43 × 10^{-04}	0	0	0	0	0	1.15 × 10^{-02}	8.69 × 10^{-04}	3.87 × 10^{-04}	1.10 × 10^{-04}
Patterson Lake	1.01 × 10^{-03}	2.62 × 10^{-04}	1.30 × 10^{-02}	1.91 × 10^{-04}	0	5.51 × 10^{-04}	0	0	0	0	0	1.70 × 10^{-02}	1.21 × 10^{-03}	4.09 × 10^{-04}	0
Lake H	4.47 × 10^{-04}	1.39 × 10^{-04}	5.86 × 10^{-03}	1.02 × 10^{-04}	0	2.90 × 10^{-04}	0	0	0	0	0	8.92 × 10^{-03}	6.93 × 10^{-04}	2.15 × 10^{-04}	0
Lake G	1.05 × 10^{-03}	3.02 × 10^{-04}	1.38 × 10^{-02}	2.23 × 10^{-04}	0	6.31 × 10^{-04}	0	0	0	0	0	1.95 × 10^{-02}	2.01 × 10^{-03}	4.83 × 10^{-04}	1.18 × 10^{-04}
Beet Lake	3.21 × 10^{-04}	1.01 × 10^{-04}	4.22 × 10^{-03}	0	0	2.12 × 10^{-04}	0	0	0	0	0	6.35 × 10^{-03}	7.87 × 10^{-04}	1.56 × 10^{-04}	0
Naomi Lake	1.35 × 10^{-04}	0	1.76 × 10^{-03}	0	0	0	0	0	0	0	0	2.02 × 10^{-03}	3.40 × 10^{-04}	0	0
Patterson Lake	1.01 × 10^{-03}	2.14 × 10^{-04}	1.34 × 10^{-02}	2.13 × 10^{-04}	0	4.39 × 10^{-04}	0	0	0	0	0	8.24 × 10^{-03}	7.72 × 10^{-04}	4.37 × 10^{-04}	1.29 × 10^{-04}
Forrest Lake	4.49 × 10^{-04}	1.01 × 10^{-04}	6.00 × 10^{-03}	0	0	2.12 × 10^{-04}	0	0	0	0	0	4.14 × 10^{-03}	4.43 × 10^{-04}	1.98 × 10^{-04}	0
Forrest Lake	8.34 × 10^{-04}	2.48 × 10^{-04}	1.09 × 10^{-02}	2.11 × 10^{-04}	0	5.20 × 10^{-04}	0	0	0	0	0	1.60 × 10^{-02}	2.05 × 10^{-03}	3.86 × 10^{-04}	0
Unnamed Lake 2	1.60 × 10^{-04}	0	2.10 × 10^{-03}	0	0	0	0	0	0	0	0	2.88 × 10^{-03}	2.68 × 10^{-04}	0	0
Lake C	1.03 × 10^{-03}	2.07 × 10^{-04}	1.36 × 10^{-02}	2.13 × 10^{-04}	0	4.29 × 10^{-04}	0	0	0	0	0	7.98 × 10^{-03}	8.80 × 10^{-04}	4.14 × 10^{-04}	1.23 × 10^{-04}
Lake E	6.14 × 10^{-04}	1.43 × 10^{-04}	8.14 × 10^{-03}	1.39 × 10^{-04}	0	2.98 × 10^{-04}	0	0	0	0	0	6.99 × 10^{-03}	5.73 × 10^{-04}	2.68 × 10^{-04}	0
Unnamed Lake 1	1.52 × 10^{-04}	0	1.98 × 10^{-03}	0	0	0	0	0	0	0	0	2.47 × 10^{-03}	5.35 × 10^{-04}	0	0
REF01	4.63 × 10^{-04}	1.62 × 10^{-04}	6.17 × 10^{-03}	1.12 × 10^{-04}	0	3.41 × 10^{-04}	0	0	0	0	0	1.02 × 10^{-02}	1.23 × 10^{-03}	2.53 × 10^{-04}	0
REF02	0	0	1.02 × 10^{-03}	0	0	0	0	0	0	0	0	9.74 × 10^{-04}	2.83 × 10^{-04}	0	0
REF03	0	0	6.15 × 10^{-04}	0	0	0	0	0	0	0	0	5.62 × 10^{-04}	1.08 × 10^{-04}	0	0

Table 7A-125: Reasonably Foreseeable Development Case Metal Deposition Predictions (Manganese to Zinc) at Selected Receptors

Receptor Name	Deposition														
	Manganese	Molybdenum	Sodium	Nickel in TSP	Nickel in PM_{10}	Lead		Antimony	Selenium	Tin	Thorium	Uranium in TSP	Uranium in PM_{10}	Vanadium	Zinc
	Annual	Annual	Annual	Annual	Annual	Annual	Monthly	Annual	Annual	Annual	Annual	Annual	Annual	Annual	Annual
	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr
19REF04	0	0	1.20×10^{-03}	0	0	0	0	0	0	0	0	6.41×10^{-04}	1.54×10^{-04}	0	0
19REF05	0	0	5.40×10^{-04}	0	0	0	0	0	0	0	0	3.25×10^{-04}	0	0	0
19REF06	4.48×10^{-04}	0	5.80×10^{-03}	0	0	1.71×10^{-04}	0	0	0	0	0	3.42×10^{-03}	6.46×10^{-04}	1.62×10^{-04}	0
19EXP02	2.74×10^{-02}	9.54×10^{-03}	3.57×10^{-01}	4.84×10^{-03}	6.84×10^{-04}	2.01×10^{-02}	3.05×10^{-03}	1.22×10^{-04}	2.26×10^{-04}	2.32×10^{-04}	1.80×10^{-03}	6.28×10^{-01}	9.21×10^{-02}	1.36×10^{-02}	2.92×10^{-03}
19EXP01	4.22×10^{-02}	1.50×10^{-02}	5.50×10^{-01}	7.48×10^{-03}	1.08×10^{-03}	3.16×10^{-02}	4.94×10^{-03}	1.93×10^{-04}	3.56×10^{-04}	3.60×10^{-04}	2.84×10^{-03}	9.80×10^{-01}	1.43×10^{-01}	2.14×10^{-02}	4.59×10^{-03}
19EXP03	3.19×10^{-03}	8.41×10^{-04}	4.15×10^{-02}	5.63×10^{-04}	0	1.76×10^{-03}	3.14×10^{-04}	0	0	0	1.81×10^{-04}	5.47×10^{-02}	5.59×10^{-03}	1.34×10^{-03}	3.28×10^{-04}
Preston Lake	0	0	4.06×10^{-04}	0	0	0	0	0	0	0	0	2.61×10^{-04}	0	0	0
Wegner Lake	0	0	3.70×10^{-04}	0	0	0	0	0	0	0	0	2.00×10^{-04}	0	0	0
Overall	2.58×10^{-02}	9.67×10^{-03}	3.41×10^{-01}	4.95×10^{-03}	6.27×10^{-04}	2.04×10^{-02}	2.91×10^{-03}	1.24×10^{-04}	2.30×10^{-04}	2.24×10^{-04}	1.92×10^{-03}	6.24×10^{-01}	7.59×10^{-02}	1.42×10^{-02}	3.14×10^{-03}

Note: Where values are shown as zero (0), assume it is less than 1×10^{-04}.
VC = valued component; PM_{10} = particulate matter with a diameter of 10 microns or less; TSP = total suspended particulates; HH = human health.

7A3.2.13.4 Dioxins and Furans Concentrations

Table 7A-126 lists the predicted D&F concentrations at selected receptors at the Application Case during Construction.

Table 7A-126: Application Case Construction Predicted Dioxins and Furans Concentrations at Selected Receptors

Receptor Name	Concentration (pg TEQ/m^3)				
	1-hour 1st Highest	1-hour 9th Highest	24-hour 1st Highest	24-hour 2nd Highest	Annual Average
Hodge Lake Reference HH VC	6.35×10^{-04}	2.56×10^{-04}	2.53×10^{-05}	2.38×10^{-05}	6.84×10^{-07}
Broach Lake	1.11×10^{-03}	5.16×10^{-04}	7.28×10^{-05}	5.75×10^{-05}	1.77×10^{-06}
Camp Worker HH VC	1.92×10^{-02}	4.28×10^{-03}	9.27×10^{-04}	7.89×10^{-04}	7.54×10^{-05}
Patterson Lake HH VC	5.23×10^{-04}	2.05×10^{-04}	3.15×10^{-05}	1.20×10^{-05}	5.55×10^{-07}
Patterson Lake Eco VC	1.57×10^{-03}	9.81×10^{-04}	1.56×10^{-04}	9.61×10^{-05}	4.11×10^{-06}
Forrest Lake	7.82×10^{-04}	3.44×10^{-04}	7.02×10^{-05}	3.52×10^{-05}	1.93×10^{-06}
Forrest Lake North Eco VC	9.26×10^{-04}	4.48×10^{-04}	6.63×10^{-05}	3.90×10^{-05}	3.35×10^{-06}
Beet Lake HH VC	5.94×10^{-04}	3.16×10^{-04}	3.04×10^{-05}	2.95×10^{-05}	1.49×10^{-06}
Naomi Lake	8.17×10^{-04}	3.13×10^{-04}	3.23×10^{-05}	2.18×10^{-05}	9.47×10^{-07}
Clearwater River	4.22×10^{-04}	1.73×10^{-04}	1.67×10^{-05}	1.31×10^{-05}	3.70×10^{-07}
Lloyd Lake HH VC	3.04×10^{-04}	1.50×10^{-04}	1.91×10^{-05}	1.30×10^{-05}	3.60×10^{-07}
Broach Lake	8.03×10^{-04}	3.28×10^{-04}	2.80×10^{-05}	1.88×10^{-05}	8.09×10^{-07}
Patterson Lake	8.51×10^{-04}	3.57×10^{-04}	3.46×10^{-05}	3.46×10^{-05}	1.38×10^{-06}
Patterson Lake	6.58×10^{-04}	4.08×10^{-04}	4.67×10^{-05}	3.64×10^{-05}	2.04×10^{-06}
Lake H	5.88×10^{-04}	3.58×10^{-04}	4.19×10^{-05}	2.93×10^{-05}	1.65×10^{-06}
Lake G	6.61×10^{-04}	3.93×10^{-04}	4.52×10^{-05}	4.32×10^{-05}	2.65×10^{-06}
Beet Lake	9.90×10^{-04}	3.67×10^{-04}	4.05×10^{-05}	2.54×10^{-05}	1.29×10^{-06}
Naomi Lake	8.49×10^{-04}	3.12×10^{-04}	4.65×10^{-05}	2.16×10^{-05}	9.03×10^{-07}
Patterson Lake	8.08×10^{-04}	2.26×10^{-04}	4.80×10^{-05}	2.27×10^{-05}	9.34×10^{-07}
Forrest Lake	3.72×10^{-04}	2.09×10^{-04}	2.38×10^{-05}	1.58×10^{-05}	6.67×10^{-07}
Forrest Lake	8.91×10^{-04}	4.72×10^{-04}	7.03×10^{-05}	5.78×10^{-05}	3.39×10^{-06}
Unnamed Lake 2	3.92×10^{-04}	2.19×10^{-04}	2.72×10^{-05}	1.85×10^{-05}	9.38×10^{-07}
Lake C	6.33×10^{-04}	2.84×10^{-04}	2.45×10^{-05}	1.79×10^{-05}	8.58×10^{-07}
Lake E	6.91×10^{-04}	2.28×10^{-04}	3.02×10^{-05}	2.76×10^{-05}	1.03×10^{-06}
Unnamed Lake 1	7.40×10^{-04}	3.14×10^{-04}	2.22×10^{-05}	1.71×10^{-05}	1.04×10^{-06}
REF01	7.10×10^{-04}	4.26×10^{-04}	3.65×10^{-05}	3.29×10^{-05}	1.85×10^{-06}
REF02	4.87×10^{-04}	3.11×10^{-04}	2.33×10^{-05}	2.09×10^{-05}	7.98×10^{-07}
REF03	4.21×10^{-04}	2.03×10^{-04}	1.46×10^{-05}	1.11×10^{-05}	5.51×10^{-07}
19REF04	6.92×10^{-04}	2.96×10^{-04}	3.61×10^{-05}	1.76×10^{-05}	5.95×10^{-07}
19REF05	4.28×10^{-04}	2.20×10^{-04}	2.41×10^{-05}	1.27×10^{-05}	4.45×10^{-07}
19REF06	1.11×10^{-03}	4.11×10^{-04}	4.62×10^{-05}	3.17×10^{-05}	8.27×10^{-07}
19EXP02	1.24×10^{-03}	9.74×10^{-04}	1.89×10^{-04}	1.53×10^{-04}	1.00×10^{-05}
19EXP01	1.27×10^{-03}	1.08×10^{-03}	2.40×10^{-04}	1.26×10^{-04}	1.07×10^{-05}
19EXP03	6.29×10^{-03}	2.18×10^{-03}	2.74×10^{-04}	1.64×10^{-04}	5.83×10^{-06}
Preston Lake	3.15×10^{-04}	2.40×10^{-04}	1.91×10^{-05}	1.46×10^{-05}	4.14×10^{-07}
Wegner Lake	3.03×10^{-04}	1.35×10^{-04}	1.60×10^{-05}	7.73×10^{-06}	2.72×10^{-07}
Overall	1.36×10^{-02}	7.95×10^{-03}	1.19×10^{-03}	4.16×10^{-04}	1.80×10^{-05}

VC = valued component; HH = human health; pg TEQ/m^3 = picogram toxic equivalency units per cubic metre.

Table 7A-127 lists the Application Case Operations maximum D&F concentrations at selected receptors.

Table 7A-127: Application Case Operations Predicted Dioxins and Furans Concentrations at Selected Receptors

Receptor Name	Concentration (pg TEQ/m³)				
	1-hour 1st Highest	1-hour 9th Highest	24-hour 1st Highest	24-hour 2nd Highest	Annual Average
Hodge Lake Reference HH VC	1.27×10^{-03}	5.13×10^{-04}	5.10×10^{-05}	4.73×10^{-05}	1.37×10^{-06}
Broach Lake	2.19×10^{-03}	1.04×10^{-03}	1.47×10^{-04}	1.15×10^{-04}	3.54×10^{-06}
Camp Worker HH VC	2.82×10^{-02}	8.14×10^{-03}	1.86×10^{-03}	1.54×10^{-03}	1.54×10^{-04}
Patterson Lake HH VC	1.05×10^{-03}	4.03×10^{-04}	6.31×10^{-05}	2.39×10^{-05}	1.11×10^{-06}
Patterson Lake Eco VC	3.10×10^{-03}	1.96×10^{-03}	3.10×10^{-04}	1.90×10^{-04}	8.17×10^{-06}
Forrest Lake	1.56×10^{-03}	6.81×10^{-04}	1.40×10^{-04}	7.02×10^{-05}	3.85×10^{-06}
Forrest Lake North Eco VC	1.84×10^{-03}	9.01×10^{-04}	1.30×10^{-04}	7.79×10^{-05}	6.67×10^{-06}
Beet Lake HH VC	1.19×10^{-03}	6.43×10^{-04}	6.10×10^{-05}	5.94×10^{-05}	2.98×10^{-06}
Naomi Lake	1.65×10^{-03}	6.20×10^{-04}	6.44×10^{-05}	4.33×10^{-05}	1.89×10^{-06}
Clearwater River	8.45×10^{-04}	3.44×10^{-04}	3.34×10^{-05}	2.63×10^{-05}	7.39×10^{-07}
Lloyd Lake HH VC	6.08×10^{-04}	3.00×10^{-04}	3.81×10^{-05}	2.60×10^{-05}	7.20×10^{-07}
Broach Lake	1.59×10^{-03}	6.55×10^{-04}	5.59×10^{-05}	3.74×10^{-05}	1.62×10^{-06}
Patterson Lake	1.68×10^{-03}	7.28×10^{-04}	6.92×10^{-05}	6.74×10^{-05}	2.76×10^{-06}
Patterson Lake	1.33×10^{-03}	8.19×10^{-04}	9.40×10^{-05}	7.35×10^{-05}	4.10×10^{-06}
Lake H	1.17×10^{-03}	7.20×10^{-04}	8.34×10^{-05}	5.93×10^{-05}	3.31×10^{-06}
Lake G	1.31×10^{-03}	7.91×10^{-04}	9.19×10^{-05}	8.71×10^{-05}	5.31×10^{-06}
Beet Lake	1.95×10^{-03}	7.30×10^{-04}	8.02×10^{-05}	5.10×10^{-05}	2.58×10^{-06}
Naomi Lake	1.69×10^{-03}	6.20×10^{-04}	9.28×10^{-05}	4.34×10^{-05}	1.81×10^{-06}
Patterson Lake	1.62×10^{-03}	4.51×10^{-04}	9.60×10^{-05}	4.52×10^{-05}	1.87×10^{-06}
Forrest Lake	7.44×10^{-04}	4.20×10^{-04}	4.75×10^{-05}	3.16×10^{-05}	1.33×10^{-06}
Forrest Lake	1.79×10^{-03}	9.28×10^{-04}	1.40×10^{-04}	1.16×10^{-04}	6.77×10^{-06}
Unnamed Lake 2	7.83×10^{-04}	4.33×10^{-04}	5.44×10^{-05}	3.71×10^{-05}	1.88×10^{-06}
Lake C	1.28×10^{-03}	5.55×10^{-04}	4.98×10^{-05}	3.57×10^{-05}	1.72×10^{-06}
Lake E	1.38×10^{-03}	4.56×10^{-04}	6.01×10^{-05}	5.52×10^{-05}	2.05×10^{-06}
Unnamed Lake 1	1.47×10^{-03}	6.22×10^{-04}	4.40×10^{-05}	3.38×10^{-05}	2.08×10^{-06}
REF01	1.39×10^{-03}	8.56×10^{-04}	7.29×10^{-05}	6.61×10^{-05}	3.71×10^{-06}
REF02	9.78×10^{-04}	6.34×10^{-04}	4.71×10^{-05}	4.19×10^{-05}	1.60×10^{-06}
REF03	8.46×10^{-04}	4.04×10^{-04}	2.91×10^{-05}	2.22×10^{-05}	1.10×10^{-06}
19REF04	1.39×10^{-03}	5.93×10^{-04}	7.23×10^{-05}	3.52×10^{-05}	1.19×10^{-06}
19REF05	8.50×10^{-04}	4.40×10^{-04}	4.81×10^{-05}	2.54×10^{-05}	8.89×10^{-07}
19REF06	2.25×10^{-03}	8.16×10^{-04}	9.22×10^{-05}	6.35×10^{-05}	1.65×10^{-06}
19EXP02	2.50×10^{-03}	1.96×10^{-03}	3.82×10^{-04}	3.07×10^{-04}	2.03×10^{-05}
19EXP01	2.55×10^{-03}	2.17×10^{-03}	4.85×10^{-04}	2.53×10^{-04}	2.16×10^{-05}
19EXP03	1.25×10^{-02}	4.26×10^{-03}	5.56×10^{-04}	3.37×10^{-04}	1.18×10^{-05}
Preston Lake	6.30×10^{-04}	4.80×10^{-04}	3.81×10^{-05}	2.92×10^{-05}	8.28×10^{-07}
Wegner Lake	6.10×10^{-04}	2.69×10^{-04}	3.19×10^{-05}	1.55×10^{-05}	5.43×10^{-07}
Overall	2.75×10^{-02}	1.65×10^{-02}	2.39×10^{-03}	8.24×10^{-04}	3.59×10^{-05}

VC = valued component; HH = human health; pg TEQ/m³ = picogram toxic equivalency units per cubic metre.

Table 7A-128 lists the RFD Case maximum D&F concentrations at selected receptors.

Table 7A-128: Reasonably Foreseeable Development Case Predicted Dioxins and Furans Concentrations at Selected Receptors

Receptor Name	Concentration (pg TEQ/m³)				
	1-hour 1st Highest	1-hour 9th Highest	24-hour 1st Highest	24-hour 2nd Highest	Annual Average
Hodge Lake Reference HH VC	4.67×10^{-05}	2.47×10^{-05}	3.51×10^{-06}	1.88×10^{-06}	9.80×10^{-08}
Broach Lake	7.99×10^{-05}	3.83×10^{-05}	5.43×10^{-06}	4.20×10^{-06}	2.00×10^{-07}
Camp Worker HH VC	8.69×10^{-04}	2.98×10^{-04}	6.83×10^{-05}	5.63×10^{-05}	5.75×10^{-06}
Patterson Lake HH VC	5.79×10^{-05}	3.25×10^{-05}	4.40×10^{-06}	3.53×10^{-06}	2.15×10^{-07}
Patterson Lake Eco VC	1.13×10^{-04}	7.19×10^{-05}	1.13×10^{-05}	6.92×10^{-06}	3.72×10^{-07}
Forrest Lake	6.70×10^{-05}	2.88×10^{-05}	5.11×10^{-06}	2.63×10^{-06}	2.05×10^{-07}
Forrest Lake North Eco VC	6.75×10^{-05}	3.44×10^{-05}	4.75×10^{-06}	3.14×10^{-06}	3.06×10^{-07}
Beet Lake HH VC	5.50×10^{-05}	2.42×10^{-05}	2.27×10^{-06}	2.18×10^{-06}	1.56×10^{-07}
Naomi Lake	6.04×10^{-05}	2.49×10^{-05}	2.39×10^{-06}	1.59×10^{-06}	1.08×10^{-07}
Clearwater River	3.10×10^{-05}	1.50×10^{-05}	1.23×10^{-06}	1.13×10^{-06}	4.81×10^{-08}
Lloyd Lake HH VC	2.25×10^{-05}	1.49×10^{-05}	1.70×10^{-06}	1.12×10^{-06}	4.96×10^{-08}
Broach Lake	5.82×10^{-05}	3.38×10^{-05}	4.34×10^{-06}	2.44×10^{-06}	1.94×10^{-07}
Patterson Lake	6.12×10^{-05}	3.17×10^{-05}	3.31×10^{-06}	2.46×10^{-06}	2.00×10^{-07}
Patterson Lake	4.92×10^{-05}	3.00×10^{-05}	3.56×10^{-06}	2.72×10^{-06}	2.04×10^{-07}
Lake H	5.04×10^{-05}	3.50×10^{-05}	4.12×10^{-06}	3.63×10^{-06}	1.70×10^{-07}
Lake G	6.49×10^{-05}	3.84×10^{-05}	4.11×10^{-06}	3.89×10^{-06}	2.51×10^{-07}
Beet Lake	7.11×10^{-05}	2.67×10^{-05}	2.97×10^{-06}	1.88×10^{-06}	1.40×10^{-07}
Naomi Lake	6.19×10^{-05}	2.39×10^{-05}	3.41×10^{-06}	1.61×10^{-06}	1.03×10^{-07}
Patterson Lake	5.93×10^{-05}	2.97×10^{-05}	3.53×10^{-06}	2.54×10^{-06}	1.82×10^{-07}
Forrest Lake	5.17×10^{-05}	2.29×10^{-05}	1.80×10^{-06}	1.58×10^{-06}	1.21×10^{-07}
Forrest Lake	6.58×10^{-05}	4.26×10^{-05}	5.12×10^{-06}	4.24×10^{-06}	3.06×10^{-07}
Unnamed Lake 2	4.45×10^{-05}	3.02×10^{-05}	3.12×10^{-06}	2.12×10^{-06}	1.06×10^{-07}
Lake C	4.86×10^{-05}	4.13×10^{-05}	1.02×10^{-05}	4.74×10^{-06}	2.36×10^{-07}
Lake E	5.06×10^{-05}	2.14×10^{-05}	2.21×10^{-06}	2.03×10^{-06}	1.51×10^{-07}
Unnamed Lake 1	5.37×10^{-05}	2.39×10^{-05}	1.61×10^{-06}	1.31×10^{-06}	1.15×10^{-07}
REF01	5.07×10^{-05}	3.15×10^{-05}	2.99×10^{-06}	2.58×10^{-06}	1.92×10^{-07}
REF02	3.59×10^{-05}	2.34×10^{-05}	2.27×10^{-06}	2.04×10^{-06}	1.11×10^{-07}
REF03	3.87×10^{-05}	2.54×10^{-05}	2.10×10^{-06}	2.01×10^{-06}	7.03×10^{-08}
19REF04	5.08×10^{-05}	2.84×10^{-05}	3.66×10^{-06}	1.82×10^{-06}	9.02×10^{-08}
19REF05	3.70×10^{-05}	1.79×10^{-05}	1.89×10^{-06}	1.82×10^{-06}	6.45×10^{-08}
19REF06	8.26×10^{-05}	3.39×10^{-05}	3.39×10^{-06}	2.78×10^{-06}	1.90×10^{-07}
19EXP02	9.18×10^{-05}	7.18×10^{-05}	1.40×10^{-05}	1.13×10^{-05}	8.19×10^{-07}
19EXP01	9.34×10^{-05}	7.97×10^{-05}	1.78×10^{-05}	9.28×10^{-06}	8.69×10^{-07}
19EXP03	4.56×10^{-04}	1.54×10^{-04}	2.06×10^{-05}	1.35×10^{-05}	5.10×10^{-07}
Preston Lake	2.31×10^{-05}	1.83×10^{-05}	1.43×10^{-06}	1.12×10^{-06}	5.05×10^{-08}
Wegner Lake	3.03×10^{-05}	1.63×10^{-05}	1.78×10^{-06}	7.69×10^{-07}	4.21×10^{-08}
Overall	1.01×10^{-03}	5.93×10^{-04}	1.29×10^{-04}	1.13×10^{-04}	1.39×10^{-05}

VC = valued component; HH = human health; pg TEQ/dsm³ = picogram toxic equivalency units per cubic metre.

7A3.2.13.5 Radon and Radionuclides Concentrations

Table 7A-129 and Table 7A-130 list the maximum radon concentrations at selected receptors for Application Case Operations and RFD Case.

Table 7A-129: Application Case Operations Predicted Radon Concentrations at Selected Receptors

Receptor Name	Concentration (Bq/m³)				
	1-hour 1st Highest	1-hour 9th Highest	24-hour 1st Highest	24-hour 2nd Highest	Annual Average
Hodge Lake Reference HH VC	297.2	74.9	15.2	14.9	6.5
Broach Lake	1,963.2	386.1	176.3	74.7	11.7
Camp Worker HH VC	14,502.0	4,605.0	998.9	721.5	44.5
Patterson Lake HH VC	1,049.4	120.6	46.6	35.9	5.8
Patterson Lake Eco VC	5,519.0	1,036.4	242.8	175.3	14.8
Forrest Lake	1,927.4	414.0	86.7	73.5	9.1
Forrest Lake North Eco VC	3,600.1	562.1	159.7	109.0	11.8
Beet Lake HH VC	1,199.2	337.6	69.3	52.4	11.5
Naomi Lake	485.2	166.8	36.6	26.3	7.2
Clearwater River	290.9	56.4	20.6	13.0	5.0
Lloyd Lake HH VC	136.3	25.7	8.7	7.3	4.4
Broach Lake	836.2	108.0	44.3	35.6	6.8
Patterson Lake	2,673.7	701.0	177.8	88.1	8.8
Patterson Lake	3,994.4	1,354.9	277.6	170.1	17.3
Lake H	1,716.7	373.3	74.4	67.9	11.7
Lake G	3,903.1	1,138.6	170.3	148.7	18.4
Beet Lake	1,934.3	312.2	83.4	60.0	9.5
Naomi Lake	740.2	171.1	34.0	33.5	8.0
Patterson Lake	1,746.4	234.7	95.1	60.4	6.9
Forrest Lake	772.0	286.8	114.2	35.0	6.3
Forrest Lake	2,458.1	585.3	111.3	104.8	12.4
Unnamed Lake 2	719.5	141.9	34.1	27.3	8.1
Lake C	1,322.1	296.8	101.2	58.4	8.0
Lake E	1,935.8	422.5	159.9	83.5	6.6
Unnamed Lake 1	660.8	59.1	30.4	16.4	7.8
REF01	1,704.0	175.5	164.0	25.1	12.5
REF02	687.8	76.9	31.5	23.6	8.2
REF03	361.3	97.4	20.8	14.0	5.9
19REF04	416.4	64.7	51.0	15.0	5.5
19REF05	317.9	93.8	40.2	14.2	5.0
19REF06	1,142.1	173.8	50.4	33.6	6.7
19EXP02	18,233.6	7,134.9	1,459.5	891.7	261.8
19EXP01	21,124.4	9,230.4	1,896.1	1,218.6	378.9
19EXP03	2,067.3	819.2	155.3	106.2	76.7
Preston Lake	181.9	45.8	10.7	8.7	4.6
Wegner Lake	201.5	33.4	11.2	7.0	4.1
Overall	18,992.1	8,115.0	2,319.1	1,191.6	322.7

VC = valued component; Bq/m^3 = becquerels per cubic metre; HH = human health.

Table 7A-130: Reasonably Foreseeable Development Case Predicted Radon Concentrations at Selected Receptors

Receptor Name	Concentration (Bq/m³)				
	1-hour 1st Highest	1-hour 9th Highest	24-hour 1st Highest	24-hour 2nd Highest	Annual Average
Hodge Lake Reference HH VC	1,208.1	570.9	163.3	98.1	8.1
Broach Lake	1,942.7	1,111.3	228.0	188.5	15.9
Camp Worker HH VC	9,270.2	3,569.1	741.5	574.0	49.3
Patterson Lake HH VC	1,494.7	600.6	134.7	94.7	13.8
Patterson Lake Eco VC	4,244.9	2,352.4	389.7	379.0	22.1
Forrest Lake	2,076.8	612.2	110.0	96.4	11.2
Forrest Lake North Eco VC	2,094.8	629.0	128.3	107.4	13.8
Beet Lake HH VC	1,592.7	583.9	142.1	109.0	13.0
Naomi Lake	1,030.1	496.1	91.9	87.1	8.6
Clearwater River	607.3	271.7	62.8	56.1	5.6
Lloyd Lake HH VC	417.3	215.9	54.9	46.9	5.1
Broach Lake	1,498.1	646.5	152.6	122.8	10.2
Patterson Lake	1,587.9	633.2	182.5	110.4	11.8
Patterson Lake	4,454.8	1,369.3	425.6	284.7	19.0
Lake H	1,303.2	624.2	169.7	154.8	13.2
Lake G	2,944.0	1,238.5	260.2	200.1	20.3
Beet Lake	1,442.2	641.8	138.9	98.5	11.2
Naomi Lake	959.1	695.8	126.7	104.2	9.4
Patterson Lake	1,590.2	550.0	139.6	106.5	11.9
Forrest Lake	1,004.5	565.1	205.2	118.9	8.9
Forrest Lake	1,440.4	552.3	132.3	117.3	14.2
Unnamed Lake 2	1,235.6	654.7	155.9	101.5	9.2
Lake C	2,145.7	935.4	205.4	148.2	15.1
Lake E	1,388.9	498.6	106.3	68.4	10.2
Unnamed Lake 1	921.2	450.4	102.3	86.1	9.3
REF01	1,561.1	1,021.1	216.3	166.6	14.5
REF02	1,620.0	844.5	220.9	119.2	10.8
REF03	1,164.5	413.8	99.9	78.5	6.8
19REF04	930.6	523.3	175.9	89.0	6.9
19REF05	1,209.8	499.7	147.1	83.6	6.8
19REF06	2,498.2	1,110.8	354.4	167.8	13.5
19EXP02	12,327.4	7,064.2	2,068.5	2,027.2	263.2
19EXP01	15,549.6	9,123.8	3,737.4	3,484.1	380.4
19EXP03	16,727.3	8,200.9	1,777.3	1,291.8	80.8
Preston Lake	635.2	225.9	54.4	40.4	5.2
Wegner Lake	833.8	366.1	64.9	54.4	4.8
Overall	219,390.0	15,850.4	9,516.5	3,516.7	324.4

VC = valued component; Bq/m³ = becquerels per cubic metre; HH = human health.

Table 7A-131 and Table 7A-132 list the maximum radionuclide concentrations expressed as becquerels per cubic metre (Bq/m^3) at selected receptors for Application Case Operations and RFD Case, respectively.

Table 7A-131: Application Case Operations Predicted Radionuclide Concentrations at Selected Receptors

Receptor Name	Concentration (Bq/m³)		
	24-hour 1st Highest	24-hour 2nd Highest	Annual Average
Hodge Lake Reference HH VC	2.57×10^{-05}	1.98×10^{-05}	7.70×10^{-07}
Broach Lake	3.73×10^{-04}	1.79×10^{-04}	5.16×10^{-06}
Camp Worker HH VC	3.09×10^{-03}	2.68×10^{-03}	9.26×10^{-05}
Patterson Lake HH VC	1.24×10^{-04}	7.30×10^{-05}	2.34×10^{-06}
Patterson Lake Eco VC	5.59×10^{-04}	5.39×10^{-04}	1.51×10^{-05}
Forrest Lake	3.09×10^{-04}	2.41×10^{-04}	9.51×10^{-06}
Forrest Lake North Eco VC	4.49×10^{-04}	3.14×10^{-04}	1.31×10^{-05}
Beet Lake HH VC	4.42×10^{-04}	2.92×10^{-04}	8.80×10^{-06}
Naomi Lake	1.79×10^{-04}	5.96×10^{-05}	2.42×10^{-06}
Clearwater River	2.26×10^{-05}	1.57×10^{-05}	5.48×10^{-07}
Lloyd Lake HH VC	8.97×10^{-06}	7.87×10^{-06}	2.94×10^{-07}
Broach Lake	1.33×10^{-04}	7.41×10^{-05}	2.22×10^{-06}
Patterson Lake	3.50×10^{-04}	2.92×10^{-04}	8.04×10^{-06}
Patterson Lake	7.31×10^{-04}	4.02×10^{-04}	1.75×10^{-05}
Lake H	4.63×10^{-04}	1.98×10^{-04}	1.05×10^{-05}
Lake G	6.21×10^{-04}	4.45×10^{-04}	1.73×10^{-05}
Beet Lake	4.56×10^{-04}	1.53×10^{-04}	5.75×10^{-06}
Naomi Lake	1.44×10^{-04}	1.09×10^{-04}	2.83×10^{-06}
Patterson Lake	4.95×10^{-04}	1.73×10^{-04}	5.27×10^{-06}
Forrest Lake	1.39×10^{-04}	8.00×10^{-05}	2.75×10^{-06}
Forrest Lake	3.17×10^{-04}	2.78×10^{-04}	1.06×10^{-05}
Unnamed Lake 2	1.52×10^{-04}	8.63×10^{-05}	3.79×10^{-06}
Lake C	2.53×10^{-04}	1.42×10^{-04}	4.19×10^{-06}
Lake E	4.22×10^{-04}	2.14×10^{-04}	7.27×10^{-06}
Unnamed Lake 1	1.13×10^{-04}	6.61×10^{-05}	2.21×10^{-06}
REF01	2.44×10^{-04}	2.23×10^{-04}	7.17×10^{-06}
REF02	5.05×10^{-05}	4.33×10^{-05}	1.26×10^{-06}
REF03	2.88×10^{-05}	1.88×10^{-05}	9.19×10^{-07}
19REF04	4.34×10^{-05}	2.72×10^{-05}	7.69×10^{-07}
19REF05	2.62×10^{-05}	2.21×10^{-05}	5.83×10^{-07}
19REF06	1.39×10^{-04}	1.22×10^{-04}	2.49×10^{-06}
19EXP02	6.00×10^{-03}	4.25×10^{-03}	2.07×10^{-04}
19EXP01	9.63×10^{-03}	5.82×10^{-03}	3.06×10^{-04}
19EXP03	8.12×10^{-04}	5.15×10^{-04}	3.57×10^{-05}
Preston Lake	2.21×10^{-05}	2.06×10^{-05}	4.27×10^{-07}
Wegner Lake	1.62×10^{-05}	1.13×10^{-05}	2.91×10^{-07}
Overall	1.05×10^{-02}	4.22×10^{-03}	2.51×10^{-04}

VC = valued component; Bq/m^3 = becquerels per cubic metre; HH = human health.

Table 7A-132: Reasonably Foreseeable Development Case Predicted Radionuclide Concentrations at Selected Receptors

Receptor Name	Concentration (Bq/m³)		
	24-hour 1st Highest	24-hour 2nd Highest	Annual Average
Hodge Lake Reference HH VC	3.56×10^{-05}	2.55×10^{-05}	1.15×10^{-06}
Broach Lake	3.73×10^{-04}	1.79×10^{-04}	6.40×10^{-06}
Camp Worker HH VC	3.09×10^{-03}	2.68×10^{-03}	9.43×10^{-05}
Patterson Lake HH VC	2.88×10^{-04}	2.06×10^{-04}	8.22×10^{-06}
Patterson Lake Eco VC	5.60×10^{-04}	5.50×10^{-04}	1.81×10^{-05}
Forrest Lake	3.12×10^{-04}	2.44×10^{-04}	1.17×10^{-05}
Forrest Lake North Eco VC	4.55×10^{-04}	3.17×10^{-04}	1.53×10^{-05}
Beet Lake HH VC	4.42×10^{-04}	3.15×10^{-04}	9.92×10^{-06}
Naomi Lake	1.79×10^{-04}	6.50×10^{-05}	2.97×10^{-06}
Clearwater River	2.43×10^{-05}	1.62×10^{-05}	7.23×10^{-07}
Lloyd Lake HH VC	1.03×10^{-05}	9.20×10^{-06}	4.73×10^{-07}
Broach Lake	1.33×10^{-04}	8.85×10^{-05}	3.87×10^{-06}
Patterson Lake	3.67×10^{-04}	2.94×10^{-04}	1.32×10^{-05}
Patterson Lake	7.36×10^{-04}	4.31×10^{-04}	1.88×10^{-05}
Lake H	4.68×10^{-04}	2.07×10^{-04}	1.13×10^{-05}
Lake G	6.24×10^{-04}	4.45×10^{-04}	1.85×10^{-05}
Beet Lake	4.56×10^{-04}	1.53×10^{-04}	6.54×10^{-06}
Naomi Lake	1.44×10^{-04}	1.12×10^{-04}	3.28×10^{-06}
Patterson Lake	4.97×10^{-04}	1.77×10^{-04}	1.11×10^{-05}
Forrest Lake	3.00×10^{-04}	1.41×10^{-04}	5.50×10^{-06}
Forrest Lake	3.17×10^{-04}	2.78×10^{-04}	1.26×10^{-05}
Unnamed Lake 2	1.55×10^{-04}	8.65×10^{-05}	4.23×10^{-06}
Lake C	2.54×10^{-04}	1.94×10^{-04}	1.00×10^{-05}
Lake E	4.45×10^{-04}	2.19×10^{-04}	1.06×10^{-05}
Unnamed Lake 1	1.14×10^{-04}	6.63×10^{-05}	2.90×10^{-06}
REF01	2.47×10^{-04}	2.23×10^{-04}	8.60×10^{-06}
REF02	5.28×10^{-05}	4.64×10^{-05}	1.79×10^{-06}
REF03	2.93×10^{-05}	2.07×10^{-05}	1.17×10^{-06}
19REF04	5.71×10^{-05}	2.92×10^{-05}	1.49×10^{-06}
19REF05	3.54×10^{-05}	2.79×10^{-05}	9.24×10^{-07}
19REF06	1.39×10^{-04}	1.28×10^{-04}	5.06×10^{-06}
19EXP02	6.00×10^{-03}	4.25×10^{-03}	2.09×10^{-04}
19EXP01	9.64×10^{-03}	5.82×10^{-03}	3.08×10^{-04}
19EXP03	8.19×10^{-04}	5.22×10^{-04}	3.69×10^{-05}
Preston Lake	2.25×10^{-05}	2.12×10^{-05}	6.01×10^{-07}
Wegner Lake	2.34×10^{-05}	1.55×10^{-05}	5.96×10^{-07}
Overall	1.05×10^{-02}	4.22×10^{-03}	2.53×10^{-04}

VC = valued component; Bq/m^3 = becquerels per cubic metre; HH = human health.

7A3.2.13.6 Radionuclides Deposition Rates

Table 7A-133 lists the annual deposition rate of radionuclides in the unit of becquerels per square centimetre per year at selected receptors for Application Case Operations and RFD Case.

Table 7A-133: Application Case Operations and Reasonably Foreseeable Development Case Predicted Radionuclide Deposition Rates at Selected Receptors

Receptor Name	Annual Average Deposition Rates (Bq/cm²/yr)	
	Application Case – Operations	RFD Case
Hodge Lake Reference HH VC	7.70×10^{-05}	1.04×10^{-04}
Broach Lake	5.16×10^{-04}	7.10×10^{-04}
Camp Worker HH VC	9.26×10^{-03}	1.25×10^{-02}
Patterson Lake HH VC	2.34×10^{-04}	2.41×10^{-03}
Patterson Lake Eco VC	1.51×10^{-03}	1.77×10^{-03}
Forrest Lake	9.51×10^{-04}	1.27×10^{-03}
Forrest Lake North Eco VC	1.31×10^{-03}	1.83×10^{-03}
Beet Lake HH VC	8.80×10^{-04}	1.33×10^{-03}
Naomi Lake	2.42×10^{-04}	2.54×10^{-04}
Clearwater River	5.48×10^{-05}	4.78×10^{-05}
Lloyd Lake HH VC	2.94×10^{-05}	3.15×10^{-05}
Broach Lake	2.22×10^{-04}	4.62×10^{-04}
Patterson Lake	8.04×10^{-04}	1.55×10^{-03}
Patterson Lake	1.75×10^{-03}	2.02×10^{-03}
Lake H	1.05×10^{-03}	1.06×10^{-03}
Lake G	1.73×10^{-03}	2.31×10^{-03}
Beet Lake	5.75×10^{-04}	7.72×10^{-04}
Naomi Lake	2.83×10^{-04}	2.50×10^{-04}
Patterson Lake	5.27×10^{-04}	1.45×10^{-03}
Forrest Lake	2.75×10^{-04}	7.11×10^{-04}
Forrest Lake	1.06×10^{-03}	1.90×10^{-03}
Unnamed Lake 2	3.79×10^{-04}	3.49×10^{-04}
Lake C	4.19×10^{-04}	1.39×10^{-03}
Lake E	7.27×10^{-04}	1.03×10^{-03}
Unnamed Lake 1	2.21×10^{-04}	3.03×10^{-04}
REF01	7.17×10^{-04}	1.24×10^{-03}
REF02	1.26×10^{-04}	1.24×10^{-04}
REF03	9.19×10^{-05}	7.16×10^{-05}
19REF04	7.69×10^{-05}	1.03×10^{-04}
19REF05	5.83×10^{-05}	4.97×10^{-05}
19REF06	2.49×10^{-04}	5.29×10^{-04}
19EXP02	2.07×10^{-02}	7.47×10^{-02}
19EXP01	3.06×10^{-02}	1.18×10^{-01}
19EXP03	3.57×10^{-03}	6.46×10^{-03}
Preston Lake	4.27×10^{-05}	3.83×10^{-05}
Wegner Lake	2.91×10^{-05}	3.05×10^{-05}
Overall	2.51×10^{-02}	7.57×10^{-02}

VC = valued component; RFD = reasonably foreseeable development; Bq/cm^2/yr = becquerels per square centimetre per year; HH = human health.

CLOSING

WSP Canada Inc. (WSP; formerly Golder Associates Ltd.) is pleased to submit this report to NexGen in support of the environmental assessment for the Rook I Project. For details on the limitations and use of information presented in this report, please refer to the Study Limitations section following this page. If you have any questions or require additional details related to this study, please contact the undersigned.

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STUDY LIMITATIONS

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REFERENCES

Acts and Regulations

Canadian Off-Road Compression-Ignition Engine Emission Regulations (DORS/2011-261) under the *Canadian Environmental Protection Act, 1999*. Last amended 3 June 2021. Available at https://laws-lois.justice.gc.ca/eng/regulations/SOR-2005-32/20120116/P1TT3xt3.html.

Sulphur in Diesel Fuel Regulations. SOR/2002-254 under the *Canadian Environmental Protection Act, 1999*. Last amended 2 June 2017. Available at https://laws-lois.justice.gc.ca/eng/regulations/SOR-2002-254/index.html.

Multi-Sector Air Pollutants Regulations. S0R/2016-151 under the *Canadian Environmental Protection Act, 1999*. Last amended 1 January 2021. Available at https://laws-lois.justice.gc.ca/eng/regulations/SOR-2016-151/index.html.

Literature Cited

Arcadis (Arcadis Canada Inc.). 2019. Estimate of Emissions for Incineration of Low Level Radioactive Waste. November 2019.

AREVA (AREVA Resources Canada Inc.). 2014.Kiggavik Project FEIS, Tier3 Technical Appendix 4B: Air Dispersion Assessment, Attachment A: Air Emissions Calculation Methods. September 2014.

Attalla IM, Stuart DJ, Lange T, Lilley W, Morgan S. 2008. NOx Emissions from Blasting Operations in Open-cut Coal Mining. Atmospheric Environment. 42: 7874-7883.

Australian Government. 2016. National Pollutant Inventory: Emission Estimation Technique Manual for Explosives Detonation and Firing Ranges. Version 3.1. Available at http://www.npi.gov.au/system/files/resources/e635847A-22ef-9f74-71bA-c10705d09e59/files/explosives-detonation-and-firing-ranges.pdf.

CCME (Canadian Council of Ministers of the Environment). 1998. National Emission Guideline for Commercial/Industrial Boilers and Heaters. CCME NOX/VOC Management Plan, N306 Multi-stakeholders Working Group and Steering Committee. Winnipeg, MB.

CCME. 2000. Canada-Wide Standards for Mercury Emissions. June 2000.

CCME. 2001. Canada-Wide Standards for Dioxins and Furans – emissions from waste incinerators and coastal pulp and paper boilers. May 2001.

CCME. 2012. Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone. PN 1483. Available at https://ccme.ca/en/res/pn1483_gdad_eng-secured.pdf.

CCME. 2020a. Guidance Document on Achievement Determination for Canadian Ambient Air Quality Standards for Nitrogen Dioxide. PN 1608. Available at https://ccme.ca/en/res/gdadforcaaqsfornitrogendioxide_en1.0.pdf.

CCME. 2020b. Guidance Document on Achievement Determination for Canadian Ambient Air Quality Standards for Sulphur Dioxide. PN 1610. Available at https://ccme.ca/en/res/gdadforcaaqsforsulphurdioxide_en1.0.pdf.

CCME. 2021. Canada's Air. Air Quality Report. Accessed August 2021. Available at https://www.ccme.ca/en/air-quality-report.

CEPEI (Canadian Energy Partnership for Environmental Innovation). 2021. CEPEI Methodologies Manual for the Calculator for Airborne Contaminant Emissions from Natural Gas Combustion – 2020 Inventory Year (Reporting in 2021). 12 March 2021.

ECCC (Environment Canada and Climate Change). 2021. Report to the National Pollutant Release Inventory: Pit and quarries reporting guide. Accessed in August 2021. Available online at: https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/report/pits-quarries-guide.html.

ENV (Saskatchewan Ministry of Environment). 2012. Saskatchewan Air Quality Modelling Guideline. Government of Saskatchewan. March 2012.

Environment Canada. 2010. Technical Document for Batch Waste Incineration. January 2010. Available at https://publications.gc.ca/collections/collection_2010/ec/En14-17-1-2010-eng.pdf.

Fission (Fission Uranium Corp.). 2019. Technical Report on the Pre-feasibility Study on the Patterson Lake South Property Using Underground Mining Methods, Northern Saskatchewan, Canada. NI 43-101 Report. Prepared by Roscoe Postle Associates Inc. for Fission Uranium Corp. November 2019

Government of Saskatchewan. 2015. Table 20: Saskatchewan Ambient Air Quality Standards. Accessed August 2021. Available at https://envrbrportal.crm.saskatchewan.ca/Pages/SEQS/Table20-SEQS-SAAQS.pdf.

Government of Saskatchewan. 2021. Saskatchewan Digital Landcover. Accessed in August 2021. Available at https://geohub.saskatchewan.ca/datasets/a287612147ab4f0a9863148f76170f00/about.

MDAQMD (Mojave Desert Air Quality Management District). 2000. Emissions Inventory Guidance Mineral Handling and Processing Industries. Available at https://avaqmd.ca.gov/files/d40533505/Mineral+Handlin+Guide.pdf.

MECC (Ontario Ministry of the Environment and Climate Change). 2018. Procedure for Preparing an Emission Summary and Dispersion Modelling Report. Guideline A-10. Government of Ontario.

NexGen (NexGen Energy Ltd.). 2018. NI 43-101 Technical report on Pre-feasibility study of the Arrow Deposit, Rook I Property, Saskatchewan, Canada. Technical report prepared by O'Hara P, Cox J, Robson DM, Mathisen M (Wood and RPA) for NexGen Energy Ltd., effective date 5 November 2018, p. 269.

NexGen. 2019. Project Description for the Rook I Project. Submitted to Saskatchewan Ministry of Environment and Canadian Nuclear Safety Commission. April 2019.

USEPA (United States Environmental Protection Agency). 1986. Appendix B.1: Particle Size Distribution Data and Sized Emission Factors for Selected Sources. US EPA AP-42: Compilation of Air Pollutant Emissions Factors. October 1986. Available at https://www.epa.gov/sites/default/files/2020-11/documents/appb-1.pdf.

USEPA. 1996a. Appendix B.2: Generalized Particle Size Distributions. US EPA AP-42: Compilation of Air Pollutant Emissions Factors. September 1996. Available at https://www.epa.gov/sites/default/files/2020-11/documents/appb-2.pdf.

USEPA. 1996b. Chapter 2.1 Refuse Combustion. US EPA AP-42: Compilation of Air Pollutant Emissions Factors. October 1996. Available at https://www.epa.gov/sites/default/files/2020-10/documents/c02s01.pdf.

USEPA. 1998. AP-42. Chapter 11.9 Western Surface Coal Mining. US EPA AP-42: Compilation of Air Pollutant Emissions Factors. October 1998. Available at https://www.epa.gov/sites/default/files/2020-10/documents/c11s09.pdf.

USEPA. 1999. Chapter 1.3 Fuel Oil Combustion. US EPA AP-42: Compilation of Air Pollutant Emissions Factors. September 1999. Available at https://www.epa.gov/sites/default/files/2020-09/documents/1.3_fuel_oil_combustion.pdf.

USEPA. 2004a. AP-42. Chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing. US EPA AP-42: Compilation of Air Pollutant Emissions Factors. August 2004. Available at https://www.epa.gov/sites/default/files/2020-10/documents/c11s1902.pdf.

USEPA. 2004b. USEPA 40 CFR Parts 9, 69, et al. Control of Emissions of Air Pollution From Nonroad Diesel Engines and Fuel; Final Rule. Available at https://www.govinfo.gov/content/pkg/FR-2004-06-29/pdf/04-11293.pdf.

USEPA. 2006a. Chapter 11.12 Concrete Batching. USEPA AP-42: Compilation of Air Emission Factors. June 2006. https://www.epa.gov/sites/default/files/2020-10/documents/c11s12.pdf.

USEPA. 2006b. Chapter 13.2.2 Unpaved Road Dust. USEPA AP-42: Compilation of Air Emission Factors. November 2006. Available at https://www.epa.gov/sites/default/files/2020-10/documents/13.2.2_unpaved_roads.pdf.

USEPA. 2006c. Chapter 13.2.5. Industry Wind Erosion. USEPA AP-42: Compilation of Air Emission Factors. November 2006. Available at https://www.epa.gov/sites/default/files/2020-10/documents/13.2.5_industrial_wind_erosion.pdf.

USEPA. 2008. AERSURFACE User's Guide. January 2008. Available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P1009S1K.PDF?Dockey=P1009S1K.pdf.

USEPA. 2010a. Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling—Compression-Ignition. EPA-420-R-10-018. NR-009d. July 2010.

USEPA. 2010b. Conversion Factors for Hydrocarbon Emission Components. EPA-420-R-10-015. NR-002d. July 2010.

USEPA. 2010c. Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling. EPA-420-R-10-016. NR-005d. July 2010.

USEPA. 2012. Haul Road Workgroup Final Report Submission to EPA-OAQPS. March 2012. Available at https://www.epa.gov/sites/default/files/2020-10/documents/haul_road_workgroup-final_report_package-20120302.pdf.

USEPA. 2015. USEPA CFR Title 40 Volume 7 Part 60 Subpart H. Standards of Performance for Sulphuric Acid Plants. July 2015.

USEPA. 2021a. AERMOD Implementation Guide. July 2021. Available at https://gaftp.epa.gov/Air/aqmg/SCRAM/models/preferred/aermod/aermod_implementation_guide.pdf.

USEPA. 2021b. User's Guide for the AMS/EPA Regulatory Model (AERMOD). April 2021. Available at https://gaftp.epa.gov/Air/aqmg/SCRAM/models/preferred/aermod/aermod_userguide.pdf.

USEPA. 2021c. Nitrogen Dioxide/Nitrogen Oxide In-Stack Ratio (ISR) Database. Accessed in August 2021. Available at https://www.epa.gov/scram/nitrogen-dioxidenitrogen-oxide-stack-ratio-isr-database.

WRAP (Western Regional Air Partnership). 2006. WRAP Fugitive Dust Handbook. September 2006.

Attachment 7A-1 Radon Releases Memo

Memo

ARCADIS

SUBJECT
Radon Releases Final

DATE
7 April 2022

TO
Jon Henderson

PROJECT NUMBER
30064042-11

COPIES TO
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Radon released to the environment from mining and processing of uranium ores is an important issue when considering potential radiation exposures to members of the public who live, work, or recreate near such a facility.

This report provides estimates of radon released to the environment from radon sources underground (UG), from the process plant (including paste preparation) and water treatment ponds.

1. UNDERGROUND RADON SOURCES

Underground sources of radon include:

- Emanation from mine walls;
- Radon from pore space radon arising from drilling, blasting, mucking, etc. (materials handling);
- Radon entering the mine with mine water and de-emanating;
- Radon from placing tailings UG.

1.1 Emanation from Mine Walls

The details around the emanation factor can be complicated and can vary with mineral characteristics, water content and ore grade.

In the absence of mine specific information (i.e., surface area), a notional emanation factor of 0.5 to 1 Bq/m^2s per Bq/g factor is often assumed which is consistent with past practice and has been accepted by the CNSC.

The information needed is:

- Surface areas of waste, ore, and back filled stopes that are open (i.e., being ventilated) at any one time (notional).
- The contribution from waste surface is typically a very small fraction of total from this source, so surfaces open in ore and backfill stopes is the key factor, along with average grade.

The exposed surface area of general mine openings will vary over the life of the mine; however,

- The average grade of ore is 2.37% U_3O_8 in the 11 year EA Case (diluted grade);

- The average grade of ore is 1.37% U_3O_8 in the 24 year EA Case (diluted grade);
- Maximum annual grade of ore is 4.41 %U_3O_8 (Year 1);
- Waste is assumed to be 0.001% on average up to 0.03% U_3O_8 (Max).

On an activity basis, natural uranium contains approximately 1.24 x 10^4 Bq/g U-238 and the same activity of Ra-226, the parent or Rn-222. On the basis that uranium is approximately 84.8% of U_3O_8 by mass, and that 1 gU_{nat} contains approximately 2.48 x 10^2 Bq/g U-238 (and the same activity of Ra-226), then,

- At an average grade of ore is 2.37% U_3O_8 in the 11 year EA case contains 2.48 x 10^2 Bq/g Ra-226;
- At an average grade of ore is 1.37% U_3O_8 in the 24 year EA case contains 1.43 x 10^2 Bq/g Ra-226;
- At the maximum annual grade of ore of 4.41% U_3O_8 (Year 1) contains 4.62 x 10^2 Bq/g Ra-226;

Waste at an assumed average grade of 0.001% U_3O_8 contains 0.1 Bq/g Ra-226. However, as the majority of the surface area will be in waste, as opposed to ore, this source is expected to be very small compared to the sources discussed below and is not discussed further in this memorandum.

1.2 Radon from Pore Space Radon Arising from Drilling, Blasting, Mucking, etc. (Materials Handling)

For radon from breaking ore/waste, in the absence of mine specific data we would typically assume that 20% of pore space radon (i.e., radon in equilibrium with the Ra-226 content of the waste/ore) is released from drilling/mucking.

The contribution from drilling can be estimated but is very small compared to breakage of ore (mucking for example) and for present purposes, is not considered.

To illustrate the calculation, consider the radon released from mucking ore at 2.37% U_3O_8.

A muck pile will be created after each blast. The mass of the muck pile amount is determined by the advance distance (for illustration, assume 3 m/d), cross section assumed at 5 m x 5 m, and the density of the rock - ore or waste - is assumed at 2.5 t/m^3. Therefore, the mass of rock in the muck pile is:

$$m_{rock} = d \times area \times \rho_{ore}$$

Where:

m_{rock} is the mass of rock in the muck pile;

d is advance distance = 3 m;

area is cross-sectional area = 5 m by 5 m;

ρ_{ore} is the density for ore (2.5 t/m^3).

The mass of rock corresponding mass of waste/ore is 187.5 tons. The radon released from rock (waste/ore) while being mucked is calculated from the mass of the rock, the uranium concentration and the emanation fraction according to:

$$a_{Rn\ rock} = m_{rock} \times C_{rock} \times EF$$

$a_{Rn\ rock}$ is the radon total activity released (Bq);

m_{rock} is the mass of the muck pile (with a correction factor of 10^6 g/t);

C_{rock} in this example is the average ore grade of 2.37% U_3O_8 which converts to about 2.48 x 10^2 Bq/g Ra-226;

EF is the emanation fraction of 0.2 from the rock to the pore space.

In order to get an average release rate over the duration of mucking, the radon total activity released ($a_{Rn\ rock}$) is averaged over the year (t_m in seconds per year), or

Avg Rn release rate = $a_{Rn\ rock}/t_m$ in units of Bq/s

Assuming an annual production of ore at 14 x 10^6 kg U_3O_8 per year, and an average grade of 2.37% U_3O_8, we estimate that on average, the annual radon release from mining is:

Ore: 14 x 10^6 kg U_3O_8 x (10^3 g/kg) x (2.48 x 10^2 Bq Ra-226/g U_3O_8) x 0.2 (emanation fraction) = 6.95E+11 Bq

Assuming for purposes of EA, the radon is released uniformly over the year this converts to a radon release rate of about 2.20E+04 Bq/s

Waste For 14 tonnes of U_3O_8 per year, the ore production 100/2.37 larger or about 600 tonnes ore per tonne of U_3O_8. Assuming waste production at about 2x that of ore, the radon from waste rock production would be:

2 x 600 x 10^6 kg waste x (10^3 g/kg) x (0.1 Bq Ra-226/g U_3O_8) x 0.2 (emanation fraction) = 2.5E+10 Bq

Assuming for purposes of EA, the radon is released uniformly over the year this converts to a radon release rate of about 7.96E+02 Bq/s.

The following Table summarizes radon released from mining for a range of ore grades.

Material (Grade)	Total Radon Release (Bq/s)	
Ore (2.37% U_3O_8)	2.20E+04	11 year EA Case
Ore (1.37% U_3O_8)	1.27E+04	24 year EA case
Ore (4.41% U_3O_8)	4.10E+04	Max Year
Waste (0.001% U_3O_8)	7.96E+02	Average waste

1.3 Radon Entering the Mine with Mine water and De-emanating

The Itasca memo to NexGen dated indicates a mine water to the underground mine workings and development areas in the range of 50 to 70m^3/hr or from 14 to 20 L/s. Radon is soluble in water and as groundwater flows through rock (ore or waste) it will accumulate some level of radon as described below. This radon in mine water is assumed to be released to the mine atmosphere as the mine water enters the mine.

In the absence of mine specific radon emanation fractions, the amount of radon released from solid rock and reaching the pore space, for ore and waste as noted above, is assumed at 0.2. This radon is transferred from groundwater to mine water and de-emanated upon entry of mine water into the mine[1].

The nominal concentration of radon in mine water released is based on 2.37% U_3O_8 grade in ore and 0.001% U_3O_8 grade in waste and is given by:

$$C_{radon} = \frac{EF \times G_{U3O8}(as\ Ra226) \times \rho_{ore}}{PV \times 1{,}000}$$

Where:

C_{radon} is the radon concentration within the mine water with units of Bq/L;

EF is the emanation fraction with a based assumption of 0.2 from the rock to the pore space;

G_{U3O8} is the uranium grade in %U_3O_8 – for ore and waste is:

- At an average grade 2.37% U_3O_8, the ore contains 2.48 x 10^2 Bq/g Ra-226;
- Waste at an assumed grade of 0.001% U_3O_8 contains 0.1 Bq/g Ra-226;

ρ_{ore} is the density for in situ ore (2.5x10^6 g/m^3), the density for waste rock (2.5x10^6 g/m^3 (assumed));

PV is the pore volume of the rock with an assumed value of 0.1 m^3 pore space per m^3;

1,000 is the conversion from m^3 to L.

For the above assumptions at 2.37% U_3O_8, the concentration of radon in mine water after passing through the ore zone is:

[1] The radon released to the porewater is assumed to move along with the groundwater and when entering a mine, the radon in mine water is released to mine air much like the carbonation from a coke bottle.

$$C_{radon/ore} = \frac{0.2\times2.48\times10^{2}\times2.5\times10^{6}}{0.1\times1{,}000}$$=3.35E+07 Bq/L

For mine water passing through waste, the corresponding value is 1.41E+04 Bq/L

Only some fraction of the mine water will flow through ore, the rest will flow through host rock. We are uncertain at the moment about how to assign mine water flows; however, for present purposes, we have assumed that 1/3 of the mine water flows through ore and 2/3 flows through waste before entering the mine. Thus, the estimated radon release is calculated, for example as:

Mine water Rn = ((2/3*1.41E+04 Bq/L) + (1/3*3.35E+07 Bq/L))*20 L/s = 2.24E+08 Bq/s

The following Table summarizes the radon release from mine water.

Material	Total Radon Release from mine water (Bq/s)	
Ore (2.37% U_3O_8)	2.23E+08	11 year EA Case
Ore (1.37% U_3O_8)	1.29E+08	24 year EA case
Ore (4.41% U_3O_8)	4.16E+08	Max Year
Waste (0.001% U_3O_8)	1.89E+05	Average waste

1.4 Radon from Placing Tailings in the UGTMF

The paste tailings will contain (essentially) all of the Ra-226 that was present in the ore. The pore space radon is assumed to be released during placement and on average, would be the same as the radon from breaking ore.

Once placed, the emanation testing at SRC shows that very little radon will be released from paste backfill once in place.

Thus, the radon released from placement of paste tailings is assumed to be about 2.28E+04 Bq/s (for the 11 year EA case).

1.5 Summary of Radon Released from UG at NexGen Rook I

Source of Radon	Estimated Rate of Release (Bq/s): 11 year EA Case	Estimated Rate of Release (Bq/s): 24 year EA Case	Estimated Rate of Release (Bq/s): Max Year
Emanation from mine surfaces	Expected to be relatively minor	Expected to be relatively minor	Expected to be relatively minor
Materials handling	2.28E+04	1.35E+04	4.18E+04
Mine water	2.24E+08	1.29E+08	4.16E+08
Placement of paste tails UG	2.28E+04	1.35E+04	4.18E+04
Total rate of radon release	2.28E+08	1.29E+08	4.16E+08

2. PROCESS PLANT RADON SOURCES

The radon sources in the process plant include:

- Ore storage;
- Radon released from materials handling (sorting and blending, entry to mill and grinding);
- Radon released from storage and leaching tanks containing ore in slurry;
- Paste tailings plant and backfill plant.

2.1 Surface Storage

Areas for consideration include the ore stockpile, special waste stockpile and the waste stockpile.

Once placed in a stockpile, uranium containing materials, notably ore, special waste and waste rock stockpiles will continue to release radon at a constant rate[2]. In the absence of mine specific information (i.e., surface area), a notional emanation factor of 0.5 Bq/m^{2}s per Bq/g factor is often assumed. Radon released from the surface of an ore storage pile can be estimated as:

- Rn from ore surfaces = Surface Area x Bq Ra-226/g x 0.5 Bq/m^{2}s per Bq/g;

The estimated radon releases from the storage piles are summarized in the following Table.

[2] The actual rate of radon release will depend on a number of factors, among them the nature of the mineralization, grade and weather. For present purposes, a notional average- rate of release per unit area of 0.5 Bq/m^{2}s is assumed.

Source*	Description	Area (m^2)*	Radon Release (Bq/s): 11 year EA case	Radon Release (Bq/s): 24 year EA case	Radon Release (Bq/s): Max year case
Ore surface	Ore Storage Stockpiles (pad area)	13,965	1.73E+06	1.00E+06	3.22E+06
Special waste surface	Special Waste Rock Stockpile (pad area)	11,772	3.08E+04	1.78E+04	5.74E+04
Waste rock	Minimal		-	-	-
		Total	1.76E+06	1.02E+06	3.28E+06

*Email from Arthur Lieu Re: Additional IRs for Arcadia on the mill design (16 April 2021).

2.2 Materials Handling

For handling/processing of ore – crushing, grinding, loading/dumping etc., pore space radon can be released to the atmosphere.

In the absence of mine specific data, we would typically assume that 20% of pore space radon (i.e., radon in equilibrium with the Ra-226 content of the waste/ore) is released from materials processing/handling.

For handling/processing of ore – crushing, grinding, loading/dumping etc., pore space radon can be released to the atmosphere.

We assume as previously, that 20% of pore space radon (i.e., radon in equilibrium with the Ra-226 content of the waste/ore) is released from materials processing/handling.

2.2.1 Sorting, Storage and Entry to the Mill

To illustrate the calculation, consider the radon released from loading to a stockpile for example. For present purposes, we assume that 20% of pore space radon is released to the atmosphere via the combination of sorting and dumping to a stockpile.

Assume for illustration that the mill processes about 1300 tpd of ore at 2.37% U_3O_8 and that the ore has been stored to allow re-growth of radon. Then, the radon release can be estimated as:

$$a_{Rnore} = m_{rock} \times C_{rock} \times EF$$

$a_{Rn\ ore}$ is the radon total activity released (Bq/d);

m_{rock} is the mass of the ore pile (1300 tpd x 10 g/t);

C_{rock} in this example is the average ore grade of 2.37% U_3O_8 which converts to about 2.48E+02 BqRa-226/g;

EF is the emanation fraction of 0.2 from the rock to the pore space (a very generic assumption).

Which converts to a radon release of:

1300 tonnes/day x 10^6 g/tonne *(2.48E+02 Bq Rn/g) x 0.2 (emanation fraction) = 6.45E+10 Bq/day

For the 11 year EA case, this converts to an average radon release rate of about:

Avg radon release rate = (6.45E+10 Bq/day) / (24 hr*3600 s/hr) = 7.47E+05 Bq/s

The radon release from sorting storage and entry to mill is summarized in the following Table.

Sorting Storage and Entry to Mill	Radon Release (Bq/s)
EA 11 year case	7.47E+05
EA 24 year case	4.32E+05
Max year	1.39E+06

2.2.2 Ore Storage Vessels in Process Plant

Radium-226 produces radon-222 on a continuous basis at the rate of 2.1 x 10^{-6} Bq/s radon per Bq Ra-226.

As previously noted, the amount of radon released from solid rock and reaching the pore space, is assumed at 0.2. This radon is released to the slurry and it is assumed that all slurry tanks are agitated and vented directly to the atmosphere, which will release the radon in the slurry to the atmosphere.

The estimation of radon release depends on the inventory of U_3O_8 at any time in the process plant.

The Mill PFS restart drawings indicated a solids flow of about 1740 kg/h of U_3O_8 (2 tanks) and 6 leach tanks. At any given time, there is an inventory of uranium in the mill which is producing radon at a constant rate of 2.1 x 10^{-6} Bq/s per Bq Ra-226 is the radon produced per second from 1 Bq of radium.

Thus, in any given hour, there is an inventory of uranium in ore storage vessels as solids and/or liquids.

Assuming that 20% or radon from solids and 100% from leach tans is released to the atmosphere, the radon release rate is:

(2 x 1740 kg x 1000 g/kg x 2.48E+02 BqRa-226/g x 0.2 x 2.1E-06 Bq/s per Bq Ra-226) + (6 x 1740 kg x 1000 g/kg x 2.48E+02 BqRa-226/g x 0.2 x 2.1E-06 Bq/s per Bq Ra-226) = 1.45E+03 Bq/s

The radon release from process vessels is:

Sorting Storage and Entry to Mill	Radon Release (Bq/s)
EA 11 year case	1.45E+03
EA 24 year case	8.39E+02
Max year	2.70E+03

2.2.3 Paste Tailings Preparation

As indicated above, ore is assumed entered to the mill at a rate of 1740 kg/h U_3O_8. Radium-226 is transferred through the process plant at the same rate that it enters the mill.

For the present, we assumed that paste tailings are produced on a continuous basis at the mill at a rate assumed to match the amount of ore entered into the mill in the same time period.

We assume that the tailing preparation vessels are agitated and hence radon released to pore space will be released to atmosphere. On this basis, the rate of radon release from the preparation of paste tailings is the same as the rate of radon being release upon entry to the mill, namely 7.47E+05, 4.32E+05, and 1.39E+06 Bq/s, respectively for the 11 year EA case, the 24 year EA case and the Max year respectively.

2.2.4 Summary of Radon from Process Plant

Source of Radon	EA 11 year case (Bq/s)	EA 24 year case (Bq/s)	Max Year case (Bq/s)
Surface storage	1.76E+06	1.02E+06	3.28E+06
Materials handling into mill	7.47E+05	4.32E+05	1.39E+06
Ore storage vessels	1.45E+03	8.39E+02	2.70E+03
Paste Tailings prep	7.47E+05	4.32E+05	1.39E+06
Total	3.26+06	1.88E+06	6.06E+06

3. WATER TREATMENT POND RADON SOURCES

As previously indicated, radon-222 is produced continuously from its parent radium-226 at the rate of 2.1E-06 Bq/s radon per Bq radium-226. In concept, radon-222 is produced from radium-226 contained in sediments on the bottom of water treatment ponds. However, the diffusion coefficient of radon-222 in water is << less than the diffusion coefficient in air (about 1/100th) and for practical purposes, radon produced from radium-226 in water covered sediments (or tailings solids) decays before it can escape the to the water column and is not available for release from the surface of the pond.

Water in uranium mine water treatment ponds will contain some level of radium-226 and thus is a potential source of radon. While diffusion from the radium containing water is a theoretical source of radon, diffusion in water is very slow and this source can typically be neglected and that turbulence in the water is most likely the dominant source of radon from ponds.

Water in uranium mine water treatment ponds will contain some level of Ra-226 and thus is a potential source of radon. While diffusion from the radium containing water is a theoretical source of radon, diffusion in water is very slow and this source can typically be neglected and that turbulence in the water is most likely the dominant source of radon from ponds. Consider that Rn-222 is produced at the rate of 2.1 x 10^{-6} /s (Bq/s per Bq Ra-226) and that radon is released at surface as it is produced from Ra-226 within the "turbulent" layer. The turbulent layer is determined through wind action or mechanical mixing. The following table illustrates the concept.

Ra-226 (Bq/L)	Depth of (Mixing) Layer (cm)	Rn-222 Flux (Bq/m^{2}s)*
1	10	0.0002
	50	0.001
	100	0.002
10	10	0.002
	50	0.01
	100	0.02
100	10	0.02
	50	0.1
	100	0.2

Data from the PFS Report Table 81 (p.1882) indicates that feed solution to the WTP contains about 600 Bq/L. Following treatment, this level should decrease to <0.6 Bq/L.

Assuming for the moment that wind driven turbulence extends to a metre depth, then the average radon flux from water treatment ponds at NexGen would be of the order of 0.0014 Bq Rn-222 per m^2 per s.

Assuming that all ponds as shown below are the same level of ra-226, and the radon emissions from the ponds would be calculated as illustrated below for the monitoring pond.

i.e., 12,236 m^2 x 0.0014 Bq Rn-222 per m^2 per s = 17 Bq/s and similarly low for the other ponds.

Description	Area (m^2)
Monitoring Pond (4 incl. intermediate berm)	12,236
Contingency Pond (to top of pond inside edge)	2,888
Settling Pond (to top of pond inside edge)	5,890

Appendix 7B Noise Modelling Summary Report

Abbreviations and Units of Measure

Abbreviation	Definition
AER	Alberta Energy Regulator
ECAC	European Civil Aviation Conference
ECCC	Environment and Climate Change Canada
EIS	Environmental Impact Statement
ISO	International Organization for Standardization
L_{dn}	day-night sound level
$L_{eq,day}$	energy equivalent sound level for the daytime period
$L_{eq,night}$	energy equivalent sound level for the nighttime period
L_{max}	maximum sound level
LFN	low frequency noise
LiDAR	light detection and ranging
LSA	local study area
NexGen	NexGen Energy Ltd.
Project	Rook I Project
RSA	regional study area

Unit	Definition
%	percent
%HA	percent highly annoyed
°C	degrees Celsius
±	plus or minus
dBA	A-weighted decibel
dBC	C-weighted decibel
dBZ	unweighted decibel
ha	hectare
hp	horsepower
Hz	hertz
kHz	kilohertz
km	kilometre
m/s	metres per second
t	tonne

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7B1 ANALYSIS APPROACH

7B1.1 Regulatory Guidance

Saskatchewan does not have regulations or guidelines for the analysis of environmental noise from industrial facilities. In the absence of Saskatchewan-specific regulations or guidelines, the analysis of Rook I Project (Project) noise effects makes use of methods and thresholds from two federal guidance documents and one noise regulation applicable to facilities in Alberta:

- *Environmental Code of Practice for Metal Mines* (Environment Canada 2009);
- *Guidance for Evaluating Human Health Impacts in Environmental Assessment – Noise* (Health Canada 2017); and
- Alberta Energy Regulator (AER) *Directive 038: Noise Control* (AER 2007).

7B1.2 Noise Study Area and Receptors

Noise emitted by Project equipment and activities will propagate into the environment beyond the Project footprint. A maximum disturbance area of 981 ha was used for the assessment of terrain and soils, vegetation, and wildlife and wildlife habitat to address uncertainty in the final design of the Project so that adverse effects would not be underestimated. The local study area (LSA) for the noise analysis was defined as a 1.5 km buffer surrounding the maximum disturbance area for the Project. The LSA was defined in accordance with AER Directive 038 (AER 2007), which states that noise effects should be analyzed at receptors located within 1.5 km of the Project. The LSA was defined at a scale that captures most of the expected noise effects from the Project.

The regional study area (RSA) for the noise analysis was defined as a 10 km buffer surrounding the maximum disturbance area for the Project. This buffer distance was selected for consistency with the RSA used in the baseline study, which sought to characterize both existing noise and light conditions (Annex II, Noise and Light Baseline Report). The RSA was defined at a scale that is appropriate for analysis of cumulative effects arising from the spatial overlap of the Project and the Fission Patterson Lake South Property, which is a reasonably foreseeable development proposed by Fission Uranium Corp. (Fission 2019).

Receptors for the noise analysis were identified through engagement and Joint Working Group meetings with Indigenous Groups. A total of 16 noise receptors were identified in the LSA and RSA. Noise receptors include active and historical cabins, lodges, and campgrounds, as well as locations used for fishing.

Table 7B-1 provides geographical coordinates and a short description for each of these receptors. A map showing the receptor locations is presented in Environmental Impact Statement (EIS) Figure 7.3.4.

Table 7B-1: Noise Receptors

Noise Receptor	Description[a]	Universal Transverse Mercator Coordinates (Zone 12)	
		Easting (m)	Northing (m)
R-04	Cabin	600523	6398606
R-05	Lodge	608757	6389632
R-06	Cabin (old cabin)	609329	6389420
R-07	Cabin	614387	6391050
R-08	Camp (tourist camp)	609942	6389235
R-09	Camp (tourist camp)	605286	6388706
R-22	Fishing (nets)	599851	6391630
R-26	Plane crash	606543	6389350
R-30	Historical camp	600546	6391678
R-31	Camp (rough camp)	605282	6388662
R-40	Fishing	595924	6397789
R-41	Fishing	607681	6394910
R-42	Fishing	600992	6388870
R-43	Fishing	605233	6386971
R-48	Fishing	601140	6393297
R-49	Fishing	600042	6393020

a) Receptor description provided during stakeholder engagement meetings.

7B1.3 Assessment Criteria

7B1.3.1 Environment and Climate Change Canada

Noise effects are analyzed in the context of Environment and Climate Change Canada (ECCC) guidance using the energy equivalent sound level for the daytime period ($L_{eq,day}$) and the energy equivalent sound level for the nighttime period ($L_{eq,night}$). Noise levels may fluctuate over time; energy equivalent sound levels represent the average value for a specified time period. The daytime period begins at 07:00 and ends at 22:00. The nighttime period begins at 22:00 and ends at 07:00.

Environment and Climate Change Canada recommends that $L_{eq,day}$ noise levels not exceed 55 A-weighted decibels (dBA) and that $L_{eq,night}$ noise levels not exceed 45 dBA (Environment Canada 2009). Noise levels expressed in dBA units have been scaled to reflect the frequency sensitivity of the human auditory system; however, the ECCC noise thresholds are applicable to both human and wildlife receptors (Environment Canada 2009).

Thresholds from ECCC apply to continuous noise from “mining activities” in isolation from other sources (Environment Canada 2009). As such, existing noise levels are not considered when analyzing noise effects in the context of ECCC thresholds.

7B1.3.2 Health Canada

Noise effects are analyzed in the context of Health Canada guidance using $L_{eq,night}$, combined day-night sound levels (L_{dn}), and maximum sound levels (L_{max}). The L_{dn} noise level is calculated by combining $L_{eq,day}$ and $L_{eq,night}$ noise levels after applying a 10 dBA penalty to the $L_{eq,night}$ value, since nighttime noise is generally considered more disruptive than daytime noise. The L_{max} noise level is used to characterize intermittent noise sources; L_{max} represents the maximum value rather than a time-averaged noise level.

Health Canada provides a formula for calculating the percentage of a typical population that would be highly annoyed (percent highly annoyed [%HA]) by a given L_{dn} noise level and recommends that changes in %HA not exceed 6.5% (Health Canada 2017). Analyzing noise effects in the context of this 6.5% threshold requires the calculation of %HA based on existing L_{dn} noise levels, calculating %HA based on cumulative L_{dn} noise levels (i.e., existing conditions plus Project contribution or existing conditions plus Project contribution plus Fission Patterson Lake South Property contribution), and then calculating the difference between these two %HA values. Formulae for calculating %HA based on noise level have been established through statistical analysis of dose-response data for large populations (Health Canada 2017); however, use of the %HA parameter is not limited to large populations.

To protect against sleep disturbance from continuous noise, Health Canada recommends that annual average $L_{eq,night}$ noise levels not exceed 40 dBA at locations where people sleep. This sleep disturbance threshold is understood to apply to cumulative noise levels (i.e., existing conditions + Project contribution or existing conditions + Project contribution + Fission Patterson Lake South Property contribution).

To protect against sleep disturbance from intermittent noise, Health Canada recommends that indoor L_{max} noise levels not exceed 45 dBA more than 10 to 15 times per nighttime period (Health Canada 2017). Health Canada further recommends that an outdoor-to-indoor transmission loss of 15 dBA be used to simulate a bedroom with partially open windows (Health Canada 2017). Combining these two Health Canada recommendations yields a L_{max} sleep disturbance target of 60 dBA outdoors (i.e., 45 dBA indoors plus 15 dBA transmission loss).

7B1.3.3 Alberta Energy Regulator

Low frequency noise (LFN) can have adverse effects even when overall or total noise levels are otherwise acceptable. The AER Directive 038 sets out a two-part test to evaluate LFN effects (AER 2007). First, $L_{eq,day}$ and $L_{eq,night}$ noise levels expressed in C-weighted decibels (dBC) are compared to $L_{eq,day}$ and $L_{eq,night}$ noise levels expressed in dBA. Second, the spectral content of the noise is examined to check for the presence of tonal components at or below a frequency of 250 Hz. The AER Directive 038 indicates that an LFN effect may be present if the difference between dBC and dBA noise levels is greater than or equal to 20 and there is a clear tonal component at or below 250 Hz. Both parts of the LFN test must be satisfied for an LFN effect to exist.

Both parts of the LFN test from AER Directive 038 apply to noise from industrial activities in combination with existing noise levels. However, the test for tonal components requires access to high-resolution spectral data, which are available from measurements but not from computer modelling. Therefore, in practice, the second part of the LFN test can only be applied to measured existing noise levels. The AER Directive 038 indicates that the LFN test is only applicable to normal or representative operations and does not apply to temporary construction activities (AER 2007).

7B1.4 Noise Prediction Methods

7B1.4.1 Continuous Sources

Most noise sources associated with the Project and with the Fission Patterson Lake South Property will be effectively continuous or steady state. Sources in this category include equipment associated with land clearing, site preparation and construction of facilities and infrastructure, underground shaft/mine development, site traffic, power generation, and process plant and underground operations. These types of sources will emit noise into the environment continuously throughout the daytime and nighttime periods.

Computer models of continuous noise sources are based on an algorithm from the International Organization for Standardization (ISO) 9613-2 technical standard (ISO 1996), as implemented in the DataKustik CadnaA® software tool. Inputs to the ISO 9613-2 models consist of source emissions in the form of octave band sound power levels, as well as environmental parameters that can influence propagation (e.g., wind speed, wind direction, temperature, ground cover).

When calculating noise levels at receptors, the ISO 9613-2 algorithm uses environmental parameters to account for four noise attenuation mechanisms:

- geometric divergence;
- atmospheric absorption;
- ground absorption; and
- screening by barriers.

Geometric divergence accounts for the fact that a given noise source radiates a finite amount of acoustic energy and as this finite amount of energy propagates into the environment it is spread over a larger and larger area (i.e., the surface of an ever-expanding sphere). This geometric spreading means that the farther away a receptor is located from a source, the less energy will be received (i.e., the lower the observed noise level).

Atmospheric absorption accounts for the fact that acoustic energy associated with a given noise source is absorbed via interaction with molecules in the air through which it propagates. Attenuation effects associated with atmospheric absorption are most substantial at high frequencies but can be important at lower frequencies for large propagation distances.

Ground absorption accounts for the fact that each time the acoustic energy emitted by a noise source interacts with the ground, some of it is absorbed. The amount of energy absorbed depends on the type of ground surface. During interactions with hard ground, very little energy is absorbed, but during interactions with porous ground, a substantial amount of energy is absorbed. Thus, if all other factors are held constant, observed noise levels associated with sources operating in an area of hard ground will be higher than observed noise levels associated with sources operating in an area of porous ground.

Screening by barriers accounts for the fact that a physical object (either terrain-based or anthropogenic) placed between a noise source and receptor can block acoustic energy and reduce observed noise levels at the receptor.

The ISO 9613-2 models were used to predict Project noise levels in the form of $L_{eq,day}$, $L_{eq,night}$, and L_{dn} for one snapshot of Project construction activities and one snapshot of Project operation activities. The modelling snapshots were selected to capture maximum noise effects from the Project. The ISO 9613-2 models were also used to predict noise levels from the most intense period of construction at the Fission Patterson Lake South Property and from full-scale operations at the Fission Patterson Lake South Property.

Emissions data used to model continuous noise sources associated with the Project and with the Fission Patterson Lake South Property are presented in Section 7B2 of this technical appendix. A summary of environmental inputs to the computer models of continuous noise sources is presented in Table 7B-2.

Table 7B-2: Environmental Inputs to Computer Models of Continuous Noise Sources

Parameter	Model Setting	Description/Notes
Propagation standard	ISO 9613-2 (ISO 1996)	Models treat noise sources and noise propagation in accordance with this standard.
Ground factor	0.0 – lakes and other waterbodies 0.2 – within the Project footprint and the Fission Patterson Lake South Property 1.0 – elsewhere in the LSA / RSA	These values represent the acoustic properties of the ground in accordance with ISO 9613-2. A value of 0.0 represents hard/reflective ground. A value of 1.0 represents porous/absorptive ground.
Temperature/humidity	10°C / 70% relative humidity	There are typical default values for ISO 9613-2.
Wind conditions	1-5 m/s from source to receptor	These are default ISO 9613-2 wind conditions – moderate temperature inversion, wind from source to receptor 100% of the time.
Terrain	Ground elevation contours at 1 m intervals throughout the LSA / RSA	Ground elevation contours were generated using site-specific LiDAR data.

ISO = International Organization for Standardization; LSA = local study area; RSA = regional study area.

According to the ISO 9613-2 standard, the overall accuracy of the propagation algorithm is plus or minus (±) 3 dBA (or dBC) for distances between source and receptor up to 1 km. The accuracy for propagation distances greater than 1 km is not stated in the standard.

Conservative assumptions regarding propagation conditions were made to account for the level of uncertainty inherent in the noise level predictions. Most importantly, each receptor was assumed to be downwind from each source 100% of the time. Because downwind conditions tend to enhance noise propagation, this assumption is conservative and likely overestimates noise levels at receptors. A complete list of conservative assumptions incorporated into the noise assessment is presented in EIS Section 7.3.6, Prediction Confidence and Uncertainty.

7B1.4.2 Airstrip

In contrast to the continuous noise sources discussed in Section 7B1.4.1 of this technical appendix, noise associated with the Project airstrip and the Fission Patterson Lake South Property airstrip will be intermittent. The airstrips will emit noise into the environment when airplanes take off or land, but the airstrips will be effectively silent at other times. Because noise emissions and noise effects from the airstrips are qualitatively different than noise emissions and noise effects from other equipment and activities, noise from the airstrips was modelled independently from other sources.

Computer models of the Project airstrip and the Fission Patterson Lake South Property airstrip are based on an algorithm from European Civil Aviation Conference (ECAC) Document 29 (ECAC 2016), as implemented in the DataKustik CadnaA® software tool. European Civil Aviation Conference Document 29 provides a method of modelling noise from take off and landing events. Inputs to the ECAC models consist of aircraft types, which are used to establish noise emissions based on historical measurements and empirical formulae, runway orientation and length, and take-off / landing frequencies, as well as ground elevation contours, which can influence noise propagation. For each take off and landing event, the ECAC models predict L_{max} noise levels at receptor locations. The CadnaA® software tool is used to tabulate L_{max} values for all take off and landing events within a representative six-month period.

The ECAC models were used to predict L_{max} noise levels for one snapshot of Project Construction, one snapshot of Project Operations, one snapshot corresponding to the most intense period of construction at the Fission Patterson Lake South Property, and one snapshot corresponding to full-scale operations at the Fission Patterson Lake South Property. Modelling snapshots for the airstrips are consistent with the snapshots used to model continuous noise sources and were selected to capture maximum noise effects from the Project and from the Fission Patterson Lake South Property.

Table 7B-3 presents aircraft types and take-off / landing frequencies used to model the Project airstrip. For each modelling snapshot, the expected number of aircraft take offs and landings during a 24-hour period, and a 6-month period is presented, as required by the ECAC modelling algorithm. The Fission Patterson Lake South Property airstrip was modelled with identical take off and landing frequencies.

Table 7B-3: Rook I Project Airstrip Activities

Aircraft Type	Project Phase	Aircraft Activities per 24-Hour Period		Aircraft Activities per 6-Month Period	
		Take Offs	Landings	Take Offs	Landings
Dash 8 Q300 (50+ passenger aircraft)	Construction	2	2	360	360
	Operations	2	2	360	360
ATR 42 (40+ passenger aircraft)	Construction	2	2	360	360
	Operations	1	1	180	180
Beech 99 (passenger aircraft)	Construction	1	1	180	180
	Operations	1	1	180	180
King Air (8 passenger aircraft)	Construction	1	1	180	180
	Operations	1	1	180	180

Based on current plans for the Project airstrip, all take offs and landings will occur during the daytime period. However, to provide flexibility for future operational changes and to evaluate the full scope of potential noise effects from the Project airstrip, nighttime take offs and landings were also modelled. In particular:

- when modelling the daytime period, it was assumed that all take offs and landings will occur during the 15-hour daytime period (i.e., 07:00 to 22:00); and
- when modelling the nighttime period, it was assumed that take offs and landings will be evenly distributed across the 15-hour daytime period and nine-hour nighttime period (22:00 to 07:00).

The same assumptions were used when modelling the airstrip at the Fission Patterson Lake South Property.

Note that this modelling approach effectively double counts some take off and landing activities by modelling them in both the daytime and nighttime periods. Table 7B-4 presents a breakdown of daytime and nighttime take off and landing activities used in the ECAC computer models of the Project airstrip. The values in Table 7B-4 represent the total number of daytime and nighttime take offs and landings during a typical six-month period, as required by the ECAC modelling algorithm. The Fission Patterson Lake South Property airstrip was modelled with identical take off and landing frequencies.

Table 7B-4: Daytime and Nighttime Rook I Project Airstrip Activities

Aircraft Type	Project Phase	Aircraft Activities per Six-Month Period			
		Daytime Period (07:00-22:00)		Nighttime Period (22:00-07:00)	
		Take Offs	Landings	Take Offs	Landings
Dash 8 Q300 (50+ passenger aircraft)	Construction	360	360	135	135
	Operations	360	360	135	135
ATR 42 (40+ passenger aircraft)	Construction	360	360	135	135
	Operations	180	180	68	68
Beech 99 (passenger aircraft)	Construction	180	180	68	68
	Operations	180	180	68	68
King Air (8 passenger aircraft)	Construction	180	180	68	68
	Operations	180	180	68	68

When calculating noise levels at receptors, the ECAC algorithm accounts for noise attenuation due to geometric divergence, atmospheric absorption, and screening by barriers in a manner similar to the ISO 9613-2 algorithm. Although ECAC does not quantify the accuracy or uncertainty associated with its modelling algorithm, it is likely the ECAC algorithm has an overall accuracy level comparable to the ±3 dBA value specified for ISO 9613-2 since the ECAC algorithm uses similar methods to simulate propagation effects.

Conservative assumptions were made to account for the level of uncertainty inherent in the noise level predictions. Most importantly, take off and landings activities were modelled during the nighttime period, even though current plans for the Project airstrip call for all take offs and landings to occur during the daytime period. A complete list of conservative assumptions incorporated into the noise assessment is presented in EIS Section 7.3.7.

7B2 NOISE EMISSIONS

7B2.1 Continuous Sources

Inputs to the ISO 9613-2 models of continuous sources include noise emissions in the form of octave band sound power levels. Noise emissions for Project modelling were established using a combination of manufacturer/vendor data sheets, empirical formulae from acoustics handbooks, measurements of similar equipment operating at other facilities, and professional judgment/experience.

In the absence of publicly available design details, noise emissions for Fission Patterson Lake South Property modelling were assumed to be comparable to noise emissions from the Project. This approach was taken because the Fission Patterson Lake South Property is a similar type of development to the Project and is anticipated to have similar equipment and noise emissions.

7B2.1.1 Project Construction

Table 7B-5 presents noise emissions for traffic on the Project access road during Construction. Octave band noise emissions are presented in unweighted decibels (dBZ) and total noise emissions are presented in A-weighted decibels. Table 7B-5 presents each type of vehicle that will use the Project access road, and the maximum number of one-way trips per daytime period and per nighttime period. The maximum number of one-way trips was established for consistency with the Project traffic effects assessment (Technical Support Document [TSD] IX, Transportation Risk Assessment Report). Using the maximum number of one-way trips to model noise from the Project access road is a conservative approach that will tend to overestimate Project noise levels on days with less than maximum traffic volumes. A complete list of conservative assumptions incorporated into the noise assessment is presented in EIS Section 7.3.7.

Table 7B-6 presents noise emissions for mobile equipment that will be active on-site during Project Construction. Noise emissions presented in Table 7B-6 include the time-weighted contribution from a tonal back-up alarm in the 1 kHz octave band. A penalty of 5 dBZ has been added to the back-up alarm noise emissions (i.e., the noise emissions have been artificially increased by 5 dBZ) to reflect the fact that tonal noise is typically more disturbing than other types of noise (ISO 2016). Table 7B-6 also presents the quantity of each type of mobile equipment and the number of hours the equipment will be active during a typical 24-hour period.

Table 7B-7 presents noise emissions for stationary equipment that will be active outdoors during Project Construction. Table 7B-7 also presents the unique tag number used to identify each piece of equipment in NexGen Energy Ltd. (NexGen) engineering materials and the number of hours each piece of equipment will be active during a typical 24-hour period.

Table 7B-8 presents noise emissions for buildings that will be active during Project Construction. These emissions values represent noise breakout from indoor equipment (i.e., the amount of noise that will be emitted to the outdoor environment).

Table 7B-5: Noise Emissions from Access Road – Rook I Project Construction

Vehicle Type	One-Way Trips		Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
	Daytime	Nighttime	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Crew bus	39	24	121.0	121.0	114.0	104.0	104.0	101.0	100.0	92.0	87.0	107.2	DEFRA (2007)
Transport truck	413	248	121.0	121.0	114.0	104.0	104.0	101.0	100.0	92.0	87.0	107.2	DEFRA (2007)

DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; dBZ = unweighted decibel; dBA = A-weighted decibel.

Table 7B-6: Noise Emissions from Mobile Equipment – Rook I Project Construction

Equipment	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Fuel truck 5000 gallon capacity	1	3.0	106.0	108.0	115.0	111.0	112.0	112.4	110.0	104.0	96.0	116.4	Suncor (2016)
Caterpillar D9T track-type tractor	2	6.0	108.2	111.2	113.2	115.2	107.2	112.1	106.2	104.2	98.2	115.2	Manufacturer data sheet
Caterpillar D8T track-type tractor	2	6.0	100.1	103.1	121.1	112.1	109.1	111.2	105.1	99.1	90.1	114.4	Manufacturer data sheet
Caterpillar PS-150C pneumatic compactor	1	6.0	121.9	116.9	111.9	107.9	108.9	110.1	107.9	103.9	98.9	114.3	DOT (2006)
Caterpillar 815F series 2 soil compactor	2	6.0	120.3	115.3	110.3	106.3	107.3	109.2	106.3	102.3	97.3	113.0	Manufacturer data sheet
Generator 125 kVA	6	17.0	108.1	111.1	114.1	115.1	112.1	105.1	101.1	96.1	89.1	112.6	DOT (2006)
Generator 70-80 kVA	5	11.4	108.1	111.1	114.1	115.1	112.1	105.1	101.1	96.1	89.1	112.6	DOT (2006)
Caterpillar 623G wheel tractor scraper	3	6.0	97.6	102.6	113.6	107.6	107.6	108.7	103.6	98.6	96.6	112.0	Manufacturer data sheet
Caterpillar 450E backhoe loader	1	3.0	122.5	113.5	104.5	108.5	108.5	108.3	103.5	97.5	91.5	111.8	Manufacturer data sheet
Caterpillar 140M/140M all-wheel Drive motor grader	2	7.5	96.1	101.1	112.1	106.1	106.1	109.1	102.1	97.1	95.1	111.5	Manufacturer data sheet
Ditch witch RT45	1	3.0	120.0	111.0	102.0	106.0	106.0	107.5	101.0	95.0	89.0	110.1	Manufacturer data sheet
Caterpillar 725 articulated truck	6	12.0	110.0	113.0	116.0	105.0	103.0	106.8	102.0	97.0	91.0	110.0	DEFRA (2007)
Caterpillar 345D L hydraulic excavator	2	12.0	101.3	100.3	113.3	103.3	105.3	106.3	102.3	96.3	91.3	109.8	Manufacturer data sheet
Chicago pneumatic CPS 375 portable compressor	4	3.0	113.7	109.7	105.7	99.7	104.7	105.7	103.7	96.7	91.7	109.6	DOT (2006)

Table 7B-6: Noise Emissions from Mobile Equipment – Rook I Project Construction

Equipment	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Caterpillar TL1055 telehandler	3	3.0	95.6	97.8	113.0	109.3	101.6	107.0	99.0	92.3	84.0	109.4	EU (2000)
Caterpillar CP64 vibratory soil compactor	2	6.0	114.0	109.0	104.0	100.0	101.0	107.0	100.0	96.0	91.0	108.9	DEFRA (2007)
Caterpillar CS64 vibratory soil compactor	2	6.0	114.0	109.0	104.0	100.0	101.0	107.0	100.0	96.0	91.0	108.9	DEFRA (2007)
Caterpillar TL943 telehandler	5	4.2	94.4	96.6	111.8	108.1	100.4	106.8	97.8	91.1	82.8	108.8	EU (2000)
Caterpillar 928Hz wheel loader	2	4.5	118.0	113.0	108.0	103.0	104.0	106.8	96.0	90.0	83.0	108.5	Manufacturer data sheet
Caterpillar TH255 telehandler	1	3.0	93.7	95.9	111.1	107.4	99.7	106.7	97.1	90.4	82.1	108.5	EU (2000)
10 ton picker truck	2	3.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Volvo VHD13 trailering truck	3	3.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Volvo VHD13 dump truck	4	3.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Volvo VHD concrete mixer	2	6.0	122.0	112.0	102.0	102.0	101.0	104.5	103.0	93.0	87.0	108.2	DEFRA (2007)
JLG 1250A manlift	3	3.0	113.2	108.2	103.2	104.2	103.2	103.8	100.2	98.2	91.2	107.9	DOT (2006)
JLG 3394RT scissor lift	6	3.0	113.2	108.2	103.2	104.2	103.2	103.8	100.2	98.2	91.2	107.9	DOT (2006)
JLG 600SJ manlift	6	3.0	113.2	108.2	103.2	104.2	103.2	103.8	100.2	98.2	91.2	107.9	DOT (2006)
Grove RT9130E rough terrain crane (130 t)	1	3.0	109.0	108.0	107.0	101.0	102.0	104.5	101.0	92.0	83.0	107.6	DEFRA (2007)
Caterpillar 242B series 3 skid steer loader	3	4.0	89.9	92.1	107.3	103.6	95.9	106.3	93.3	86.6	78.3	107.2	EU (2000)
Caterpillar 314D LCR hydraulic excavator	1	12.0	92.3	91.3	104.3	94.3	96.3	106.4	93.3	87.3	82.3	107.0	Manufacturer data sheet
Caterpillar 311D LRR hydraulic excavator	1	6.0	91.3	90.3	103.3	93.3	95.3	106.3	92.3	86.3	81.3	106.8	Manufacturer data sheet
Grove RT700E rough terrain crane (60 t)	4	3.0	120.0	115.0	110.0	106.0	102.0	103.8	95.0	88.0	80.0	106.6	DEFRA (2007)
Concord CCP-52XZ-170 concrete pumper	1	6.0	102.0	97.0	92.0	92.0	94.0	106.1	87.0	81.0	75.0	106.3	DEFRA (2007)
Commander 500 portable welder	9	3.2	106.3	103.6	101.5	99.1	99.0	100.5	97.0	92.5	89.5	104.2	DEFRA (2007)
Manitowoc 18000 crawler crane (600 t)	1	3.0	93.0	96.0	99.0	96.0	90.0	102.6	94.0	83.0	74.0	103.6	DEFRA (2007)
Manitowoc 2250 crawler crane (300 t)	1	3.0	93.0	96.0	99.0	96.0	90.0	102.6	94.0	83.0	74.0	103.6	DEFRA (2007)

Table 7B-6: Noise Emissions from Mobile Equipment – Rook I Project Construction

Equipment	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Manitowoc 777 crawler crane (181 t)	1	3.0	93.0	96.0	99.0	96.0	90.0	102.6	94.0	83.0	74.0	103.6	DEFRA (2007)
Manitowoc 999 crawler crane (250 t)	1	3.0	93.0	96.0	99.0	96.0	90.0	102.6	94.0	83.0	74.0	103.6	DEFRA (2007)
National crane 1400H truck crane	2	3.0	112.0	108.0	104.0	99.0	91.0	102.4	91.0	84.0	78.0	103.4	DEFRA (2007)
Manitowoc 5540F carry deck (15 t)	1	3.0	112.0	108.0	104.0	99.0	91.0	102.4	91.0	84.0	78.0	103.4	DEFRA (2007)
Manitowoc 7755 carry deck (22 t)	2	3.0	112.0	108.0	104.0	99.0	91.0	102.4	91.0	84.0	78.0	103.4	DEFRA (2007)
Grove YB4409 carry deck (8.5 t)	1	3.0	112.0	108.0	104.0	99.0	91.0	102.4	91.0	84.0	78.0	103.4	DEFRA (2007)
Grove RT540E rough terrain crane (40 t)	6	3.0	115.0	106.0	97.0	95.0	92.0	102.3	85.0	77.0	68.0	102.8	DEFRA (2007)
Ford F150 pickup truck	8	2.9	68.0	79.4	98.6	85.9	84.0	102.0	77.8	70.3	63.1	102.1	DOT (2006)
Ford F350 truck	6	2.8	68.0	79.4	98.6	85.9	84.0	102.0	77.8	70.3	63.1	102.1	DOT (2006)
Ditch witch RT12	1	3.0	66.4	83.4	100.4	92.4	91.4	91.4	93.4	97.4	96.4	102.0	Manufacturer data sheet
350,000 BTU frost fighter	22	24.0	87.7	87.7	86.7	84.7	81.7	78.7	75.7	72.7	69.7	84.4	Manufacturer data sheet

DOT = United States Department of Transportation; DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; EU = European Parliament and the Council of the European Union; dBZ = unweighted decibel; dBA = A-weighted decibel JLG = JLG Industries Inc.; kVA = kilovolt-ampere; BTU = British thermal unit.

Table 7B-7: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Construction

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
1170-FN-1003	Return air fan No. 1	1	24	120.7	126.7	117.7	119.7	120.7	118.7	115.7	113.7	103.7	123.5	Bies and Hansen (2003)
1170-HE-1001	Fresh air heater No. 1 natural gas burner	1	24	101.2	104.2	110.2	116.2	122.2	116.2	110.2	104.2	101.2	121.6	Professional experience
5110-GE-1001	Generator unit 01 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1002	Generator unit 02 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1003	Generator unit 03 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1004	Generator unit 04 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1005	Generator unit 05 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1006	Generator unit 06 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1007	Generator unit 07 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1008	Generator unit 08 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1009	Generator unit 09 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
1170-FN-1005	Off-shaft development fan	1	24	111.7	117.5	109.2	111.2	112.6	111.2	109.0	105.9	96.6	116.0	Bies and Hansen (2003)
1170-VFD-1001	Fresh air fan VFD No. 1	1	24	99.8	99.8	102.8	104.8	107.8	107.8	106.8	101.8	93.8	112.5	Bies and Hansen (2003)
1110-AC-1001	AC unit No. 1	1	24	97.8	102.8	103.8	106.8	107.8	106.8	103.8	99.8	94.8	111.1	Bies and Hansen (2003)
1110-AC-1002	AC unit No. 2	1	24	97.8	102.8	103.8	106.8	107.8	106.8	103.8	99.8	94.8	111.1	Bies and Hansen (2003)
1170-FN-1001	Fresh air fan No. 1	1	24	101.9	107.9	98.9	100.9	101.9	99.9	96.9	94.9	84.9	104.8	Bies and Hansen (2003)
1110-AC-1004	AC unit	1	24	92.8	96.8	97.8	98.8	99.8	97.8	95.8	91.8	85.8	102.8	Bies and Hansen (2003)

Table 7B-7: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Construction

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
1110-AC-1003	Thru-wall AC	1	24	92.8	96.8	97.8	98.8	99.8	97.8	95.8	91.8	85.8	102.8	Bies and Hansen (2003)
1170-VFD-1003	Return air fan VFD No. 1	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
1130-VFD-5002	VFD for 1000 hp fan	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
1130-VFD-5003	VFD for 1000 hp fan	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
5110-GE-1001	Generator unit 01 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1002	Generator unit 02 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1003	Generator unit 03 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1004	Generator unit 04 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1005	Generator unit 05 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1006	Generator unit 06 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1007	Generator unit 07 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1008	Generator unit 08 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1009	Generator unit 09 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
1110-VFD-5008	VFD for auxiliary hoist	1	24	86.0	87.0	88.0	88.0	88.0	98.0	88.0	78.0	68.0	98.8	DEFRA (2007)
1110-VFD-5006	VFD for service hoist	1	24	86.0	87.0	88.0	88.0	88.0	98.0	88.0	78.0	68.0	98.8	DEFRA (2007)
1110-T-5002	Production hoist transformer	1	24	90.9	96.9	98.9	93.9	93.9	87.9	82.9	77.9	70.9	94.3	NEMA (2000)
1110-T-5010	Compressors and hoist house transformer	1	24	90.6	96.6	98.6	93.6	93.6	87.6	82.6	77.6	70.6	94.0	NEMA (2000)
1130-T-5003	Exhaust shaft hoist house transformer	1	24	90.6	96.6	98.6	93.6	93.6	87.6	82.6	77.6	70.6	94.0	NEMA (2000)
1110-T-5005	Service hoist transformer	1	24	90.4	96.4	98.4	93.4	93.4	87.4	82.4	77.4	70.4	93.8	NEMA (2000)
1110-T-5007	Auxiliary hoist transformer	1	24	89.9	95.9	97.9	92.9	92.9	86.9	81.9	76.9	69.9	93.3	NEMA (2000)

Table 7B-7: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Construction

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
5600-SP-1	Diesel dispenser #1	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
5600-SP-1	Diesel dispenser #2	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
5600-SP-1	Gasoline dispenser #1	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
5630-PP-1001	LNG pump 01	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
5630-PP-1002	LNG pump 02	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
1170-T-5001	Fresh air fans transformer	1	24	82.3	88.3	90.3	85.3	85.3	79.3	74.3	69.3	62.3	85.7	NEMA (2000)
1130-T-5001	Exhaust shaft building services transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1120-T-5001	Head frame building services transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1110-T-5003	Production hoist auxiliaries transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1110-T-5004	Service hoist auxiliaries transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1110-T-5001	Batch plant transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1110-T-5009	Auxiliary hoist auxiliaries transformer	1	24	81.3	87.3	89.3	84.3	84.3	78.3	73.3	68.3	61.3	84.7	NEMA (2000)
1120-LT-5003	Lighting transformer	1	24	79.8	85.8	87.8	82.8	82.8	76.8	71.8	66.8	59.8	83.2	NEMA (2000)
1120-LT-5001	Lighting transformer	1	24	79.8	85.8	87.8	82.8	82.8	76.8	71.8	66.8	59.8	83.2	NEMA (2000)

DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; NEMA = National Electrical Manufacturers Association; dBZ = unweighted decibel; dBA = A-weighted decibel; VFD = variable frequency drive; AC = air conditioning; LNG = liquified natural gas; FN = fan; HE = heater; GE = generator; T = transformer; SP = system with pump; PP = pump; LT = lighting transformer.

Table 7B-8: Noise Emissions from Buildings – Rook I Project Construction

Building	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Power plant	1	24	127.7	127.9	133.0	128.3	125.7	127.0	122.9	131.7	133.6	136.7	Manufacturer data sheet and professional experience
Production shaft hoist room	1	24	127.6	122.0	113.9	113.8	111.0	109.0	110.3	106.4	99.1	115.9	Bies and Hansen (2003), DEFRA (2007), and professional experience
Intake water facility	1	24	109.7	105.6	104.8	106.0	107.7	108.4	106.7	101.9	94.7	112.7	Bies and Hansen (2003) and professional experience
Production shaft collar house	1	24	117.6	112.3	103.5	105.0	100.2	89.8	89.7	79.7	73.7	101.0	DEFRA (2007) and professional experience
Exhaust shaft headframe	1	24	96.5	91.1	86.9	84.9	82.5	78.9	70.9	58.4	51.5	83.8	Bies and Hansen (2003) and professional experience
Production shaft tower	1	24	82.3	76.8	75.2	75.1	76.8	76.1	74.8	69.7	61.7	80.9	Bies and Hansen (2003), NEMA (2000), and professional experience

DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; NEMA = National Electrical Manufacturers Association; dBZ = unweighted decibel; dBA = A-weighted decibel.

7B2.1.2 Project Operations

Table 7B-9 presents noise emissions for traffic on the Project access road during Operations. Octave band noise emissions are presented in dBZ, and total noise emissions are presented in dBA. For each type of vehicle that will use the Project access road, Table 7B-9 also presents the maximum number of one-way trips per daytime period and per nighttime period. The maximum number of one-way trips was established for consistency with the Project traffic effects assessment (NexGen 2019). Using the maximum number of one-way trips to model noise from the Project access road is a conservative approach that will tend to overestimate Project noise levels on days with less than maximum traffic volumes. A complete list of conservative assumptions incorporated into the noise assessment is presented in EIS Section 7.3.6.

Table 7B-10 presents noise emissions for mobile equipment that will be active on-site during Project Operations. Noise emissions presented in Table 7B-10 include the time-weighted contribution from a tonal back-up alarm in the 1 kHz octave band. A penalty of 5 dBZ has been added to the back-up alarm noise emissions to reflect the fact that tonal noise is typically more disturbing than other types of noise (ISO 2016). Table 7B-10 also presents the quantity of each type of mobile equipment and the number of hours the equipment will be active during a typical 24-hour period.

Table 7B-11 presents noise emissions for stationary equipment that will be active outdoors during Project Operations. Table 7B-11 also presents the unique tag number used to identify each piece of equipment in NexGen engineering materials and the number of hours each piece of equipment will be active during a typical 24-hour period.

Table 7B-12 presents noise emissions for buildings that will be active during Project Operations. These emissions values represent noise breakout from indoor equipment (i.e., the amount of noise that will be emitted to the outdoor environment).

Table 7B-13 presents noise emissions for equipment that will be used to deter birds from landing on Project ponds. Table 7B-13 also presents the number of cannons and the cannon firing rate.

Table 7B-9: Noise Emissions from Access Road – Rook I Project Operations

Vehicle Type	One-Way Trips		Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
	Daytime	Nighttime	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Transport truck	74	44	121.0	121.0	114.0	104.0	104.0	101.0	100.0	92.0	87.0	107.2	DEFRA (2007)
Pickup truck	8	5	68.0	79.4	98.6	85.9	84.0	82.2	77.8	70.3	63.1	87.8	DOT (2006)

DOT = United States Department of Transportation; DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; dBZ = unweighted decibel; dBA = A-weighted decibel.

Table 7B-10: Noise Emissions from Mobile Equipment – Rook I Project Operations

Equipment	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Mobile rock breaker	1	4.0	117.2	119.5	121.8	119.9	113.5	113.8	111.7	111.0	105.3	119.5	professional experience
Fire truck	1	0.1	106.0	108.0	115.0	111.0	112.0	112.4	110.0	104.0	96.0	116.4	Suncor (2016)
Water truck (dust suppression)	1	4.0	106.0	108.0	115.0	111.0	112.0	112.4	110.0	104.0	96.0	116.4	Suncor (2016)
Sanitation tank truck	1	4.0	106.0	108.0	115.0	111.0	112.0	112.4	110.0	104.0	96.0	116.4	Suncor (2016)
Dump truck equipped with snowplow and sander	2	1.3	106.0	108.0	115.0	111.0	112.0	112.4	110.0	104.0	96.0	116.4	Suncor (2016)
Caterpillar 980 loader	2	8.0	101.3	103.3	117.3	115.3	106.3	108.7	104.3	97.3	89.3	113.0	manufacturer data sheet
Caterpillar 140M/140M all-wheel drive motor grader	1	6.0	96.1	101.1	112.1	106.1	106.1	109.1	102.1	97.1	95.1	111.5	manufacturer data sheet
Caterpillar D8 dozer	1	6.0	95.0	98.0	116.0	107.0	104.0	109.8	100.0	94.0	85.0	111.5	manufacturer data sheet
Caterpillar 725 articulated truck	2	10.0	110.0	113.0	116.0	105.0	103.0	106.8	102.0	97.0	91.0	110.0	DEFRA (2007)
Caterpillar 345D L hydraulic excavator	1	6.0	101.3	100.3	113.3	103.3	105.3	106.3	102.3	96.3	91.3	109.8	manufacturer data sheet
Caterpillar TL943 telehandler	2	0.5	94.4	96.6	111.8	108.1	100.4	106.8	97.8	91.1	82.8	108.8	EU (2000)
Boom truck	1	6.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Bus (transport to/from airstrip and mine)	2	1.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
JLG 1250A manlift	1	0.5	113.2	108.2	103.2	104.2	103.2	103.8	100.2	98.2	91.2	107.9	DOT (2006)
Kubota forklift	4	2.5	89.9	92.1	107.3	103.6	95.9	106.3	93.3	86.6	78.3	107.2	EU (2000)
Grove RT700E rough terrain crane (60 t)	1	2.0	120.0	115.0	110.0	106.0	102.0	103.8	95.0	88.0	80.0	106.6	DEFRA (2007)
Concrete/shotcrete haulage trucks	2	1.3	102.0	97.0	92.0	92.0	94.0	106.1	87.0	81.0	75.0	106.3	DEFRA (2007)
Pickup truck	10	10.0	68.0	79.4	98.6	85.9	84.0	102.0	77.8	70.3	63.1	102.1	DOT (2006)

Table 7B-10: Noise Emissions from Mobile Equipment – Rook I Project Operations

Equipment	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Ambulance	1	0.1	68.0	79.4	98.6	85.9	84.0	102.0	77.8	70.3	63.1	102.1	DOT (2006)
Ford F350 with flatbed	1	1.3	68.0	79.4	98.6	85.9	84.0	102.0	77.8	70.3	63.1	102.1	DOT (2006)
De-icing unit	1	2.0	87.7	87.7	86.7	84.7	81.7	78.7	75.7	72.7	69.7	84.4	manufacturer data sheet

DOT = United States Department of Transportation; DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; EU = European Parliament and the Council of the European Union; dBZ = unweighted decibel; dBA = A-weighted decibel; JLG = JLG Industries Inc.

Table 7B-11: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Operations

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
1170-FN-1003	Return air fan No. 1	1	24	120.7	126.7	117.7	119.7	120.7	118.7	115.7	113.7	103.7	123.5	Bies and Hansen (2003)
1170-HE-1001	Fresh air heater No. 1 natural gas burner	1	24	101.2	104.2	110.2	116.2	122.2	116.2	110.2	104.2	101.2	121.6	Professional experience
5110-GE-1001	Generator unit 01 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1002	Generator unit 02 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1003	Generator unit 03 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1004	Generator unit 04 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1005	Generator unit 05 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1006	Generator unit 06 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1007	Generator unit 07 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
5110-GE-1008	Generator unit 08 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet

Table 7B-11: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Operations

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
5110-GE-1009	Generator unit 09 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
3100-CV-1001	Ore transport conveyor	1	24	113.9	114.8	122.6	115.3	116.1	109.2	108.3	107.7	106.1	117.5	Professional experience
1110-FN-1005	Air curtain blower No. 1	1	24	113.0	116.0	115.0	113.0	111.0	110.0	105.0	97.0	89.0	113.9	Bies and Hansen (2003)
1110-FN-1006	Air curtain blower No. 2	1	24	113.0	116.0	115.0	113.0	111.0	110.0	105.0	97.0	89.0	113.9	Bies and Hansen (2003)
1110-FN-1007	Air curtain blower No. 3	1	24	113.0	116.0	115.0	113.0	111.0	110.0	105.0	97.0	89.0	113.9	Bies and Hansen (2003)
1110-FN-1008	Air curtain blower No. 4	1	24	113.0	116.0	115.0	113.0	111.0	110.0	105.0	97.0	89.0	113.9	Bies and Hansen (2003)
1110-FN-1009	Air curtain blower No. 5	1	24	113.0	116.0	115.0	113.0	111.0	110.0	105.0	97.0	89.0	113.9	Bies and Hansen (2003)
1170-VFD-1001	Fresh air fan VFD No. 1	1	24	99.8	99.8	102.8	104.8	107.8	107.8	106.8	101.8	93.8	112.5	Bies and Hansen (2003)
1110-AC-1001	AC unit No. 1	1	24	97.8	102.8	103.8	106.8	107.8	106.8	103.8	99.8	94.8	111.1	Bies and Hansen (2003)
1110-AC-1002	AC unit No. 2	1	24	97.8	102.8	103.8	106.8	107.8	106.8	103.8	99.8	94.8	111.1	Bies and Hansen (2003)
3000-AC-1001	Self-Contained AC unit	1	24	95.8	99.8	100.8	101.8	102.8	100.8	98.8	94.8	88.8	105.8	Bies and Hansen (2003)
3000-AC-1002	Self-Contained AC unit	1	24	95.8	99.8	100.8	101.8	102.8	100.8	98.8	94.8	88.8	105.8	Bies and Hansen (2003)
5310-AC-1001	Self-Contained AC unit	1	24	94.7	98.7	99.7	100.7	101.7	99.7	97.7	93.7	87.7	104.7	Bies and Hansen (2003)
1170-FN-1001	Fresh air fan No. 1	1	24	101.9	107.9	98.9	100.9	101.9	99.9	96.9	94.9	84.9	104.7	Bies and Hansen (2003)
3100-CV-1002	Ore Hopper/Grizzly feeder	1	24	100.3	101.2	109.0	101.7	102.5	95.6	94.7	94.1	92.5	103.9	Professional experience
5310-AC-1002	Self-Contained AC unit	1	24	93.3	97.3	98.3	99.3	100.3	98.3	96.3	92.3	86.3	103.3	Bies and Hansen (2003)
3100-CV-1003	Waste pan feeder	1	24	99.7	100.6	108.4	101.1	101.9	95.0	94.1	93.5	91.9	103.3	Professional experience

Table 7B-11: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Operations

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
3100-CV-1004	Ore pan feeder	1	24	99.7	100.6	108.4	101.1	101.9	95.0	94.1	93.5	91.9	103.3	Professional experience
3500-AC-1002	Split AC unit	1	24	93.3	97.3	98.3	99.3	100.3	98.3	96.3	92.3	86.3	103.3	Bies and Hansen (2003)
1110-CD-1001	Condenser unit	1	24	92.8	96.8	97.8	98.8	99.8	97.8	95.8	91.8	85.8	102.8	Bies and Hansen (2003)
1110-AC-1004	AC unit	1	24	92.8	96.8	97.8	98.8	99.8	97.8	95.8	91.8	85.8	102.8	Bies and Hansen (2003)
1110-AC-1003	Thru-wall AC unit	1	24	92.8	96.8	97.8	98.8	99.8	97.8	95.8	91.8	85.8	102.8	Bies and Hansen (2003)
3000-FN-1001	Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
3000-FN-1002	Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
3000-FN-1003	Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
3000-FN-1004	Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
3000-FN-1005	Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
3000-FN-1006	Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
3000-FN-1007	Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
3000-FN-1008	Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
3500-AC-1001	Self-Contained AC unit	1	24	91.8	95.8	96.8	97.8	98.8	96.8	94.8	90.8	84.8	101.8	Bies and Hansen (2003)
1130-VFD-5002	VFD for 1000 hp fan	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
1130-VFD-5003	VFD for 1000 hp fan	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
1170-VFD-1003	Return air fan VFD No. 1	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)

Table 7B-11: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Operations

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
5110-GE-1001	Generator unit 01 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1002	Generator unit 02 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1003	Generator unit 03 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1004	Generator unit 04 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1005	Generator unit 05 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1006	Generator unit 06 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1007	Generator unit 07 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1008	Generator unit 08 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
5110-GE-1009	Generator unit 09 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
3500-FN-1001	Exhaust fan	1	24	89.1	94.9	91.2	95.1	95.3	95.3	93.4	90.2	84.1	100.0	Bies and Hansen (2003)
3500-FN-1002	Exhaust fan	1	24	89.1	94.9	91.2	95.1	95.3	95.3	93.4	90.2	84.1	100.0	Bies and Hansen (2003)
3500-FN-1003	Exhaust fan	1	24	89.1	94.9	91.2	95.1	95.3	95.3	93.4	90.2	84.1	100.0	Bies and Hansen (2003)
3500-FN-1004	Exhaust fan	1	24	89.1	94.9	91.2	95.1	95.3	95.3	93.4	90.2	84.1	100.0	Bies and Hansen (2003)
3100-PU-1008	Ore stockpile sump pump	1	24	88.3	88.9	90.7	92.7	94.3	95.7	93.7	89.2	82.3	99.8	Bies and Hansen (2003)
3000-MU-1001	Make-Up air unit	1	24	98.5	98.3	98.1	94.6	95.6	95.3	91.6	85.9	75.3	99.1	Professional experience
3000-MU-1002	Make-Up air unit	1	24	98.5	98.3	98.1	94.6	95.6	95.3	91.6	85.9	75.3	99.1	Professional experience
3000-MU-1003	Make-Up air unit	1	24	98.5	98.3	98.1	94.6	95.6	95.3	91.6	85.9	75.3	99.1	Professional experience

Table 7B-11: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Operations

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
3000-MU-1004	Make-Up air unit	1	24	98.5	98.3	98.1	94.6	95.6	95.3	91.6	85.9	75.3	99.1	Professional experience
1110-VFD-5006	VFD for service hoist	1	24	86.0	87.0	88.0	88.0	88.0	98.0	88.0	78.0	68.0	98.8	Bies and Hansen (2003)
1110-VFD-5008	VFD for auxiliary hoist	1	24	86.0	87.0	88.0	88.0	88.0	98.0	88.0	78.0	68.0	98.8	Bies and Hansen (2003)
5310-FN-1001	Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
5310-FN-1002	Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
5310-FN-1003	Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
3970-FN-1001	Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
3970-FN-1002	Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
3970-FN-1003	Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
3970-FN-1004	Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
3970-FN-1005	Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
3970-FN-1006	Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
3400-FN-1001	Liquids/solids separating area process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3400-FN-1002	Liquids/solids separating area process ventilation fan #2	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3600-FN-1004	Precipitation area process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3600-FN-1005	Precipitation area process ventilation fan #2	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3700-FN-1001	Tails neutralization area process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)

Table 7B-11: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Operations

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
3700-FN-1002	Tails neutralization area process ventilation fan #12	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3965-FN-1006	Precipitation area process ventilation fan #3	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3800-FN-1012	Product drying and packaging area process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3800-FN-1013	Product drying and packaging area process ventilation fan #2	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
5310-FN-1004	Effluent treatment area process ventilation fan	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3200-FN-1001	Grinding area process ventilation fan	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3300-FN-1001	Leaching area process ventilation fan	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3500-FN-1005	SX process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3500-FN-1006	SX process ventilation fan #2	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
3500-FN-1007	SX process ventilation fan #3	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
2520-PU-1125	Run-Off pond #1 pump	1	24	85.6	86.3	87.9	89.9	91.2	92.9	90.7	86.3	79.6	96.9	Bies and Hansen (2003)
2520-PU-1126	Run-Off pond #2 pump	1	24	85.6	86.3	87.9	89.9	91.2	92.9	90.7	86.3	79.6	96.9	Bies and Hansen (2003)
3200-AG-1001	Ore storage tank #1 agitator	1	24	82.5	82.5	85.5	87.5	90.5	90.5	89.5	84.5	76.5	95.2	Bies and Hansen (2003)
3500-MU-1001	Make-Up air unit	1	24	95.7	95.1	94.6	90.9	91.5	90.9	86.0	81.0	71.2	94.5	Professional experience
3500-MU-1002	Make-Up air unit	1	24	95.7	95.1	94.6	90.9	91.5	90.9	86.0	81.0	71.2	94.5	Professional experience
1110-T-5002	Transformer production hoist transformer	1	24	90.9	96.9	98.9	93.9	93.9	87.9	82.9	77.9	70.9	94.3	NEMA (2000)

Table 7B-11: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Operations

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
1110-FN-1001	Exhaust fan No. 1 axial fan	1	24	81.9	84.2	84.7	87.1	89.5	89.5	88.3	83.7	76.1	94.2	Bies and Hansen (2003)
1110-FN-1002	Exhaust fan No. 2 axial fan	1	24	81.9	84.2	84.7	87.1	89.5	89.5	88.3	83.7	76.1	94.2	Bies and Hansen (2003)
1110-FN-1003	Exhaust fan No. 3 axial fan	1	24	81.9	84.2	84.7	87.1	89.5	89.5	88.3	83.7	76.1	94.2	Bies and Hansen (2003)
1110-FN-1004	Exhaust fan No. 4 axial fan	1	24	81.9	84.2	84.7	87.1	89.5	89.5	88.3	83.7	76.1	94.2	Bies and Hansen (2003)
1130-T-5003	Exhaust shaft hoist house transformer	1	24	90.6	96.6	98.6	93.6	93.6	87.6	82.6	77.6	70.6	94.0	NEMA (2000)
1110-T-5010	Compressors and hoist house transformer	1	24	90.6	96.6	98.6	93.6	93.6	87.6	82.6	77.6	70.6	94.0	NEMA (2000)
1110-T-5005	Service hoist transformer	1	24	90.4	96.4	98.4	93.4	93.4	87.4	82.4	77.4	70.4	93.8	NEMA (2000)
3800-FN-1011	Intake fan	1	24	82.7	88.6	84.7	88.6	88.7	88.7	86.8	83.7	77.6	93.4	Bies and Hansen (2003)
1110-T-5007	Auxiliary hoist transformer	1	24	89.9	95.9	97.9	92.9	92.9	86.9	81.9	76.9	69.9	93.3	NEMA (2000)
3800-FN-1008	Exhaust fan	1	24	82.5	88.5	84.6	88.5	88.6	88.6	86.6	83.6	77.5	93.2	Bies and Hansen (2003)
3970-MU-1001	Make-Up air unit	1	24	94.1	93.3	92.5	88.7	89.0	88.4	82.7	78.1	68.7	91.9	Professional experience
3970-MU-1002	Make-Up air unit	1	24	94.1	93.3	92.5	88.7	89.0	88.4	82.7	78.1	68.7	91.9	Professional experience
3970-MU-1003	Make-Up air unit	1	24	94.1	93.3	92.5	88.7	89.0	88.4	82.7	78.1	68.7	91.9	Professional experience
5310-MU-1001	Make-Up air unit	1	24	94.1	93.3	92.5	88.7	89.0	88.4	82.7	78.1	68.7	91.9	Professional experience
1110-FN-1010	Exhaust fan	1	24	81.1	87.1	83.1	87.1	87.1	87.1	85.1	82.1	76.1	91.8	Bies and Hansen (2003)
5600-SP-1	Diesel dispenser #1	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
5600-SP-1	Diesel dispenser #2	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
5600-SP-1	Gasoline dispenser #1	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)

Table 7B-11: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Operations

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
5630-PP-1001	LNG pump 01	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
5630-PP-1002	LNG pump 02	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
3800-FN-1009	Exhaust fan	1	24	79.4	85.4	81.4	85.4	85.5	85.5	83.5	80.4	74.4	90.1	Bies and Hansen (2003)
3800-FN-1010	Exhaust fan	1	24	79.4	85.4	81.4	85.4	85.5	85.5	83.5	80.4	74.4	90.1	Bies and Hansen (2003)
3800-MU-1001	Make up air unit	1	24	92.7	91.8	90.9	86.9	87.0	86.3	80.0	75.8	66.7	89.8	Professional experience
1120-FN-1001	Wall mounted exhaust fan	1	24	85.8	91.8	82.8	84.8	85.8	83.8	80.8	78.8	68.8	88.6	Bies and Hansen (2003)
3600-FN-1001	Intake fan	1	24	76.0	81.9	78.0	82.0	82.0	82.0	80.0	77.0	71.0	86.7	Bies and Hansen (2003)
3600-FN-1002	Exhaust fan	1	24	76.0	81.9	78.0	82.0	82.0	82.0	80.0	77.0	71.0	86.7	Bies and Hansen (2003)
3600-FN-1003	Exhaust fan	1	24	76.0	81.9	78.0	82.0	82.0	82.0	80.0	77.0	71.0	86.7	Bies and Hansen (2003)
3600-HE-1001	Heater/blower	1	24	76.0	81.9	78.0	82.0	82.0	82.0	80.0	77.0	71.0	86.7	Bies and Hansen (2003)
1170-T-5001	Fresh air fans transformer	1	24	82.3	88.3	90.3	85.3	85.3	79.3	74.3	69.3	62.3	85.7	NEMA (2000)
1110-T-5001	Batch plant transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1130-T-5001	Exhaust shaft building services transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1110-T-5003	Production hoist auxiliaries transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1110-T-5004	Service hoist auxiliaries transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1120-T-5001	Head frame building services transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)
1110-T-5009	Auxiliary hoist auxiliaries transformer	1	24	81.3	87.3	89.3	84.3	84.3	78.3	73.3	68.3	61.3	84.7	NEMA (2000)
1120-LT-5001	Lighting transformer	1	24	79.8	85.8	87.8	82.8	82.8	76.8	71.8	66.8	59.8	83.2	NEMA (2000)

Table 7B-11: Noise Emissions from Outdoor Stationary Equipment – Rook I Project Operations

Equipment Tag No.	Equipment Name and Description	Quantity	Usage (Hours per Day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
				31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
1120-LT-5003	Lighting transformer	1	24	79.8	85.8	87.8	82.8	82.8	76.8	71.8	66.8	59.8	83.2	NEMA (2000)

NEMA = National Electrical Manufacturers Association; dBZ = unweighted decibel; dBA = A-weighted decibel; VFD = variable frequency drive; AC = air conditioning; LNG = liquified natural gas; FN = fan; HE = heater; GE = generator; CV = conveyor; CD = condenser; PU = pump; MU = make up unit; AG = agitator; T = transformer; SP = system with pump; PP = pump; LT = lighting transformer; SX = solvent extractor.

Table 7B-12: Noise Emissions from Buildings – Rook I Project Operations

Building	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Power plant	1	24	127.7	127.9	133.0	128.3	125.7	127.0	122.9	131.7	133.6	136.7	Manufacturer data sheet and professional experience
Effluent treatment plant	1	24	128.0	127.8	120.0	119.7	117.8	116.5	114.0	110.6	104.7	121.5	Bies and Hansen (2003) and professional experience
Production shaft hoist room	1	24	128.1	122.5	114.2	114.3	111.3	109.1	110.4	106.4	99.1	116.0	Bies and Hansen (2003), DEFRA (2007), and professional experience
Intake water facility	1	24	109.7	105.6	104.8	106.0	107.7	108.4	106.7	101.9	94.7	112.7	Bies and Hansen (2003) and professional experience
Process plant	1	24	127.6	119.7	115.0	111.5	109.0	105.9	105.8	101.7	95.1	112.5	Bies and Hansen (2003), DEFRA (2007), and professional experience
Acid plant	1	24	118.6	113.7	114.8	108.1	107.8	106.0	103.9	99.6	94.3	111.2	Bies and Hansen (2003) and professional experience
Production shaft tower	1	24	104.8	100.0	97.7	98.6	100.9	98.8	95.9	91.2	84.7	103.4	Bies and Hansen (2003), NEMA (2000), and professional experience

Table 7B-12: Noise Emissions from Buildings – Rook I Project Operations

Building	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Solvent extraction	1	24	119.3	113.7	104.3	104.4	100.4	97.5	95.2	90.5	83.7	103.4	Bies and Hansen (2003), DEFRA (2007), and professional experience
Production shaft collar house	1	24	117.6	112.3	103.5	105.0	100.2	89.8	89.7	79.7	73.7	101.0	DEFRA (2007) and professional experience
Admin building	1	24	105.6	100.3	97.1	96.2	96.0	95.6	93.3	88.4	81.3	100.0	Bies and Hansen (2003) and professional experience
Exhaust shaft headframe	1	24	96.5	91.1	86.9	84.9	82.5	78.9	70.9	58.4	51.5	83.8	Bies and Hansen (2003) and professional experience
Production shaft electrical room	1	24	74.8	76.0	69.0	71.9	71.4	71.1	69.0	66.0	60.0	75.8	Bies and Hansen (2003) and professional experience
Warehouse/shop	1	24	69.9	70.3	61.8	63.7	62.4	61.6	59.4	56.3	50.3	66.5	Bies and Hansen (2003) and professional experience

DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; NEMA = National Electrical Manufacturers Association; dBZ = unweighted decibel; dBA = A-weighted decibel.

Table 7B-13: Noise Emissions from Bird Deterrents – Rook I Project Operations

Equipment	Quantity	Firing Rate	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Bird deterrent cannon	4	1 shot every 3 minutes	135.0	143.0	150.0	149.0	143.0	135.0	140.0	132.0	127.0	146.2	Canadian Natural (2018)

dBZ = unweighted decibel; dBA = A-weighted decibel.

7B2.1.3 Fission Patterson Lake South Property Construction Activities

Noise emissions from construction activities at the Fission Patterson Lake South Property were assumed to be generally consistent with noise emissions from the Project Construction phase (Table 7B-5 through Table 7B-8). This approach was taken because the Fission Patterson Lake South Property is a similar type of development to the Project and is anticipated to have comparable equipment and noise emissions. However, publicly available information suggests there are no headframes associated with the Fission Patterson Lake South Property; instead, ore will be hauled to the surface using trucks (Fission 2019). As such, noise sources associated with headframe construction were not included in the models of the Fission Patterson Lake South Property.

Table 7B-14 presents noise emissions for traffic on the Fission Patterson Lake South Property access road during construction activities. Octave band noise emissions are presented in dBZ, and total noise emissions are presented in dBA. For each type of vehicle that will use the Fission Patterson Lake South Property access road, Table 7B-14 also presents the maximum number of one-way trips per daytime period and per nighttime period.

Table 7B-15 presents noise emissions for mobile equipment that will be active on-site during the Fission Patterson Lake South Property construction activities. Noise emissions presented in Table 7B-15 include the time-weighted contribution from a tonal back-up alarm in the 1 kHz octave band. A penalty of 5 dBZ has been added to the back-up alarm noise emissions (i.e., the noise emissions have been artificially increased by 5 dBZ) to reflect the fact that tonal noise is typically more disturbing than other types of noise (ISO 2016). Table 7B-15 also presents the quantity of each type of mobile equipment and the number of hours the equipment will be active during a typical 24-hour period.

Table 7B-16 presents noise emissions for stationary equipment that will be active outdoors during construction of the Fission Patterson Lake South Property. Table 7B-16 also presents the number of hours each piece of equipment will be active during a typical 24-hour period.

Table 7B-17 presents noise emissions for buildings that will be active during the construction of the Fission Patterson Lake South Property. These emissions values represent noise breakout from indoor equipment (i.e., the amount of noise that will be emitted to the outdoor environment).

Table 7B-14: Noise Emissions from Access Road – Fission Patterson Lake South Property Construction

Vehicle Type	One-Way Trips		Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
	Daytime	Nighttime	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Crew bus	39	24	121.0	121.0	114.0	104.0	104.0	101.0	100.0	92.0	87.0	107.2	DEFRA (2007)
Transport truck	413	248	121.0	121.0	114.0	104.0	104.0	101.0	100.0	92.0	87.0	107.2	DEFRA (2007)

DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; dBZ = unweighted decibel; dBA = A-weighted decibel.

Table 7B-15: Noise Emissions from Mobile Equipment – Fission Patterson Lake South Property Construction

Equipment	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Fuel truck 5000 gallon capacity	1	3.0	106.0	108.0	115.0	111.0	112.0	112.4	110.0	104.0	96.0	116.4	Suncor (2016)
Caterpillar D9T track-type tractor	2	6.0	108.2	111.2	113.2	115.2	107.2	112.1	106.2	104.2	98.2	115.2	Manufacturer data sheet
Caterpillar D8T track-type tractor	2	6.0	100.1	103.1	121.1	112.1	109.1	111.2	105.1	99.1	90.1	114.4	Manufacturer data sheet
Caterpillar PS-150C pneumatic compactor	1	6.0	121.9	116.9	111.9	107.9	108.9	110.1	107.9	103.9	98.9	114.3	DOT (2006)
Caterpillar 815F series 2 soil compactor	2	6.0	120.3	115.3	110.3	106.3	107.3	109.2	106.3	102.3	97.3	113.0	Manufacturer data sheet
Generator 125 kVA	6	17.0	108.1	111.1	114.1	115.1	112.1	105.1	101.1	96.1	89.1	112.6	DOT (2006)
Generator 70-80 kVA	5	11.4	108.1	111.1	114.1	115.1	112.1	105.1	101.1	96.1	89.1	112.6	DOT (2006)
Caterpillar 623G wheel tractor scraper	3	6.0	97.6	102.6	113.6	107.6	107.6	108.7	103.6	98.6	96.6	112.0	Manufacturer data sheet
Caterpillar 450E backhoe loader	1	3.0	122.5	113.5	104.5	108.5	108.5	108.3	103.5	97.5	91.5	111.8	Manufacturer data sheet
Caterpillar 140M/140M all-wheel drive motor grader	2	7.5	96.1	101.1	112.1	106.1	106.1	109.1	102.1	97.1	95.1	111.5	Manufacturer data sheet
Ditch witch RT45	1	3.0	120.0	111.0	102.0	106.0	106.0	107.5	101.0	95.0	89.0	110.1	Manufacturer data sheet
Caterpillar 725 articulated truck	6	12.0	110.0	113.0	116.0	105.0	103.0	106.8	102.0	97.0	91.0	110.0	DEFRA (2007)
Caterpillar 345D L hydraulic excavator	2	12.0	101.3	100.3	113.3	103.3	105.3	106.3	102.3	96.3	91.3	109.8	Manufacturer data sheet
Chicago pneumatic CPS 375 portable compressor	4	3.0	113.7	109.7	105.7	99.7	104.7	105.7	103.7	96.7	91.7	109.6	DOT (2006)

Table 7B-15: Noise Emissions from Mobile Equipment – Fission Patterson Lake South Property Construction

Equipment	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Caterpillar TL1055 telehandler	3	3.0	95.6	97.8	113.0	109.3	101.6	107.0	99.0	92.3	84.0	109.4	EU (2000)
Caterpillar CP64 vibratory soil compactor	2	6.0	114.0	109.0	104.0	100.0	101.0	107.0	100.0	96.0	91.0	108.9	DEFRA (2007)
Caterpillar CS64 vibratory soil compactor	2	6.0	114.0	109.0	104.0	100.0	101.0	107.0	100.0	96.0	91.0	108.9	DEFRA (2007)
Caterpillar TL943 telehandler	5	4.2	94.4	96.6	111.8	108.1	100.4	106.8	97.8	91.1	82.8	108.8	EU (2000)
Caterpillar 928Hz wheel loader	2	4.5	118.0	113.0	108.0	103.0	104.0	106.8	96.0	90.0	83.0	108.5	Manufacturer data sheet
Caterpillar TH255 telehandler	1	3.0	93.7	95.9	111.1	107.4	99.7	106.7	97.1	90.4	82.1	108.5	EU (2000)
10 t picker truck	2	3.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Volvo VHD13 trailering truck	3	3.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Volvo VHD13 dump truck	4	3.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Volvo VHD concrete mixer	2	6.0	122.0	112.0	102.0	102.0	101.0	104.5	103.0	93.0	87.0	108.2	DEFRA (2007)
JLG 1250A manlift	3	3.0	113.2	108.2	103.2	104.2	103.2	103.8	100.2	98.2	91.2	107.9	DOT (2006)
JLG 3394RT scissor lift	6	3.0	113.2	108.2	103.2	104.2	103.2	103.8	100.2	98.2	91.2	107.9	DOT (2006)
JLG 600SJ manlift	6	3.0	113.2	108.2	103.2	104.2	103.2	103.8	100.2	98.2	91.2	107.9	DOT (2006)
Grove RT9130E rough terrain crane (130 t)	1	3.0	109.0	108.0	107.0	101.0	102.0	104.5	101.0	92.0	83.0	107.6	DEFRA (2007)
Caterpillar 242B series 3 skid steer loader	3	4.0	89.9	92.1	107.3	103.6	95.9	106.3	93.3	86.6	78.3	107.2	EU (2000)
Caterpillar 314D LCR hydraulic excavator	1	12.0	92.3	91.3	104.3	94.3	96.3	106.4	93.3	87.3	82.3	107.0	Manufacturer data sheet
Caterpillar 311D LRR hydraulic excavator	1	6.0	91.3	90.3	103.3	93.3	95.3	106.3	92.3	86.3	81.3	106.8	Manufacturer data sheet
Grove RT700E rough terrain crane (60 t)	4	3.0	120.0	115.0	110.0	106.0	102.0	103.8	95.0	88.0	80.0	106.6	DEFRA (2007)
Concord CCP-52XZ-170 concrete pumper	1	6.0	102.0	97.0	92.0	92.0	94.0	106.1	87.0	81.0	75.0	106.3	DEFRA (2007)
Commander 500 portable welder	9	3.2	106.3	103.6	101.5	99.1	99.0	100.5	97.0	92.5	89.5	104.2	DEFRA (2007)
Manitowoc 18000 crawler crane (600 t)	1	3.0	93.0	96.0	99.0	96.0	90.0	102.6	94.0	83.0	74.0	103.6	DEFRA (2007)
Manitowoc 2250 crawler crane (300 t)	1	3.0	93.0	96.0	99.0	96.0	90.0	102.6	94.0	83.0	74.0	103.6	DEFRA (2007)
Manitowoc 777 crawler crane (181 t)	1	3.0	93.0	96.0	99.0	96.0	90.0	102.6	94.0	83.0	74.0	103.6	DEFRA (2007)

Table 7B-15: Noise Emissions from Mobile Equipment – Fission Patterson Lake South Property Construction

Equipment	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Manitowoc 999 crawler crane (250 t)	1	3.0	93.0	96.0	99.0	96.0	90.0	102.6	94.0	83.0	74.0	103.6	DEFRA (2007)
National Crane 1400H truck crane	2	3.0	112.0	108.0	104.0	99.0	91.0	102.4	91.0	84.0	78.0	103.4	DEFRA (2007)
Manitowoc 5540F carry deck (15 t)	1	3.0	112.0	108.0	104.0	99.0	91.0	102.4	91.0	84.0	78.0	103.4	DEFRA (2007)
Manitowoc 7755 carry deck (22 t)	2	3.0	112.0	108.0	104.0	99.0	91.0	102.4	91.0	84.0	78.0	103.4	DEFRA (2007)
Grove YB4409 carry deck (8.5 t)	1	3.0	112.0	108.0	104.0	99.0	91.0	102.4	91.0	84.0	78.0	103.4	DEFRA (2007)
Grove RT540E rough terrain crane (40 t)	6	3.0	115.0	106.0	97.0	95.0	92.0	102.3	85.0	77.0	68.0	102.8	DEFRA (2007)
Ford F150 pickup truck	8	2.9	68.0	79.4	98.6	85.9	84.0	102.0	77.8	70.3	63.1	102.1	DOT (2006)
Ford F350 truck	6	2.8	68.0	79.4	98.6	85.9	84.0	102.0	77.8	70.3	63.1	102.1	DOT (2006)
Ditch witch RT12	1	3.0	66.4	83.4	100.4	92.4	91.4	91.4	93.4	97.4	96.4	102.0	Manufacturer data sheet
350,000 BTU frost fighter	22	24.0	87.7	87.7	86.7	84.7	81.7	78.7	75.7	72.7	69.7	84.4	Manufacturer data sheet

DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; DOT = United States Department of Transportation; dBZ = unweighted decibel; dBA = A-weighted decibel; JLG = JLG Industries Inc.; kVA = kilovolt-ampere.

Table 7B-16: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Construction

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Return air fan No. 1	1	24	120.7	126.7	117.7	119.7	120.7	118.7	115.7	113.7	103.7	123.5	Bies and Hansen (2003)
Fresh air heater No. 1 natural gas burner	1	24	101.2	104.2	110.2	116.2	122.2	116.2	110.2	104.2	101.2	121.6	Professional experience
Generator unit 01 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 02 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 03 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 04 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet

Table 7B-16: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Construction

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Generator unit 05 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 06 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 07 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 08 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 09 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Off-Shaft development fan	1	24	111.7	117.5	109.2	111.2	112.6	111.2	109.0	105.9	96.6	116.0	Bies and Hansen (2003)
Fresh air fan VFD No. 1	1	24	99.8	99.8	102.8	104.8	107.8	107.8	106.8	101.8	93.8	112.5	Bies and Hansen (2003)
Fresh air fan No.1	1	24	101.9	107.9	98.9	100.9	101.9	99.9	96.9	94.9	84.9	104.8	Bies and Hansen (2003)
Thru-wall AC	1	24	92.8	96.8	97.8	98.8	99.8	97.8	95.8	91.8	85.8	102.8	Bies and Hansen (2003)
Return air fan VFD No. 1	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
VFD for 1000 hp fan	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
VFD for 1000 hp fan	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
Generator unit 01 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 02 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 03 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 04 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 05 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 06 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience

Table 7B-16: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Construction

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Generator unit 07 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 08 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 09 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Diesel dispenser #1	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
Diesel dispenser #2	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
Gasoline dispenser #1	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
LNG pump 01	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
LNG pump 02	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
Fresh air fans transformer	1	24	82.3	88.3	90.3	85.3	85.3	79.3	74.3	69.3	62.3	85.7	NEMA (2000)
Batch plant transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)

NEMA = National Electrical Manufacturer Association; dBZ = unweighted decibel; dBA = A-weighted decibel; VFD = variable frequency drive; AC = air conditioning; LNG = liquified natural gas; FN = fan; HE = heater; GE = generator; T = transformer; SP = system with pump; PP = pump.

Table 7B-17: Noise Emissions from Buildings – Fission Patterson Lake South Property Construction

Building	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Power plant	1	24	127.7	127.9	133.0	128.3	125.7	127.0	122.9	131.7	133.6	136.7	Manufacturer data sheet and professional experience
Intake water facility	1	24	109.7	105.6	104.8	106.0	107.7	108.4	106.7	101.9	94.7	112.7	Bies and Hansen (2003) and professional experience

dBZ = unweighted decibel; dBA = A-weighted decibel.

7B2.1.4 Fission Patterson Lake South Property Operations Activities

With the exception of the mobile equipment, noise emissions from operations activities at the Fission Patterson Lake South Property were assumed to be generally consistent with noise emissions from Project Operations (Table 7B-9 through Table 7B-13). However, the number of bird deterrents assumed for the Fission Patterson Lake South Property was increased relative to the Project because the Fission Patterson Lake South Property will make use of a large above-ground tailings management facility (Fission 2019). In addition, the mobile equipment fleet for Fission Patterson Lake South Property operations is publicly available and was used to estimate noise emission from this equipment (Fission 2019).

Table 7B-18 presents noise emissions for traffic on the Fission Patterson Lake South Property access road during operations. Octave band noise emissions are presented in dBZ, and total noise emissions are presented in dBA. For each type of vehicle that will use the Project access road, Table 7B-18 also presents the maximum number of one-way trips per daytime period and per nighttime period.

Table 7B-19 presents noise emissions for mobile equipment that will be active on-site during Fission Patterson Lake South Property operations. Noise emissions presented in Table 7B-19 include the time-weighted contribution from a tonal back-up alarm in the 1 kHz octave band. A penalty of 5 dBZ has been added to the back-up alarm noise emissions to reflect the fact that tonal noise is typically more disturbing than other types of noise (ISO 2016). Table 7B-19 also presents the quantity of each type of mobile equipment and the number of hours the equipment will be active during a typical 24-hour period.

Table 7B-20 presents noise emissions for stationary equipment that will be active outdoors during Fission Patterson Lake South Property operations. Table 7B-20 also presents the number of hours each piece of equipment will be active during a typical 24-hour period.

Table 7B-21 presents noise emissions for buildings that will be active during Fission Patterson Lake South Property operations. These emissions values represent noise breakout from indoor equipment (i.e., the amount of noise that will be emitted to the outdoor environment).

Table 7B-22 presents noise emissions for equipment that will be used to deter birds from landing on the Fission Patterson Lake South Property tailings management facility. Table 7B-22 also presents the number of cannons and the cannon firing rate.

Table 7B-18: Noise Emissions from Access Road – Fission Patterson Lake South Property Operations

Vehicle Type	One-Way Trips		Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
	Daytime	Nighttime	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Transport truck	74	44	121.0	121.0	114.0	104.0	104.0	101.0	100.0	92.0	87.0	107.2	DEFRA (2007)
Pickup truck	8	5	68.0	79.4	98.6	85.9	84.0	82.2	77.8	70.3	63.1	87.8	DOT (2006)

DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; DOT = United States Department of Transportation; dBZ = unweighted decibel; dBA = A-weighted decibel.

Table 7B-19: Noise Emissions from Mobile Equipment – Fission Patterson Lake South Property Operations

Equipment	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Scamec 2000 mobile rock breaker	1	4.0	117.2	119.5	121.8	119.9	113.5	113.8	111.7	111.0	105.3	119.5	Professional experience
Epiroc ST14 LHD loader	5	8.0	101.3	103.3	117.3	115.3	106.3	108.7	104.3	97.3	89.3	113.0	Manufacturer data sheet
Grader	1	6.0	96.1	101.1	112.1	106.1	106.1	109.1	102.1	97.1	95.1	111.5	Manufacturer data sheet
Epiroc MT 431B haul truck	5	10.0	110.0	113.0	116.0	105.0	103.0	106.8	102.0	97.0	91.0	110.0	DEFRA (2007)
Charmec MF 605 ANFO loader truck	1	10.0	110.0	113.0	116.0	105.0	103.0	106.8	102.0	97.0	91.0	110.0	DEFRA (2007)
Utimec MF 400 lube truck	1	10.0	110.0	113.0	116.0	105.0	103.0	106.8	102.0	97.0	91.0	110.0	DEFRA (2007)
Multimec MF 100 casette truck	1	10.0	110.0	113.0	116.0	105.0	103.0	106.8	102.0	97.0	91.0	110.0	DEFRA (2007)
Himec MF 905 basket truck	2	10.0	110.0	113.0	116.0	105.0	103.0	106.8	102.0	97.0	91.0	110.0	DEFRA (2007)
Epiroc two-boom M2 jumbo	3	6.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Epiroc Boltec rock bolter	2	6.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Epiroc Simba E7C production drill	2	6.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Epiroc Easer L-Mobile raise boring machine	1	6.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Epiroc Cabletec cable bolt drill	1	6.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.4	DEFRA (2007)
Utimec MF 164 personnel carrier	3	1.0	121.0	121.0	114.0	104.0	104.0	104.5	100.0	92.0	87.0	108.3	DEFRA (2007)
Utilift MF 540 scissor lift	3	0.5	113.2	108.2	103.2	104.2	103.2	103.8	100.2	98.2	91.2	107.9	DOT (2006)
Utimec LF 600 transmixer	3	1.0	102.0	97.0	92.0	92.0	94.0	106.1	87.0	81.0	75.0	106.3	DEFRA (2007)
Spraymec MF 050 shotcrete sprayer	2	1.0	102.0	97.0	92.0	92.0	94.0	106.1	87.0	81.0	75.0	106.3	DEFRA (2007)

Table 7B-19: Noise Emissions from Mobile Equipment – Fission Patterson Lake South Property Operations

Equipment	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Flat deck truck with Utimec LF 130 crane	2	1.0	68.0	79.4	98.6	85.9	84.0	102.0	77.8	70.3	63.1	102.1	DEFRA (2007)
Small vehicle	10	10.0	68.0	79.4	98.6	85.9	84.0	102.0	77.8	70.3	63.1	102.1	DEFRA (2007)

DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; DOT = United States Department of Transportation; dBZ = unweighted decibel; dBA = A-weighted decibel; ANFO = ammonium nitrate fuel oil.

Table 7B-20: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Operations

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Return air fan No. 1	1	24	120.7	126.7	117.7	119.7	120.7	118.7	115.7	113.7	103.7	123.5	Bies and Hansen (2003)
Fresh air heater No. 1 natural gas burner	1	24	101.2	104.2	110.2	116.2	122.2	116.2	110.2	104.2	101.2	121.6	Professional experience
Generator unit 01 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 02 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 03 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 04 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 05 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 06 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 07 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 08 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet
Generator unit 09 exhaust	1	24	120.0	123.4	111.5	110.3	111.7	111.4	110.1	114.4	107.1	118.8	Manufacturer data sheet

Table 7B-20: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Operations

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Ore transport conveyor	1	24	113.9	114.8	122.6	115.3	116.1	109.2	108.3	107.7	106.1	117.5	Professional experience
Fresh air fan VFD No. 1	1	24	99.8	99.8	102.8	104.8	107.8	107.8	106.8	101.8	93.8	112.5	Bies and Hansen (2003)
Self-Contained AC unit	1	24	95.8	99.8	100.8	101.8	102.8	100.8	98.8	94.8	88.8	105.8	Bies and Hansen (2003)
Self-Contained AC unit	1	24	95.8	99.8	100.8	101.8	102.8	100.8	98.8	94.8	88.8	105.8	Bies and Hansen (2003)
Fresh air fan No. 1	1	24	101.9	107.9	98.9	100.9	101.9	99.9	96.9	94.9	84.9	104.7	Bies and Hansen (2003)
Self-Contained AC unit	1	24	94.7	98.7	99.7	100.7	101.7	99.7	97.7	93.7	87.7	104.7	Bies and Hansen (2003)
Ore Hopper/Grizzly feeder	1	24	100.3	101.2	109.0	101.7	102.5	95.6	94.7	94.1	92.5	103.9	Professional experience
Waste pan feeder	1	24	99.7	100.6	108.4	101.1	101.9	95.0	94.1	93.5	91.9	103.3	Professional experience
Ore pan feeder	1	24	99.7	100.6	108.4	101.1	101.9	95.0	94.1	93.5	91.9	103.3	Professional experience
Split AC unit	1	24	93.3	97.3	98.3	99.3	100.3	98.3	96.3	92.3	86.3	103.3	Bies and Hansen (2003)
Self-Contained AC unit	1	24	93.3	97.3	98.3	99.3	100.3	98.3	96.3	92.3	86.3	103.3	Bies and Hansen (2003)
Thru-wall AC unit	1	24	92.8	96.8	97.8	98.8	99.8	97.8	95.8	91.8	85.8	102.8	Bies and Hansen (2003)
Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)

Table 7B-20: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Operations

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
Exhaust fan	1	24	91.5	97.3	93.6	97.5	97.7	97.7	95.8	92.6	86.5	102.4	Bies and Hansen (2003)
Self-Contained AC unit	1	24	91.8	95.8	96.8	97.8	98.8	96.8	94.8	90.8	84.8	101.8	Bies and Hansen (2003)
VFD for 1000 hp fan	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
VFD for 1000 hp fan	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
Return air fan VFD No. 1	1	24	91.0	93.0	95.0	95.0	95.0	95.0	95.0	92.0	85.0	100.6	Bies and Hansen (2003)
Generator unit 01 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 02 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 03 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 04 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 05 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 06 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 07 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 08 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Generator unit 09 cooler	1	24	104.9	107.6	104.4	101.3	95.6	94.3	93.4	90.0	79.2	100.5	Professional experience
Exhaust fan	1	24	89.1	94.9	91.2	95.1	95.3	95.3	93.4	90.2	84.1	100.0	Bies and Hansen (2003)

Table 7B-20: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Operations

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Exhaust fan	1	24	89.1	94.9	91.2	95.1	95.3	95.3	93.4	90.2	84.1	100.0	Bies and Hansen (2003)
Exhaust fan	1	24	89.1	94.9	91.2	95.1	95.3	95.3	93.4	90.2	84.1	100.0	Bies and Hansen (2003)
Exhaust fan	1	24	89.1	94.9	91.2	95.1	95.3	95.3	93.4	90.2	84.1	100.0	Bies and Hansen (2003)
Ore stockpile sump pump	1	24	88.3	88.9	90.7	92.7	94.3	95.7	93.7	89.2	82.3	99.8	Bies and Hansen (2003)
Make-Up air unit	1	24	98.5	98.3	98.1	94.6	95.6	95.3	91.6	85.9	75.3	99.1	Professional experience
Make-Up air unit	1	24	98.5	98.3	98.1	94.6	95.6	95.3	91.6	85.9	75.3	99.1	Professional experience
Make-Up air unit	1	24	98.5	98.3	98.1	94.6	95.6	95.3	91.6	85.9	75.3	99.1	Professional experience
Make-Up air unit	1	24	98.5	98.3	98.1	94.6	95.6	95.3	91.6	85.9	75.3	99.1	Professional experience
Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)
Exhaust fan	1	24	86.7	92.5	88.8	92.7	92.9	92.9	91.0	87.8	81.7	97.6	Bies and Hansen (2003)

Table 7B-20: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Operations

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Grinding area process ventilation fan	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Leaching area process ventilation fan	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Liquids/solids separating area process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Liquids/solids separating area process ventilation fan #2	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
SX process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
SX process ventilation fan #2	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
SX process ventilation fan #3	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Precipitation area process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Precipitation area process ventilation fan #2	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Tails neutralization area process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Tails neutralization area process ventilation fan #12	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Product drying and packaging area process ventilation fan #1	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Product drying and packaging area process ventilation fan #2	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Precipitation area process ventilation fan #3	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Effluent treatment area process ventilation fan	1	24	86.3	92.1	88.4	92.3	92.5	92.5	90.6	87.4	81.3	97.2	Bies and Hansen (2003)
Run-Off pond #1 pump	1	24	85.6	86.3	87.9	89.9	91.2	92.9	90.7	86.3	79.6	96.9	Bies and Hansen (2003)
Run-Off pond #2 pump	1	24	85.6	86.3	87.9	89.9	91.2	92.9	90.7	86.3	79.6	96.9	Bies and Hansen (2003)

Table 7B-20: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Operations

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Ore storage tank #1 agitator	1	24	82.5	82.5	85.5	87.5	90.5	90.5	89.5	84.5	76.5	95.2	Bies and Hansen (2003)
Make-Up air unit	1	24	95.7	95.1	94.6	90.9	91.5	90.9	86.0	81.0	71.2	94.5	Professional experience
Make-Up air unit	1	24	95.7	95.1	94.6	90.9	91.5	90.9	86.0	81.0	71.2	94.5	Professional experience
Intake fan	1	24	82.7	88.6	84.7	88.6	88.7	88.7	86.8	83.7	77.6	93.4	Bies and Hansen (2003)
Exhaust fan	1	24	82.5	88.5	84.6	88.5	88.6	88.6	86.6	83.6	77.5	93.2	Bies and Hansen (2003)
Make-Up air unit	1	24	94.1	93.3	92.5	88.7	89.0	88.4	82.7	78.1	68.7	91.9	Professional experience
Make-Up air unit	1	24	94.1	93.3	92.5	88.7	89.0	88.4	82.7	78.1	68.7	91.9	Professional experience
Make-Up air unit	1	24	94.1	93.3	92.5	88.7	89.0	88.4	82.7	78.1	68.7	91.9	Professional experience
Make-Up air unit	1	24	94.1	93.3	92.5	88.7	89.0	88.4	82.7	78.1	68.7	91.9	Professional experience
Diesel dispenser #1	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
Diesel dispenser #2	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
Gasoline dispenser #1	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
LNG pump 01	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
LNG pump 02	1	24	80.4	81.3	82.7	84.7	85.6	87.7	85.2	80.9	74.4	91.5	Bies and Hansen (2003)
Exhaust Ffan	1	24	79.4	85.4	81.4	85.4	85.5	85.5	83.5	80.4	74.4	90.1	Bies and Hansen (2003)
Exhaust fan	1	24	79.4	85.4	81.4	85.4	85.5	85.5	83.5	80.4	74.4	90.1	Bies and Hansen (2003)
Make-Up air unit	1	24	92.7	91.8	90.9	86.9	87.0	86.3	80.0	75.8	66.7	89.8	Professional experience

Table 7B-20: Noise Emissions from Outdoor Stationary Equipment – Fission Patterson Lake South Property Operations

Equipment Name and Description	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Intake fan	1	24	76.0	81.9	78.0	82.0	82.0	82.0	80.0	77.0	71.0	86.7	Bies and Hansen (2003)
Exhaust fan	1	24	76.0	81.9	78.0	82.0	82.0	82.0	80.0	77.0	71.0	86.7	Bies and Hansen (2003)
Exhaust fan	1	24	76.0	81.9	78.0	82.0	82.0	82.0	80.0	77.0	71.0	86.7	Bies and Hansen (2003)
Heater/blower	1	24	76.0	81.9	78.0	82.0	82.0	82.0	80.0	77.0	71.0	86.7	Bies and Hansen (2003)
Fresh air fans transformer	1	24	82.3	88.3	90.3	85.3	85.3	79.3	74.3	69.3	62.3	85.7	NEMA (2000)
Batch plant transformer	1	24	81.8	87.8	89.8	84.8	84.8	78.8	73.8	68.8	61.8	85.2	NEMA (2000)

NEMA = National Electrical Manufacturer Association; dBZ = unweighted decibel; dBA = A-weighted decibel; AC = air conditioner; VFD = variable frequency drive; SX = solvent extraction; LNG = liquified natural gas.

Table 7B-21: Noise Emissions from Buildings – Fission Patterson Lake South Property Operations

Building	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Power plant	1	24	127.7	127.9	133.0	128.3	125.7	127.0	122.9	131.7	133.6	136.7	Manufacturer data sheet and professional experience
Effluent treatment plant	1	24	128.0	127.8	120.0	119.7	117.8	116.5	114.0	110.6	104.7	121.5	Bies and Hansen (2003) and professional experience
Intake water facility	1	24	109.7	105.6	104.8	106.0	107.7	108.4	106.7	101.9	94.7	112.7	Bies and Hansen (2003) and professional experience
Process plant	1	24	127.6	119.7	115.0	111.5	109.0	105.9	105.8	101.7	95.1	112.5	Bies and Hansen (2003), DEFRA (2007), and professional experience

Table 7B-21: Noise Emissions from Buildings – Fission Patterson Lake South Property Operations

Building	Quantity	Usage (hours per day)	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Acid plant	1	24	118.6	113.7	114.8	108.1	107.8	106.0	103.9	99.6	94.3	111.2	Bies and Hansen (2003) and professional experience
Solvent extraction	1	24	119.3	113.7	104.3	104.4	100.4	97.5	95.2	90.5	83.7	103.4	Bies and Hansen (2003), DEFRA (2007), and professional experience
Admin building	1	24	105.6	100.3	97.1	96.2	96.0	95.6	93.3	88.4	81.3	100.0	Bies and Hansen (2003), DEFRA (2007), and professional experience
Warehouse/shop	1	24	69.9	70.3	61.8	63.7	62.4	61.6	59.4	56.3	50.3	66.5	Bies and Hansen (2003), DEFRA (2007), and professional experience

DEFRA = United Kingdom Department for Environment, Food, and Rural Affairs; dBZ = unweighted decibel; dBA = A-weighted decibel.

Table 7B-22: Noise Emissions from Bird Deterrents – Fission Patterson Lake South Property Operations

Equipment	Quantity	Firing Rate	Octave Band Sound Power Level (dBZ)									Total Sound Power Level (dBA)	Emissions Reference
			31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Bird deterrent cannon	92	1 shot every 3 minutes	135.0	143.0	150.0	149.0	143.0	135.0	140.0	132.0	127.0	146.2	Canadian Natural (2018)

dBZ = unweighted decibel; dBA = A-weighted decibel.

7B2.2 Airstrip

Inputs to the ECAC noise models of the Project airstrip and the Fission Patterson Lake South Property airstrip include aircraft types and take-off / landing frequencies for a typical six-month period (Table 7B-4). The ECAC algorithm assigns noise emissions to individual take off and landing activities based on the maximum take off weight and engine power of the aircraft involved. In contrast to the ISO 9613-2 algorithm, which makes use of noise emissions in the form of sound power levels, the ECAC algorithm specifies noise emissions in the form of sound pressure levels at 300 m from the aircraft. Sound power levels used in the ISO 9613-2 algorithm represent the total amount of acoustic energy radiated by a given source; sound pressure levels used in the ECAC algorithm represent the noise level from a given source observed at a specific location in the environment.

Table 7B-23 presents noise emissions used to model the Project airstrip and the Fission Patterson Lake South Property airstrip. Octave band sound pressure levels are presented in dBZ, and total sound pressure levels are presented in dBA. Because the same types of aircraft will make use of the Project airstrip and the Fission Patterson Lake South Property airstrip, the same noise emissions are used in the ECAC models of both airstrips. Similarly, the same noise emissions are used in the ECAC models of Construction and Operations; the only difference between Construction and Operations ECAC models is the number of take off and landing activities (Table 7B-4).

Table 7B-23: Noise Emissions for Airstrips

Aircraft Type	Activity	Octave Band Sound Pressure Level at 300 m (dBZ)								Total Sound Pressure Level at 300 m (dBA)	Emissions Reference
		63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz		
Dash 8 Q300	take off	87.0	85.5	81.5	77.0	73.5	69.5	69.5	64.5	80.0	ECAC (2016)
	landing	77.5	72.0	73.5	74.5	71.0	69.5	71.5	60.5	77.8	ECAC (2016)
ATR 42	take off	87.0	85.5	81.5	77.0	73.5	69.5	69.5	64.5	80.0	ECAC (2016)
	landing	77.5	72.0	73.5	74.5	71.0	69.5	71.5	60.5	77.8	ECAC (2016)
Beech 99	take off	84.5	83.0	81.0	78.5	73.5	67.5	60.5	52.5	79.5	ECAC (2016)
	landing	77.5	76.0	74.0	71.5	66.5	60.5	53.5	45.5	72.5	ECAC (2016)
King Air	take off	87.0	85.5	81.5	77.0	73.5	69.5	69.5	64.5	80.0	ECAC (2016)
	landing	77.5	72.0	73.5	74.5	71.0	69.5	71.5	60.5	77.8	ECAC (2016)

ECAC = European Civil Aviation Conference; dBZ = unweighted decibel; dBA = A-weighted decibel.

7B3 PREDICTED SPATIAL EXTENT OF INDUSTRIAL NOISE

Measurements collected during the baseline field study indicated that representative existing noise levels in the LSA and RSA range from a minimum of 21 dBA during the nighttime period to a maximum of 42 dBA during the daytime period (EIS Section 7.3.3, Existing Conditions; EIS Table 7.3-6). Table 7B-24 presents the minimum and maximum distance at which noise from the Project is predicted to attenuate to existing noise levels. Table 7B-24 presents distance predictions for Construction and Operations of the Project. Table 7B-25 presents similar information for the Fission Patterson Lake South Property.

Table 7B-24: Predicted Spatial Extent of Noise from the Rook I Project

Project Phase	Predicted Distance to 21 dBA Noise Contour[(a)]		Predicted Distance to 42 dBA Noise Contour[(b)]	
	Minimum Distance (km)	Maximum Distance (km)	Minimum Distance (km)	Maximum Distance (km)
Construction	1.4	9.2	0[(c)]	2.1
Operations	0.6	9.2	0[(c)]	2.2

a) The minimum existing noise level representative of the LSA / RSA is 21 dBA (EIS Section 7.3.3).
b) The maximum existing noise level representative of the LSA / RSA is 42 dBA (EIS Section 7.3.3).
c) In some areas the 42 dBA noise contour lies within the maximum disturbance area for the Project and so the minimum distance is effectively 0.
dBA = A-weighted noise decibel; LSA = local study area; RSA = regional study area.

Table 7B-25: Predicted Spatial Extent of Noise from Fission Patterson Lake South Property

Temporal Snapshot	Predicted Distance to 21 dBA Noise Contour[(a)]		Predicted Distance to 42 dBA Noise Contour[(b)]	
	Minimum Distance (km)	Maximum Distance (km)	Minimum Distance (km)	Maximum Distance (km)
Construction	5.4	9.5	0[(c)]	2.0
Operations	7.6	8.8	0.6	2.1

a) The minimum existing noise level representative of the LSA / RSA is 21 dBA (EIS Section 7.3.3).
b) The maximum existing noise level representative of the LSA / RSA is 42 dBA (EIS Section 7.3.3).
c) In some areas the 42 dBA noise contour lies within the maximum disturbance area for the Fission Patterson Lake South Property and so the minimum distance is effectively 0.
dBA = A-weighted noise decibel; LSA = local study area; RSA = regional study area.

CLOSING

WSP Canada Inc. (WSP; formerly Golder Associates Ltd. [Golder]) is pleased to submit this report to NexGen in support of the environmental assessment for the Rook I Project. For details on the limitations and use of information presented in this report, please refer to the Study Limitations section following this page. If you have any questions or require additional details related to this study, please contact the undersigned.

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STUDY LIMITATIONS

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REFERENCES

AER (Alberta Energy Regulator). 2007. Directive 038: Noise Control.

Bies DA, Hansen CH. 2003. Engineering Noise Control – Theory and Practice. Third Edition. Chapter 11 – Sound Power and Sound Pressure Level Estimation Procedures. Spon Press. New York.

Canadian Natural (Canadian Natural Resources Ltd.). 2018. Horizon North Pit Extension. Volume 3: Environmental Impact Assessment. Section 3.0: Noise. Submitted to the Alberta Energy Regulator as Application No. 1909112.

DEFRA (United Kingdom Department for Environment, Food, and Rural Affairs). 2007. Update of Noise Database for Prediction of Noise on Construction and Open Sites.

DOT (United States Department of Transportation – Federal Highway Administration). 2006. Highway Construction Noise Handbook. Chapter 9: Construction Equipment Noise Levels and Ranges.

ECAC (European Civil Aviation Conference). 2016. Document 29 – Report on Standard Method of Computing Noise Contours Around Civil Airports.

Environment Canada. 2009. Environmental Code of Practice for Metal Mines.

EU (European Parliament and Council of the European Union). 2000. Directive 2000/14/EC on the Approximation of the Laws of the Member States Relating to the Noise Emission in the Environment by Equipment for Use Outdoors.

Fission (Fission Uranium Corp.). 2019. Technical Report on the Pre-Feasibility Study of the Patterson Lake South Property using Underground Mining Methods, Northern Saskatchewan, Canada. NI 43-101 Report. Prepared by Roscoe Postle Associates Inc. for Fission Uranium Corp. November 2019.

Health Canada. 2017. Guidance for Evaluating Human Health Impacts in Environmental Assessment – Noise.

ISO (International Organization for Standardization). 1996. ISO 9613-2 Acoustics – Attenuation of Sound During Propagation Outdoors – Part 2: General Method of Calculation.

ISO. 2016. ISO 1996-1 Acoustics – Description, Measurement and Assessment of Environmental Noise – Part 1: Basic Quantities and Assessment Procedures.

NEMA (National Electrical Manufacturers Association). 2000. NEMA Standards Publication No. TR 1-1993 (R2000) – Transformers, Regulators and Reactors.

NexGen. 2019. Transportation and Logistics Study Traffic Impact Study Report for the Rook I Project Feasibility Study. Rev B. Doc No. 0000-DY00-RPT-0010. Prepared for NexGen Energy Ltd. Rook. 15 October 2019.

Suncor (Suncor Energy Inc.). 2016. Applications for Millennium Operational Amendment and Base Plant Tailings Management Plan. Appendix G – Noise Impact Assessment. Submitted to the Alberta Energy Regulator as Application No. 1890348.

Appendix 7C Greenhouse Gas Emissions Estimation Methodology Report

Abbreviations and Units of Measure

Abbreviation	Definition
CNSC	Canadian Nuclear Safety Commission
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CH_4	methane
EIS	Environmental Impact Statement
GHG	greenhouse gas
GHG Protocol	*The Greenhouse Gas Reporting Protocol: A Corporate Accounting and Reporting Standard*
GHGRP	Greenhouse Gas Reporting Program
GWP	global warming potential
HHV	higher heating value
IPCC	Intergovernmental Panel on Climate Change
N_2O	nitrous oxide
NexGen	NexGen Energy Ltd.
Project	Rook I Project

Unit	Definition
%	percent
°C	degrees Celsius
g	gram
g/L	grams per litre
g/m^3	grams per cubic metre
ha	hectare
kg	kilogram
kg/kg	kilogram per kilogram
kg/t	kilograms per tonne
kPa	kilopascal
L	litre
L/yr	litres per year
lb	pound
m	metre
m^3	cubic metre
MJ/m^3	megajoule per cubic metre
t	tonne
t/ha	tonnes per hectare
t/ha/yr	tonnes per hectare per year

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7C1 INTRODUCTION

This appendix supplements Environmental Impact Statement (EIS) Section 7.4, Climate Change. This appendix documents the methods, data, and assumptions that were used to estimate greenhouse gas (GHG) emissions for the Rook I Project (Project) and to calculate the Project's emissions intensity.

Greenhouse gases are defined as gases that trap radiation, essentially heating the atmosphere. The most common GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone, perfluorocarbons, hydrofluorocarbons, and sulphur hexafluoride. Greenhouse gas emissions occur as a result of various natural and anthropogenic activities, with the combustion of fossil fuels being the most widely attributed anthropogenic source. Emissions intensity represents the emissions produced per product produced and allows for comparison with similar projects.

The calculated GHG emissions described herein are based on conservative estimates and may overestimate the actual emissions. GHG reporting requirements should be based on actual annual emission totals and not those reported in this document.

7C2 IDENTIFICATION OF GREENHOUSE GAS EMISSION SOURCES

The GHG emissions vary by Project phase and were estimated for Project Construction, Operations, and Decommissioning and Reclamation (i.e., Closure) based on information provided by NexGen Energy Ltd. (NexGen) or included in the Project description.

Construction and Operations include GHG emissions from stationary combustion, heating, electricity generation, explosives, waste incinerators, on-site mobile equipment, industrial processes, and land-use change. It is expected that the GHG emission sources in Closure will vary depending on the stage. The Active Closure Stage is assumed to include the same GHG emission sources as Construction (i.e., stationary combustion, heating, electricity generation, explosives, waste incinerators, on-site mobile equipment, industrial processes, and land-use change), whereas the Transitional Monitoring Stage is expected to include GHG emissions from on-site mobile equipment associated with monitoring activities only.

Based on the Project description, activities that would result in GHG emissions within each Project phase are listed in Table 7C-1.

Table 7C-1: Greenhouse Gas Emission Sources

GHG Emission Source	Indicator Compound Producing Activity	Construction and Operations	Closure	
			Active Closure Stage	Transitional Monitoring Stage
Electricity generation	CO_2, CH_4, N_2O	Y	Y	N
On-site mobile equipment	CO_2, CH_4, N_2O	Y	Y	Y
Heating	CO_2, CH_4, N_2O	Y	Y	N
Land-use change	CO_2	Y	Y	Y
Stationary combustion	CO_2, CH_4, N_2O	Y	Y	N
Waste incinerators	CO_2, CH_4, N_2O	Y	Y	N
Industrial processes	CO_2	Y	N	N
Explosives	CO_2, CH_4, N_2O	Y	N	N

CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent; GHG = greenhouse gas; Y = included; N = not included.

7C3 GREENHOUSE GAS EMISSION ESTIMATE FRAMEWORK

The emissions estimation methods described follow generally accepted practices for assessing GHGs for Environmental Assessments and, where applicable, federal regulatory reporting guidance documents and other international guidance. Table 7C-2 presents the relevant guidelines that form the basis of GHG emission estimates for the Project.

Table 7C-2: Applicable Guidelines for Estimation of Greenhouse Gas Emissions

Guideline	Program	Source	Date
Canada's Greenhouse Gas Quantification Requirements, Version 4.0 and the Technical Guidance on Reporting Greenhouse Gas Emissions	Greenhouse Gas Reporting Program	Environment and Climate Change Canada	December 2020
The Greenhouse Gas Protocol/A Corporate Accounting and Reporting Standard	Multiple Programs (e.g., Global Reporting Initiative); International Organization for Standardization (14001)	World Business Council for Sustainable Development and World Resources Institute	February 2013 Amendment
Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories	United Nations Framework Convention on Climate Change National Greenhouse Gas Inventories Programme	Intergovernmental Panel on Climate Change	2006

7C3.1 Canada's Greenhouse Gas Quantification Requirements (2020)

Canada's Greenhouse Gas Quantification Requirement (the Greenhouse Gas Reporting Program [GHGRP] Guideline; ECCC 2020a) provides direction in determining if facilities are required to submit a GHG report to Environment and Climate Change Canada, an overview of the reporting process, and technical information related to GHG emissions estimations. Technical information includes GHG emission sources subject to reporting and information on emission estimation methodologies.

The GHGRP Guideline references GHG estimation methodologies from the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change (IPCC). The GHGRP Guideline states that "no specific estimation methods are prescribed" and that facilities should choose estimation methods that are most appropriate for their industry. However, the GHGRP Guideline is consistent with the guidelines adopted by the United Nations Framework Convention on Climate Change for preparing national GHG inventories.

7C3.2 The Greenhouse Gas Protocol

The World Business Council for Sustainable Development and the World Resources Institute have developed *The Greenhouse Gas Reporting Protocol: A Corporate Accounting and Reporting Standard* (GHG Protocol; World Resources Institute & World Business Council for Sustainable Development 2013), which provides guidance for preparing corporate GHG inventories as well as sector-specific and general calculation tools that can be used for estimating GHG emissions. The GHG Protocol has been adopted by the Global Reporting Initiative, which provides guidance on sustainability reporting for industry.

Following the GHG Protocol, emissions are classified as either direct or indirect. Direct emissions are those generated from sources that are owned by the proponent (e.g., NexGen). Indirect emissions are those that result from activities of the operating proponent, but occur at sources owned by another proponent, such as electrical power consumption. For the purposes of accounting and reporting, these are typically classified as Scope 1, Scope 2, or Scope 3, and are defined in EIS Section 7.4.

The GHG Protocol requires reporting of Scope 1 (direct emissions from site) and Scope 2 (emissions from on-site energy consumption) emissions only. Scope 1 and Scope 2 emissions are typically the focus of most corporate inventories, though many organizations choose to account for other activities such as employee travel and downstream emissions from waste. These sources are classified as Scope 3 (indirect) emissions and are reported as an option. The GHG inventory focuses on the emissions directly linked to the Project (i.e., Scope 1 and Scope 2 emissions). However, the Project does not generate any Scope 2 emissions, as there is no purchased electricity, heat, or steam. Electricity and heat are generated on site; therefore, the emissions are within the ownership and control of the company and are included in Scope 1 emissions. The inclusion of Scope 1 emissions is in accordance with the guidance from the Canadian Nuclear Safety Commission (CNSC; 2017).

7C3.3 Emissions Inventory Boundary

The definition of the inventory boundary, which frames the GHG emission sources that are included in the GHG emissions inventory for the Project, is based on the GHGRP and IPCC's Guidelines for National Greenhouse Gas Inventories. Table 7C-3 outlines the GHG inventory boundaries of the guidelines and presents the source categories included in the Project GHG inventory.

Table 7C-3: Emission Source Categories Included in the Greenhouse Gas Reporting Program, Intergovernmental Panel on Climate Change, and The Greenhouse Gas Protocol and Assessed in the Application

Emission Source Category	GHGRP	IPCC	GHG Protocol	Assessed in EIS
Electricity generation (Scope 1)	Y	Y	Y	Y
On-site mobile equipment (Scope 1)	Y	Y	Y	Y
Heating (Scope 1)	Y	Y	Y	Y
Land-use change (Scope 1)	N	Y	N	Y
Stationary combustion (Scope 1)	Y	Y	Y	Y
Waste incineration (Scope 1)	Y	Y	N	Y
Industrial processes (Scope 1)	Y	Y	Y	Y
Explosives (Scope 1)	N	N	N	Y

GHGRP = Greenhouse Gas Reporting Program; IPCC = Intergovernmental Panel on Climate Change; GHG Protocol = *The Greenhouse Gas Reporting Protocol: A Corporate Accounting and Reporting Standard*; EIS = Environmental Impact Statement; Y = yes; N = no.

7C4 DATA REQUIREMENTS

Table 7C-4 documents the data sources and assumptions made to estimate GHG emissions.

Table 7C-4: Greenhouse Gas Emissions Assessment Data Source and Assumptions List

Emission Source	Data Sources / Assumptions			
	Parameter	Value	Unit	Source/Assumption
Electricity generation	Annual diesel consumption for gensets	17,585,312	L	Information provided by NexGen. Diesel generators are only used in Year -4 of Construction while natural gas power generation scales up.
	Annual natural gas consumption for gensets	Varied	m^3	Information provided by NexGen. Various values were provided for each year of Construction and Operations. For reference, the maximum annual value occurs in Year 3 and is 26,121,156 (m^3). It was assumed the annual natural gas consumption in the Active Closure Stage is equal to the annual natural gas consumption from the Construction year with the highest emissions.
	HHV of natural gas	38.26	MJ/m^3	Section 2.A.2 of the 2020 GHGRP Guidance Document outlines the CO_2 calculation method for variable fuels (e.g., natural gas)[(a)].
	Emission factor for natural gas combustion (CH_4)	0.490	g/m^3	Emission factors taken from the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Table A6.1-3 electric utilities[(b)].
	Emission factor for natural gas combustion (N_2O)	0.049	g/m^3	
	Emission factor for diesel combustion (CO_2)	2,681	g/L	Emission factors taken from the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Table A6.1-5 refineries and others[(b)].
	Emission factor for diesel combustion (CH_4)	0.078	g/L	
	Emission factor for diesel combustion (N_2O)	0.022	g/L	
On-site mobile equipment	Annual diesel consumption per piece of equipment	Varied	L/yr	Data provided by NexGen. Specific for each piece of equipment for each year of Construction and Operations. It was assumed the annual diesel consumption in the Active Closure Stage is equal to the annual diesel consumption from the Construction year with the highest emissions. It was assumed the Transitional Monitoring Stage of Closure will only include pickup trucks for monitoring. The annual fuel consumption for these pieces of equipment was assumed to equal the total maximum annual fuel consumption of the pickup trucks from Construction.
	Emission factor for diesel combustion (CO_2)	2,681	g/L	Emission factors taken from the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Table A6.1-14[(b)].
	Emission factor for diesel combustion (CH_4)	0.078	g/L	
	Emission factor for diesel combustion (N_2O)	0.022	g/L	

Table 7C-4: Greenhouse Gas Emissions Assessment Data Source and Assumptions List

Emission Source	Data Sources / Assumptions			
	Parameter	Value	Unit	Source/Assumption
Stationary combustion: heating	Annual natural gas consumption for mine heaters	Varied	m^3	Information provided by NexGen. Various values were provided for each year of Construction and Operations. For reference, the maximum annual value occurs in Year 1 and is 5,917,623 (m^3). It was assumed the annual natural gas consumption in the Active Closure Stage is equal to the annual natural gas consumption from the Construction year with the highest emissions.
	Annual natural gas consumption for small heaters	Varied	m^3	Information provided by NexGen. Various values were provided for each year of Construction and Operations. For reference, the maximum annual value occurs in Year 1 and is 326,713 (m^3). It was assumed the annual natural gas consumption in the Active Closure Stage is equal to the annual natural gas consumption from the Construction year with the highest emissions.
	HHV of natural gas	38.26	MJ/m^3	Section 2.A.2 of the 2020 GHGRP Guidance Document outlines the CO_2 calculation method for variable fuels (e.g., natural gas)[(a)].
	Emission factor for natural gas combustion (CH_4)	0.037	g/m^3	Emission factors taken from the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2* Table A6.1-3 residential, construction, commercial/institutional, agriculture[(b)].
	Emission factor for natural gas combustion (N_2O)	0.035	g/m^3	
Land-use change: carbon sink loss	Area – forest	868.4	ha	Data provided by NexGen.
	Area – grassland	27.8	ha	Data provided by NexGen.
	Average annual above-ground biomass growth – forest	1.0	t/ha/yr	Table 4.12 of IPCC 2006 Vol 4, Chapter 4. Assumes boreal coniferous forest[(c)].
	Average annual above-ground biomass growth – grassland	0.4	t/ha/yr	Table 4.12 of IPCC 2006 Vol 4, Chapter 4. Default value from forest-type closest to non-forest vegetation[(c)].
	Ratio of below-ground to above-ground biomass – forest	0.39	n/a	Table 4.4 of IPCC 2006 Vol 4, Chapter 4. Assumes boreal forest with biomass density <75 t/ha[(c)].
	Ratio of below-ground to above-ground biomass – grassland	4.0	n/a	Table 6.1 of IPCC Vol 4, Chapter 6. Boreal climate zone[(c)].
	Carbon fraction of dry matter	0.47	t	Table 4.3 of IPCC 2006 Vol 4, Chapter 4. Assumes boreal forest with broad-leaves and conifers (all; IPCC 2006). Section 6.3.1. of IPCC 2006 Vol 4, Chapter 6. Default value for herbaceous biomass[(c)].
	Conversion factor carbon to CO_2	3.67	n/a	Molecular weights.

Table 7C-4: Greenhouse Gas Emissions Assessment Data Source and Assumptions List

Emission Source	Data Sources / Assumptions			
	Parameter	Value	Unit	Source/Assumption
Land-use change: loss of carbon from disturbance	Area – forest	868.4	ha	Data provided by NexGen.
	Area – grassland	27.8	ha	Data provided by NexGen.
	Average above-ground biomass affected by disturbance – forest	50.00	t/ha	Table 4.7 of IPCC 2006 Vol 4, Chapter 4. Assume mixed-age boreal coniferous forest[c].
	Average above-ground biomass affected by disturbance – grassland	50.00	t/ha	Table 4.7 of IPCC 2006 Vol 4, Chapter 4. Default value from forest-type closest to non-forest vegetation[c].
	Ratio of below-ground to above-ground biomass – forest	0.39	n/a	Table 4.4 of IPCC 2006 Vol 4, Chapter 4. Assumes boreal forest with biomass density <75 t/ha[c].
	Ratio of below-ground to above-ground biomass – grassland	4.0	n/a	Table 6.1 of IPCC Vol 4, Chapter 6. Boreal climate zone[c].
	Carbon fraction of dry matter	0.47	t	Table 4.3 of IPCC 2006 Vol 4, Chapter 4. Assumes boreal forest with broad-leaves and conifers[c]. Section 6.3.1. of IPCC 2006 Vol 4, Chapter 6. Default value for herbaceous biomass[c].
	Fraction of biomass lost	1	n/a	Equation 2.14 of IPCC 2006 Vol 4, Chapter 4. Assumes all biomass is lost[c].
	Conversion factor carbon to CO_2	3.67	n/a	Molecular weight.
Stationary combustion	Annual natural gas consumption for calciner burner	Varied	m^3	Information provided by NexGen. Values were provided for each year of Construction and Operations. For reference, the maximum annual value occurs in Year 3 and is 1,200,680 (m^3). It was assumed the annual natural gas consumption in the Active Closure Stage is equal to the annual natural gas consumption from the Construction year with the highest emissions.
	Annual diesel consumption for domestic waste incinerator	175,200	L	Information provided by NexGen. It was assumed the annual diesel consumption in the Active Closure Stage is equal to the annual diesel consumption from Construction year with the highest emissions.
	Annual diesel consumption for low-level radiological waste incinerator	175,200	L	Information provided by NexGen. It was assumed the annual diesel consumption in the Active Closure Stage is equal to the annual diesel consumption from the Construction year with the highest emissions.
	HHV of natural gas	38.26	MJ/m^3	Section 2.A.2 of the 2020 GHGRP Guidance Document outlines the CO_2 calculation method for variable fuels (e.g., natural gas)[a].
	Emission factor for natural gas combustion (CH_4)	0.037	g/m^3	Emission factors taken from the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2* Table A6.1-3 residential, construction, commercial/institutional, agriculture[b].
	Emission factor for natural gas combustion (N_2O)	0.035	g/m^3	
	Emission factor for diesel combustion (CO_2)	2,681	g/L	Emission factors taken from the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Table A6.1-5 refineries and others[b].
	Emission factor for diesel combustion (CH_4)	0.078	g/L	
	Emission factor for diesel combustion (N_2O)	0.022	g/L	

Table 7C-4: Greenhouse Gas Emissions Assessment Data Source and Assumptions List

Emission Source	Data Sources / Assumptions			
	Parameter	Value	Unit	Source/Assumption
Waste incineration	Annual amount of domestic waste (Construction)	218,573	kg	Information provided by NexGen. It was assumed that the annual amount of waste is consistent across each year of Construction. Waste volumes by component: plastic (non-recyclable) = 2.9%; plastic film = 5.4%; paper = 14.7%; cardboard = 29.0%; food scraps = 24.2%; and wood=23.8%. It is assumed the annual amount of waste in the Active Closure Stage is equal to the annual amount of waste from Construction.
	Annual amount of domestic waste (Operations)	109,402	kg	Information provided by NexGen. It was assumed the annual amount of waste is consistent across each year of Operations. Waste volumes by component: plastic (non-recyclable) = 2.8%; plastic film = 5.4%; paper (non-recyclable) = 14.6%; cardboard (non-recyclable) = 28.9%; food scraps (non-diverted) = 24.2%; and wood = 23.9%.
	Annual amount of low-level radiological waste (Construction)	252,559	kg	Information provided by NexGen. It was assumed the annual amount of waste is consistent across each year of Construction. It is assumed the annual amount of waste in the Active Closure Stage is equal to the annual amount of waste from Construction.
	Annual amount of low-level radiological waste (Operations)	499,723	kg	Information provided by NexGen. It was assumed the annual amount of waste is consistent across each year of Operations.
	Dry matter content	Varied	Fraction of total	Default factors provided in the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Table A3.6-11[b].
	Total carbon content (domestic waste)	Varied	Fraction of total	Default factors provided in the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Table A3.6-11[b].
	Fossil carbon fraction (domestic waste)	Varied	Fraction of total	Default factors provided in the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Table A3.6-11[b].
	Oxidation factor	1	Unitless	Default factor provided in the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Section A3.6.3.1.1[b].
	Total carbon content (low-level radiological waste)	0.5	Fraction of total	Default factors provided in the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Table A3.6-11[b].
	Fossil carbon fraction (low-level radiological waste)	0.9	Fraction of total	Default factors provided in the *National Inventory Report 1990-2019: GHG Sources and Sinks in Canada Part 2,* Table A3.6-11[b].
Industrial processes	Annual sulphuric acid production	0.35	t	Data provided by NexGen. There are no annual industrial process emissions during Years -4 to -2 of Construction and for the duration of Closure.
	Emission factor for sulphuric acid production (CO_2)	4.05	kg/t	Section 8.10 of USEPA AP-42 provides the CO_2 emissions factor associated with sulphuric acid production. No data for CH_4 or N_2O emissions were available[d].
	Annual amount of ore processed	Varied	t	Data provided by NexGen.
	Percent calcite contained in ore	0.140	%	Data provided by NexGen.

Table 7C-4: Greenhouse Gas Emissions Assessment Data Source and Assumptions List

Emission Source	Data Sources / Assumptions			
	Parameter	Value	Unit	Source/Assumption
Explosives	Annual amount of dynamite explosive	Varied	kg	Data provided by NexGen. Various values were provided for each year of Construction and Operations. For reference, the annual value for Year 3 is 184,562 (kg). No explosive use is expected in Closure.
	Annual amount of emulsion explosive	Varied	kg	Data provided by NexGen. Various values were provided for each year of Construction and Operations. For reference, the annual value for Year 3 is 696,145 (kg). No explosive use is expected in Closure.
	Annual amount of Ammonium Nitrate / Fuel Oil explosive	Varied	kg	Data provided by NexGen. Various values were provided for each year of Construction and Operations. For reference, the annual value for Year 3 is 424,639 (kg). No explosive use is expected in Closure.
	Emission factor for emulsion explosives (CO_2e)	0.189	kg/kg	Emission factors taken from the life cycle analysis for a uranium mine in Saskatchewan[e] and the Mining Association of Canada's *Energy and GHG Emissions Management Reference Guide*[f]. The higher emission factor was chosen for conservatism in emissions estimates.
	Emission factor for Ammonium Nitrate / Fuel Oil explosives (CO_2e)	0.190	kg/kg	
GWP	CO_2 emissions	1	n/a	GWPs for CO_2 taken from Table 1 of the CNSC *Proposed CNSC Path Forward for Assessing Total GHG Production from Nuclear Facilities*[g].
	CH_4 emissions	25	n/a	GWPs for CH_4 taken from Table 1 of the *CNSC Proposed CNSC Path Forward for Assessing Total GHG Production from Nuclear Facilities*[g].
	N_2O emissions	298	n/a	GWPs for N_2O taken from Table 1 of the CNSC *Proposed CNSC Path Forward for Assessing Total GHG Production from Nuclear Facilities*[g].

a) Source: ECCC 2020a.
b) Source: ECCC 2021.
c) Source: IPCC 2006.
d) Source: USEPA 1995.
e) Source: Parker 2015.
f) Source: MAC 2014.
g) Source: CNSC 2017.
< = less than; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2e = carbon dioxide equivalent; HHV = higher heating value; MJ/m^3 = megajoules per cubic metre; USEPA = United States Environmental Protection Agency; CNSC = Canadian Nuclear Safety Commission; GHG = greenhouse gas; GHGRP = Greenhouse Gas Reporting Program; GWP = global warming potential; IPCC = Intergovernmental Panel on Climate Change; n/a = not applicable.

7C5 GREENHOUSE GAS EMISSION ESTIMATION METHODOLOGY

This subsection includes information on the methods used to calculate emissions from stationary fuel combustion, electricity generation, explosives, waste incineration, on-site mobile equipment, industrial processes, and land-use change.

The basic equation for estimating the total Project GHG emissions is presented in Equation 1.

Equation 1

$$ER = \sum (ER_{CO_2} \times GWP_{CO_2} + ER_{CH_4} \times GWP_{CH_4} + ER_{N_2O} \times GWP_{N_2O})$$

Where:

ER = annual emission rate, in tonnes of carbon dioxide equivalent (CO_2e) per year;

ER_{CO2} = annual emission rate of CO_2, in tonnes of CO_2 per year;

ER_{CH4} = annual emission rate of CH_4, in tonnes of CH_4 per year;

ER_{N2O} = annual emission rate of N_2O, in tonnes of N_2O per year;

GWP_{CO2} = global warming potential (GWP) of CO_2; the value used was 1 (CNSC 2017);

GWP_{CH4} = GWP of CH_4; the value used was 25 (CNSC 2017); and

GWP_{N2O} = GWP of N_2O; the value used was 298 (CNSC 2017).

7C5.1 Electricity Generation Emissions

The annual CO_2, CH_4, and N_2O emissions from the combustion of diesel and natural gas generators used to provide electricity to the Project were calculated using the same method as Section 7C5.5, Stationary Fuel Combustion Emissions. Refer to Equations 4, 5, and 6.

7C5.2 On-Site Mobile Equipment Emissions

The annual CO_2, CH_4, and N_2O emissions from the diesel combustion within on-site mobile equipment were calculated using the same method as Section 7C5.5. Refer to Equations 4 and 6.

7C5.3 Heating Emissions

The annual CO_2, CH_4, and N_2O emissions from heating (i.e., the combustion of natural gas) were calculated using the same method as Section 7C5.5. Refer to Equations 5 and 6.

7C5.4 Land-Use Change Emissions

Carbon dioxide emissions from land-use change include the annual carbon sink loss and the one-time loss of carbon from land clearing activities. The emissions were calculated using the method described in 2006 IPCC Volume 4, Chapter 2 (IPCC 2006). The land area cleared is primarily classified as boreal forest, with some non-forest area classified as grassland. The sum of these land area types is calculated using Equation 2 and Equation 3. The calculation of the total carbon stored annually, and therefore lost with the removal of vegetation, was calculated based on Equation 2.9 and Equation 2.10 (Tier 1) in Section 2.3.1.1.A of the 2006 IPCC Volume 4, Chapter 2, presented in Equation 2 (IPCC 2006).

Equation 2

$$CO_2 = \Delta C \times 44/14 \; and$$
$$\Delta \mathrm{C} = \sum \mathrm{A} \times G_W \times (1+R) \times CF$$

Where:

CO_2 = annual mass of CO_2 emissions from the removal of carbon sinks, in tonnes of CO_2 per year;

ΔC = annual carbon stored due to biomass growth by vegetation type and climatic zone, in tonnes of carbon per year;

A = area of land, in hectares;

GW = average annual above-ground biomass growth for a specific woody vegetation type, in tonnes of dry matter per hectare per year;

R = ratio of below-ground biomass to above-ground biomass for a specific vegetation type, in tonnes of dry matter below-ground biomass per tonne dry matter above-ground biomass;

CF = carbon fraction of dry matter, tonnes of carbon per tonne dry matter; and

44/12 = conversion factor carbon to CO_2.

The one-time loss of carbon from disturbances was calculated based on Equation 2.14 in Section 2.3.1.1.A.2 of the 2006 IPCC Volume 4, Chapter 2, presented in Equation 3 (IPCC 2006).

Equation 3

$$CO_2 = L \times 44/14 \; and$$
$$L = \sum A \times B_W \times (1+R) \times CF \times fd$$

Where:

CO_2 = annual mass of CO_2 emissions from the loss of carbon due to disturbances, in tonnes of CO_2 per year;

L = annual loss of carbon due to disturbances, in tonnes of carbon per year;

A = area affected by disturbances, in hectares per year;

B_W = average above-ground biomass of land area affected by disturbances, in tonnes of dry matter per hectare;

R = ratio of below-ground biomass to above-ground biomass, in tonnes of dry matter below-ground biomass per tonne dry matter above-ground biomass;

CF = carbon fraction of dry matter, tonnes of carbon per tonne dry matter;

fd = fraction of biomass lost in disturbance; and

44/12 = conversion factor carbon to CO_2.

7C5.5 Stationary Fuel Combustion Emissions

The annual CO_2, CH_4, and N_2O emissions from general stationary combustion were calculated using the method described in the 2020 GHGRP Guidance Document (ECCC 2020a).

Carbon dioxide emissions were calculated using the method described in Equation 2-2 in Section 2.A.1 of the 2020 GHGRP Guidance Document is presented in Equation 4 (ECCC 2020a). This method outlines the calculation for non-variable fuels (e.g., propane, ethane, butane, gasoline, diesel, ethanol, and biodiesel).

Equation 4

$$CO_2 = \sum Fuel \times EF \times 10^{-6}$$

Where:

CO_2 = annual mass of CO_2 emissions for a specific fuel type, in tonnes per year;

Fuel = mass or volume of the specific fuel type combusted per year (volume in litres for liquid fuel or volume in cubic metres, at 15°C and 101.325 kPa, for gaseous fuel);

EF = fuel type specific CO_2 emission factors, in grams of CO_2 per volume of fuel (litres or cubic metres); and

10^{-6} = conversion factor from grams to tonnes.

Carbon dioxide emissions for variable fuels, including natural gas, were calculated using the method described in Equation 2-9: Natural Gas in Section 2.A.2 of the 2020 GHGRP Guidance Document is presented in Equation 5 (ECCC 2020a).

Equation 5

$$CO_2\ NG = Fuel \times (60.554 \times HHV - 404.15) \times 10^{-6}$$

Where:

CO_2 NG = annual mass of CO_2 emissions from combustion of natural gas expressed in tonnes per year;

Fuel = volume of natural gas fuel combusted per year (m^3 at 15°C and 101.325 kPa);

HHV = higher heating value (HHV) of natural gas (MJ/m^3, at 15°C and 101.325 kPa);

(60.554 × HHV – 404.15) = empirical equation (g of CO_2/m^3 of natural gas) representing a very close relationship between CO_2 and volume of natural gas determined through HHV with a discrete set of available data, where 60.554 is the slope and 404.15 the intercept (ECCC 2020a); and

10^{-6} = conversion factor from grams to tonnes.

Methane and N_2O emissions were calculated using the method described in Equation 2-13: CH_4 and N_2O HHV Value Methods, in Physical Units in Section 2.B(2), from the 2020 GHGRP Guidance Document is presented in Equation 6 (ECCC 2020a).

Equation 6

$$CH_4\ or\ N_2O = \sum Fuel \times EF \times 10^{-6}$$

Where:

CH_4 or N_2O = annual mass of CH_4 or N_2O emissions for each specific fuel type, in tonnes of CH_4 or N_2O per year;

Fuel = mass or volume of the specific fuel type combusted per year (volume in litres for liquid fuel or volume in cubic metres, at 15°C and 101.325 kPa, for gaseous fuel);

EF = CH_4 or N_2O emission factor by fuel type, in grams of CH_4 or N_2O per volume of fuel (litres or cubic metres); and

10^{-6} = conversion factor from grams to tonnes.

7C5.6 Waste Incineration Emissions

The annual CO_2, CH_4, and N_2O emissions generated from waste incineration for both domestic waste and low-level radiological waste were calculated using the method described in the National Inventory Report 1990-2019 (ECCC 2021).

Carbon dioxide emissions from the incineration of waste were calculated using Equation A3.6-10 in Section A3.6.3.1 of the National Inventory Report 1990-2019, is presented in Equation 6 (ECCC 2021). Equation 7 was used to calculate the CO_2 emissions from domestic waste incineration separately from the CO_2 emissions from low-level radiological (i.e., hazardous) waste incineration.

Equation 7

$$CO_2 = \mathrm{W} \times \sum(WF_j \times dm_j \times CF_j \times FCF_j \times \mathrm{OF}) \times 44/12$$

Where:

CO_2 = annual mass of CO_2 emissions from waste incineration, in tonnes of CO_2 per year;

W = annual amount of waste incinerated, in kilograms;

J = component of waste incinerated, such as, paper/ cardboard, textiles, food waste, wood, plastic, garden waste, plastics, metal, glass;

WF_j = fraction of waste type/material j in total waste incinerated;

dm_j = dry matter content of component j in total waste incinerated;

CF_j = fraction of carbon in the dry matter (i.e., carbon content) of component j;

FCF_j = fraction of fossil carbon in the total carbon of component j;

OF = oxidation factor; and

44/12 = conversion factor from carbon to CO_2.

Methane and N_2O emissions from domestic and hazardous waste incineration were calculated using Equations A3.6-11 and A3.6-12 with the emission factors provided in Tables A3.6-12 the National Inventory Report 1990-2019 and is presented in Equation 8 (ECCC 2021).

Equation 8

$$CH_4 \; or \; N_2O = \sum \mathrm{W} \times \mathrm{EF}$$

Where:

CH_4 or N_2O = annual mass of CH_4 or N_2O emissions from waste incineration, in tonnes of CH_4 or N_2O per year;

W = annual amount of waste incinerated, in kilograms; and

EF = CH_4 or N_2O emission factor for a batch-type incinerator by waste type, in tonnes of CH_4 or N_2O per tonne of waste.

7C5.7 Industrial Process Emissions

The annual CO_2, CH_4, and N_2O from the sulphuric acid production plant were calculated using the method described in the IPCC 2006 Guidelines, Volume 3 (IPCC 2006). Only CO_2 emissions are quantified as no data were found for CH_4 or N_2O emissions from sulphuric acid production (USEPA 1995). The emissions are calculated using the generic emission-factor approach described in Table 1.7 in Chapter 1 of the IPCC 2006 Guidelines, Volume 3, and is presented in Equation 9 (IPCC 2006).

Equation 9

$$CO_2 = mass \; of \; H_2SO_4 \times EF \times 10^{-3}$$

Where:

CO_2 = annual mass of CO_2 emissions from sulphuric acid production, in tonnes of CO_2 per year;

Mass of H_2SO_4 = annual mass of sulphuric acid produced, in tonnes;

EF = CO_2 emission factor for sulphuric acid production, in kilograms of CO_2 per tonne of sulphuric acid produced (USEPA 1995); and

10^{-3} = conversion factor from kilograms to tonnes.

Acid-induced CO_2 emissions are produced from the addition of sulphuric acid to the ore material when carbonate exists within the ore (IPCC 2006). There are no CH_4 or N_2O emissions from the acidification of uranium ores. The addition of sulphuric acid to uranium ore releases CO_2 through the chemical reaction with calcium carbonate (Parker 2015).

Equation 10

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$$

The annual CO_2 emissions from the acidification of ore material were calculated using the mass balance method described in 2020 GHGRP Guidance Document, presented in Equation 11 (ECCC 2020b). Using the chemical reaction in Equation 10, the law of conservation of mass is applied to determine the CO_2 emissions of the acidification of ore material.

Equation 11

$$CO_2 = \frac{mass\ of\ ore \times \%\ CaCO_3}{MM_{CaCO_3}} \times \frac{1\ mol\ CO_2}{1\ mol\ CaCO_3} \times MM_{CO_2}$$

Where:

CO_2 = annual mass of CO_2 emissions from the acidification of calcium carbonate in uranium ore, in tonnes of CO_2 per year;

Mass of ore = annual mass of ore processed, in tonnes;

% $CaCO_3$ = amount of carbonate within ore, in percentage;

$MMCaCO_3$ = molar mass of calcium carbonate, in grams per mole;

$MMCO_2$ = molar mass of CO_2, in grams per mole; and

1 mol CO_2 / 1 mol $CaCO_3$ = molar ratio of CO_2 to calcium carbonate from the chemical equation.

7C5.8 Explosive Emissions

The annual CO_2e emissions generated from explosives used in blasting were calculated using the method described in the IPCC 2006 Guidelines, Volume 3 (IPCC 2006). Because there are no emission factors for each gas separately, CO_2e emissions were quantified.

As a less common emission source, standardized methodologies for GHG emission calculations are not included in the GHGRP, the GHG Protocol, or other available guidance documents (ECCC 2020a; World Resources Institute & World Business Council for Sustainable Development 2013). Therefore, the general calculation approach using published emission factors was used. The emission factors used were from a life cycle analysis of GHG emissions for a similar uranium mine in Saskatchewan (Parker 2015) and supported by the emission factor provided in the Mining Association of Canada’s Energy and Greenhouse Gas Emissions Management Reference Guide (MAC 2014). Carbon dioxide equivalent emissions were calculated using the generic emission-factor approach described in Table 1.7 in Chapter 1 of the IPCC 2006 Guidelines, Volume 3 is presented in Equation 12 (IPCC 2006).

Equation 12

$$CO_2e = \sum Mass\ of\ explosive \times EF \times 10^{-3}$$

Where:

CO_2e = annual mass of CO_2e emissions for each specific explosive type, in tonnes of CO_2e per year;

Mass of explosive = annual mass of each explosive type used, in kilograms;

EF = CO_2e emission factor for each explosive type, in kilograms of CO_2e per kilogram of explosive (Parker 2015; MAC 2014); and

10^{-3} = conversion factor from kilograms to tonnes.

7C6 METHODS SUMMARY

Table 7C-5 presents a summary of the various methods used to estimate the GHG emissions associated with the Project.

Table 7C-5: Greenhouse Gas Emissions Methods Summary

Phase	Emission Source	Scope	Method
Construction	**Direct Emissions**		
	Land-Use change	Scope 1	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 2*[(a)].
	Electricity generation	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[(b)].
	On-Site mobile equipment	Scope 1	Canada's Greenhouse Gas Quantification Requirements, GHGRP, Section 2.A.1[(b)].
	Waste incineration	Scope 1	*National Inventory Report 1990-2019*, Section A3.6.3.1[(c)].
	Heating	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.2[(b)].
	Explosives	Scope 1	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Energy, Chapter 1*[(a)].
	Stationary combustion	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[(b)].
	Industrial processes[(d)]	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, Technical Guidance on Reporting Greenhouse Gas Emissions, Section 3.2.1 *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Energy, Chapter 1*[(a)].
Operations	**Direct Emissions**		
	Electricity generation	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[(b)].
	Heating	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.2[(b)].
	On-Site mobile equipment	Scope 1	Canada's Greenhouse Gas Quantification Requirements, GHGRP, Section 2.A.1[(b)].
	Waste incineration	Scope 1	*National Inventory Report 1990-2019*, Section A3.6.3.1[(c)].
	Stationary combustion	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[(b)].
	Land-Use change	Scope 1	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 2*[(a)].
	Industrial processes	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, Technical Guidance on Reporting Greenhouse Gas Emissions, Section 3.2.1 *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Energy, Chapter 1*[(a)].
	Explosives	Scope 1	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Energy, Chapter 1*[(a)].

Table 7C-5: Greenhouse Gas Emissions Methods Summary

Phase	Emission Source	Scope	Method
Closure	**Direct Emissions**		
	Electricity generation[e]	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[b].
	On-Site mobile equipment	Scope 1	Canada's Greenhouse Gas Quantification Requirements, GHGRP, Section 2.A.1[b].
	Heating[e]	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.2[b].
	Land-Use change (annual loss of carbon sink only)	Scope 1	*2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 2*[a].
	Waste incineration[e]	Scope 1	*National Inventory Report 1990-2019*, Section A3.6.3.1[c].
	Stationary combustion[e]	Scope 1	*Canada's Greenhouse Gas Quantification Requirements*, GHGRP, Section 2.A.1 and Section 2.A.2[b].

a) Source: IPCC 2006.
b) Source: ECCC 2020a.
c) Source: ECCC 2021.
d) Industrial process emissions occur only in Year -1 of Construction.
e) Stationary combustion emissions, heating emissions, electricity generation emissions, and waste incineration emissions are only expected to occur in the Active Closure Stage of Closure.
GHGRP = Greenhouse Gas Reporting Program; IPCC = Intergovernmental Panel on Climate Change.

7C7 CONSERVATISM IN GREENHOUSE GAS EMISSION QUANTIFICATION

Table 7C-6 outlines the areas where conservatism was used in the emission calculations that resulted in an assessment that was not likely to underpredict the emissions associated with the Project.

Table 7C-6: Conservatism in Greenhouse Gas Emission Calculations

Source Area	Conservatism
Electricity generation	The natural gas consumption for electricity generation was conservatively estimated using the maximum estimates rather than the average estimates provided by NexGen. It is expected that in most years electricity generation will require less natural gas consumption than estimated. The annual electricity generation emissions for the Active Closure Stage were conservatively estimated to be equal to the annual electricity generation emissions from the Construction year with the highest emissions from natural gas combustion only. This estimate is necessary due to the uncertainty around the Active Closure Stage activities.
On-Site mobile equipment	The maximum volume of fuel consumed for each piece of equipment were used in the calculations. The annual on-site mobile equipment emissions for the Active Closure Stage were conservatively estimated to be equal to the annual on-site mobile equipment emissions from the Construction year with the highest total emissions. This estimate is necessary due to the uncertainty around the Active Closure Stage activities. The annual on-site mobile equipment emissions for the Transitional Monitoring Stage of Closure were conservatively estimated by assuming the equipment during this stage would include pickup trucks for civil works and site services. The fuel consumption for these pieces of equipment was conservatively assumed to equal the annual fuel consumption from the Construction year with the highest fuel consumption for the same pieces of equipment. This is a conservative estimate as the Transitional Monitoring Stage emissions are expected to be limited to periodic monitoring activities.
Heating	Fuel consumption values for stationary combustion were estimated using the highest annual estimate of fuel use over the mine life phase. The annual heating emissions for the Active Closure Stage were conservatively estimated to be equal to the annual heating emissions from the Construction year with the highest emissions. This estimate is necessary due to the unknowns and uncertainty around the Active Closure Stage activities.

Table 7C-6: Conservatism in Greenhouse Gas Emission Calculations

Source Area	Conservatism
Land-Use change	It has been conservatively estimated that the total Project footprint will be cleared of vegetation. This is expected to be an over-estimation due to the area that has previously been changed including the exploration camp and existing trails. The annual land-use change emissions for Closure were conservatively estimated to be equal to the annual land-use change emissions from the loss of the carbon sink. This is a conservative estimate as Closure includes the revegetation of disturbed areas, which will sequester carbon and increase the carbon sink.
Stationary combustion	Fuel consumption values for stationary combustion were estimated using the highest annual estimate of fuel use over the mine life phase. The annual stationary combustion emissions for the Active Closure Stage were conservatively estimated to be equal to the annual stationary combustion emissions from the Construction year with the highest stationary combustion emissions. This estimate is necessary due to the unknowns and uncertainty around the Active Closure Stage activities.
Waste incineration	Maximum values for annual waste volumes were used in the calculations. The annual waste incineration emissions for the Active Closure Stage were conservatively estimated to be equal to the annual waste incineration emissions from the Construction year with the highest total emissions. This estimate is necessary due to the uncertainty around the Active Closure Stage activities.
Explosive and industrial processes	Explosive emissions and industrial process emissions were quantified for conservativeness and completeness of the emissions inventory despite the relatively low proportion of total Project emissions from these sources. No explosive use is expected in Closure. Industrial process emissions occur only in Year -1 of Construction. There are no annual industrial process emissions for Closure.

7C8 EMISSION INTENSITY METHODS

This subsection explains the data requirements, assumptions, and methods used to calculate the Project's GHG emission intensity.

7C8.1 Data Requirements

Table 7C-7 documents the data sources and assumptions made as part of the estimation of the Project's GHG emission intensity.

Table 7C-7: Emission Intensity Data Source and Assumptions List

Data Sources and Assumptions			
Parameter	**Value**	**Unit**	**Source and Assumption**
Total annual Project GHG emissions	Varied	t CO_2e	Estimated using Equation 1 in Section 7C5.
Total uranium concentrate produced (packaged lb)	Varied	lb uranium concentrate	Information provided by NexGen. Total packaged lb of uranium concentrate. For reference, the value in Year 1 is 25,481,226 (lb).
Total uranium concentrate produced (contained lb)	Varied	lb uranium concentrate	Information provided by NexGen. Total packaged lb of uranium concentrate. For reference, the value in Year 1 is 26,111,530 (lb).

CO_2e = carbon dioxide equivalent; GHG = greenhouse gas.

7C8.2 Methods

The Project GHG emission intensity was calculated to meet the definition of physical intensity ratio from Chapter 9 of the GHG Protocol (World Resources Institute & World Business Council for Sustainable Development 2013). It is informed by Section 3.1.2. of the Strategic Assessment of Climate Change (ECCC 2020c) to calculate the emission intensity for each year of Operations of the Project.

Equation 13

$$Emission\ intensity = \frac{GHG\ emissions}{units\ produced}$$

Where:

Emission intensity = annual GHG emission intensity, in tonnes CO_2e per pound of uranium concentrate;

GHG emissions = annual Project emissions, in tonnes CO_2e; and

Units produced = annual uranium concentrate produced in each year of Operations of the Project, in pounds of uranium concentrate.

CLOSING

WSP Canada Inc. (WSP; formerly Golder Associates Ltd. [Golder]) is pleased to submit this report to NexGen in support of the environmental assessment for the Rook I Project. For details on the limitations and use of information presented in this report, please refer to the Study Limitations section following this page. If you have any questions or require additional details related to this study, please contact the undersigned.

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STUDY LIMITATIONS

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REFERENCES

CNSC (Canadian Nuclear Safety Commission). 2017. Proposed CNSC Path Forward for Assessing Total GHG Production from Nuclear Facilities. Internal Document. Draft. e-Doc: 6515289.

ECCC (Environment and Climate Change Canada). 2021. National Inventory Report 1990-2019: Greenhouse Gas Sources and Sinks in Canada. Canada's Submission to the United Nations Framework Convention on Climate Change. Available at https://unfccc.int/documents/271493.

ECCC. 2020a. Canada's Greenhouse Gas Quantification Requirements, Version 4.0. Greenhouse Gas Reporting Program. Available at https://publications.gc.ca/collections/collection_2021/eccc/En81-28-2020-eng.pdf.

ECCC. 2020b. Technical Guidance on Reporting Greenhouse Gas Emissions, 2020 Data. Facility Greenhouse Gas Reporting. Available at https://publications.gc.ca/collections/collection_2021/eccc/En81-29-2020-eng.pdf.

ECCC. 2020c. Strategic Assessment of Climate Change. Available at https://www.strategicassessmentclimatechange.ca/.

IPCC (Intergovernmental Panel on Climate Change). 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4, Agriculture, Forestry and Other Land Use. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, editors. Hayama: Institute for Global Environmental Strategies. Available at https://ucanr.edu/sites/mendocino/files/17401.pdf.

MAC (Mining Association of Canada). 2014. Energy and Greenhouse Gas Emissions Management Reference Guide. Towards Sustainable Mining. Available at https://mining.ca/resources/guides-manuals/energy-and-ghg-emissions-management-reference-guide/.

Parker DJ. 2015. Life Cycle Analysis of Greenhouse Gas Emissions from the Mining and Milling of Uranium in Saskatchewan. Available at https://harvest.usask.ca/handle/10388/ETD-2015-06-2120.

USEPA (United States Environmental Protection Agency). 1995. AP-42: Compilation of Air Emissions Factors. Air Emissions Factors and Quantification. Available at https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors.

World Resources Institute & World Business Council for Sustainable Development. 2013. The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard. Available at https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

Rook I Project

Environmental Impact Statement

Section 8 Hydrogeology

Submitted to:
Canadian Nuclear Safety Commission
Saskatchewan Ministry of Environment

Submitted by:
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November 2024

Executive Summary

Section Purpose

Section 8 of the Environmental Impact Statement (EIS) provides a comprehensive assessment of potential effects of the Rook I Project (Project) on hydrogeology, which includes both groundwater quantity and quality. This assessment included consideration of both potential effects from the Project and cumulative effects from the Project and other reasonably foreseeable developments (RFDs). The hydrogeology assessment used widely accepted scientific practices and incorporated Indigenous and Local Knowledge.

Hydrogeology represented an intermediate component in the Environmental Assessment (EA); the selection was based on how changes in groundwater quantity and quality could influence surface water quality and alter aquatic and terrestrial ecosystems, which could in turn affect the biota and people who use these natural resources. The hydrogeology assessment provided information that was used to support valued component assessments such as fish and fish habitat, vegetation, wildlife and wildlife habitat, as well as the assessments of other intermediate components such as hydrology, surface water quality, sediment quality, terrain, and soils. Intermediate components, such as hydrogeology, were not assessed for significance.

Setting

At a regional scale, the Project would be situated within the southern Athabasca Basin adjacent to Patterson Lake, along the upper Clearwater River system, approximately 40 km east of the Saskatchewan-Alberta border and 640 km northwest of the city of Saskatoon. The hydrogeology assessment focused on a local study area (LSA), which is in the area of the Project where direct environmental effects are most likely, and a regional study area (RSA) where cumulative effects may occur. The LSA is defined by the Clearwater River watershed boundary up to the Naomi Lake outlet and covers a surface area of 685 km^2. The RSA is defined by the Clearwater River watershed boundary upstream of the confluence with the Mirror River and covers an area of 1,076 km^2.

Existing Conditions (Section 8.3)

The Arrow deposit consists of several high-grade uranium veins and is hosted in Paleoproterozoic basement rocks. The basement rock in the RSA is predominantly composed of granite or gneiss. Athabasca Supergroup sandstones of variable thickness overlie the basement rocks unconformably. Sedimentary rocks overlie the Athabasca sandstones, with glacial drift deposits (i.e., materials such as gravel, sand, silt, and clay) capping the geologic sequence and forming the present-day topography.

Hydrostratigraphic units were defined based primarily on the geological units that exhibit similar hydraulic properties and structures. The basement rock was identified to have relatively low porosity and permeability, and the primary hydraulic pathways are anticipated to be fractures, faults, and shear zones. These enhanced conductivity features defined the overall hydraulic conditions of the basement rock. The layers of the overlying Athabasca sandstone bedrock are the dominant areas in which groundwater flow occurs and are considered to be the primary aquifer. Interbedded zones of clay-rich cementation act as an aquitard within the Athabasca Supergroup, inhibiting the vertical movement of water. Therefore, the vertical hydraulic conductivity in this layer is considered to be lower than the horizontal hydraulic conductivity. The overlying, unconsolidated glacial drift deposits are present throughout the RSA. Based on the relatively coarse-grained nature of the unconsolidated glacial drift deposits within the vicinity of the Project, the unit is considered to be an unconfined aquifer.

The predominant deep groundwater west to east flow direction is controlled by regional topography. Local to the proposed underground mine, deep groundwater flows north and upward towards Patterson Lake.

Shallow groundwater flow patterns mimic local topography, infiltrating in highlands and discharging in low-lying water bodies and drainages. At the peninsula where the Project would be located, a shallow groundwater flow divide exists south of the proposed mine. Shallow groundwater within glacial drift flows north and south from the divide, discharging to Patterson Lake in both directions.

During baseline assessments, representative groundwater samples were collected and analysed for water chemistry. Based on the interpreted bedrock groundwater type, it was considered likely that the groundwater in bedrock is “older” and indicative of groundwater moving along a flow path as it transitions from calcium- to sodium- type with increasing depth and age of the geologic formation. In contrast, the glacial drift groundwater type was considered “young” based on calcium-type and indicative of geologically recent recharge from the surface. Limited mixing likely occurs with older water from the geologic formation below.

Potential Effects and Proposed Mitigation (Section 8.4)

An analysis was completed to evaluate Project components and activities and associated effects pathways that could potentially affect hydrogeology. The evaluation also considered combined effects from the Fission Patterson Lake South Property, the identified RFD for the hydrogeology assessment.

Project activities that would have the potential to affect hydrogeology during the Project lifespan include:

- underground mine development;
- underground operations;
- storage and handling of waste rock, special waste rock[1], and ore;
- storage of cemented paste tailings in the underground tailings management facility (UGTMF); and
- storage of cemented paste backfill in the mined-out underground production stopes.

As the pathways associated with these activities do not have the potential to overlap with the pathways of the Fission Patterson Lake South Property, only the potential effects of the Project were considered in the subsequent steps of the assessment process.

As part of the pathways analysis, proposed environmental design features and mitigation measures were considered to determine whether effects on the environment could be avoided or reduced to negligible levels, thereby removing the pathway. Project environmental design features such as the UGTMF, isolation of mine workings from groundwater inflow with a hydrostatic liner in the shafts, and use of engineered cemented paste tailings to control source concentrations were designed to minimize the Project’s effects on hydrogeology. The placement of cemented paste tailings within the UGTMF reduces the risks associated with shallow groundwater effects and surface infrastructure stability compared to placement as conventional tailings in an above-ground tailings management facility. In addition, the Project would design, maintain, and monitor infrastructure such as a mine dewatering system to control the inflow of groundwater to the underground mine.

Proposed mitigations such as robust site water management procedures, segregation and separate storage of potentially acid generating (PAG) and non-potentially acid generating (NPAG) materials, engineered

[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.

containment and management of PAG materials, and implementation of Project-specific management plans would also reduce effects on hydrogeology.

After mitigation measures were considered, the pathways screening analysis determined that the Project could adversely affect hydrogeology from the following pathways:

- groundwater inflow to the underground mine;
- seepage from the waste rock storage areas (WRSAs) during Construction, Operations, and Closure;
- seepage from the WRSAs after Closure; and
- seepage from the UGTMF and backfilled stopes after Closure.

Therefore, these pathways were carried forward into the residual effects analysis.

Residual Effects Analysis (Section 8.5)

A residual effects analysis was conducted to determine the potential effects of the Project on hydrogeology. The residual effects analysis considered three measurement indicators:

- groundwater elevations;
- groundwater flow directions and rates; and
- groundwater quality.

The residual effects analysis used a precautionary approach that conservatively represented the potential Project-related effects on hydrogeology. Groundwater quantity and quality were characterized through an evaluation of baseline data and groundwater flow and solute transport modelling.

Groundwater Quantity

The main objectives of the predictive modelling with respect to groundwater quantity were to estimate the groundwater inflows to the underground development, the extent of depressurization, and the resulting potential influence on groundwater discharge to surface water features during Operations. For the far-future projection, the model was used to delineate groundwater flow pathways and flow rates through the various source areas to surface water receptors.

During Operations, seepage to the underground mine would result in a depressurization of the surrounding bedrock, which would be observed as a reduction in groundwater elevation at monitoring locations. The extent of the simulated groundwater drawdown in bedrock resulting from the mine dewatering at the end of Operations extends approximately 2 km to the north, 4 km to the south, and 3.5 km in both the east and west directions. Vertically, the extent of depressurization was generally limited to the basement rock, as the overlying sandstone aquifer had greater hydraulic conductivity. The maximum simulated drawdown within the sandstone was estimated to be less than 5 m in the immediate area of the mine workings.

During Construction and Operations, groundwater inflows to the underground development are predicted to range from approximately 1,200 cubic metres per day (m^3/d) to 3,900 m^3/d. These conservatively assessed inflows values were used in the surface water modelling for the Project.

During Operations, the groundwater seepage collected from the underground mine would be treated, monitored, and discharged to Patterson Lake. Assuming that all groundwater seepage collected at the underground mine originates as surface infiltration from the Patterson Lake catchment, the resulting long-term net change to the overall water balance of the surface water system was identified to be negligible.

Based on the particle tracking modelling, groundwater originating at the UGTMF and production stope backfill source areas is predicted to migrate vertically upward primarily through the fault and shear zones, then laterally through the sandstone, before discharging within Patterson Lake. The approximate advective groundwater travel time from the upper horizon of the mine to the discharge location at Patterson Lake is estimated to be approximately 1,000 years.

Seepage from beneath the WRSAs was predicted to infiltrate vertically to the water table, then laterally towards Patterson Lake in both the northernly and southernly directions. For the overburden groundwater flow paths, the approximate advective groundwater travel time from the WRSAs to Patterson Lake was 43 years to the north and 77 years to the south.

Groundwater Quality

The main objective of the predictive modelling with respect to groundwater quality was to estimate the solute mass loading rates from waste rock and cemented paste tailings and backfill to surface receptors during Operations and in the long-term following Closure.

Based on modelling of groundwater quality, the magnitude of the effects was variable and specific to the solute being modelled. Solute-specific effects ranged from negligible effects beyond background values to multiple orders of magnitude above background values. Spatially, these effects were considered to be limited to the groundwater discharge within Patterson Lake. The temporal scale of these effects was long-term, spanning a period from the late stages of Operations to long-term following Closure (i.e., permanent). Changes to groundwater quality that affect surface water quality in the receiving environment were subsequently considered in the surface water and sediment quality assessment (Section 10, Surface Water Quality and Sediment Quality).

Prediction Confidence and Uncertainty (Section 8.6)

Overall, there was a moderate degree of confidence in the predictions related to the hydrogeology assessment. Uncertainty was addressed by making assumptions that conservatively overestimated rather than underestimated potential effects (i.e., a precautionary assessment), and by varying model inputs in model sensitivity scenarios. Such scenarios included increasing modelled hydraulic conductivity of geological pathways and using the upper-bound concentrations for all sources (i.e., cemented paste tailings, cemented paste backfill, underground wall rock and waste rock).

Monitoring and Follow-Up (Section 8.7)

Follow-up and monitoring programs would be implemented to monitor for changes in groundwater quantity and quality, including continued monitoring of background wells located upgradient of the Project footprint. These monitoring and follow-up activities would also evaluate the chemical and physical characteristics of waste rock, cemented paste backfill, and cemented paste tailings to verify effects predictions and effectiveness of mitigation on hydrogeology, identify unanticipated effects (i.e., manage the residual uncertainty in the effects prediction), and apply adaptive management, if required. The specific plan for monitoring groundwater quantity and quality as a part of the Project would be detailed in the Environmental Monitoring Plan. The groundwater focus of that plan would be the establishment of monitoring systems to evaluate the effectiveness of groundwater protection controls.

Abbreviations and Units of Measure

Abbreviation	Definition
BNDN	Birch Narrows Dene Nation
BRDN	Buffalo River Dene Nation
CRDN	Clearwater River Dene Nation
EA	Environmental Assessment
EIS	Environmental Impact Statement
JWG	Joint Working Group
LPA	local priority area
LSA	local study area
MN-S	Métis Nation – Saskatchewan
NexGen	NexGen Energy Ltd.
NPAG	non-potentially acid generating
Project	Rook I Project
PAG	potentially acid generating
RFD	reasonably foreseeable development
RSA	regional study area
TSD	technical support document
WRSA	waste rock storage area
UGTMF	underground tailings management facility
VC	valued component
VWP	vibrating wire piezometer

Unit	Definition
%	percent
3-D	three-dimensional
µg/L	micrograms per litre
Bq/L	becquerels per litre
g/yr	grams per year
km	kilometre
m	metre
m/L	metres per litre
m/m	metres per metre
m/s	metres per second
m^2	square metre
m^3/d	cubic metres per day
masl	metres above sea level
mg	milligram
mg/L	milligrams per litre
mm	Millimetre

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Appendix 8A Geology Supplement

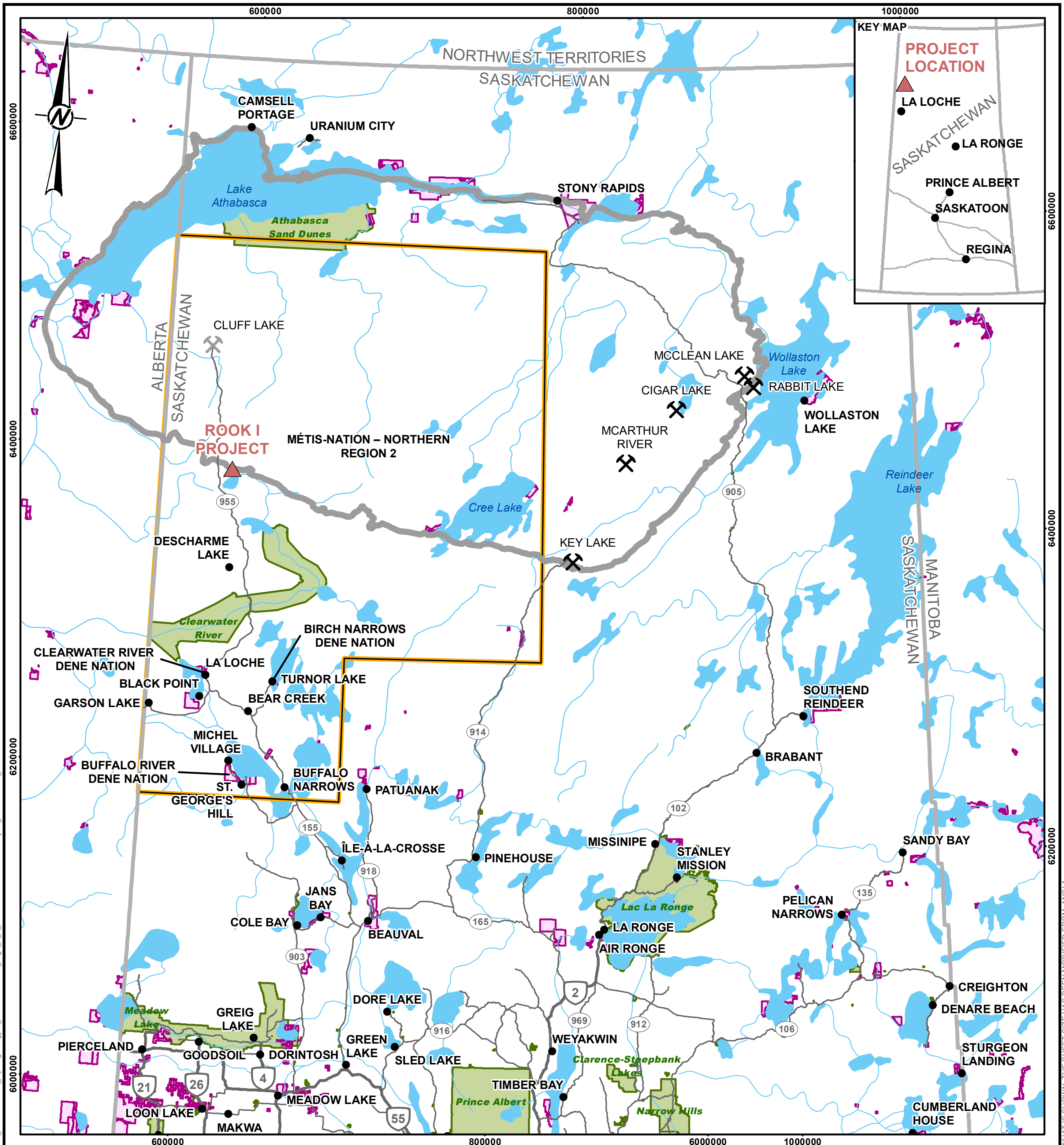
8 HYDROGEOLOGY

8.1 Introduction

NexGen Energy Ltd. (NexGen) is proposing to develop a new uranium mining and milling operation in western Saskatchewan, called the Rook I Project (Project). The Project would be located approximately 40 km east of the Saskatchewan-Alberta border, 130 km north of the Northern Village of La Loche, and 640 km northwest of the city of Saskatoon (Figure 8.1-1). 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 8.1-2), with on-site worker accommodation serviced by fly-in/fly-out access.

Section 8, Hydrogeology, of the Environmental Impact Statement (EIS) characterizes the potential residual effects of the Project on hydrogeology, or groundwater quantity and quality, which are attributes or components of the aquatic environment. Hydrogeology represents an intermediate component for the Environmental Assessment (EA). Geology and geological formations are important attributes of hydrogeological patterns and processes, and therefore, this section also describes existing geological conditions for the Project. The Project has the potential to cause adverse effects on groundwater quantity and quality through the dewatering of planned mine workings during Construction and Operations and seepage of water from the waste rock storage areas (WRSAs), underground tailings management facility (UGTMF) and underground mine workings at Closure.

Changes in groundwater quantity and quality could influence surface water quality and alter aquatic and terrestrial ecosystems, which could in turn affect the people who use these natural resources. For these reasons, the hydrogeological assessment provides information that is used to support the assessments of other intermediate components, such as hydrology (Section 9, Hydrology), surface water and sediment quality (Section 10, Surface Water Quality and Sediment Quality), and terrain and soils (Section 12, Terrain and Soils), and valued components (VCs) such as fish and fish habitat VCs (Section 11, Fish and Fish Habitat), vegetation VCs (Section 13, Vegetation), wildlife and wildlife habitat VCs (Section 14, Wildlife and Wildlife Habitat), human health (Section 15, Human Health), Indigenous land and resource use (Section 16, Cultural and Heritage Resources and Indigenous Land and Resource Use), and other land and resource use (Section 17, Other Land and Resource Use). A simplified linkage diagram, Figure 8.1-3, illustrates how proposed Project activities could result in direct or indirect effects on groundwater quantity and quality, and the VCs that could be influenced through changes to groundwater quantity and quality.



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

0 100 200
1:3,500,000 KILOMETRES

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

wsp

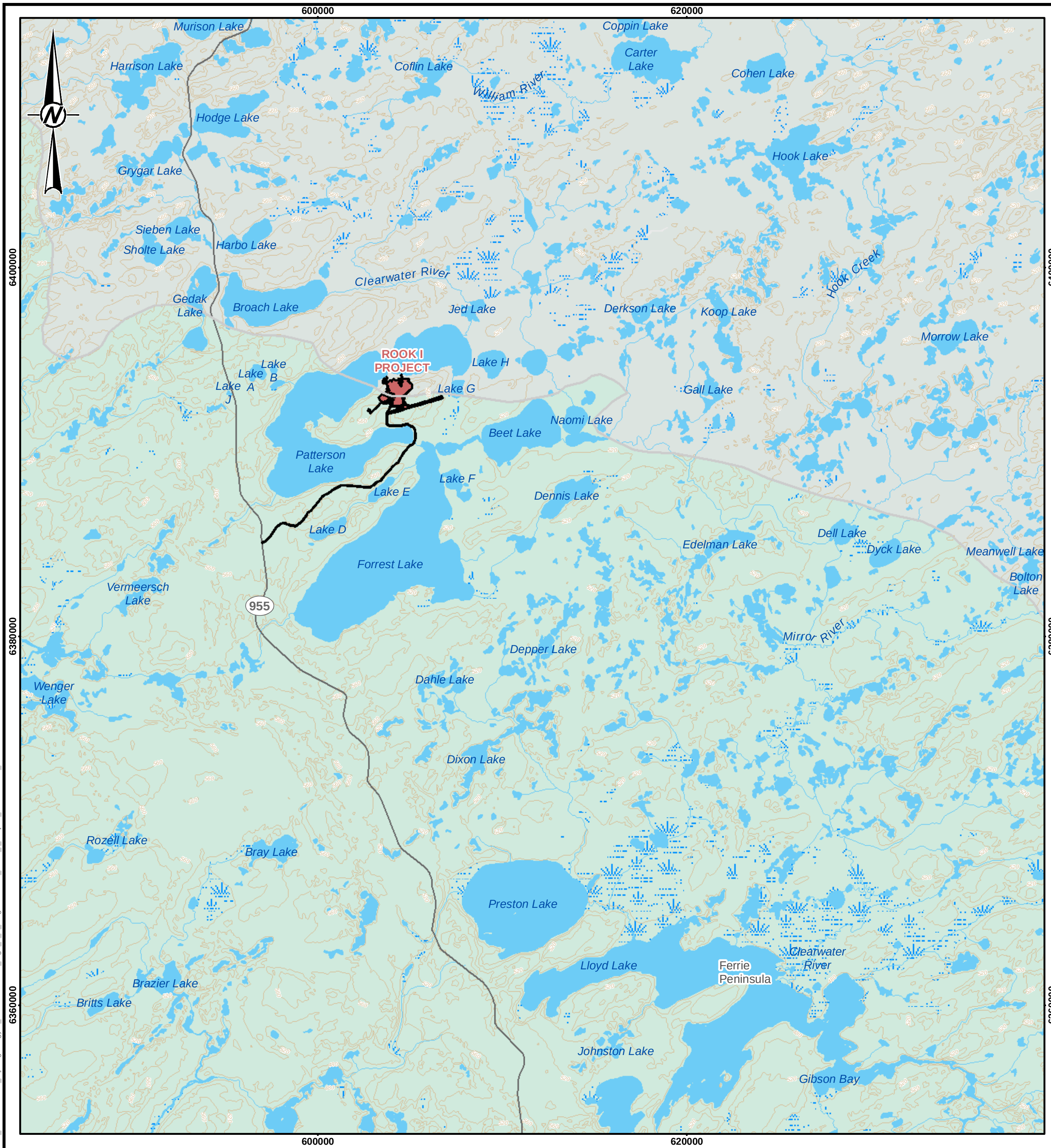
PROJECT	20144150	SCALE AS SHOWN	REV. 0

FIGURE 8.1-1

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\08_Hydrogeology\8_5x11\20144150_Fig8_1_1_Location-of-the-RookI-Project_NoTitleblock_Rev0.mxd PRINTED ON: 2023-02-10 AT: 9:35:23 AM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

25mm



LEGEND

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

0 5 10
1:300,000 KILOMETRES

PROJECT

NexGen Energy Ltd

ROOK I PROJECT

TITLE

REGIONAL AREA OF THE ROOK I PROJECT

CONSULTANT

wsp

PROJECT	20144150	SCALE AS SHOWN	REV. 0

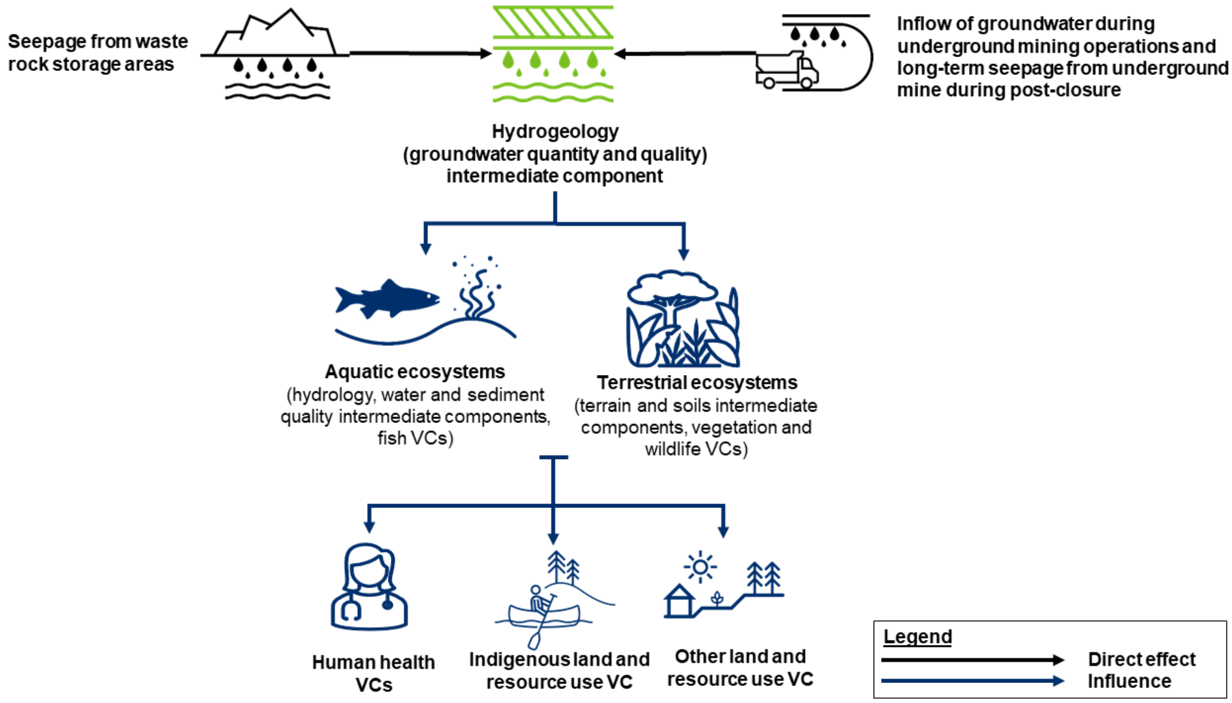
FIGURE 8.1-2

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

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\08_Hydrogeology\8_5x11\20144150_Fig8_1_2_Regional-Area_Rook_I_Project_NoTitleblock_Rev0.mxd PRINTED ON: 2023-02-07 AT: 1:24:39 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25mm
0

Figure 8.1-3: Linkage Diagram of Project Effects on Hydrogeology and Influenced Valued Components



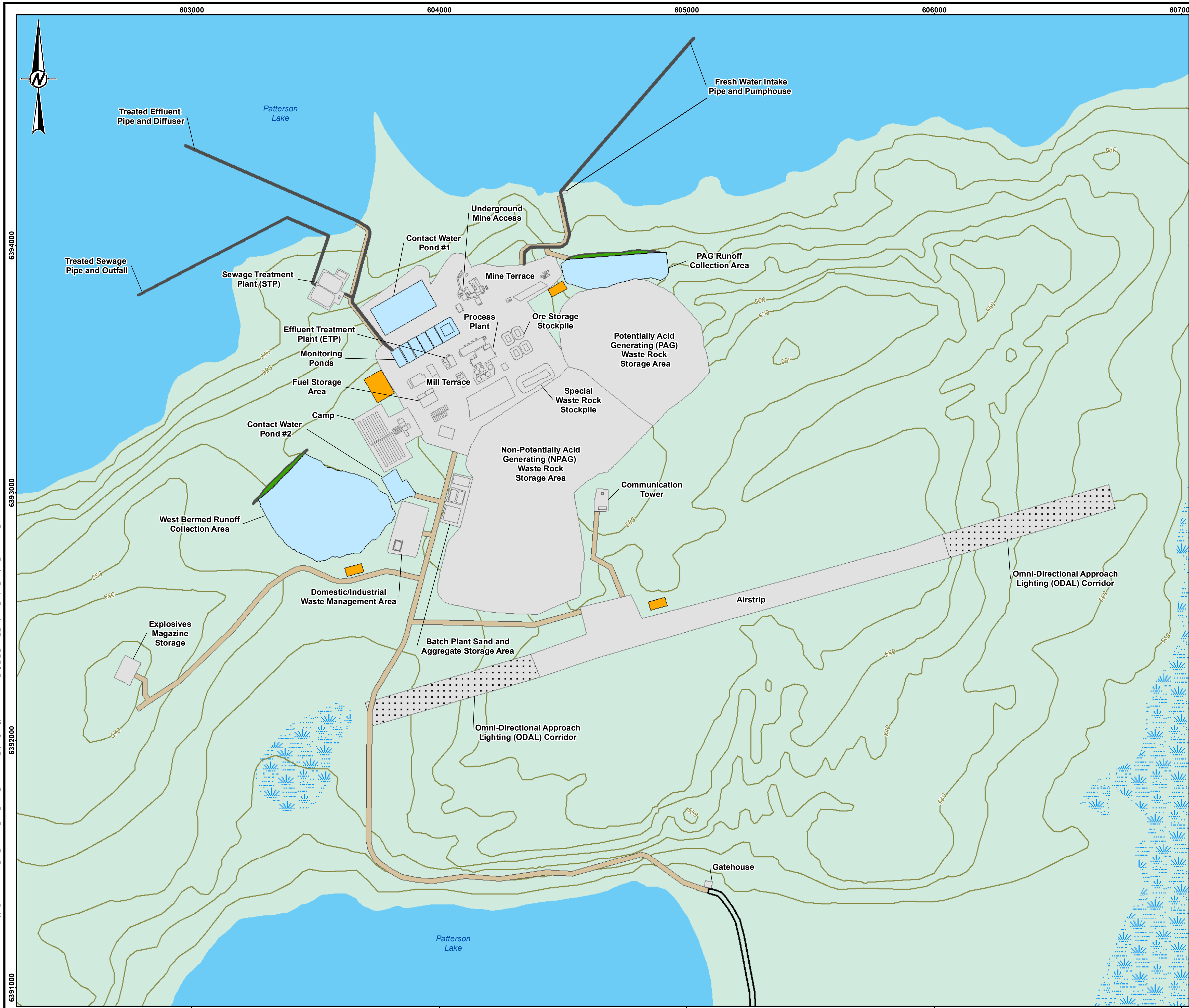
VC = valued component.

8.1.1 Project Summary

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 8.1-4):

- underground mine development;
- process plant buildings, including uranium concentrate packaging facilities;
- paste tailings distribution system;
- UGTMF;
- potentially acid generating (PAG) WRSA;
- non-potentially acid generating (NPAG) WRSA;
- special waste rock[2] and ore storage stockpiles;
- surface and underground water management infrastructure, including water management ponds, effluent treatment plant, 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.

[2] 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

- 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	SCALE AS SHOWN	REV. 0

FIGURE 8.1-4

8.1.2 Purpose and Approach to the Assessment

The purpose of Section 8 is to provide a detailed and comprehensive assessment of all potential Project-specific effects and cumulative effects from the Project and other previous, existing, and reasonably foreseeable developments (RFDs), if applicable, on hydrogeology. This section meets the Terms of Reference for the Project submitted to the Saskatchewan Ministry of Environment and the Canadian Nuclear Safety Commission Section *Generic Guidelines for the Preparation of an Environmental Impact Statement Pursuant to the Canadian Environmental Assessment Act, 2012* (Appendix 1A, Concordance Tables). The assessment of hydrogeology followed the overall EA approach and methods (Section 6, Environmental Assessment Approach and Methods) and includes the following primary steps:

Step 1 – Define the component-specific methods (Section 8.2): presents the specific approaches and methods used to measure and assess the effects of the Project on hydrogeology as well as cumulative effects from the Project, other previous and existing projects and activities, and RFDs, if applicable.

Step 2 – Characterize existing conditions (Section 8.3): describes and characterizes existing conditions to provide context and a basis for evaluating potential changes to hydrogeology caused by the Project.

Step 3 – Evaluate Project interactions and mitigations (Section 8.4): identifies Project components and/or activities with the potential to affect hydrogeology and provides environmental design features and mitigation policies and actions committed to by NexGen to avoid or minimize potential adverse effects. A pathways analysis was used to focus further assessment on key interactions between the Project and hydrogeology by evaluating the different effects pathways to determine if, after incorporation of mitigation, there is still potential to cause residual adverse effects. Primary pathways anticipated to result in residual adverse effects after incorporation of mitigation are carried forward to Step 4 for further analysis. Where potential adverse effects are adequately mitigated and thus not forwarded for further analysis (i.e., where mitigation results in negligible effects or avoids the pathway altogether), the reasons for concluding the assessment at this stage are provided.

Step 4 – Analyze and classify residual effects (Section 8.5): evaluates and describes the potential Project effects on hydrogeology that are anticipated to occur through the primary pathways. The residual effects analysis is presented as an integrated narrative that describes the effects of the Project over time and highlights predicted effects at the point when adverse effects of the Project are expected to be greatest. This step also includes an analysis of residual cumulative effects from the Project, other previous and existing projects and activities, and RFDs. Residual effects are classified and tabulated using the criteria direction, magnitude, geographic extent, duration, reversibility, and frequency to provide structure and comparability across all VCs and intermediate components in the EA.

Step 5 – Describe uncertainty and define prediction confidence (Section 8.6): identifies key uncertainties and explains how these uncertainties have been addressed to achieve a conservative, precautionary assessment. The implications of the approaches used to address uncertainties and the level of confidence in the residual effects analysis are discussed.

Step 6 – Identify monitoring and follow-up (Section 8.7): outlines the proposed actions to verify predicted residual effects. The purpose of these actions is to evaluate effectiveness of planned mitigation designs, policies, and practices, and address key sources of uncertainty.

8.2 Component Methods

8.2.1 Incorporation of Indigenous and Local Knowledge

Indigenous and Local Knowledge included in the assessment of hydrogeology was shared by potentially affected First Nations and Métis Groups (collectively referred to as Indigenous Groups) and local priority area (LPA)[3] community members through the Project engagement process. The overall approach and methods for the incorporation of Indigenous and Local Knowledge into the EA is discussed in detail in Section 3, Indigenous and Local Knowledge. Issues and concerns related to hydrogeology raised by Indigenous Groups and LPA community members, and how these comments were addressed, are summarized in Appendix 2B, Summary of Issues and Concerns Identified by Indigenous Groups, and are identified and addressed in this assessment, where applicable.

A key source of Indigenous and Local Knowledge is the Project specific studies completed by Indigenous Groups, including Traditional Land Use and Occupancy studies, Traditional Knowledge and Use studies, and Indigenous Rights and Knowledge studies (henceforth referred collectively as Indigenous Knowledge and Traditional Land Use Studies). The Indigenous Knowledge and Traditional Land Use Studies that were reviewed and referenced in the EIS as technical support documents (TSDs) are listed below:

- TSD II (BNDN), Birch Narrows Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD III (BRDN), Buffalo River Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD IV (MN-S), Métis Nation – Saskatchewan Northern Region 2 Traditional Land Use & Diet Study for The NexGen Rook 1 Project;
- TSD V.1 (CRDN), Preliminary Identification of Issues and Concerns Related to the Proposed NexGen Energy Ltd. Rook 1 Project in the Patterson Lake Area; A Review; Clearwater River Dene Nation; Traditional Land Use and Occupancy Mapping Interviews; 2010 – 2016;
- TSD V.2 (CRDN), Clearwater River Dene Nation Indigenous Rights and Knowledge Survey related to the proposed NexGen Energy Ltd. Rook 1 Project in the Patterson Lake Area;
- TSD V.3 (CRDN), Socio-economic and Harvest Study; Clearwater River Dene Nation; NexGen Rook 1 Project; and
- TSD VI (YNLR), Provision of Athabasca Denesųłiné Traditional Knowledge, Land Use and Occupancy Information for the NexGen Rook I Project Environmental Assessment.

Another key source of Indigenous and Local Knowledge was information shared by Indigenous Group representatives during Joint Working Group (JWG) meetings. The JWGs represent an agreed-upon primary engagement mechanism as outlined in the Study Agreements signed by each Indigenous Group and NexGen. More details regarding the JWGs can be found in Section 2, Indigenous, Regulatory, and Public Engagement and Section 3, Indigenous and Local Knowledge. There are four JWGs with the Project's primary Indigenous Groups (Section 2.4.1, Identification of Indigenous Groups for Engagement):

[3] The LPA consists of the local communities closest to the Project that would experience most of the Project effects and for which NexGen would prioritize local training, employment, and business opportunities for the Project. These communities are located along, or accessed via, Highways 155 and 955 north of the intersection of Highways 155 and 925.

- Clearwater River Dene Nation (CRDN) JWG;
- Métis Nation – Saskatchewan (MN-S) JWG representing MN-S Northern Region 2 (NR2);
- Birch Narrows Dene Nation (BNDN) JWG; and
- Buffalo River Dene Nation (BRDN) JWG.

The leadership of each Indigenous Group selected their JWG participants with consideration of group diversity; where possible, members included Elders, youth, different genders, a range of ages, and land users around Patterson Lake.

In addition to the Indigenous Knowledge and Traditional Land Use Studies and JWGs, Indigenous and Local Knowledge shared during specific engagement activities undertaken through the EA development process was incorporated into the assessment, where appropriate. These engagement activities included, but were not limited to:

- community information sessions held in four locations in 2019 (NexGen 2019a);
- site tours;
- comments from the CRDN (2019a) on the Cluff Lake Mine licence renewal;
- other formal and informal meetings;
- workshops with specific groups (e.g., Fur Block N-19 trapper's workshop); and
- environmental and socio-economic baseline data collection.

Comments submitted by Indigenous Groups on the Project Description (CRDN 2019b; MN-S 2019; YNLRO 2019; ACFN 2019; CNSC 2019) were also reviewed for applicable Indigenous and Local Knowledge.

Indigenous and Local Knowledge related to hydrogeology was incorporated into the assessment by viewing the information as complementary and influential alongside scientific information. Where possible, knowledge from each potentially affected Indigenous Group or LPA community member was described separately and cited accordingly. Where information is described for multiple potentially affected Indigenous Groups, they are collectively referred to as "Indigenous Groups" throughout the assessment.

Indigenous and Local Knowledge was included in the hydrogeology assessment in the following ways:

- **Component Methods – Valued Components and Intermediate Components:** Indigenous and Local Knowledge was considered in the selection of the hydrogeology intermediate component and reflects the importance of both aboveground and underground water to Indigenous Groups for supporting traditional land use activities and contributing to the health of local communities. The importance of water was also reflected in the holistic perspective related to the interconnectedness of underground and aboveground water systems, and to other aquatic and terrestrial environmental components. The value of Patterson Lake and the Clearwater River as an interconnected system and fresh water resource was highlighted (Section 8.2.2.1).
- **Project Interactions and Mitigation:** Indigenous and Local Knowledge helped to inform the scoping of Project interactions, pathway analysis, and consideration of mitigation measures (Section 8.4). This includes observations and experiences of land users related to the cumulative effects from industry, including mining activities, on discipline-specific measurement indicators / effect pathways.

- **Monitoring, Follow-Up, and Management:** Feedback provided by Indigenous Groups during engagement, including recommendations, was considered in the development of monitoring and follow-up activities (Section 8.7). In addition, it is planned that ongoing feedback from Indigenous Groups on the effectiveness of mitigations would be considered when updating monitoring and management plans. Independent Indigenous Monitors chosen by each primary Indigenous Group would have opportunities to participate in environmental monitoring programs for the proposed Project.

Specific references to Indigenous and Local Knowledge, and Project comments and concerns related to hydrogeology raised by Indigenous Groups and LPA community members, are included in the applicable subsections of this assessment.

8.2.2 Valued Components, Intermediate Components, and Measurement Indicators

8.2.2.1 Valued Components and Intermediate Components

Valued components are aspects of the biophysical, cultural, and socio-economic environments that are considered to have scientific, social, cultural, economic, historical, archaeological, or aesthetic importance (Beanlands and Duinker 1983; CNSC 2021). Intermediate components include physical attributes of the biophysical environment or media upon which VCs rely, such as air quality, terrain and soils, hydrogeology, hydrology, and water and sediment quality (Section 6.3.3, Intermediate Components). Valued components and intermediate components are assessed using the same steps; however, unlike VCs, intermediate components do not have assessment endpoints or significance criteria. Instead, the significance of changes in intermediate components is evaluated in the context of related influences to VCs, which are the ultimate receptors.

Hydrogeology was selected as an intermediate component based on the connection to hydrology and surface water quality and the associated influence on the health of aquatic and terrestrial ecosystems and people (Table 8.2-1). Hydrogeology is critical to the assessment of VCs for the EA; as examples, understanding what potential changes to hydrogeology would mean to fish and fish habitat, vegetation, and human health VCs. Therefore, the assessment of hydrogeology is fundamental to understanding the total effects of the proposed Project on the biophysical environment (Section 6.3.3).

Indigenous Groups have described the fundamental importance of water for all forms of life and supporting traditional land use activities, including hunting, trapping, fishing and gathering. For the CRDN, “respect for water is at the core of Denesųłiné teachings and practices because clean water is the fundamental requirement for all life . . . . Clean water is therefore inextricably connected to CRDN livelihoods, practices, customs and spirituality” (TSD V.2: CRDN). The Ya’thi Néné Lands and Resources commented on the importance of water to the community “I want this for the future generations. Water should be monitored, it should be kept clean, water is sacred for us” (TSD VI: YNLR). The BNDN noted that “Water is the most important thing, vital to life” (BNDN-JWG 2019).

Water is central to BNDN and BRDN culture, community well-being and health (TSD II: BNDN; TSD III: BRDN). Examples of comments received on the importance of water are as follows:

> Drinking water is . . . a number one medicine. [Without] drinking water, you can't live . . . . And there's so many things around the lake . . . . like [medicines] in the water that you can get . . . . [including] all along the shore. (TSD II: BNDN)

> Most important thing because we drink that water and the fish lives on water. Creatures, they drink the water . . . . Like moose, caribou, everything . . . . That's the most important thing is – we drink a lot of water ourselves, you know. (TSD II: BNDN)

LPA community members also frequently noted water quality and the protection of water as one of the most important components of the environment (NexGen 2019a).

Indigenous Groups have highlighted the interconnectedness of the region's waterways and their connection to groundwater (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.2: CRDN; BNDN-JWG 2021b; BRDN-JWG 2019a; BRDN-JWG 2020; CRDN-JWG 2021). The Clearwater River is described by the CRDN as a holistic river system and Patterson, Forrest, Beet, Preston, and Lloyd lakes are intrinsically connected to and integral to the river (TSD V.2: CRDN). The water quality in Patterson Lake, which is understood to be connected to the surface waterways and groundwater in the area, is of upmost importance to Indigenous Groups for the health of the environment, including the resources that depend on it, as well as to human health and the maintenance of traditional land use activities (TSD II: BNDN; TSD III BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). The BRDN also commented on the interconnectedness of Patterson Lake and groundwater resources (BRDN-JWG 2020). Examples of comments received on the interconnection of surface water and groundwater systems are as follows:

> But Mother Earth is just like a sponge. It collects everything. And also, water flows. It goes wherever. It goes where – it connects all over the place. (TSD III: BRDN)

> But everything works, like, in a circle….And what annoys the heck out of me is that people just think one lake operates in isolation. It has veins everywhere. It has veins going everywhere. If you're going to [speaking Dene] take all the water out from here, you're not only stopping the flow of water that comes from Clearwater [River]. It goes all the way over here. You're stopping the flow of all kinds of veins that come around here. You're going to dry up all these things. (TSD V.2: CRDN)

Water is also understood to be present underground in different substrates, including muskegs and sandstone units (TSD V.2: CRDN; BRDN-JWG 2019b).

8.2.2.2 Measurement Indicators

Measurement indicators are used to characterize changes to attributes of the environment from the Project, other human developments, and natural factors. The changes in measurement indicators are used to predict overall effects on VCs and intermediate components (Section 6.3.2, Assessment Endpoints and Measurement Indicators). Three measurement indicators were identified and used for the hydrogeology assessment (Table 8.2-1).

Table 8.2-1: Rationale and Measurement Indicators for the Hydrogeology Intermediate Component

Intermediate Component	Rationale	Measurement Indicators
▪ Hydrogeology (groundwater quantity and quality)	▪ Important component in the hydrologic cycle, linked to surface water quantity through exchange with overlying surface water features, important to fish and fish habitat ▪ Linked to surface water quality through overlying surface water features, which is important for fish and fish habitat, human use (i.e., drinking water or other consumption), and overall ecological integrity	▪ Groundwater elevations ▪ Groundwater flow directions and rates ▪ Groundwater quality

Measurement indicators for hydrogeology are defined as follows:

- **Groundwater elevations:** Groundwater elevation refers to the spatial (i.e., changing in space) and temporal (i.e., changing with time) distribution of total hydraulic head within geological strata (i.e., rock layers) relative to a geodetic datum (i.e., a reference elevation). The standard units used to describe groundwater levels are metres above sea level (masl).
- **Groundwater flow directions and rates:** Groundwater flow directions and rates refer to the spatial and temporal changes in the direction and quantity of groundwater flow, which are directly related to the changes in groundwater elevations defined above.
- **Groundwater quality:** Groundwater quality includes the spatial and temporal distribution of concentrations of major ions and nutrients, dissolved metals, and radionuclides, as well as physical properties (e.g., electrical conductivity).

8.2.3 Spatial Boundaries

The spatial boundaries selected for the hydrogeology assessment (Table 8.2-2) support a description of the existing environment in sufficient detail to identify, understand, and assess potential Project interactions with the hydrogeology intermediate component, including the contribution of the Project to residual effects. The spatial boundaries for the assessment of hydrogeology consisted of a local study area (LSA) and a regional study area (RSA). The spatial extents of the LSA and RSA are presented in Figure 8.2-1.

The LSA is defined as the area where direct changes to the physical-chemical groundwater environment as a result of the proposed Project would be expected. The LSA is consistent with the Hydrology LSA (Section 9) and is defined by the Clearwater River watershed boundary up to the Naomi Lake outlet, which covers a surface area of 685 km^2. The LSA was selected to capture the local effects of the proposed mine footprint on the groundwater environment and provides local context for assessing Project effects.

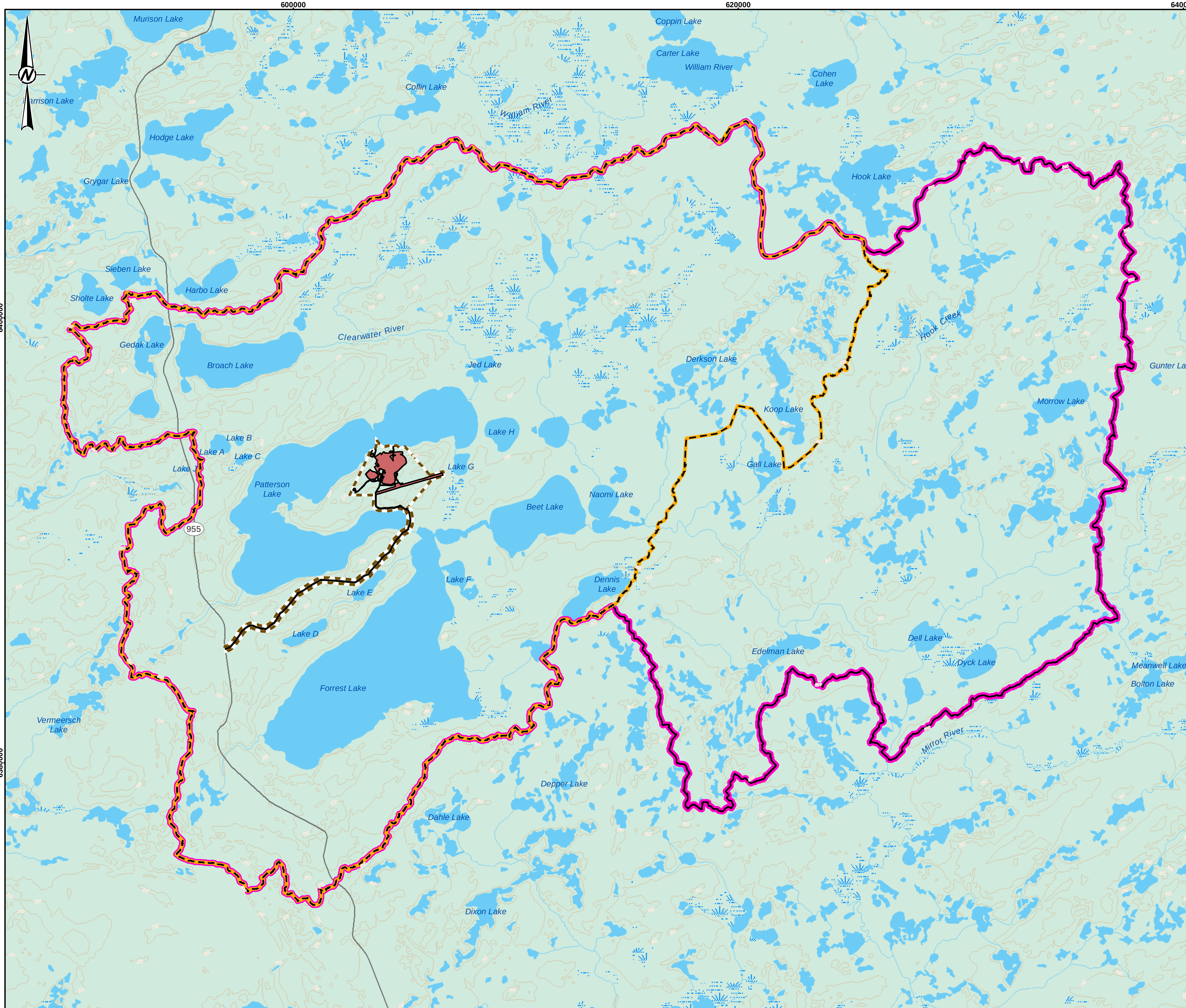
The RSA for the hydrogeology assessment encompasses NexGen's Arrow deposit. The RSA is defined by the Clearwater River watershed boundary upstream of the Mirror River confluence. The RSA is considered large enough to provide an ecologically relevant and confident assessment of the direct and indirect effects on hydrogeology from the Project, and the cumulative effects from the Project and other previous, existing, and approved projects and RFDs. The RSA is the largest scale at which data were collected, compiled, and analyzed, and includes the area where indirect effects that extend beyond the LSA may occur (CEA Agency 2018).

The groundwater flow model domain is defined as an approximately 26.5 km by 18.5 km rectangular area overlapping the RSA that is oriented based on the general regional surface drainage of the Patterson Lake watershed, with the northwest portion situated along a topographic high and the southeast portion situated along a topographic low with drainage to the Clearwater River.

Table 8.2-2: Spatial Boundaries for Assessment of Hydrogeology

Study Area	Area	Description/Rationale
LSA	68,500 ha (685 km^2)	▪ Clearwater River watershed boundary up to Naomi Lake (consistent with the hydrology LSA; refer to Section 9) ▪ Defines the expected extent of the direct and indirect effects from the Project ▪ Provides local context for assessing the residual effects
RSA	107,600 ha (1,076 km^2)	▪ Watershed draining to the Clearwater River above the Mirror River confluence (consistent with the hydrology RSA; refer to Section 9) ▪ Provides broader scale context to capture and assess Project effects and is linked to terrestrial and aquatic-related exposure pathways in the ecological health risk assessment ▪ Provides broader scale context for Project effects and assess cumulative effects, if applicable

LSA = local study area; RSA = regional study area.



LEGEND

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

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
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PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd

ROOK I PROJECT

TITLE

HYDROGEOLOGY STUDY AREAS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	NB	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-07		
CHECK	NB	2023-02-07	**FIGURE 8.2-1**	
REVIEW	MT	2023-02-07		

8.2.4 Temporal Boundaries

The temporal scope of the assessment encompasses the 43-year period from initial Construction to the end of Decommissioning and Reclamation (i.e., Closure), as defined by the following Project phases (Section 6.4.2, Temporal Boundaries):

- **Construction Phase (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. The duration of Construction is expected to be four years.
- **Operations Phase (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. The duration of Operations is expected to be 24 years.
- **Decommissioning and Reclamation Phase (Closure):** includes two stages expected to occur over 15 years:
  - **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 and 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. The duration of the Active Closure Stage is expected to be five years.
  - **Transitional Monitoring Stage:** includes monitoring and reporting activities that occur post-Active Closure that 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 Canadian Nuclear Safety Commission licence would be submitted to the Canadian Nuclear Safety Commission for approval. Once that is achieved, and upon Provincial approval, the land would be transferred back under Provincial management through the Institutional Control Program. The duration of the Transitional Monitoring Stage is nominally 10 years; however, NexGen acknowledges this duration would be dependent on the achievement of performance criteria.

Concerns surrounding the interaction of groundwater, and ultimately surface water, with tailings and mine waste have been raised by the CRDN, MN-S, BNDN, and BRDN (Section 8.5.1.1.2, Groundwater Flow Patterns and Rates), including concerns related to long-term effects in general that may affect future generations (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; BNDN-JWG 2019; BNDN-JWG 2020; BNDN-JWG 2021a; BRDN-JWG 2020; BRDN-JWG 2021a; CRDN-JWG 2020a; CRDN-JWG 2020b; CRDN-JWG 2021; MN-S-JWG 2019a).

With this in mind and as a part of good EA practice, the temporal scope of the assessment for hydrogeology also includes the period for which the maximum effects on groundwater quality are predicted. Due to the relatively low groundwater velocities between the proposed Project and the receiving environment, as well as the potential for chemical reactions along the groundwater flow pathway, the temporal scope includes the 400,000-year period following Construction (i.e., the far future). The far-future projection encompasses the long-term period during which slow migration of constituents of potential concern from the UGTMF and WRSAs to the environment are anticipated.

The temporal boundaries applied to cumulative effects assessments include the duration of residual effects from previous and existing developments that overlap with residual effects from the Project, and the period during which the residual effects from RFDs overlap with the Project, if applicable.

8.2.5 Assessment Cases

The concept of assessment cases was applied to the hydrogeology assessment to estimate the incremental and cumulative effects from the Project and other developments (Section 6.5, Assessment Cases). The approach incorporated temporal boundaries for analyzing the potential effects from previous, existing, and approved projects and RFDs before, during, and after the anticipated lifespan of the Project. There are no known approved (but not yet constructed) projects in the LSA and RSA for hydrogeology. Assessment cases for the Project included a Base Case, Application Case, and RFD Case.

Base Case for hydrogeology is represented by existing conditions. The Base Case describes the existing environment in the LSA and RSA before application of the Project to provide an understanding of the current conditions that may be influenced by the Project. The temporal boundary of the Base Case includes the combined effects from previous and existing human disturbances and natural factors (e.g., fire, floods) on the environment and hydrogeology. As such, existing conditions represent the cumulative effects of historical and current environmental pressures that have influenced the observed condition and patterns of hydrogeology (CEA Agency 2018).

Application Case for hydrogeology represents predictions of the combined effects of the previous and existing projects/activities and natural factors in the Base Case plus the effects from the proposed Project. This case was also used to identify and assess incremental, Project-specific changes that are predicted to occur to hydrogeology.

Reasonably Foreseeable Development Case for hydrogeology includes the Base Case, Application Case, and RFDs that have not yet been approved. Reasonably foreseeable developments are defined as projects and activities that fit any of the first three and both of the last two criteria from the list below:

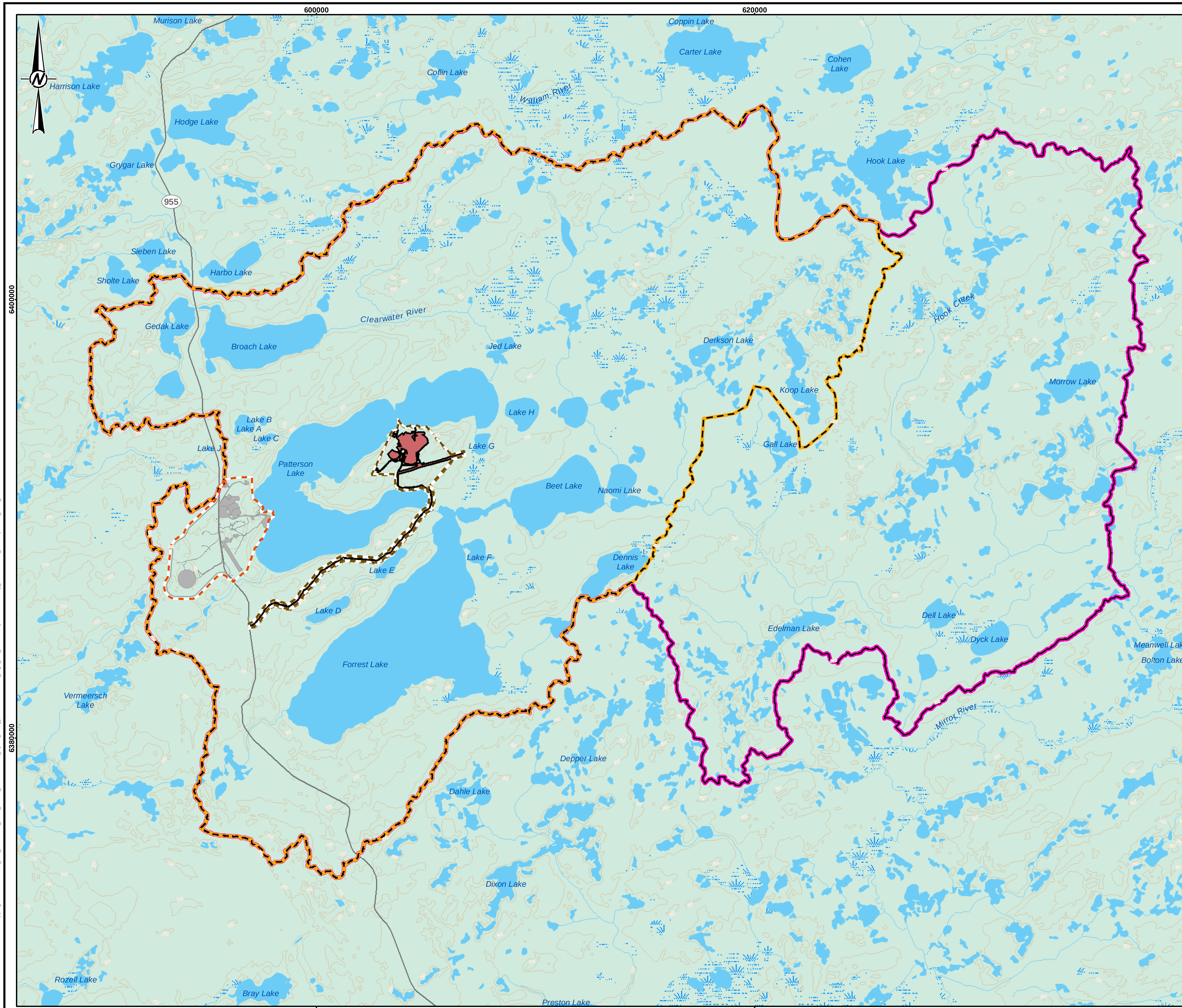
- are currently under regulatory review or have officially entered a formal regulatory application process;
- have been publicly disclosed by other proponents;
- may be induced by the Project;
- have the potential to change the Project or the effects predictions; and
- occur in the spatial assessment boundary defined for hydrogeology.

A key criterion for selecting other projects to include in the RFD Case was that those projects must cause similar effects on hydrogeology influenced the Project (Hegmann et al. 1999). The Fission Patterson Lake South Property, which is planned by Fission Uranium Corp. (Fission 2019, 2021), was included in the RFD Case (Figure 8.2-2). Public information describes a projected three-year construction period and seven-year operating period (production and processing) (Fission 2019, 2021). The anticipated start of construction and duration of active decommissioning at the Fission Patterson Lake South Property were not publicly available at the time this assessment was completed. For the assessment, it was assumed that the duration of active decommissioning for the Fission Patterson Lake South Property would be similar to the Active Closure Stage for the Project (i.e., five years; Section 6.5.3, Reasonably Foreseeable Development Case).

The CRDN and MN-S specifically mentioned the concerns regarding cumulative effects from the Project and the nearby proposed Fission Patterson Lake South Property (CRDN 2019b; MN-S-JWG 2020; CRDN-JWG 2021).

The primary residual effects from the Project on hydrogeology would include changes to groundwater quantity (i.e., elevations and flow rates) during Operations from mine dewatering, and changes in groundwater quality during Operations and following Closure (i.e., far future) due to seepage from waste rock and tailings management facilities; these residual effects were shown to be confined to the LSA (Section 8.5.1, Application Case).

Changes to groundwater measurement indicators from the Project are not predicted to overlap spatially with groundwater influenced by the Fission Patterson Lake South Property. The mitigation policies and actions implemented by the Project are expected to avoid and minimize the Project's contribution to cumulative effects. It is also expected that the Fission Patterson Lake South Property would implement appropriate mitigation and adaptive management to avoid and minimize project-specific and cumulative effects. As such, there is negligible potential for cumulative effects on the groundwater system from the Project and the Fission Patterson Lake South Property, which precludes the need to assess an RFD Case for hydrogeology (i.e., for effects on groundwater). However, the cumulative effects of groundwater seepage from the Project and the Fission Patterson Lake South Property into Patterson Lake are explicitly analyzed in the surface water quality assessment (Section 10), ecological risk assessment (TSD XXI, Environmental Risk Assessment), and fish and fish habitat assessment (Section 11).



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- HYDROGEOLOGY LOCAL STUDY AREA
- HYDROGEOLOGY REGIONAL STUDY AREA

0 5 10

1:175,000 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).
3. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd

ROOK I PROJECT

TITLE

REASONABLY FORESEEABLE DEVELOPMENT IN THE REGIONAL STUDY AREA

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	NB	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-07		
CHECK	NB	2023-02-07	**FIGURE 8.2-2**	
REVIEW	MT	2023-02-07		

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8.2.6 Existing Conditions

The existing hydrogeological conditions were evaluated as a part of baseline investigations for the Project. Detailed hydrogeology baseline methods and results are available in Annex III, Hydrogeology Baseline Report. A summary of the methods used to evaluate the baseline hydrogeological conditions is provided below.

8.2.6.1 Geology

Geological conditions were delineated through interpretation of drilling records from exploration, geotechnical and environmental boreholes, geophysical data, and previously published data sources (i.e., mapping and the literature). This information was compiled in a three-dimensional (3-D) geological model (Annex XI, Geology Baseline Report).

8.2.6.2 Hydrostratigraphy

Hydrostratigraphic units (i.e., geological formations characterized by hydraulic properties) were defined based on the geological model (Annex XI), hydraulic response testing data of the hydrostratigraphic units (i.e., measurements of their hydraulic properties), and measurements of groundwater elevation and pressure. The characteristics defining the hydraulics of each hydrostratigraphic unit included hydraulic conductivity (i.e., ability of water to move through rock), porosity of rock types (i.e., ratio of voids to rock volume), degree of weathering through chemical and mechanical degradation of the rock, natural fracture and foliation (i.e., folding) planes, and shear zones.

8.2.6.3 Groundwater Elevations

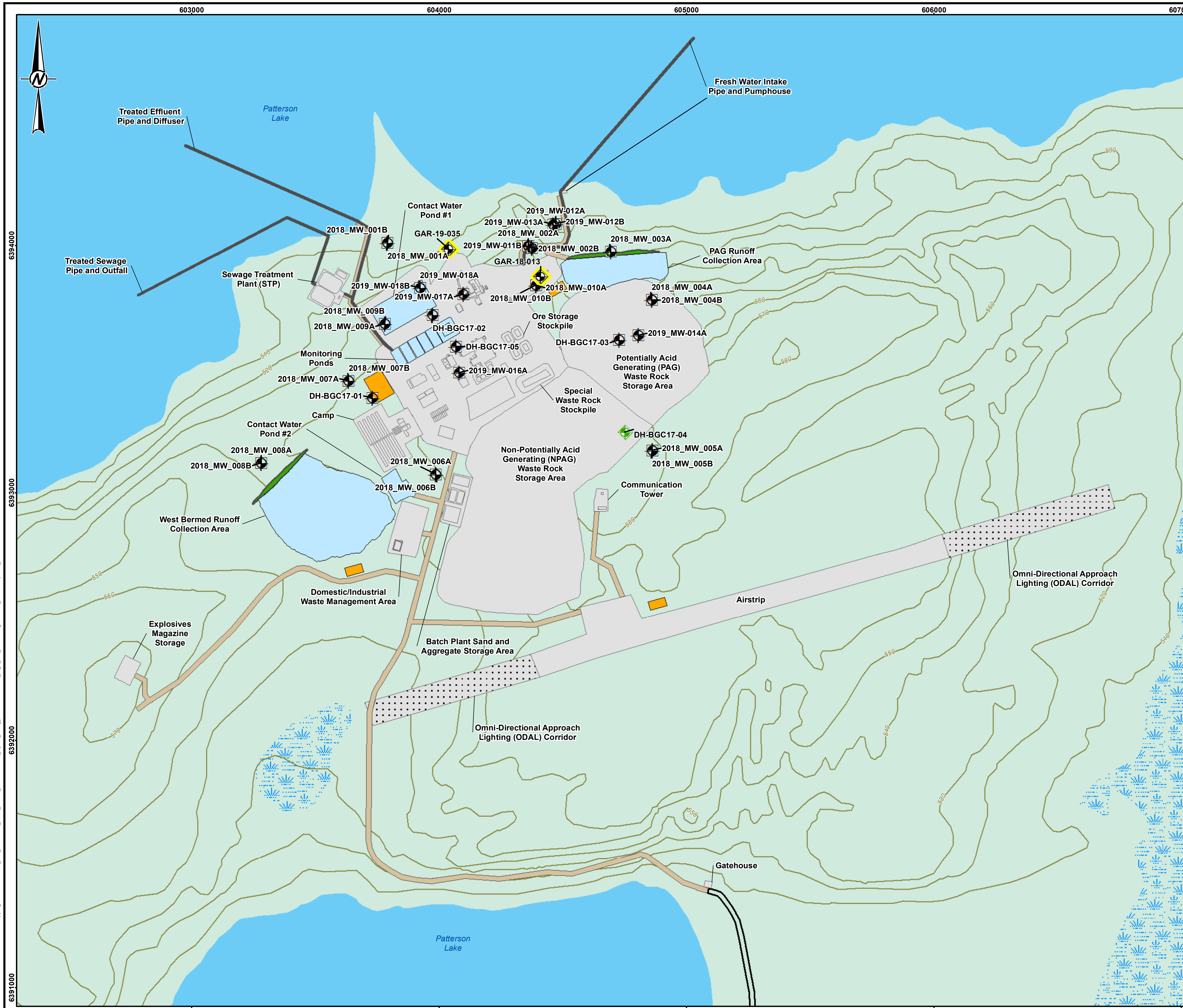
Baseline groundwater elevation and pressure data were collected using standpipe piezometers (e.g., monitoring wells), multi-level (i.e., Westbay) wells, and vibrating-wire piezometers (VWPs) (i.e., electrical pressure sensors). Vibrating-wire piezometers are used to measure pore water pressure in the bedrock. The pore water pressures are converted to hydraulic head that is used to detect groundwater flow directions. Westbay wells are a subsurface characterization technology that allows testing for hydraulic conductivity, long-term monitoring of fluid pressures (and hydraulic head), and collection of fluid samples from multiple depth intervals within a single borehole. Hydraulic head is the elevation of the water level in a well or VWP. Groundwater flows from higher to lower hydraulic head.

The monitoring network consisted of 34 standpipe piezometers installed in the overburden (i.e., glacial drift) and upper portion of the bedrock during the 2017 through 2019 seasonal groundwater investigation programs. Two deep multi-level Westbay well systems were installed to monitor groundwater in the bedrock. The Westbay wells were designed to isolate sampling intervals within each borehole to obtain groundwater samples representative of different depths. These systems were installed in boreholes GAR-18-013 and GAR-19-035 in 2018 and 2019, respectively; instrumentation locations are detailed and illustrated in Section 8.3.3, Groundwater Elevations.

Groundwater elevation and pressure data were collected within the basement rock using VWPs installed within selected boreholes; descriptions of the geological units are provided in Section 8.3.1, Geology. Twenty-seven VWPs were installed at selected depths along the borehole and were grouted in place using a cement-bentonite mixture. These VWPs were connected to a data logger and programmed to record readings at 12-hour intervals. Raw data readings were output as a frequency and temperature, which correlated to a calculated pressure based on input factors uniquely calibrated for each instrument. Hydraulic head was determined from the calculated pressure and the measured elevation of each instrument.

Manual hydraulic head measurements in the overburden and bedrock monitoring wells were taken during sampling events prior to sample collection. These measurements were made with an electronic water level tape that made an audible sound when the probe contacted groundwater in the well. Depth-to-water measurements were recorded with reference to the top of the piezometer casing.

The groundwater elevation data were reviewed according to the relative depth and hydrostratigraphic unit associated with the monitoring location. The monitoring well locations are presented on Figure 8.2-3.



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
- DECOMMISSIONED WELL
- STANDPIPE PIEZOMETER SITES
- WEST BAY MONITORING WELLS

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

MONITORING WELL LOCATION PLAN

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	CH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-07		
CHECK	NB	2023-02-07	**FIGURE 8.2-3**	
REVIEW	MT	2023-02-07		

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8.2.6.4 Hydraulic Properties

Hydraulic response (i.e., slug) testing was completed in all overburden piezometers installed within the LSA to determine the hydraulic conductivity of each screened interval. This consisted of slug testing (i.e., the injection or removal of a known volume of water into a piezometer followed by monitoring the formation's hydraulic response in the piezometer) in all the standpipe piezometers installed in 2017 (i.e., BGC17-01 through BGC17-05; refer to Section 8.3.3 for details on instrumentation locations) using falling head and rising head response testing, which is suitable for piezometers completed in fast-recovery units representing sandy strata such as glacial drift deposits present in the vicinity of the Project. The piezometers tested were installed within the lower unit of the glacial drift, as the upper unit is typically unsaturated. The response data were analyzed using the Bouwer and Rice (1976) method for evaluating hydraulic properties of the formation under unconfined aquifer conditions to obtain 16 estimates of overburden hydraulic conductivity.

In situ wireline packer testing was completed during the 2017 and 2018 hydrogeological investigations (BGC 2017; SRK 2018). This involved sealing isolated intervals within boreholes using inflatable packers and completing hydraulic response testing within the isolated interval to estimate the hydraulic properties of the formation with a finer resolution as compared to the overall borehole length. The packer testing was completed in exploration boreholes to obtain over 240 hydraulic conductivity estimates of selected geological formations and structures in locations where permanent installations, such as standpipe piezometers, were not installed. The equipment used for the testing programs included a hydraulically inflated single-packer tool in a wireline configuration. Pressure response data were collected by two pressure transducers during slug injection/withdrawal and constant rate injection testing at each location.

Testing was completed to characterize the geotechnical properties of the soils. Twenty-six wash sieves were completed to evaluate the particle size distribution of overburden samples from test pits and boreholes (BGC 2017). Seven Atterberg limits tests were completed according to American Society for Testing and Materials Standard D4318-10 to evaluate the Plastic Limit and Liquid Limit of the fine-grained materials encountered (BGC 2017). Ten moisture content tests were completed to evaluate the natural water content of soils from test pits and drill holes throughout the site at various depths (0.6 m to 57.3 m). The testing was conducted according to American Society for Testing and Materials Standard D2216.

8.2.6.5 Groundwater Quality

Representative groundwater samples were collected four times per year from all 34 standpipe monitoring locations and Westbay installations following well development. Samples were collected and submitted to various accredited laboratories in Saskatoon, Saskatchewan: ALS Environmental Laboratory and Saskatchewan Research Council Environmental Analytical Laboratory for general chemistry, dissolved metals, total metals, total suspended solids, nitrate, acidity, and radionuclide analyses; A.E. Lalonde AMS Laboratory for analyses of tritium; and Ján Veizer Stable Isotope Laboratory for stable isotope analysis.

The general chemical composition of groundwater samples collected from the standpipe piezometers was determined using a Piper plot, which is a graphical representation of water chemistry used to evaluate the sources of dissolved constituents in water. Piper plots use milliequivalent data (i.e., one thousandth of a chemical element equivalent) based on the number of charge units of each chemical species, as opposed to the mass-based data used when referring to concentrations quantified as milligrams per litre. Piper plots (also known as trilinear diagrams) are powerful tools for visualizing the relative abundance of common chemical ions such as calcium, magnesium, and chloride in water samples. They allow the plotting of multiple samples on the same plot, thus allowing for grouping of water samples by groundwater facies and other criteria. In a Piper plot, the relative contributions of each species of negative (i.e., anion) and positive (i.e., cation) major ions are plotted on the triangles at the lower portion of the diagram. Each triangle apex represents a 100% milliequivalent concentration of that species for either the cations or anions. The contributions of different positive ions (i.e., cations) to the positively charged portion of a sample are shown on the lower left triangle. The contributions of different negative ions (i.e., anions) to the negatively charged portion of a sample are shown on the lower right triangle. The points plotted on these smaller triangles are projected to the diamond shape in the centre. Points representing fresh water typically plot near the centre-left apex of the diamond, while more saline water typically plot near the centre-right apex of the diamond. As fresh water becomes more saline along a flow path, water samples generally plot along a curved path from fresh water to more saline.

8.2.6.6 Groundwater Flow Modelling

A 3-D numerical groundwater flow model was developed to reflect the conceptual hydrogeological model and calibrated based on target groundwater elevations and baseflow (i.e., the portion of streamflow sustained between precipitation events) information. The model was established to represent current (i.e., existing) conditions.

The objectives of groundwater flow modelling were to develop and calibrate a groundwater flow model representing the existing (i.e., predevelopment) conditions for the Project site extending to the RSA. This calibrated model was used to predict the Project effects through all phases (Construction, Operations, and Closure) on groundwater inflows and the extent and magnitude of groundwater depressurization, as well as to delineate groundwater flow pathways from mine waste source areas to Patterson Lake.

To achieve these objectives, a conceptual groundwater model was developed for the Project site and extending to the RSA. A conceptual groundwater model is a pictorial and descriptive representation of the groundwater regime that organizes and simplifies the site hydrogeology so that it can be modelled readily. This conceptual model must retain enough complexity to allow the numerical model developed from it to adequately reproduce or simulate the real groundwater behaviour to the degree required to meet the Project objectives.

Based on the conceptual model, a 3-D numerical groundwater model was constructed and calibrated to existing conditions data to represent the best estimate of groundwater flow conditions based on the conceptual model. The Project was then simulated in this calibrated 3-D numerical groundwater model. The results of the simulations are representative of the Application Case groundwater conditions.

The model development and calibration are described in detail in the TSD XIV, Groundwater Flow and Solute Transport Modelling Report.

8.2.7 Project Interactions and Mitigations

Interactions (i.e., linkages) between Project components or activities, and the corresponding potential changes to measurement indicators, were identified by a pathway analysis that was then used to inform the residual effects assessment for hydrogeology (Section 6.7, Pathways Analysis). The first part of the analysis identified all potential effects pathways for all phases of the Project (Section 6.7.1, Identification of Project Interactions). Each pathway was initially assumed to have a linkage to potential effects on hydrogeology.

Potential pathways from Project activities to hydrogeology were identified using the following:

- review of the Project description (Section 5) and potential effect scoping by the project development, environmental, and socio-economic teams for the Project;
- input from Indigenous, regulatory, and public engagement (Section 2) and Indigenous and Local Knowledge (Section 3);
- scientific knowledge;
- previous experience with mining projects; and
- consideration of potential effects identified from the Terms of Reference (Section 1, Appendix 1A).

Potential adverse effects of the Project were then identified, and practicable mitigation was applied to avoid, minimize, and/or rehabilitate adverse effects on hydrogeology (Section 6.7.2, Identification of Mitigation). Avoidance and minimization are widely recognized as the most important approach for biodiversity conservation (BBOP 2021). Avoidance designs and actions integrated into the Project were developed iteratively between the Project's environmental and project development teams. Minimization techniques and technology were also identified and implemented collaboratively between Project teams.

Each potential effect pathway was evaluated considering proposed mitigation to predict whether the pathway had the potential to cause residual adverse effects (Section 6.7.3, Pathway Screening). A screening-level assessment was applied using Indigenous and Local Knowledge, scientific knowledge, logic, experience with similar developments, and an understanding of the effectiveness of mitigation (i.e., level of certainty that mitigation would work) to assign each pathway to one of the following categories:

- **No pathway:** Analysis reveals that the pathway could be removed (i.e., the effect is avoided) by mitigation so that the Project would result in no measurable environmental change relative to existing conditions or guideline values and, therefore, would have no residual effect on hydrogeology.
- **Secondary pathway:** The pathway could result in a measurable but minor environmental change relative to existing conditions or guideline values, but this change would be sufficiently small that it would have a negligible residual effect on hydrogeology. Therefore, the pathway is not expected to contribute to effects of RFDs to cause a significant effect.
- **Primary pathway:** The pathway is likely to result in an environmental change relative to existing conditions or guideline values and could cause a greater than negligible effect on hydrogeology.

Project interactions determined as no pathway or secondary pathway were not carried forward for further assessment (Section 6.7.3). Primary pathways that may result in changes to the environment and one or more associated measurement indicator and have the potential to cause a greater than negligible effect on hydrogeology were carried forward to the residual effects analysis and residual effects classification (Section 8.5, Residual Effects Analysis).

8.2.8 Residual Effects Analysis

The residual effects analysis measures and describes the effects of the Project on hydrogeology relative to existing conditions. The residual effects analysis was conducted using the spatial boundaries (Section 8.2.3, Spatial Boundaries) and temporal boundaries (Section 8.2.4, Temporal Boundaries) identified for the assessment. Residual effects are described for each of the measurement indicators (i.e., groundwater elevations, groundwater flow directions and rates, and groundwater quality) for the primary pathways identified for hydrogeology in the LSA and RSA (Section 8.2.7, Project Interactions and Mitigations). The residual effects analysis was completed for the Application Case and the RFD Case (Section 6.8, Residual Effects Analysis), supported by the hydrogeological model for the Base Case conditions, modified to account for the identified primary pathways.

8.2.8.1 Groundwater Elevations, Flow Directions, and Rates

The 3-D numerical groundwater flow model described in Section 8.2.6.6, Groundwater Flow Modelling, was modified to represent various stages of Construction, Operations, and Closure. The model was reconfigured to represent operational conditions, and predictive simulations were completed to estimate groundwater inflows to the underground development during Operations and the resulting depressurization in the bedrock. This was achieved through the implementation of seepage boundaries to represent the progressive development of the mine over the development period within a transient (i.e., time-dependent) simulation. Based on the mine plan, the high permeability hydrostratigraphic units (e.g., sandstone, Cretaceous bedrock) would be sealed, and as such, would not be expected to transmit significant volumes of water to the mine. This assumption was reflected in implementation of the model seepage boundaries.

Reconfiguration of the model was also completed to represent far-future conditions (i.e., following Closure) and predictive simulations were completed to estimate the rates of groundwater flow through the source areas. A particle tracking analysis was completed where numerical groundwater particles were released from the source areas and forward-tracked through the model flow solution to delineate the groundwater flow pathways from the source areas, through the geological pathways, to the downgradient receptors.

Details of the model development, calibration, and predictive simulations can be found in TSD XIV.

8.2.8.2 Groundwater Quality

An analytical solute transport model was developed using GoldSim based on the delineation of groundwater flow pathways and rates of flow through the backfill mine waste materials, UGTMF tailings, reflooded mine workings, and waste rock remaining at surface following Closure. The model was used to estimate the solute mass release from the source areas to the surrounding environment and calculate the rate of transport of this mass to downgradient receptors (i.e., Patterson Lake). The solute transport model considered the mass of soluble constituents released to groundwater from the WRSAs during Operations, in addition to the mass released to groundwater from the underground source areas during Closure, as well as the far-future projection.

Details of the model development of the solute transport simulations can be found in TSD XIV. Development of the source terms (i.e., dissolved and solid solute concentrations) and identification of constituents of potential concern are documented in TSD XVI, Tailings Geochemical Characterization Report and TSD XVII, Waste Rock and Underground Wall Rock Source Term Predictions Report.

8.2.9 Residual Effects Classification

The residual effects analysis uses a reasoned narrative to describe anticipated changes to each measurement indicator caused by the proposed Project and other activities or projects, and the associated effects on hydrogeology. This narrative description of anticipated effects represents the foundation for the residual effects classification. Residual effects are summarized or classified in tabular form using effects criteria, which are intended to provide structure and comparability across VCs and intermediate components assessed for the Project (Section 6.9.1, Residual Effects Classification).

The residual effects classification uses direction, magnitude, geographic extent, duration, reversibility, frequency, and probability of occurrence as criteria. The approach to classify each residual effect criterion is provided in Table 8.2-3.

Table 8.2-3: Definitions Applied to Effects Criteria Classifications for the Assessment of Hydrogeology

Criterion	Rating	Definition
Direction	Positive	Change in measurement indicator results in net improvement or benefit to hydrogeology
	Neutral	Change in measurement indicator results in net balance to hydrogeology
	Negative	Change in measurement indicator results in net degradation or loss to hydrogeology
Magnitude	Qualitative narrative or numeric quantification	Change in measurement indicator is described by effect size (e.g., flow and concentration)
Geographic extent	Project footprint	Change in measurement indicator is confined to the Project footprint
	Local	Change in measurement indicator extends outside the Project footprint but within the LSA
	Regional	Change in measurement indicator extends beyond the LSA but is confined to the RSA
	Beyond regional	Change in measurement indicator extends beyond the RSA
Duration	Qualitative narrative or numeric quantification	Change in measurement indicator is described by effect duration (e.g., months, years, decades, permanent)
Reversibility	Reversible	Change in measurement indicator is reversible within a clearly defined time period
	Irreversible	Change in measurement indicator is predicted to influence hydrogeology indefinitely
Frequency	Occasional	Change in measurement indicator is expected to occur rarely (e.g., once, a few times)
	Periodic	Change in measurement indicator is expected to occur consistently at regular intervals or associated with temporal events (e.g., during dry summers)
	Continuous	Change in measurement indicator is expected to occur all the time
Probability of occurrence	Unlikely	Change in measurement indicator is not expected to occur, but not impossible
	Possible	Change in measurement indicator may occur, but is not likely
	Probable	Change in measurement indicator is likely to occur, but is uncertain
	Certain	Change in measurement indicator will occur

LSA = local study area; RSA = regional study area.

While most criteria could be assigned categorical ratings for hydrogeology, predicted effect sizes were provided in specific terms (i.e., narrative or numeric quantification) in the residual effects characterization (Table 8.2-2). Similarly, duration was described in specific terms (e.g., years). Applying a category rating to a criterion such as magnitude might lead to confusion or misinterpretation of the effects assessment or result in the criterion not being easily categorized in a meaningful way. Characterizing magnitude using an ordinal scale (i.e., low, moderate, or high) in a manner meaningful for hydrogeology is often not appropriate as additional context is required to properly characterize the effects. Universal effect size boundaries, such as a 20% change in a measurement indicator at the RSA or LSA scale used to define a high magnitude effect, work poorly because these size boundaries fail to consider context. Depending on the context of the existing conditions, a 20% change from existing conditions in the study area may be required to cause a high-magnitude effect on one measurement indicator, whereas a 2% change in the study area may be sufficient to cause a high-magnitude effect for another measurement indicator. When categorical definitions were used, magnitude was classified as negligible, low, moderate, or high and supported by a reasoned narrative (Section 6.9.1).

8.2.10 Prediction Confidence and Uncertainty

The purpose of the assessment is to predict the future conditions for hydrogeology with the addition of the Project. As with all predictions of future conditions, the predictions made in this assessment embody some degree of uncertainty. The assessment applied a precautionary (i.e., conservative) approach to address uncertainty by identifying the greatest magnitude, duration, and geographic extent of potential adverse effects when a range of possible outcomes were possible. Consequently, uncertainty was addressed in a manner that increased the level of confidence that residual effects were conservatively estimated. The key uncertainties for hydrogeology and the way they were addressed are presented as part of this assessment (Section 8.6, Prediction Confidence and Uncertainty). The groundwater flow and solute transport results presented in TSD XIV are based on the available best estimates of the input parameters, assumptions, and processes affecting solute transport. Uncertainty in the groundwater flow and solute transport modelling was evaluated through the completion of a sensitivity analysis.

8.2.11 Monitoring, Follow-Up, and Adaptive Management

Monitoring programs are proposed to address the uncertainties associated with the effect predictions and to evaluate the performance of mitigation. In general, monitoring is used to verify the effects predictions. Monitoring is also used to identify any unanticipated effects and to support the implementation of adaptive management to limit these effects. Typically, monitoring includes one or both of the following categories that may be applied during the Project lifespan:

- **Regulatory compliance monitoring:** monitoring activities, procedures, and programs undertaken to confirm the implementation of approved design standards, mitigation, and conditions of approval, and NexGen commitments (e.g., measurement of groundwater elevations and rates of groundwater inflows to the mine during Operations).
- **Follow-up monitoring:** programs designed to test the accuracy of effects predictions, reduce or address uncertainties, determine the effectiveness of mitigation, or provide appropriate feedback to operations for modifying or adopting new mitigation designs, policies, and practices (e.g., implementation of adaptive management). Results from these programs can be used to increase the certainty of effect predictions in future EAs.

Where relevant, conceptual monitoring programs would be proposed to address the uncertainties associated with the effects predictions and mitigation, and upon Project approval, would be included in NexGen's Integrated Management System.

The implementation of robust, long-term environmental testing and monitoring has also been requested by Indigenous Groups to verify protection of the environment, including community-led monitoring during Construction and Operations of the proposed Project (TSD IV: MN-S; TSD V.2: CRDN; TSD VI: YNLR). For example, the Ya'thi Néné Lands and Resources have noted the importance of closely monitoring groundwater, as well as making all monitoring results available to communities within the Athabasca Basin for regular review (YNLRO 2019).

In addition to environmental monitoring programs typically implemented for projects (i.e., as noted above), NexGen is working with local Indigenous Groups to implement independent environmental monitoring. In combination with standard Project monitoring processes, independent Indigenous monitoring would be used to verify Project performance and to determine if mitigations and controls are effective in protecting the receiving environment.

Adaptive management measures may also be proposed to address the uncertainties associated with the effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

8.3 Existing Conditions

8.3.1 Geology

8.3.1.1 Bedrock Geology

The Arrow deposit consists of several high-grade, near-vertical, uranium veins within at least six reactivated high-strain zones. These veins form part of the Patterson Lake structural corridor. The main uranium-bearing mineral present at the Arrow deposit is uraninite. The mineralized area is 315 m wide with an overall strike of 980 m. Mineralization occurs 100 m below surface and extends to a depth of 950 m.

The Arrow deposit is hosted in the Paleoproterozoic basement rocks of the Taltson Domain along the Patterson Lake corridor. The bedrock geology is composed of variably silicified and metasomatized intermediate to mafic orthogneisses. Local mafic-rich amphibolite and pyroxenite, ultrabasic and syenitic dykes, and porphyroblastic feldspar- and quartz-rich pegmatites intrude the gneissic granulite facies rocks. The main fabrics and contacts of crystalline basement rocks in the Arrow deposit area are all steeply dipping, dominantly southeast, with a northeast-southwest strike. Basement rocks are unconformably overlain by late Paleoproterozoic to Mesoproterozoic Athabasca Supergroup sandstones of variable thickness, rarely exceeding 50 m. Devonian and/or Cretaceous sedimentary rocks overlie the Athabasca sandstones, with Quaternary glacial deposits capping the geologic sequence and forming the present-day topography.

Generalized bedrock geology is presented in Figure 8.3-1 and conceptual geological cross-sections are presented in Figure 8.3-2 and Figure 8.3-3. These figures present the lateral and vertical distributions of the geological units, which are summarized from oldest to youngest as follows:

- **Basement rock:** The basement rock within the RSA is predominantly composed of granite or gneiss. The basement rock contact is encountered at elevations ranging from -150 masl to 430 masl. A series of fractures, faults, and shear zones were mapped throughout this unit based on interpretation of exploration boreholes. The primary shear and fault zones within the RSA were mapped as sub-vertical features as they were encountered during borehole drilling.
- **Paleoweathered basement rock (regolith):** Located above the basement rock is a paleoweathered (regolith) unit derived from the same basement rock. This unit ranges in thickness from 20 m to 200 m above the upper contact surface of the basement rock.
- **Athabasca sandstone bedrock:** The Athabasca Supergroup sandstones lie unconformably above paleoweathered basement rock and have been dated at 1.85 billion years to 1.54 billion years (Bosman and Ramaekers 2015). This formation is present within the northern half of the RSA and increases in thickness towards the north. The upper contact of this formation is encountered at elevations of

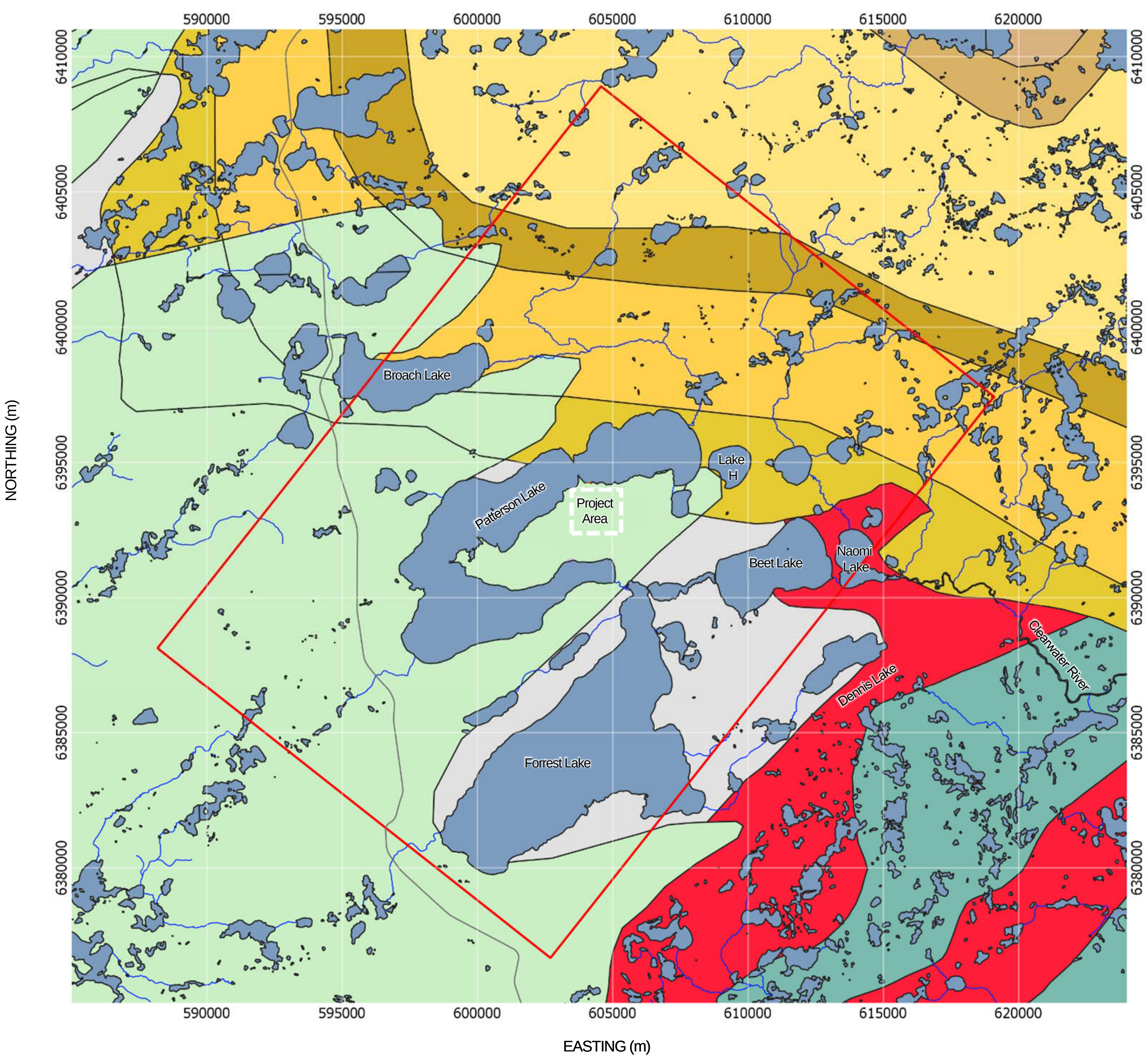
approximately 490 masl in the vicinity of the Arrow deposit but dips to approximately 340 masl in the northeastern portion of the RSA. The formation varies in thickness from 0 m near the Arrow deposit to greater than 400 m in the northern portion of the RSA. The sedimentary sandstone formations vary in grain size and matrix. Grain sizes vary from fine to coarse and are predominantly lithified with silica matrix. Zones of desilicified sandstone are present and often have a vuggy texture (i.e., containing cavities). Layers of sandstones that have been desilicified are locally very friable (i.e., easily crumbled) and weak. The sandstone formations are interbedded with zones of clay-rich cementation.

- **Devonian bedrock:** The Devonian bedrock in the RSA is composed of carbonate-rich interbedded sandstone, siltstone, and mudstone of the Elk Point Group. The Devonian age bedrock is discontinuous within the RSA but is present under the proposed Project site and in the southern portion of the RSA. The Devonian formations are present at elevations ranging from approximately 380 masl to 500 masl and in thicknesses ranging from 0 m to 60 m.
- **Cretaceous bedrock:** The Cretaceous bedrock in the RSA is subdivided into an upper unit and lower unit. The upper unit consists of a green to grey-black, fine- to medium-grained quartz sandstone interbedded with fissile mudstones. The lower unit consists of brown, fine- to coarse- grained quartz sandstones cross-bedded with minimal mudstones. This lower unit is commonly saturated with bitumen and is likely a part of the McMurray Formation (Paterson et al. 1978). The Cretaceous formations are discontinuous within the RSA but are present directly underlying the proposed Project site and encountered at elevations of 390 masl to 600 masl with thicknesses ranging from 0 m to 100 m.

Stacked, near-vertical, northeast-southwest-striking, relatively quartz-poor, low- to medium-grade mylonites and phyllonites are interpreted within the basement rock. The major high-strain zones are separated by relatively unstrained, silicified blocks of wall rock. Six individual shear zones were identified, varying in thickness from 2 m to 60 m.

The Arrow deposit deformation zone contains abundant brittle fault rocks including incohesive fault breccias, cataclasites, and fault gouge, with rare cohesive cataclasites. Metre-scale extensional fault-fill veins also overprint ductile strain and are encompassed by fault damage zones of shear fractures and linkages, tension gashes, and hydraulic (i.e., fluid over-pressuring) breccias. Cohesive quartz-healed breccias are prolific at the Arrow deposit, often showing evidence for multiple phases of brecciation with quartz matrix becoming clasts along with wall rock in younger, overprinting breccias. Fault breccia zones have been logged as deep as 1 km in drill hole depth and as shallow as the unconformity surface.

Additional details on the bedrock geology can be found in the Geology Baseline Report (Annex XI).



LEGEND

- Extent of Groundwater Flow Model
- Watercourse
- Waterbody
- Roads

Bedrock Geology

- Cretaceous Mudstone/Siltstone (Manville Group)

Athabasca Basin Sandstone

Lazenby Lake Formation

- Lartner Group
- Shiels Group

Manitou Falls Formation

- Clampitt-Dunlop Grp.
- Hodge Group
- Warnes Group
- Bird Group

Precambrian Basement Rock

- Taltson Grp. Granite
- Taltson Grp. Felsic Granulite
- Unexposed Precambrian Shield

Note:

1) Surface water features shown for Clearwater River catchment only

2) Bedrock geology data from Saskatchewan Geological Survey, Ministry of Energy and Resources, 1:250,000 Geology Map (2013)

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YYYY-MM-DD	2021-06-28
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APPROVED	MT

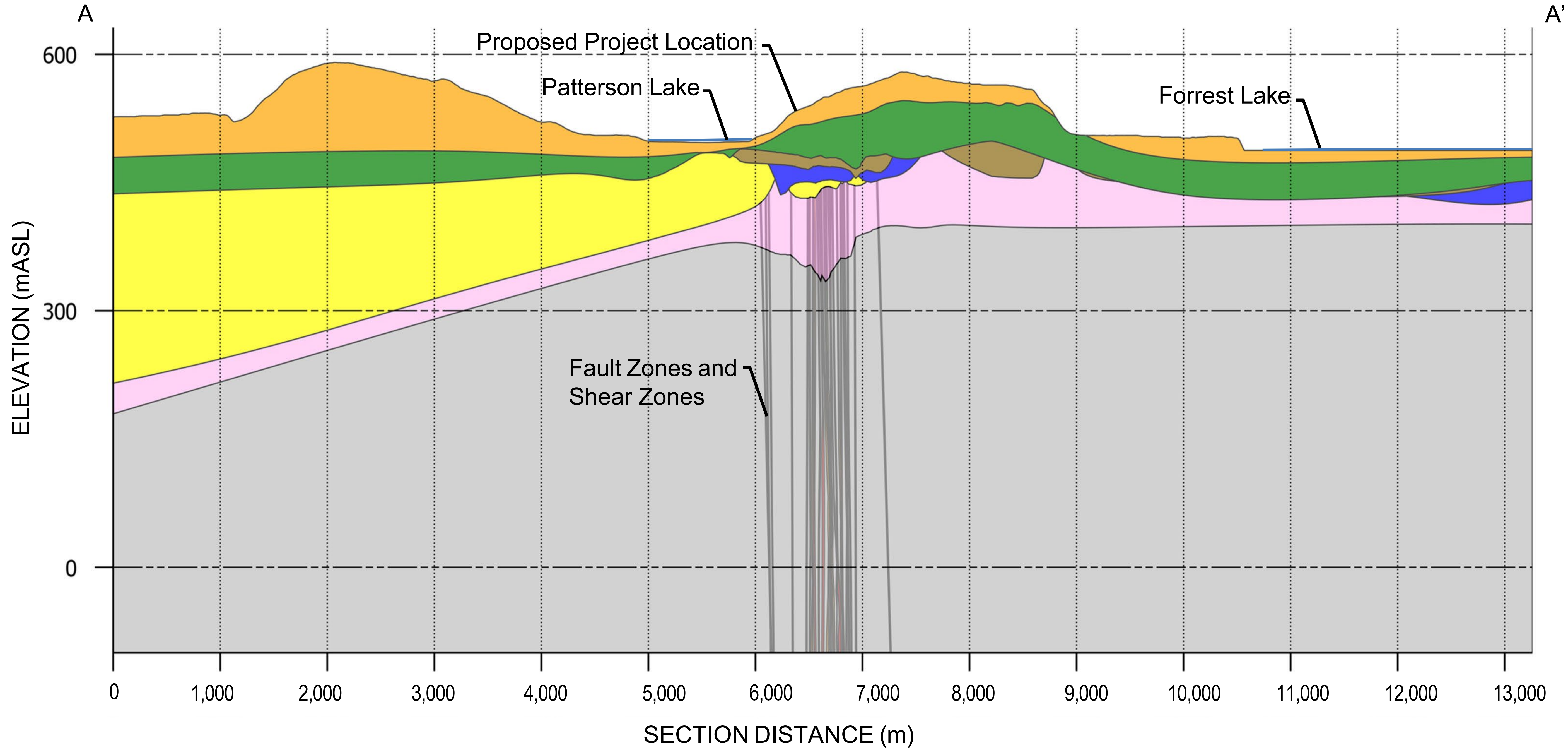
PROJECT

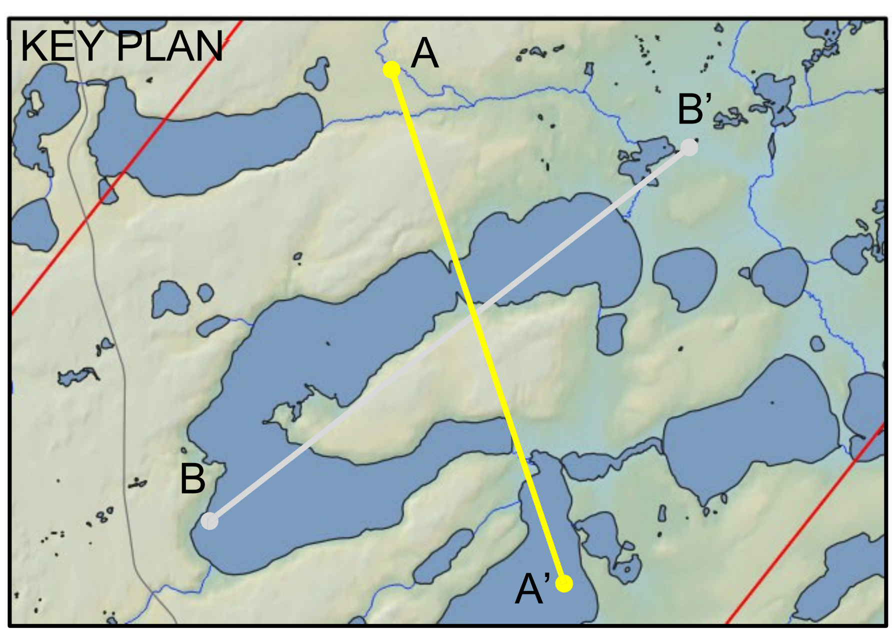
ROOK I PROJECT

TITLE

BEDROCK GEOLOGY

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	8.3-1





LEGEND

- UPPER OVERBURDEN
- LOWER OVERBURDEN (TILL)
- CRETACEOUS BEDROCK
- DEVONIAN BEDROCK
- SANDSTONE BEDROCK
- PALEOWEATHERED BASEMENT ROCK
- BASEMENT ROCK
- SHEAR ZONE
- FAULT ZONE

Notes:
Vertical exaggeration: 8x
masl – metres above sea level

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DESIGN	CT
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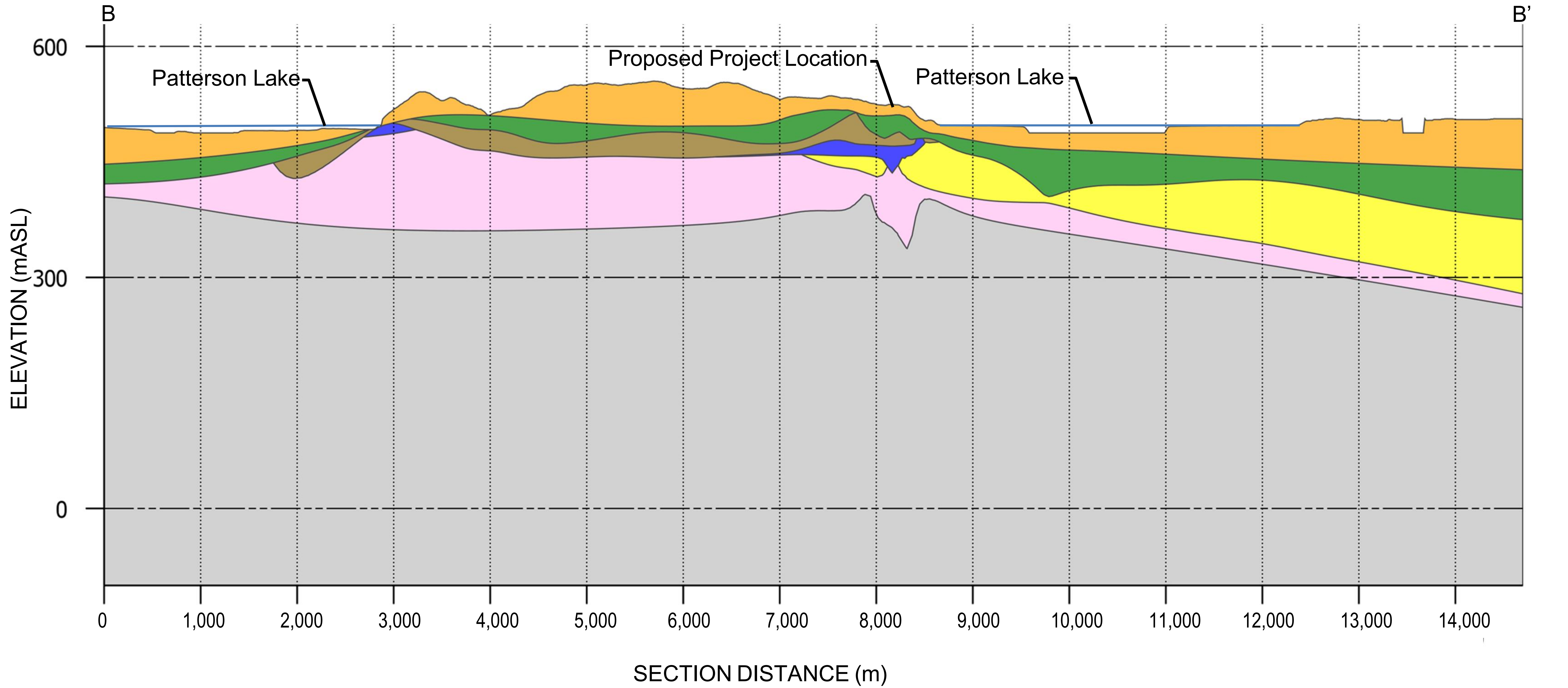
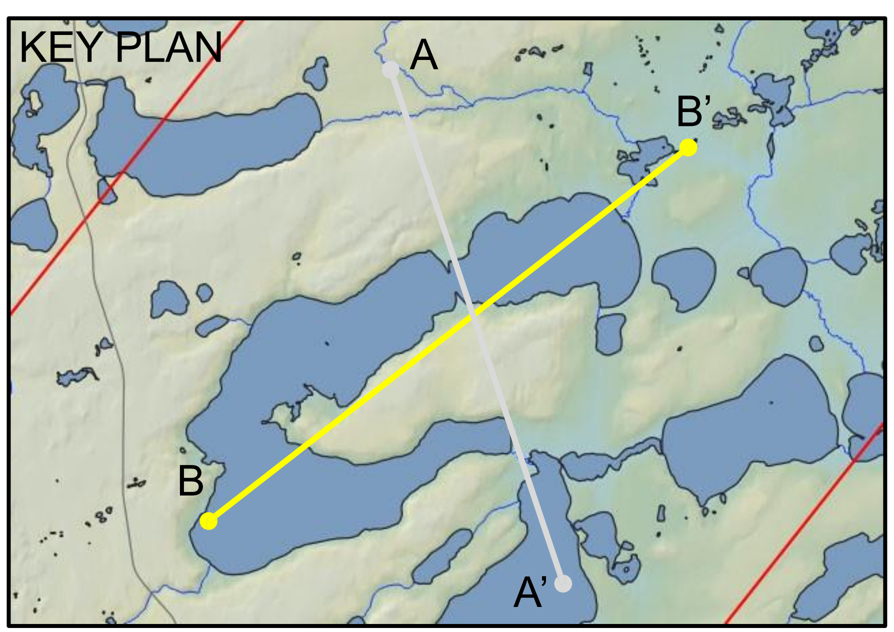
APPROVED	MT

PROJECT
ROOK I PROJECT

TITLE
GEOLOGIC CROSS-SECTION (A-A'; NORTHWEST-SOUTHEAST)

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	8.3-2





LEGEND

- UPPER OVERBURDEN
- LOWER OVERBURDEN (TILL)
- CRETACEOUS BEDROCK
- DEVONIAN BEDROCK
- SANDSTONE BEDROCK
- PALEOWEATHERED BASEMENT ROCK
- BASEMENT ROCK

Notes:
Vertical exaggeration: 8x
masl = metres above sea level

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YYYY-MM-DD	2020-06-28
PREPARED	CT
DESIGN	CT
REVIEW	NB
APPROVED	MT

PROJECT
ROOK I PROJECT

TITLE
GEOLOGIC CROSS-SECTION (B-B’; NORTHWEST-SOUTHEAST)

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	8.3-3

8.3.1.2 Surficial Geology

Mapping of the surficial geology in the vicinity of the proposed Project is illustrated in Figure 8.3-4. As shown on this figure, the surficial geology is composed of glacial drift deposits. The glacial drift is differentiated by the deposition mechanism and the materials deposited. The central portion of the RSA is primarily composed of glaciolacustrine sand, silt, and clay. The north and east corners of the RSA are composed of glaciofluvial gravel, sand, and silt deposits and the south and west corners of the RSA are composed of morainal tills. The glacial tills are derived from both crystalline basement rocks as well as relatively soft Athabasca Sandstones. In general, the thickness of the glacial tills increases towards the southwest (Campbell 2007).

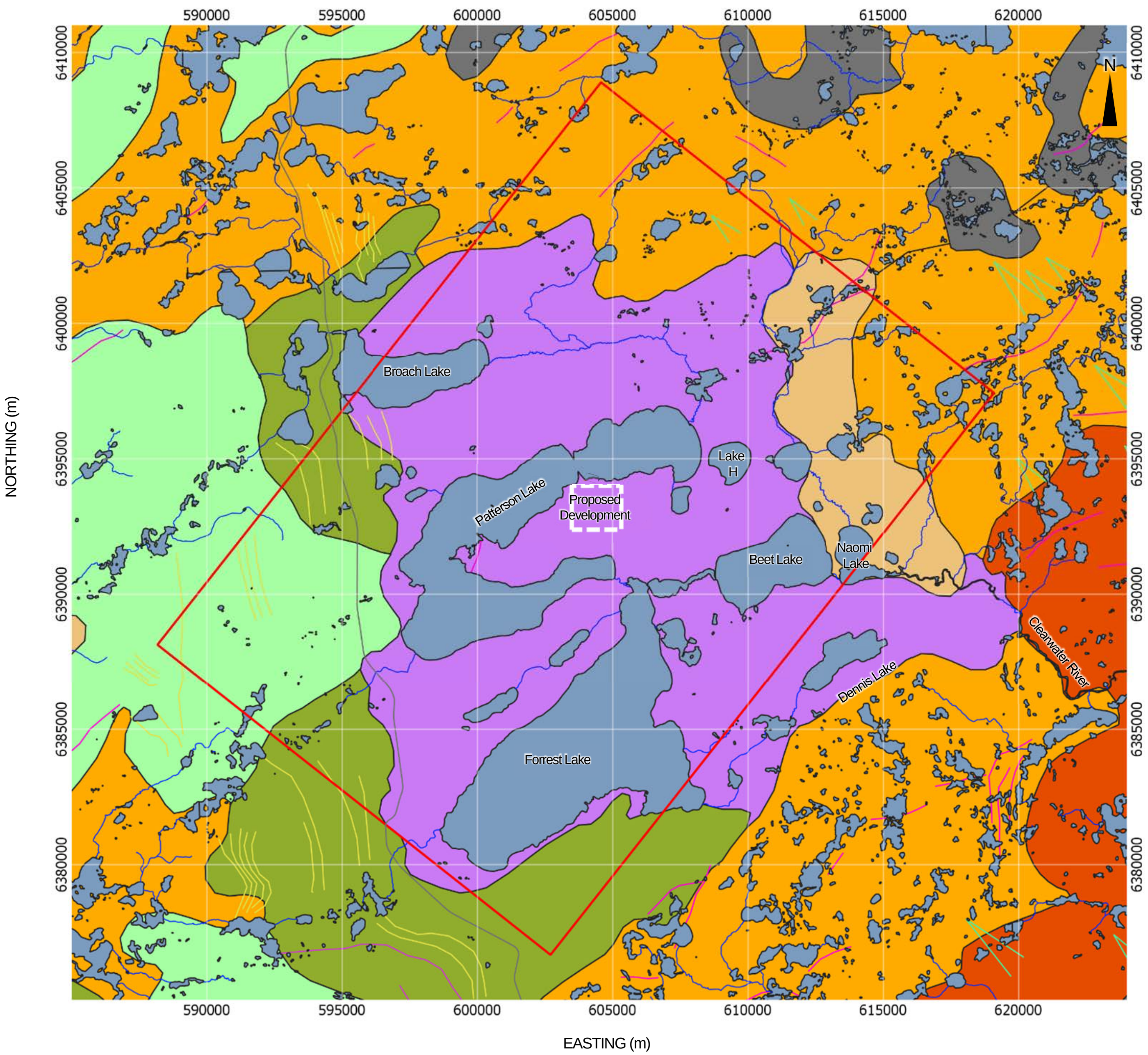
The glacial drift is divided into two sub-units, referred to as the “upper overburden” and “lower overburden”. The upper overburden is characterized by higher sand and boulder content and is generally located above the water table (NexGen 2019b). The lower overburden is characterized by higher fines content and is generally located below the water table (NexGen 2019c). The glacial drift deposits were differentiated as the upper and lower units. The total thickness of the glacial drift ranges from approximately 10 m to 200 m. Based on the available lake bathymetry and the interpreted bedrock surface, the glacial drift is not present in the deeper portions of Patterson Lake and Forrest Lake.

Results from the particle size distribution testing indicate that soils are primarily composed of fine to medium sands with trace to some gravel and trace to some silt and clay. Soil grading ranged from poorly graded to uniformly graded. Sand content ranged from 13% to 98%, with a mean of 65%, and fines content (i.e., less than 0.075 mm diameter) ranged from 1% to 87%, with a mean of 24% (BGC 2017). Gravel content ranged from 0% to 70%, with the majority in the range of 0% to 20% (indicating a trace to some gravel) and a mean of 11%. Occasional to some cobbles and boulders were encountered at all locations, generally within the upper 20 m from ground surface; as per standard practice, these cobbles and boulders are not included in the particle size distributions (BGC 2017).

Soil plasticity testing results indicated that five of seven glacial drift samples tested were non-cohesive and do not exhibit plastic soil properties. The results for the two cohesive samples tested gave a range in Plastic Limit from 16 to 18, and a range in Liquid Limit from 29 to 35. Both results indicate soil behaviour characterized as low-plasticity clay (BGC 2017).

Results from the moisture content testing indicated moisture content ranged from 8.9% to 23.6%, with most between 13% and 16%; the mean value was 15.4% (BGC 2017).

Additional details regarding geology are provided in Appendix 8A, Geology Supplement.



LEGEND

- Extent of Groundwater Flow Model
- Watercourse
- Waterbody
- Roads

Surficial Geology

- Organic Deposits
- Glaciofluvial Gravel, Sand and Silt (hummocky)
- Glaciofluvial Gravel, Sand and Silt (eroded)
- Glaciofluvial Sand Silt and Clay (outwash)
- Glaciolacustrine Sand, Silt, and Clay
- Morainal Till (plain)
- Morainal Till (Ridged)
- Eskers
- Ribbed Moraine
- Dunes

Note:

1) Surface water features shown for Clearwater River catchment only

2) Surficial geology data from Saskatchewan Geological Survey, Ministry of Energy and Resources, 1:250,000 Surficial Geology Map (2008)

3) UTM Zone 12 Datum: North American Datum 83

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YYYY-MM-DD	2021-06-28
PREPARED	NB
DESIGN	NB
REVIEW	MT
APPROVED	MT

TITLE
SURFICIAL GEOLOGY

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	8.3-4

8.3.2 Hydrostratigraphy

Hydrostratigraphic units are geological strata exhibiting similar hydraulic properties and thus have the ability to store and convey groundwater that is generally classified as aquifers (i.e., having the ability to produce relatively large quantities of water) and aquitards (i.e., barriers to groundwater flow or confining units). Hydrostratigraphic units were defined based primarily on the geological units that exhibit similar hydraulic properties and structures. The following is a summary of the hydraulic characteristics associated with these units:

- **Basement rock:** Given the relatively low porosity and permeability of this rock (Section 8.3.4, Hydraulic Properties), the primary hydraulic pathways within this unit on the scale of the mine development are anticipated to be fractured bedrock associated with fault and shear zones. These enhanced conductivity features define the overall hydraulic conditions of the formation.
- **Athabasca sandstone bedrock:** Layers of sandstones that have been desilicified are the dominant areas in which groundwater advection occurs and are considered the primary aquifer (i.e., most permeable zone) within the Athabasca Supergroup. As a result of the bedding of this unit, the enhanced permeability zones are likely to dominate the horizontal hydraulic conductivity for the sequence. The sandstone formations are interbedded with zones of clay-rich cementation, which act as an aquitard within the Athabasca Supergroup, inhibiting the vertical movement of water. The vertical hydraulic conductivity is therefore considered to be lower than the horizontal hydraulic conductivity (i.e., water is less resistant to lateral flow compared to vertical flow).
- **Devonian and cretaceous bedrock:** These units are discontinuous over the RSA. Where present, these are considered to be aquitards based on the available hydraulic conductivity estimates (Section 8.3.4). Due to interbedding within the formations, the vertical movement of groundwater is impeded by the lower conductivity units (i.e., silt/mud stones). As such, the horizontal bedding is considered to be the primary pathways of groundwater movement.
- **Glacial drift:** The unconsolidated glacial drift deposits are present throughout the RSA. Based on its relatively coarse-grained nature within the vicinity of the Project, this unit is considered to be an unconfined aquifer.

8.3.3 Groundwater Elevations

8.3.3.1 Bedrock

A summary of the groundwater elevations within the bedrock units is presented in Table 8.3-1. Figure 8.3-5 and Figure 8.3-6 present the existing bedrock groundwater elevation contours at the levels that would be associated with mid-mine (300 masl to 480 masl) and deep mine (40 masl to 300 masl), respectively. A summary of calculated total head values by bedrock hydrostratigraphic unit and instrument borehole name is presented in Table 8.3-1.

Hydraulic head measurements recorded within the bedrock Westbay wells and VWP sensors indicate that static groundwater elevations ranged from between approximately 498 masl and 513 masl. At GAR-19-035, groundwater elevation data was collected shortly after installation, and is not considered to be representative of static hydraulic conditions. Horizontal groundwater flow directions were generally towards the north, with hydraulic gradients in the range of approximately 0.003 m/m to 0.01 m/m. Comparatively, vertical gradients are typically between 0.01 m/m and 0.02 m/m (i.e., with an upwards direction of groundwater flow).

Data from continuously monitored VWPs indicate relatively minor seasonal variability in bedrock groundwater elevations (i.e., typically on the order of +/- 1 m).

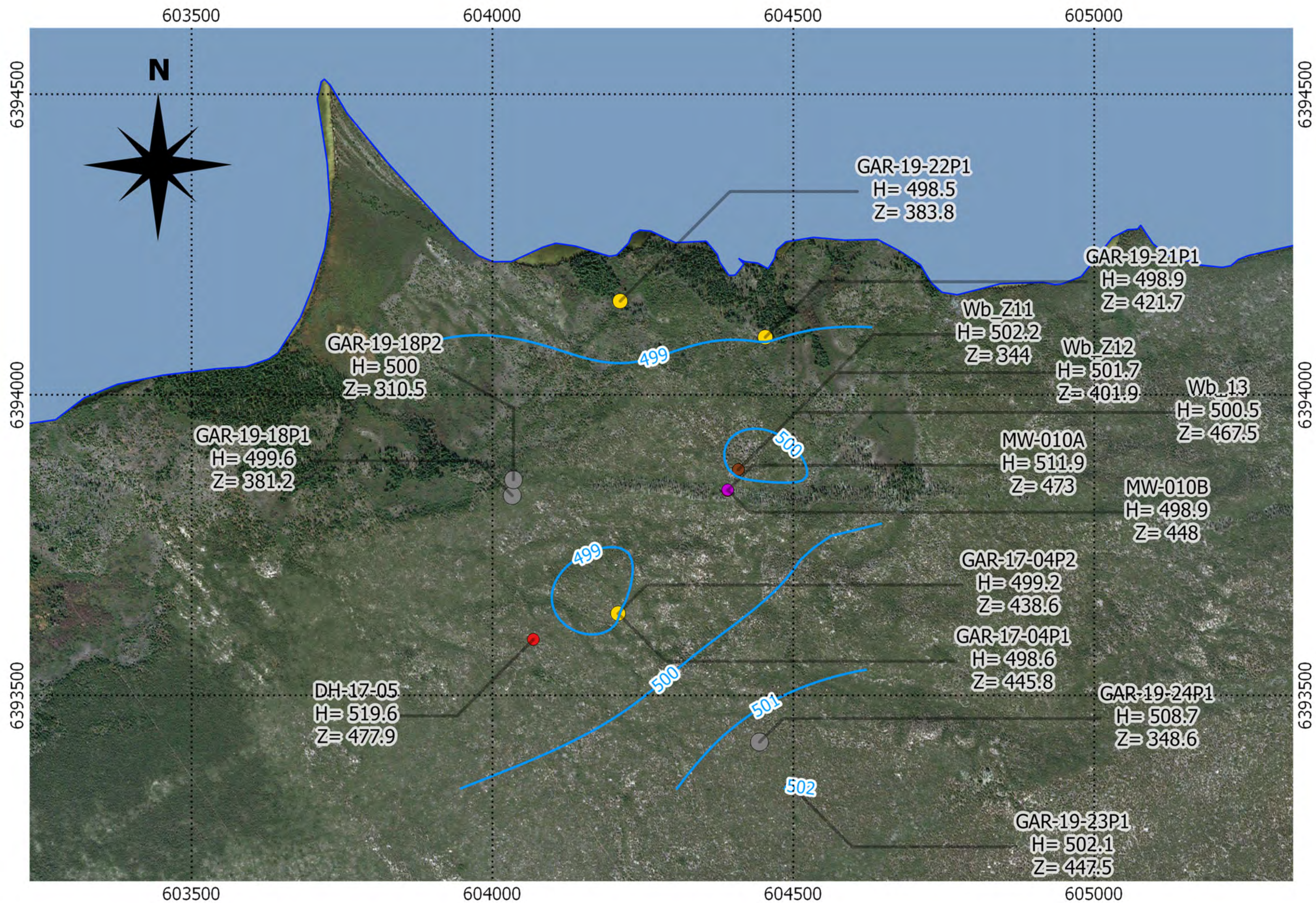
Table 8.3-1: Summary of Bedrock Groundwater Elevations

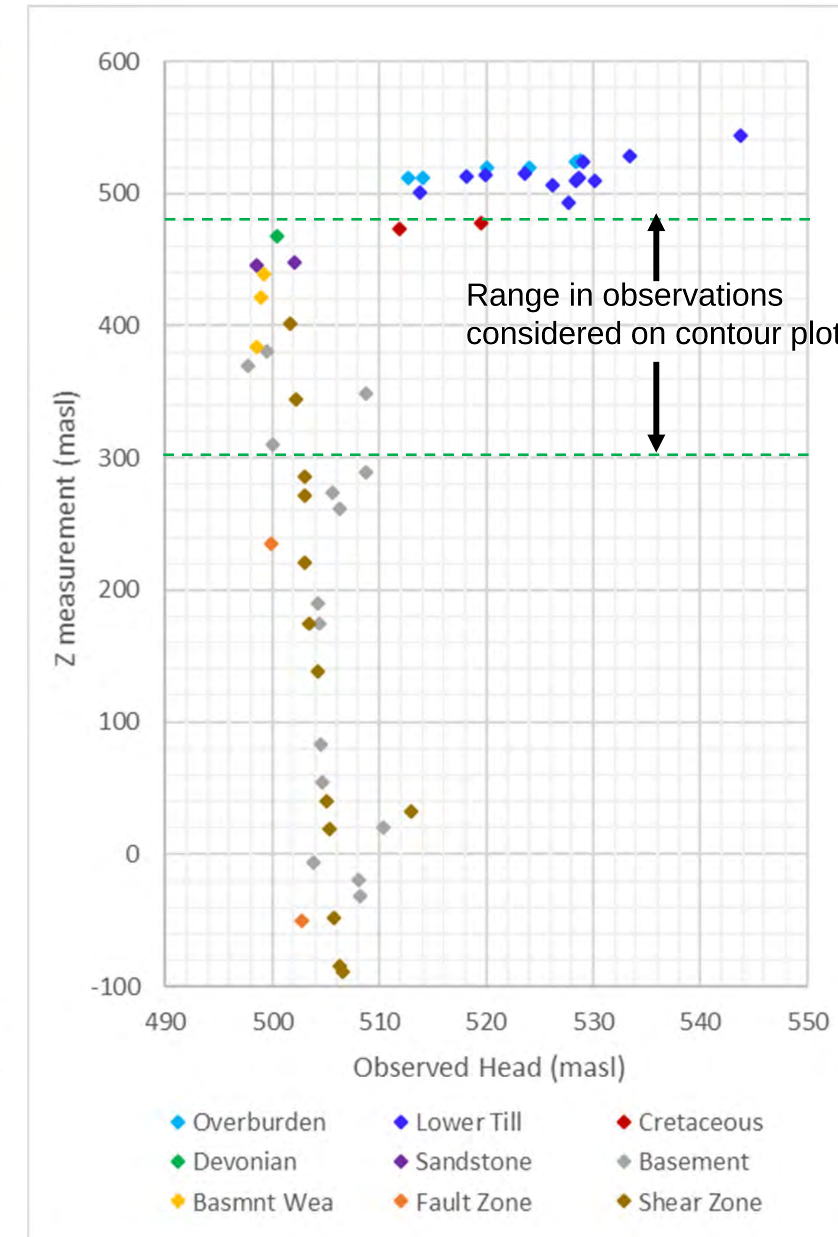
Borehole Name	Identifier	Type	Depth (mah)	Monitoring Point Elevation Midpoint (masl)	Total Head (masl)	Hydrostratigraphic Unit
GAR-17-001	VWP1-303	VWP	303.4	261.6	506.37	Basement
GAR-17-002	VWP1-654	VWP	654.0	-50.5	502.73	Basement
GAR-17-003	VWP1-276	VWP	275.6	271.7	503.09	Basement
GAR-17-004	VWP1-99	VWP	98.5	445.8	498.59	Athabasca Sandstone
	VWP2-106	VWP	105.7	438.6	499.16	Paleoweathered Basement
GAR-19-018	VWP1-159	VWP	159.0	381.2	499.55	Basement
	VWP2-235	VWP	234.5	310.5	500.00	Basement
	VWP3-363	VWP	362.5	190.5	504.23	Basement
	VWP4-544	VWP	544.4	20.6	510.41	Basement
GAR-19-019	VWP1-146	VWP	145.8	369.9	497.74	Basement
	VWP2-248	VWP	248.0	273.5	505.67	Basement
	VWP3-353	VWP	352.5	175.1	504.45	Basement
	VWP4-545	VWP	545.4	-6.2	503.86	Basement
GAR-19-021	VWP1-86	VWP	85.7	421.7	499.00	Paleoweathered Basement
GAR-19-022	VWP1-131	VWP	131.3	383.8	498.55	Paleoweathered Basement
	VWP2-287	VWP	287.2	235.5	499.90	Basement
	VWP3-482	VWP	482.2	53.9	504.69	Basement
	VWP4-576	VWP	575.5	-31.2	508.26	Basement
GAR-19-023	VWP1-116	VWP	116.0	447.5	502.06	Athabasca Sandstone
GAR-19-024	VWP1-234	VWP	233.9	348.6	508.73	Basement
	VWP2-301	VWP	301.0	289.3	508.73	Basement
	VWP3-594	VWP	594.3	32.5	513.01	Basement
	VWP4-655	VWP	654.6	-19.3	508.08	Basement
GAR-18-013	1	Westbay	623.6	-101.2	505.39	Basement
	2	Westbay	582.4	-62.8	505.38	Basement
	3	Westbay	515.3	-10.9	505.26	Basement
	4	Westbay	493.9	33.4	504.99	Basement
	5	Westbay	451.1	65.4	504.84	Basement
	6	Westbay	396.2	114.3	504.53	Basement
	7	Westbay	359.6	160.1	504.13	Basement
	8	Westbay	313.8	211.3	503.83	Basement
	9	Westbay	248.3	256.9	503.39	Basement
	10	Westbay	190.4	318.6	502.64	Basement
	11	Westbay	132.4	376.5	501.82	Basement

Table 8.3-1: Summary of Bedrock Groundwater Elevations

Borehole Name	Identifier	Type	Depth (mah)	Monitoring Point Elevation Midpoint (masl)	Total Head (masl)	Hydrostratigraphic Unit
GAR-19-035[a]	1	Westbay	646.0	-163.2	475.16	Basement
	2	Westbay	588.0	-100.5	477.17	Basement
	3	Westbay	530.0	-47.1	479.07	Basement
	4	Westbay	472.0	10.9	480.99	Basement
	5	Westbay	412.6	69.6	498.87	Basement
	6	Westbay	353.1	129.1	485.05	Basement
	7	Westbay	301.3	184.8	486.45	Basement
	8	Westbay	255.6	233.6	488.19	Basement
	9	Westbay	211.4	278.6	490.02	Basement
	10	Westbay	167.3	322.8	491.61	Basement

a) Groundwater elevations were collected soon after installation and are not considered representative of static conditions.
masl = metres above sea level; n/a = not available; VWP = vibrating wire piezometer; mah = metres along hole.





LEYEND

- WATER BODY
- GROUNDWATER CONTOUR

OBSERVATION POINT
Name
H= GW Elv
Z= Meas Elv

OBSERVATION POINT BY UNIT
- Basement
- Basement (w)
- Sandstone
- Cretaceous
- Devonian
- Shear Zone

NOTAS

1. Groundwater observation point labels shows name of the borehole, groundwater elevation (GW Elv) and measurement point elevation (Meas Elv) which considers the screen mid-point for screened boreholes, or the exact elevation for vibrating wires.
2. Groundwater contour level shown on top of the line.
3. Cretaceous and GAR-19-24P1 observations ignored for contour definition. Cretaceous water levels observed shows a behavior similar to shallow boreholes, while GAR-19-24P1 measuring location is deeper than surrounding observations.
4. masl = metres above sea level

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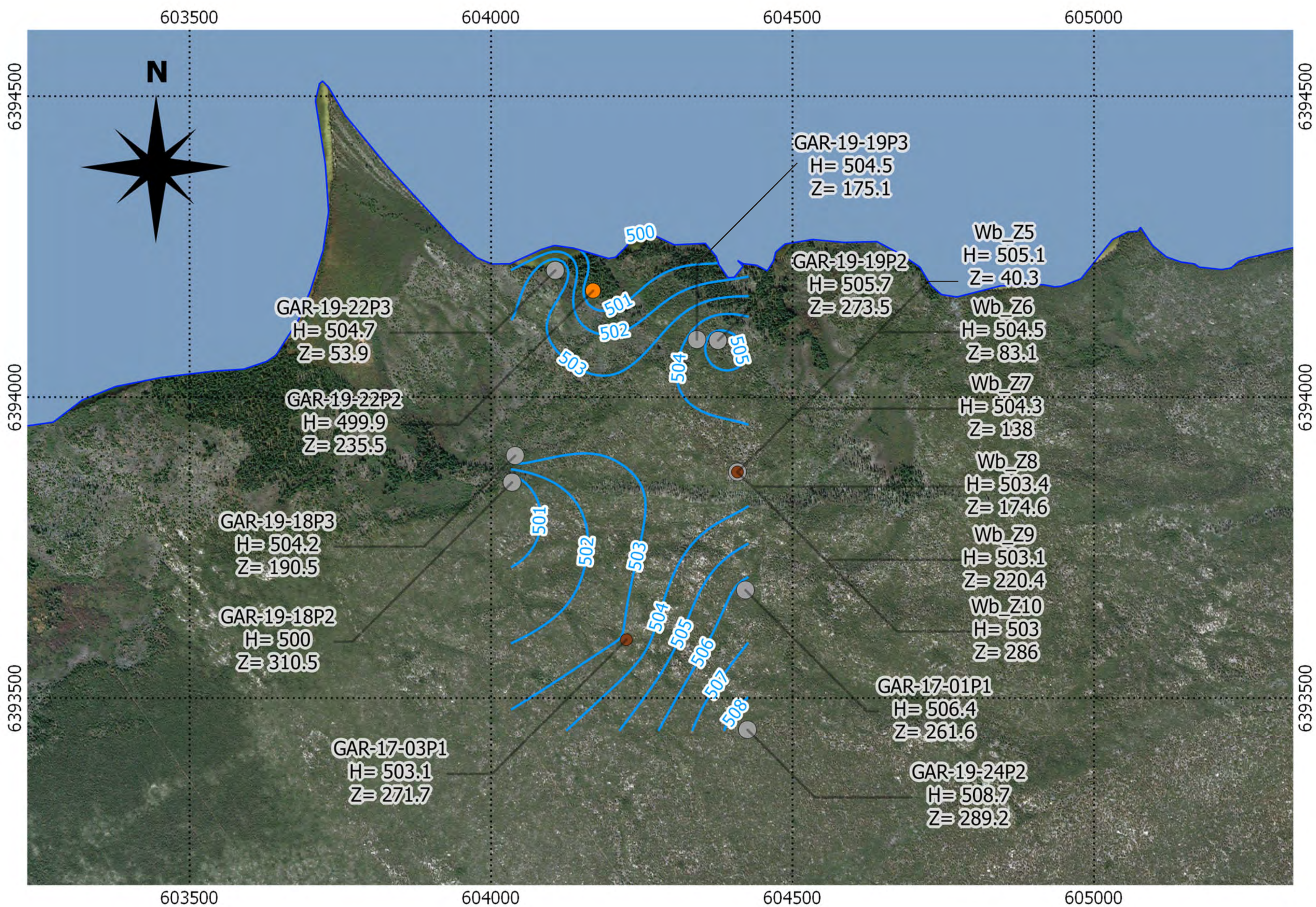
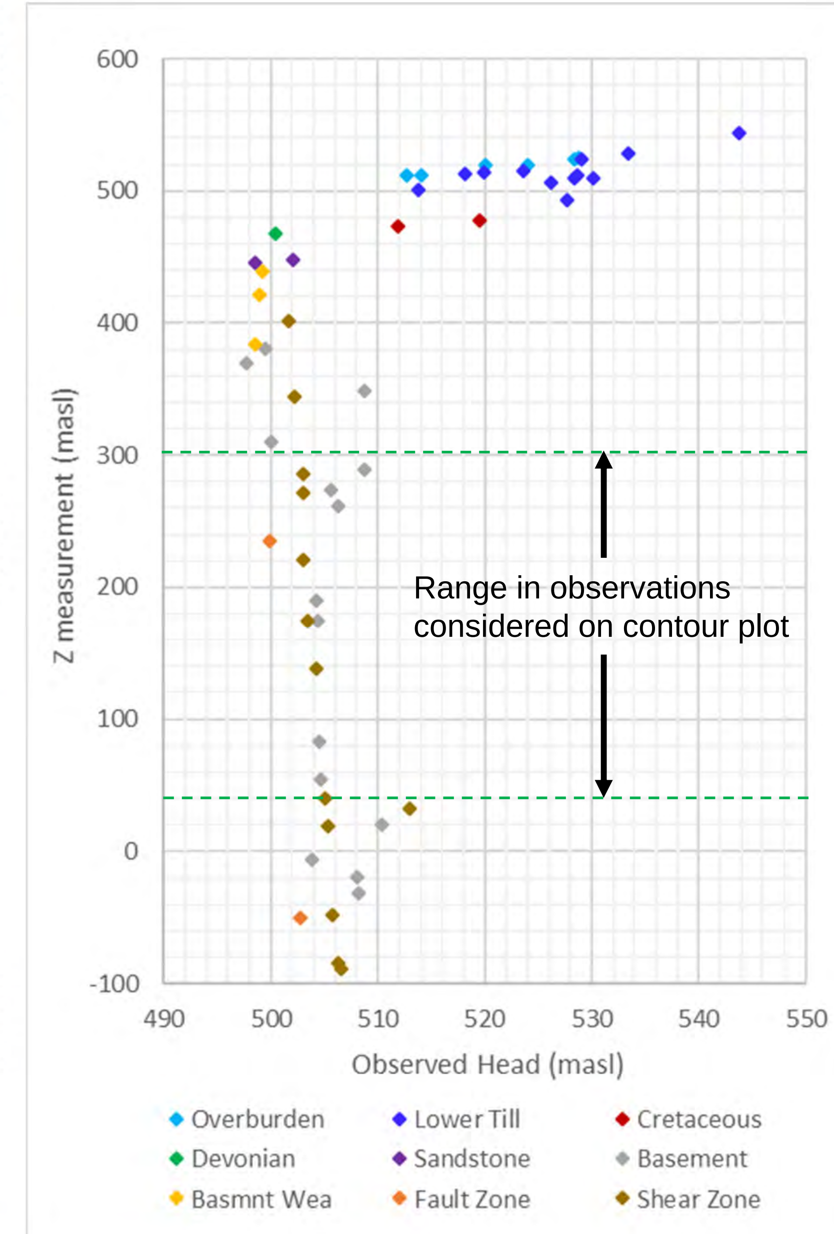
YYYY-MM-DD	2021-06-28
PREPARED	GI
DESIGN	GI
REVIEW	NB
APPROVED	MT

PROJECT
ROOK I PROJECT

TITLE
GROUNDWATER CONTOUR MAPS (MID-MINE LEVEL; 300 mASL to 480 mASL)

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	8.3-5





LEGEND

WATER BODY
GROUNDWATER CONTOUR

OBSERVATION POINT
- Name
  H= GW Elv
  Z= Meas Elv

OBSERVATION POINT BY UNIT
- Basement
- Fault Zone
- Shear Zone

NOTAS

1. Groundwater observation point labels shows name of the borehole, groundwater elevation (GW Elv) and measurement point elevation (Meas Elv) which considers the screen mid-point for screened boreholes, or the exact elevation for vibrating wires.
2. Groundwater contour level shown on top of the line.
3. masl = metres above sea level

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YYYY-MM-DD	2021-06-28
PREPARED	GI
DESIGN	GI
REVIEW	NB
APPROVED	MT

PROJECT
ROOK I PROJECT

TITLE
GROUNDWATER CONTOUR MAPS (DEEP MINE LEVEL; 40 mASL to 300 mASL)

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	8.3-6

8.3.3.2 Glacial Drift

A summary of the hydraulic head conditions within the glacial drift standpipe piezometer monitoring network is presented in Table 8.3-2. The table includes data collected in 2019 as these data provide the most complete, and therefore representative, snapshot across most monitoring locations available at the time of the assessment. Figure 8.3-7 presents the interpreted glacial drift groundwater elevation contours.

Hydraulic head measurements recorded within the glacial drift standpipe piezometer network indicated that total head varies between approximately 499 masl and 540 masl across the site. Within the area of monitoring well installations in the overburden, the direction of groundwater flow is to the north (i.e., towards Patterson Lake) with a hydraulic gradient of generally around 0.02 m/m.

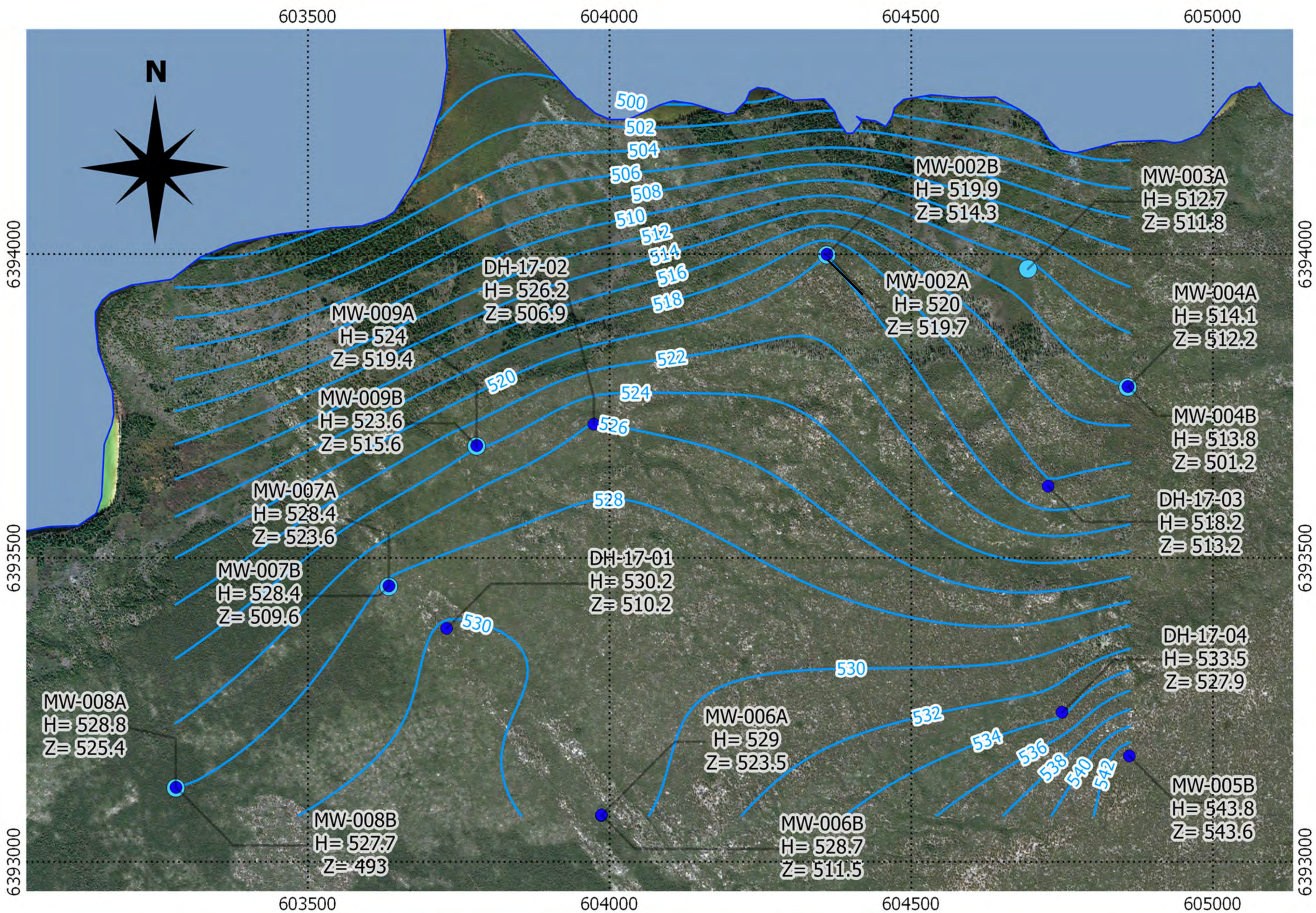
Table 8.3-2: Summary of Hydraulic Head Conditions within the Glacial Drift Standpipe Piezometer Monitoring Network Wells

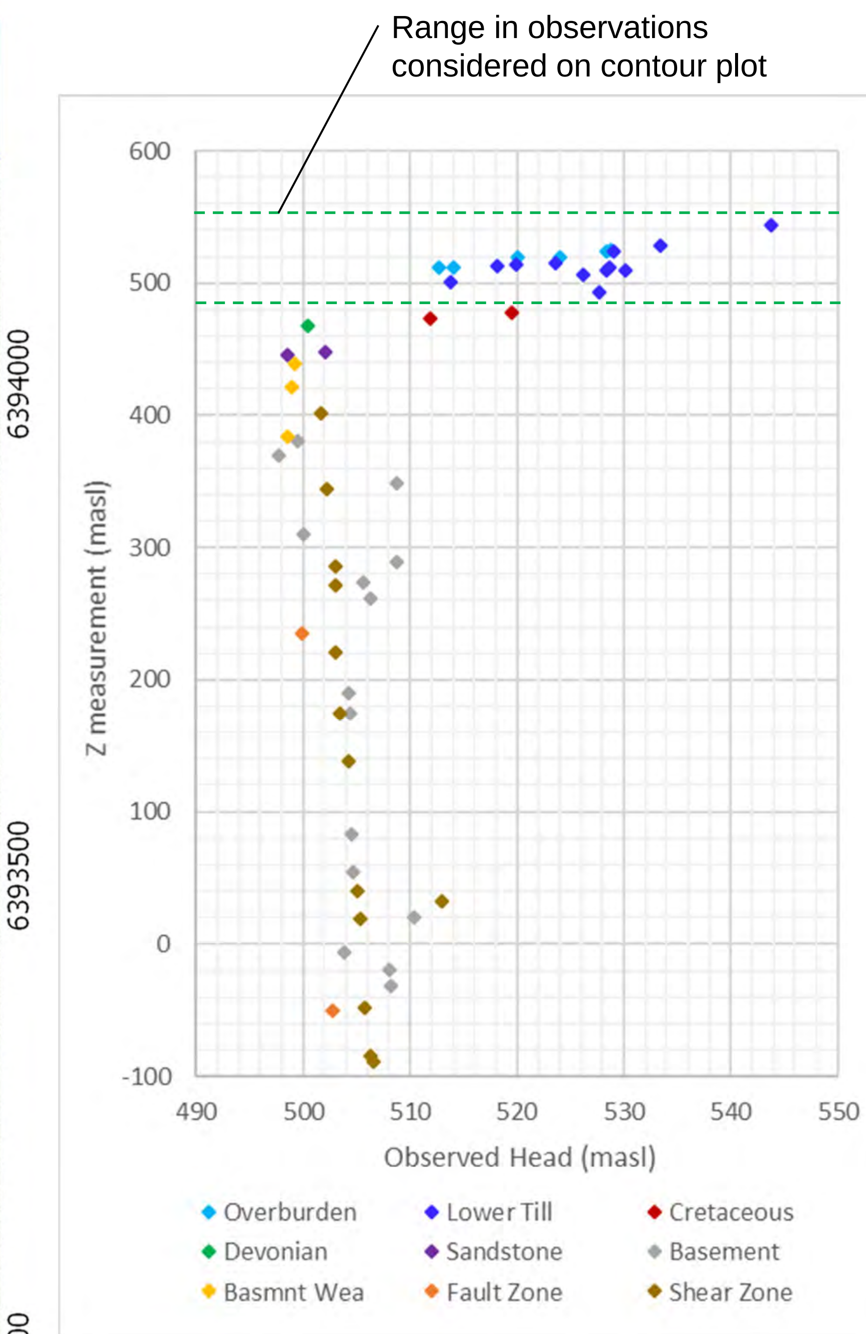
Monitoring Well ID	Ground Elevation (masl)	Borehole Total Depth (mbgs)	Screened Interval		Water Level (mbtoc)	Total Head (masl)	Measurement Date	Instrumented Formation
			From (mbgs)	To (mbgs)				
DH-BGC17-01	540.13	29.9	26.1	29.2	11.17	530.19	23-May-19	Glacial drift
DH-BGC17-02	530.71	23.8	11.1	14.2	5.51	526.15	23-May-19	Glacial drift
DH-BGC17-03	552.19	39.0	35.3	38.4	35.17	518.16	23-May-19	Glacial drift
DH-BGC17-04	576.11	48.2	44.3	47.4	48.52	528.76	16-Dec-18	Glacial drift
DH-BGC17-05	541.29	63.4	56.2	58.1	22.76	519.57	23-May-19	Cretaceous bedrock
2018-MW-001A	500.31	14.5	3.9	4.9	1.22	499.97	23-May-19	Glacial drift
2018-MW-001B			8.5	9.5	1.12	500.07	23-May-19	Glacial drift
2018-MW-002A	526.45	17.4	5.4	6.9	6.41	521.01	23-May-19	Glacial drift
2018-MW-002B			10.8	12.3	6.52	520.90	23-May-19	Glacial drift
2018-MW-003A	513.58	8.5	1.3	1.8	0.56	513.96	23-May-19	Glacial drift
2018-MW-004A	527.36	29.6	13.8	15.3	13.30	514.76	23-May-19	Glacial drift
2018-MW-004B			24.8	26.3	13.54	514.52	23-May-19	Glacial drift
2018-MW-005A	576.02	39.0	11.1	12.6	Dry	n/c	23-May-19	Glacial drift
2018-MW-005B			30.9	32.4	Dry	n/c	23-May-19	Glacial drift
2018-MW-006A	545.32	36.0	20.4	21.9	16.33	529.83	23-May-19	Glacial drift
2018-MW-006B			32.3	33.8	16.67	529.49	23-May-19	Glacial drift
2018-MW-007A	534.63	32.9	9.7	11.2	6.24	529.25	23-May-19	Glacial drift
2018-MW-007B			23.5	25.0	6.23	528.96	23-May-19	Glacial drift
2018-MW-008A	534.18	45.1	7.3	9.8	5.37	529.71	23-May-19	Glacial drift
2018-MW-008B			39.7	41.2	6.51	528.57	23-May-19	Glacial drift
2018-MW-009A	526.81	14.6	6.0	7.5	2.84	524.83	23-May-19	Glacial drift
2018-MW-009B			10.7	11.2	3.22	524.45	23-May-19	Glacial drift
2018-MW-010A	537.04	91.6	61.0	64.0	25.11	512.71	23-May-19	Cretaceous bedrock
2018-MW-010B			86.1	89.2	38.18	499.64	23-May-19	Devonian bedrock
2019-MW-011A	525.14	60.4	7.0	10.0	5.78	520.41	08-Sep-19	Glacial drift
2019-MW-011B			56.5	59.6	22.73	503.46	08-Sep-19	Glacial drift

Table 8.3-2: Summary of Hydraulic Head Conditions within the Glacial Drift Standpipe Piezometer Monitoring Network Wells

Monitoring Well ID	Ground Elevation (masl)	Borehole Total Depth (mbgs)	Screened Interval		Water Level (mbtoc)	Total Head (masl)	Measurement Date	Instrumented Formation
			From (mbgs)	To (mbgs)				
2019-MW-012A	506.39	78.4	41.0	44.1	6.09	501.65	07-Sep-19	Glacial drift
2019-MW-012B			69.0	72.1	8.03	499.32	07-Sep-19	Glacial drift
2019-MW-013A	507.02	17.7	14.2	17.3	Artesian	n/c	n/c	Glacial drift
2019-MW-014A	543.66	95.5	74.2	77.3	39.48	505.63	07-Sep-19	Glacial drift
2019-MW-016A	544.29	30.0	25.0	28.1	16.40	529.04	08-Sep-19	Glacial drift
2019-MW-017A	531.01	40.6	15.0	18.1	7.97	524.29	07-Sep-19	Glacial drift
2019-MW-018A	520.55	51.3	23.0	26.1	3.52	518.38	07-Sep-19	Glacial drift
2019-MW-018B			38.0	41.1	8.28	513.67	07-Sep-19	Glacial drift

masl = metres above sea level; mbgs = metres below ground surface; mbtoc = metres below top of casing; n/c = not calculated.





LEYEND

WATER BODY

GROUNDWATER CONTOUR

OBSERVATION POINT

- Name
  H= GW Elv
  Z= Meas Elv

OBSERVATION POINT BY UNIT

- Overburden
- Lower till

NOTAS

1. Groundwater observation point labels shows name of the borehole, groundwater elevation (GW Elv) and measurement point elevation (Meas Elv) which considers the screen mid-point for screened boreholes, or the exact elevation for vibrating wires.
2. Groundwater contour level shown on top of the line.
3. masl = metres above sea level

CLIENT

NexGen Energy Ltd.

CONSULTANT

wsp

YYYY-MM-DD	2021-06-28
PREPARED	GI
DESIGN	GI
REVIEW	NB
APPROVED	MT

PROJECT

ROOK I PROJECT

TITLE

GROUNDWATER CONTOUR MAPS (GLACIAL DRIFT; above 480 mASL)

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	8.3-7

8.3.4 Hydraulic Properties

8.3.4.1 Bedrock

A summary of the hydraulic parameters calculated for the tested intervals is presented in Figure 8.3-8. Figure 8.3-8 presents the range of testing results plotted as a probability density function, and the geometric mean of the hydraulic conductivity values was used to define the hydraulic conductivity of each hydrostratigraphic unit. The basement rock was divided into distinct hydrostratigraphic units: paleoweathered bedrock, basement bedrock, fault zones, and shear zones. The data are summarized as follows:

- The geometric mean of 28 hydraulic conductivity estimates from packer test results within the paleoweathered basement rock was 2×10^{-8} m/s and the overall range was 2×10^{-10} to 3×10^{-6} m/s.
- The geometric mean of 128 hydraulic conductivity estimates from packer test results within the basement bedrock was 1.2×10^{-9} m/s and the overall range was 6×10^{-11} to 5×10^{-7} m/s.
- The geometric mean of 23 hydraulic conductivity estimates from packer test results within fault zone was 9.0×10^{-8} m/s and the overall range was 8×10^{-10} to 7×10^{-6} m/s.
- The geometric mean of 40 hydraulic conductivity estimates from packer test results within the shear zone was 3.1×10^{-8} m/s and the overall range was 5×10^{-11} to 6×10^{-6} m/s.

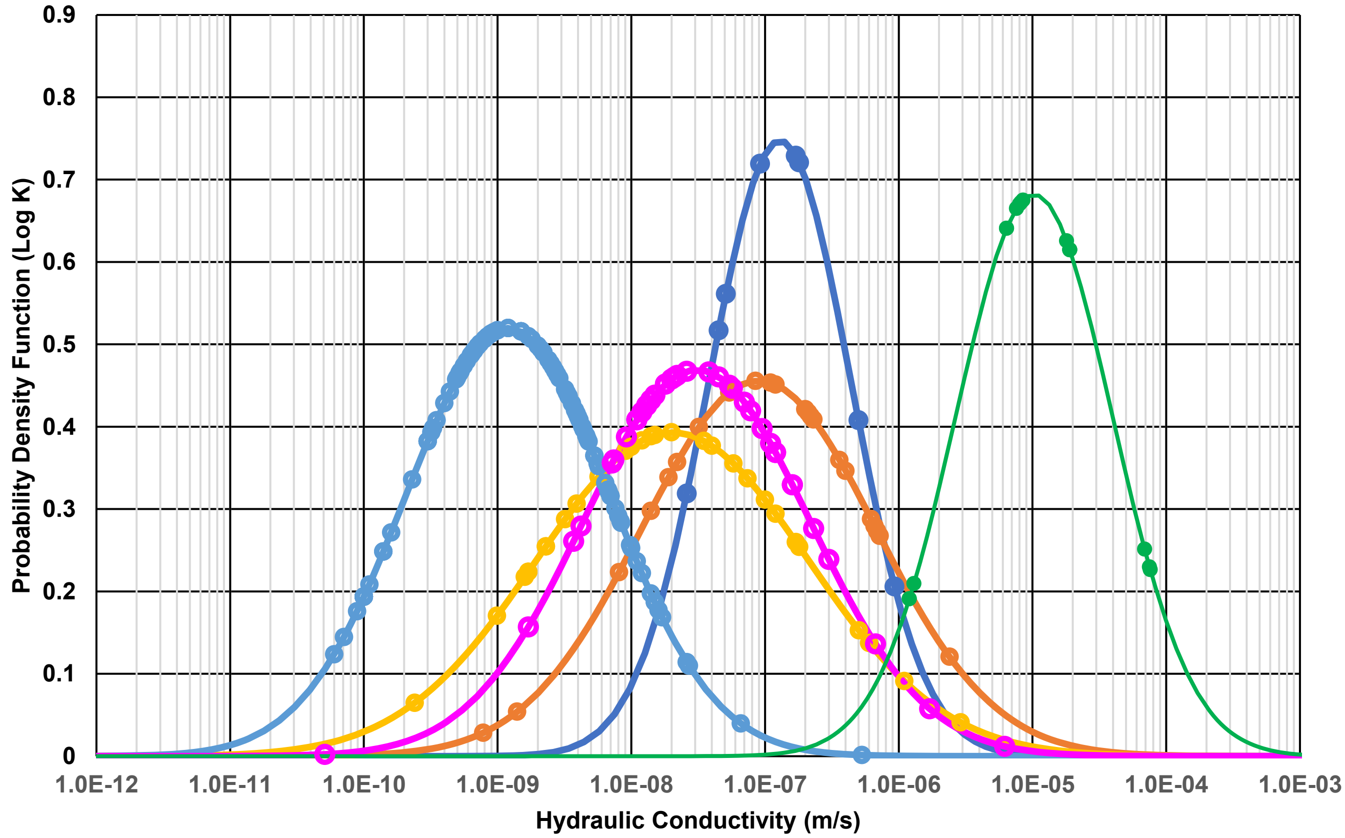
The sandstone unit is considered to be the primary bedrock aquifer in the area of the Project. Hydraulic conductivity estimates from eight packer tests in this unit ranged from 2.6×10^{-8} to 9.3×10^{-7} m/s, with a geometric mean value of 1.3×10^{-7} m/s. The limited in situ hydraulic response test data are considered to represent the lower end of the permeability of this unit, as data from laboratory permeability testing indicate higher hydraulic conductivity values (i.e., to the 10^{-5} m/s range) for the sandstone (NexGen 2019d).

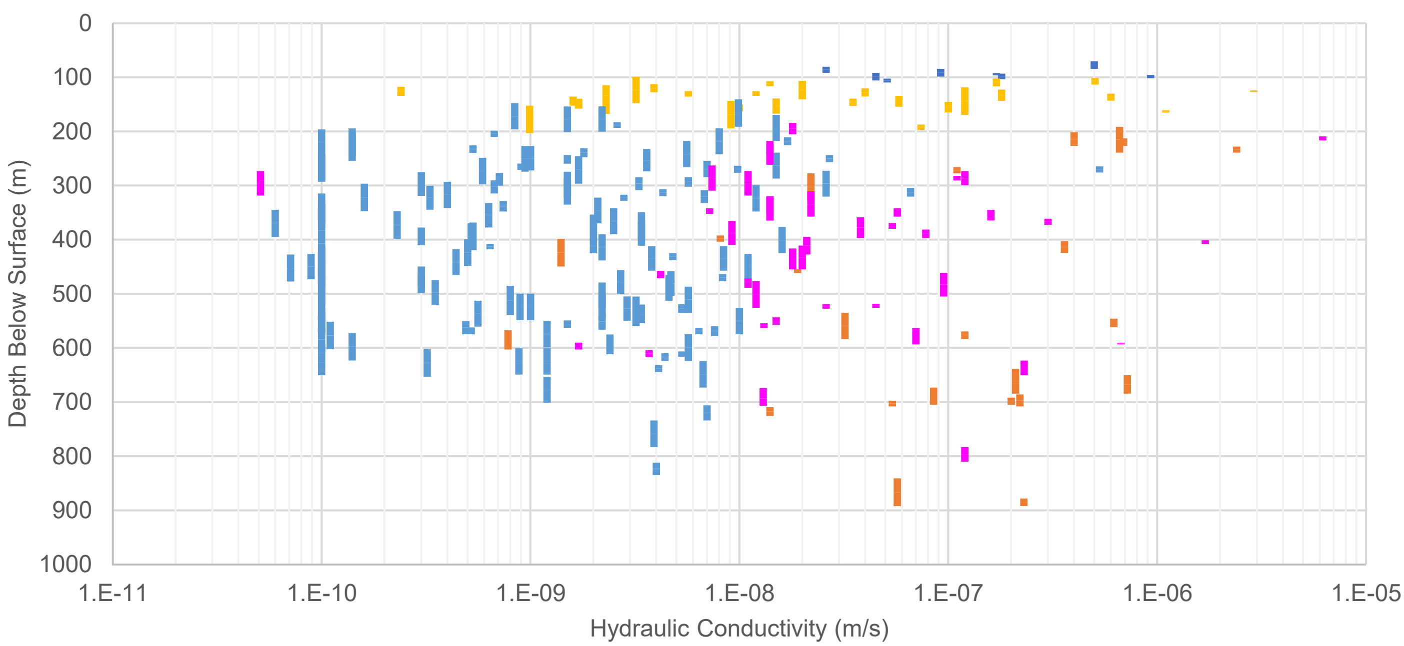
Hydraulic testing of drill core of the Devonian rock resulted in a horizontal hydraulic conductivity that ranged of 1×10^{-8} to 5×10^{-7} m/s and a vertical hydraulic conductivity that ranged 1×10^{-12} to 1×10^{-10} m/s (NexGen 2019e). The high anisotropy (i.e., ratio of hydraulic conductivity in the horizontal direction to the vertical direction) associated with this unit reflects the interbedded nature of the siltstones and mudstones.

Hydraulic testing of drill core from the Cretaceous bedrock suggested a horizontal hydraulic conductivity ranging from 1×10^{-8} to 5×10^{-7} m/s and vertical hydraulic conductivity in the range of 1×10^{-10} to 1×10^{-12} m/s (NexGen 2019f).

8.3.4.2 Glacial Drift

The hydraulic conductivity values estimated from hydraulic response testing were plotted as a probability density function to evaluate the distribution of hydraulic conductivity values within the glacial drift (Figure 8.3-8). The values ranged from approximately 1×10^{-4} to 1×10^{-6} m/s, with a geometric mean value of 1×10^{-5} m/s.





Note:

1) Not shown are the lower till, Cretaceous and Devonian units, for which specific testing data was unavailable.

Legend:

- AthabascaSS
- Fault Zone
- Paleoweathered
- SPG
- Shear Zone
- Overburden

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wsp

YYYY-MM-DD	2021-06-28
PREPARED	SK
DESIGN	SK
REVIEW	NB
APPROVED	MT

PROJECT

ROOK I PROJECT

TITLE

HYDRAULIC CONDUCTIVITY BY UNIT AND DEPTH

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	8.3-8

8.3.5 Groundwater Quality

8.3.5.1 Bedrock

Groundwater samples collected from the bedrock via the two Westbay monitoring locations were analyzed and plotted on Piper plots, as summarized in Table 8.3-3, Figure 8.3-9, and Figure 8.3-10.

In Westbay well GAR-18-013, four zones plotted as calcium chloride-type water, and seven zones plotted as sodium/potassium chloride-type water. In Westbay well GAR-19-035, all zones plotted as calcium chloride-type water. The cation dominance within the basement rock is due to the age of the groundwater and its interaction with the surrounding rock. In the low-permeable bedrock, groundwater chemistry tends to be rock-dominated because of a low water to rock ratio. The groundwater in these cases tends to be more saline than in young groundwater. The change in major cation contributions from calcium to sodium would be expected as groundwater ages. This occurs via the removal of calcium (i.e., calcium ion) and addition of sodium (i.e., sodium ion) through precipitation-dissolution and cation exchange effects along a flow path. Based on the groundwater types presented, it is considered likely that the groundwater in bedrock is older and indicative of groundwater moving along a flow path as it transitions from calcium to sodium type with the depth and age of the geologic formation.

Groundwater chemistry statistics for sampled parameters within the basement rock hydrostratigraphic units are presented in Table 8.3-4.

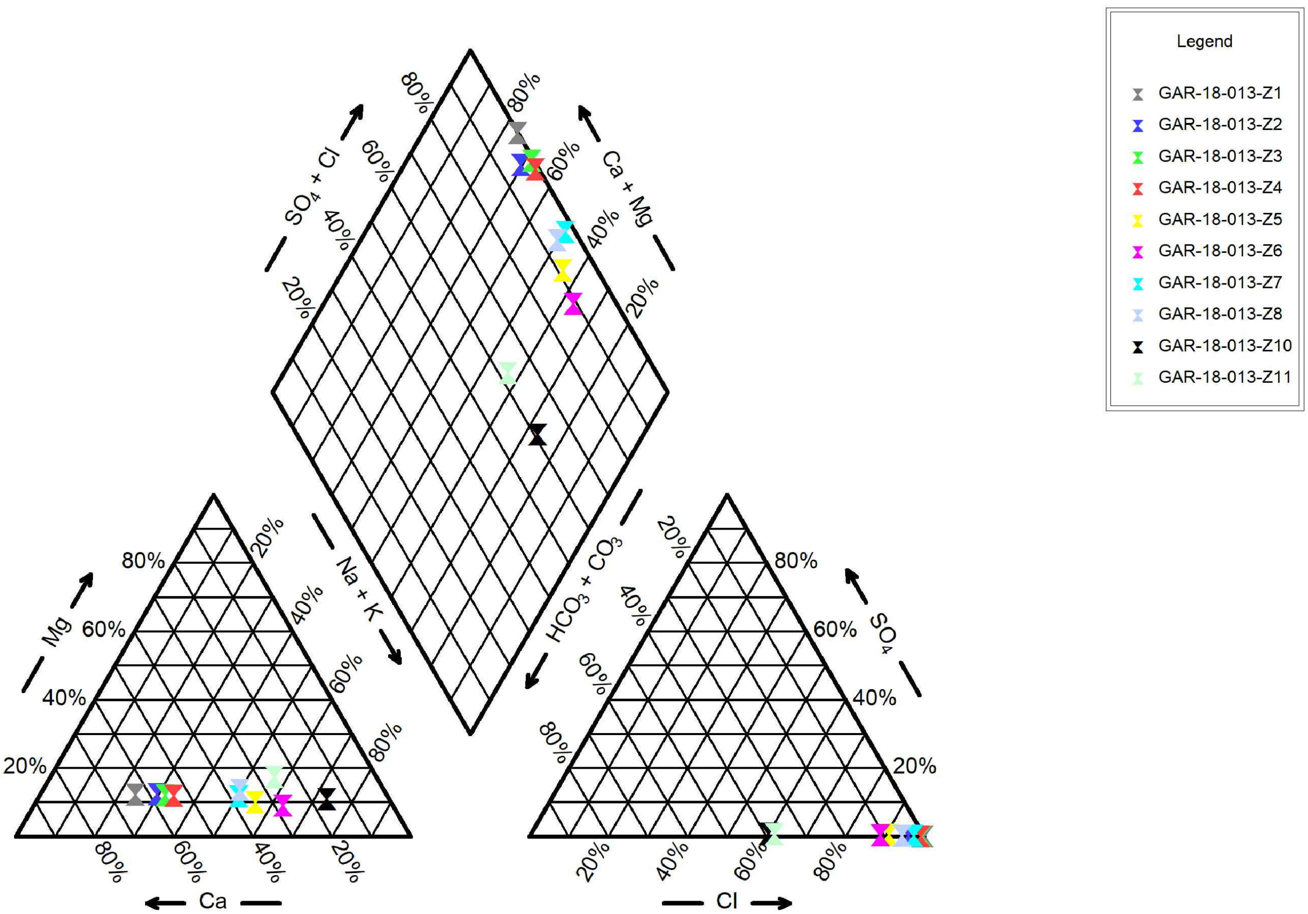
Table 8.3-3: Westbay Well Groundwater Type Summary

Monitoring Well ID	Interval	General Groundwater Type
GAR-18-013	Zone 1	Calcium chloride
	Zone 2	Calcium chloride
	Zone 3	Calcium chloride
	Zone 4	Calcium chloride
	Zone 5	Sodium/potassium chloride
	Zone 6	Sodium/potassium chloride
	Zone 7	Sodium/potassium chloride
	Zone 8	Sodium/potassium chloride
	Zone 9	Sodium/potassium chloride
	Zone 10	Sodium/potassium chloride
	Zone 11	Sodium/potassium chloride
GAR-19-035	Zone 1	Calcium chloride
	Zone 2	Calcium chloride
	Zone 5	Calcium chloride
	Zone 6	Calcium chloride
	Zone 7	Calcium chloride
	Zone 8	Calcium chloride
	Zone 9	Calcium chloride
	Zone 10	Calcium chloride

Table 8.3-4: Bedrock Groundwater Sample Parameter Statistics

Constituent	Units	Phase	Statistics[a]					
			Count	Minimum	Median	Maximum	Mean	95th Percentile
Anions / Cations								
Bicarbonate	mg/L	Total	70	1.2	48	110	49	82
Calcium	mg/L	Total	70	3.9	65	5,100	460	3,300
Carbonate	mg/L	Total	70	0.50	0.50	0.50	0.50	0.50
Chloride	mg/L	Total	70	26	270	17,000	1,500	9,600
Nitrate (as nitrogen)	mg/L	Total	70	0.0044	0.0088	0.44	0.039	0.21
Magnesium	mg/L	Total	70	1.6	13	570	59	380
Potassium	mg/L	Total	70	4.1	8.7	62	13	44
Sodium	mg/L	Total	70	7.6	76	2,200	250	440
Sulphate	mg/L	Total	70	0.30	1.0	6.4	2.8	1.1
Metals								
Aluminum	µg/L	Dissolved	71	1.0	1.4	400	40	175
Antimony	µg/L	Dissolved	71	0.10	0.10	1.0	0.25	1.0
Arsenic	µg/L	Dissolved	71	0.30	2.0	21	3.10	13
Barium	µg/L	Dissolved	71	220	1,400	4,200	1,400	2,800
Beryllium	µg/L	Dissolved	71	0.050	0.050	5.0	0.27	0.80
Bismuth	µg/L	Dissolved	39	0.10	0.10	1.0	0.27	1.0
Boron	µg/L	Dissolved	71	30	270	2,200	480	2,000
Cadmium	µg/L	Dissolved	71	0.0050	0.070	1.0	0.17	0.60
Chromium	µg/L	Dissolved	71	0.25	0.25	25	1.4	2.5
Cobalt	µg/L	Dissolved	71	0.050	2.3	37	3.7	14
Copper	µg/L	Dissolved	70	0.20	1.3	7.4	1.8	4.7
Iron	µg/L	Dissolved	71	190	2,400	18,000	4,300	13,000
Lead	µg/L	Dissolved	71	0.050	4.7	290	14	35
Manganese	µg/L	Dissolved	71	6.7	97	2,500	308	1,450
Molybdenum	µg/L	Dissolved	71	6.5	20	210	36	96
Nickel	µg/L	Dissolved	71	1.2	6.9	46	10	32
Selenium	µg/L	Dissolved	71	0.050	0.050	5.0	0.28	0.50
Silver	µg/L	Dissolved	71	0.25	0.25	2.5	0.55	2.5
Strontium	µg/L	Dissolved	71	110	1,700	140,000	13,000	83,000
Thallium	µg/L	Dissolved	71	0.10	0.10	1.0	0.25	1.0
Tin	µg/L	Dissolved	71	0.050	0.35	5.0	0.60	0.20
Titanium	µg/L	Dissolved	71	0.10	0.30	9.0	0.74	2.5
Uranium	µg/L	Dissolved	71	0.0050	0.050	0.50	0.15	0.50
Vanadium	µg/L	Dissolved	71	0.050	0.10	5.0	0.41	1.6
Zinc	µg/L	Dissolved	69	25	120	1,500	190	530
Radionuclides								
Lead-210	Bq/L	Dissolved	70	0.040	0.040	1.7	0.090	0.20
Polonium-210	Bq/L	Dissolved	70	0.010	0.010	0.34	0.63	0.020
Radium-226	Bq/L	Dissolved	70	0.010	0.11	13	0.63	2.8
Thorium-230	Bq/L	Dissolved	70	0.020	0.020	0.14	0.023	0.020

a) Values reported as less than the reportable detection limits were assumed to be half the reportable detection limits value for calculations.
Bq/L = becquerels per litre.



NOTES

GROUNDWATER CHEMISTRY RESULTS ARE REPRESENTATIVE OF THE Q1 2020 SAMPLING EVENTS.

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

WESTBAY WELL GAR-18-013
GROUNDWATER TYPE SUMMARY

CONSULTANT

wsp

PROJECT		20144150	PHASE		3104
DESIGN	CH	14-06-21	SCALE	NTS	REV. 0
CADD	JMC	14-06-21	**FIGURE 8.3-9**		
CHECK	CH	03-03-22			
REVIEW	MAT	03-03-22			

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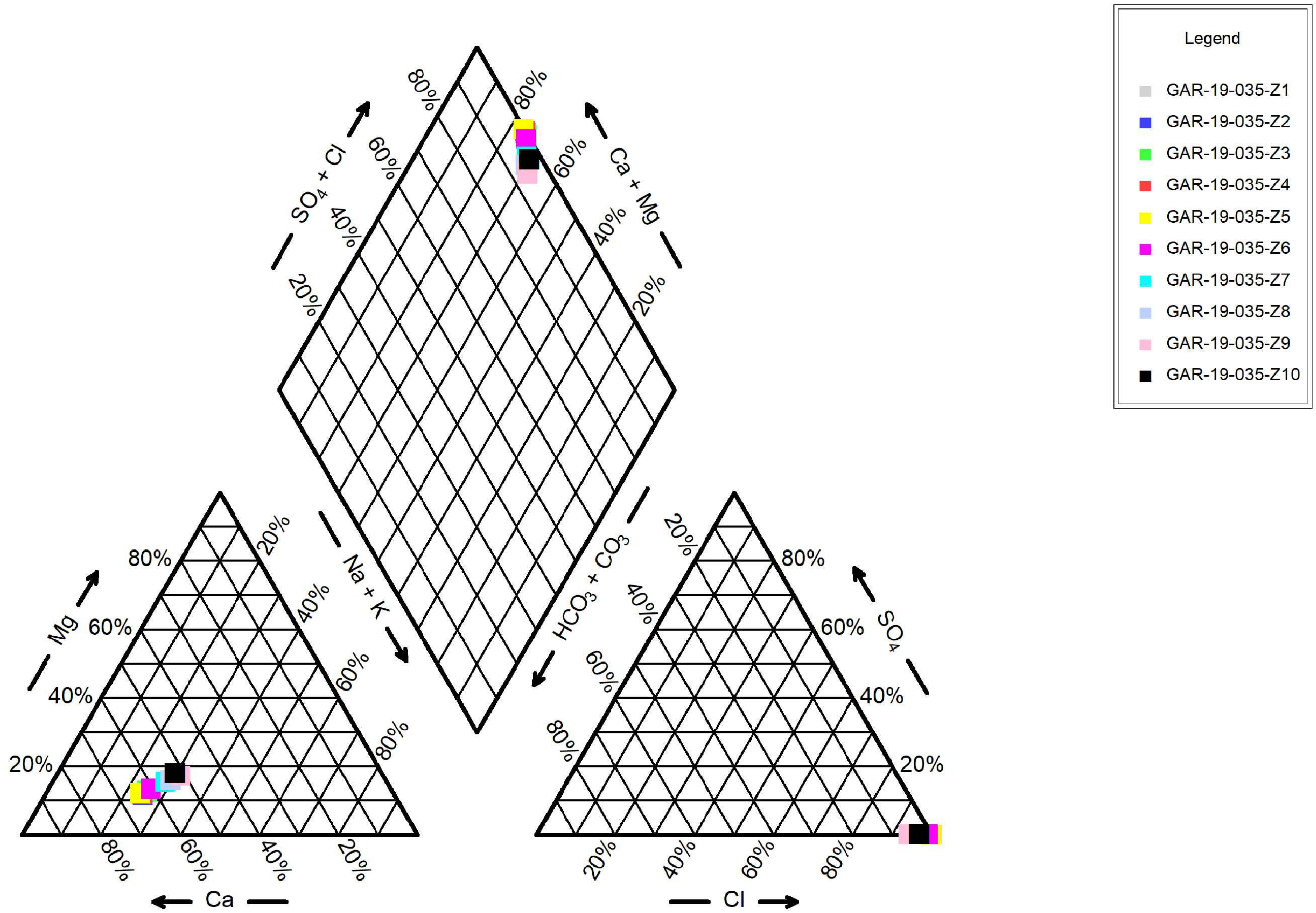

NOTES

GROUNDWATER CHEMISTRY RESULTS ARE REPRESENTATIVE OF THE Q1 2020 SAMPLING EVENTS.

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

WESTBAY WELL GAR-19-035 GROUNDWATER TYPE SUMMARY

CONSULTANT

wsp

PROJECT		20144150	PHASE	3104
DESIGN	CH	14-06-21	SCALE NTS	REV. 0
CADD	JMC	14-06-21	**FIGURE 8.3-10**	
CHECK	CH	03-03-22		
REVIEW	MAT	03-03-22		

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8.3.5.2 Glacial Drift

Groundwater samples collected from the glacial drift monitoring network that were analyzed for the required parameters were plotted on Piper plots (Section 8.2.6.5, Groundwater Quality). A summary of the water types for monitoring locations where sufficient data were available to plot is presented in Table 8.3-5. A summary Piper plot representative of the 2019 Q2 and 2019 Q3 sampling events is presented in Figure 8.3-11. Groundwater chemistry statistics for sampled parameters within the glacial drift hydrostratigraphic unit are presented in Table 8.3-6.

A difference in cation concentrations is seen when comparing between bedrock groundwater chemistry in Table 8.3-4 and glacial drift groundwater chemistry in Table 8.3-6 (e.g., calcium ion in glacial drift has a medium concentration of 7 mg/L compared to 2,100 mg/L for bedrock). The difference in cation dominance is likely due to the age of the groundwater and its interaction with the surrounding formation. In the relatively permeable glacial drift, groundwater chemistry tends to be fresh because of a higher water to rock ratio. The groundwater in these cases tends to be less saline. The change in major cation contributions from calcium to sodium would be expected as groundwater ages. This occurs via the removal of calcium ion or addition of sodium ion through precipitation-dissolution and cation exchange effects along a flow path. Based on the groundwater types presented, the groundwater in glacial drift is considered young and indicative of geologically recent recharge from the surface. In locations presenting as sodium/potassium bicarbonate type, it is likely that there is limited mixing occurring with older water from the geologic formation below.

Table 8.3-5: Standpipe Piezometer Groundwater Type Summary

Monitoring Well ID	General Groundwater Type
DH-BGC17-01	Calcium bicarbonate
DH-BGC17-02	Calcium bicarbonate
DH-BGC17-03	Calcium bicarbonate
DH-BGC17-04	Calcium bicarbonate
DH-BGC17-05	Calcium bicarbonate
2018-MW-001B	Calcium bicarbonate
2018-MW-002B	Calcium bicarbonate
2018-MW-004A	Calcium bicarbonate
2018-MW-004B	Sodium/potassium bicarbonate
2018-MW-006A	Calcium bicarbonate
2018-MW-006B	Sodium/potassium bicarbonate
2018-MW-007A	Calcium bicarbonate
2018-MW-007B	Calcium bicarbonate
2018-MW-008A	Calcium bicarbonate
2018-MW-008B	Sodium/potassium bicarbonate
2018-MW-009A	Calcium bicarbonate
2018-MW-009B	Calcium bicarbonate
2019-MW-012A	Calcium bicarbonate
2019-MW-012B	Sodium/potassium bicarbonate
2019-MW-013	Calcium bicarbonate
2019-MW-016A	Sodium/potassium bicarbonate

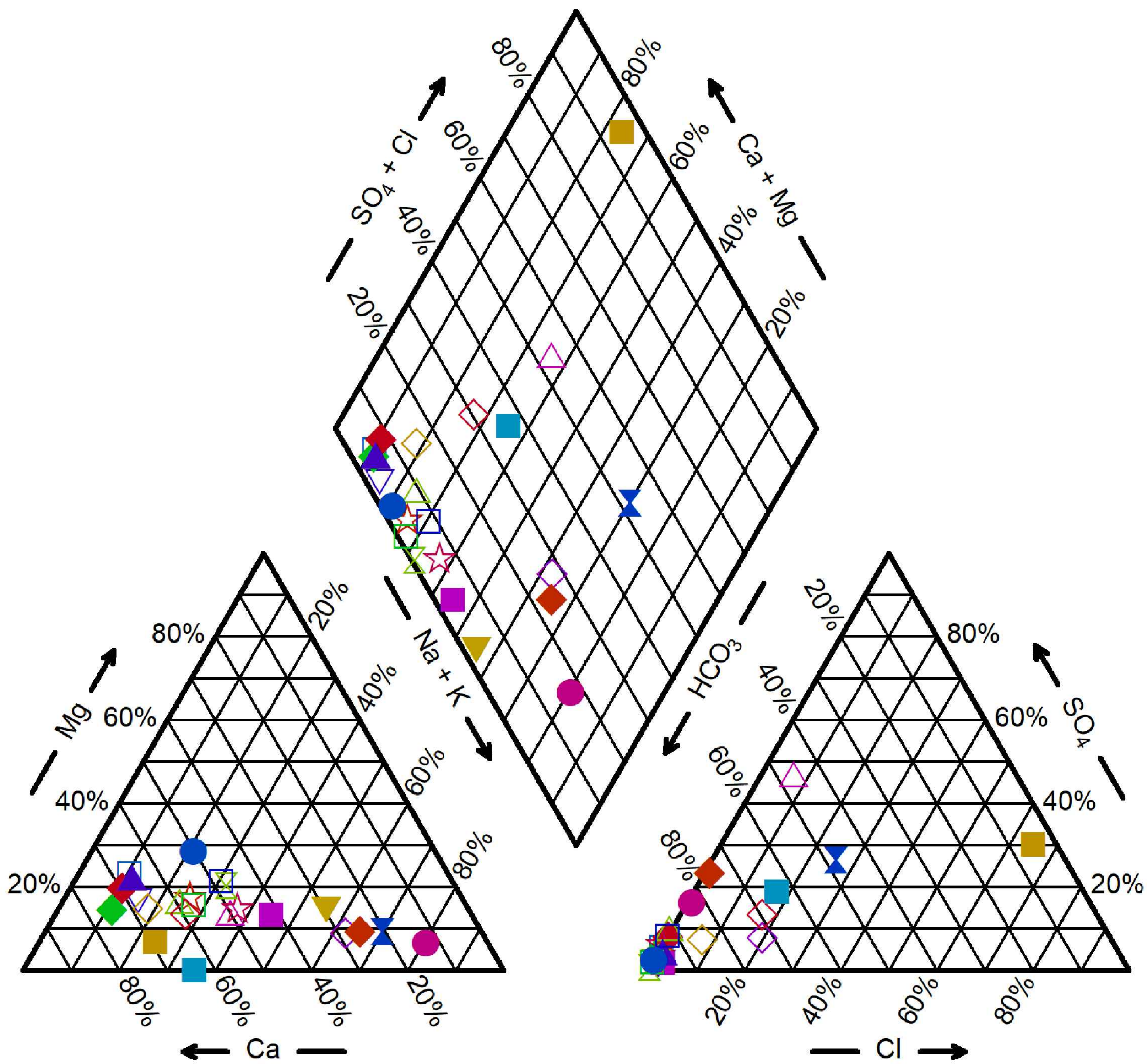
Table 8.3-6: Glacial Drift Groundwater Chemistry Statistics

Constituent	Units	Phase	Statistics					
			Count	Minimum	Median	Maximum	Mean	95th Percentile
Anions / Cations								
Ammonia (as nitrogen)	mg/L	Total	4	0.0050	0.013	0.11	0.033	0.093
Bicarbonate	mg/L	Total	71	0.50	39	140	42	72
Calcium	mg/L	Total	61	3.0	7.0	18	8.0	15
Carbonate	mg/L	Total	70	0.50[(a)]	0.50[(a)]	0.50[(a)]	0.50[(a)]	0.50[(a)]
Chloride	mg/L	Total	68	0.040	0.18	110	5.2	27
Fluoride	mg/L	Total	69	0.010	0.060	0.47	0.082	0.16
Magnesium	mg/L	Total	55	0.50	1.2	4.9	1.6	3.4
Nitrate (as nitrogen)	mg/L	Dissolved	61	0.0025	0.020	0.63	0.097	0.34
	mg/L	Total	14	0.00060	0.17	0.63	0.21	0.56
Phosphorus	mg/L	Total	20	0.020	2.6	8.8	2.8	7.6
Potassium	mg/L	Dissolved	59	0.50	1.1	7.7	1.5	3.4
Sulphate	mg/L	Total	63	0.20	1.6	37	4.3	18
Metals								
Aluminum	µg/L	Dissolved	73	0.10	13	3,300	160	700
Antimony	µg/L	Dissolved	74	0.10	0.10	1,100	46	240
Arsenic	µg/L	Dissolved	76	0.01	0.050	1.8	0.27	1.0
Barium	µg/L	Dissolved	68	0.10	11	38	12	25
Beryllium	µg/L	Dissolved	72	0.10	0.10	500	9.6	34
Bismuth	µg/L	Dissolved	32	0.010	0.10	50	3.0	18
Boron	µg/L	Dissolved	68	0.010	5	75	12	50
Cadmium	µg/L	Dissolved	72	0.0025	0.0050	0.25	0.040	0.25
Cesium	µg/L	Dissolved	2	0.0050[(a)]	0.0050[(a)]	0.0050[(a)]	0.0050[(a)]	0.0050[(a)]
Chromium	µg/L	Dissolved	75	0.010	0.25	3.5	0.43	1.1
Cobalt	µg/L	Dissolved	74	0.10	0.30	310	8.0	27
Copper	µg/L	Dissolved	76	0.10	0.10	320	31	22
Iron	µg/L	Dissolved	76	0.10	47	4,300	250	950
Lead	µg/L	Dissolved	68	0.025	0.050	20	2.1	10
Lithium	µg/L	Dissolved	22	0.10	2.5	19	14	18
Manganese	µg/L	Dissolved	71	3.2	73	17,000	320	330
Mercury	µg/L	Dissolved	30	0.00030	0.0020	0.013	0.0021	0.0079
Molybdenum	µg/L	Dissolved	74	0.050	1.7	100	3.9	10
Nickel	µg/L	Dissolved	62	0.01	0.40	2.5	0.61	1.4
Rubidium	µg/L	Dissolved	2	0.46	0.61	0.76	0.61	0.75
Selenium	µg/L	Dissolved	70	0.025	0.050	0.40	0.079	0.20
Silver	µg/L	Dissolved	76	0.0050	0.025[(a)]	0.10	0.025[(a)]	0.025[(a)]
Sodium	µg/L	Dissolved	10	40	2,800	45,000	9,800	3,3000
Strontium	µg/L	Dissolved	74	13	34	270	1,400	120
Tellurium	µg/L	Dissolved	2	0.10[(a)]	0.10[(a)]	0.10[(a)]	0.10[(a)]	0.10[(a)]
Thallium	µg/L	Dissolved	76	0.0050	0.10	4.0	0.26	1.1
Tin	µg/L	Dissolved	75	0.050	0.050	400	10	16
Titanium	µg/L	Dissolved	76	0.050	0.40	43	1.9	5.9
Uranium	µg/L	Dissolved	68	0.011	0.05	1.4	0.11	0.56
Vanadium	µg/L	Dissolved	62	0.050	0.20	7.0	0.94	4.9
Zinc	µg/L	Dissolved	64	0.25	1.2	100	5.6	19
Zirconium	µg/L	Dissolved	6	0.10	0.50	1.8	0.75	1.6

Table 8.3-6: Glacial Drift Groundwater Chemistry Statistics

Constituent	Units	Phase	Statistics					
			Count	Minimum	Median	Maximum	Mean	95th Percentile
Radionuclides								
Lead-210	Bq/L	Dissolved	50	0.010	0.010	0.58	0.023	0.020
Polonium-210	Bq/L	Dissolved	26	0.0025	0.0025	0.040	0.0051	0.018
Radium-226	Bq/L	Dissolved	26	0.0025	0.0025	0.010	0.0040	0.0085
Thorium-230	Bq/L	Dissolved	26	0.0050	0.0050	0.020	0.0060	0.010

a) Indicates values reported as less than the reportable detection limit were assumed to be half the reportable detection limits value for calculations.
Bq/L = becquerels per litre.



NOTES

GROUNDWATER CHEMISTRY RESULTS ARE REPRESENTATIVE OF THE Q2-Q3 2019 SAMPLING EVENTS.

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

GLACIAL DRIFT GROUNDWATER TYPE SUMMARY

CONSULTANT

wsp

PROJECT		20144150	PHASE	3104
DESIGN	CH	14-06-21	SCALE NTS	REV. A
CADD	JMC	14-06-21		
CHECK	CH	03-03-22	FIGURE 8.3-11	
REVIEW	MAT	03-03-22		

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8.4 Project Interactions and Mitigations

The pathway analysis identified potential adverse effects of the Project on hydrogeology, identified practicable mitigation for these potential effects, and determined whether potential effects could be sufficiently mitigated such that they are not expected to cause a residual adverse effect. As described in Section 8.2.7, the pathways analysis assigned each potential effect as:

- no pathway (i.e., mitigation results in no effect on hydrogeology);
- secondary pathway (i.e., mitigation results in a negligible effect on hydrogeology); or
- primary pathway (i.e., effect that is greater than negligible and carried forward for further assessment).

The pathway analysis is summarized in Table 8.4-1. The subsections following the table provide the rationale used to assign potential effects to the no pathway and secondary pathway categories and list primary pathways. Each Project interaction identified as a primary pathway was carried forward for detailed assessment in Section 8.5. Effects pathways apply to all Project phases, unless otherwise noted.

The environmental design features and mitigation in Table 8.4-1 represent the list of key actions used to inform the pathway analysis as part of preparing the EIS. In addition to this list of key actions, NexGen would implement the Environmental Protection Program, which would describe the processes required to monitor and characterize effects from Project facilities and activities. This program would be used to periodically evaluate mitigation performance and identify additional mitigation, where required, and prompt potential adaptive management measures (Section 8.7, Monitoring, Follow-Up, and Adaptive Management). Where relevant, adaptive management measures may also be proposed to address uncertainties associated with effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

Potential accidents and malfunctions that have the capability to influence biophysical or human environments are discussed in Section 21, Accidents and Malfunctions.

Table 8.4-1: Potential Effects Pathways for Hydrogeology

Pathway ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
HG-01	Project components/activities that may influence surface water elevations and flows during **Construction, Operations, and Closure**: ▪ underground shaft and mine development ▪ underground operations	**Groundwater inflow to underground mine:** ▪ Groundwater inflow may affect surface water elevations and flow rates	▪ **Isolate mine workings** from groundwater inflows that could occur through high permeability strata (i.e., Cretaceous sandstone) with a hydrostatic liner in the shaft ▪ Design, maintain, and monitor a mine dewatering system to manage the flow of **groundwater inflow**	Primary pathway
HG-02	Project components/activities that potentially change groundwater quality during **Construction, Operations, and Closure**: ▪ site preparation activities ▪ handling and storage of waste rock, special waste rock, and ore	**Seepage from the WRSAs during Construction, Operations, and Closure:** ▪ Seepage from the WRSAs may cause changes and alter groundwater, surface water and sediment quality in Patterson Lake	▪ **Segregate PAG material** from NPAG material and store separately ▪ **Contain and divert runoff and seepage from PAG** waste rock, special waste rock, and ore to the effluent treatment plant ▪ Implement a Project-specific **Mine Waste Management Plan** ▪ Implement a Project-specific **Environmental Protection Program** and a Project-specific **Environmental Monitoring Plan** that includes groundwater monitoring and adaptive management, if necessary ▪ Develop and implement a **Detailed Decommissioning and Reclamation Plan** to decommission and transfer the site to the province under the Institutional Control Program	Primary pathway
HG-03	Project components/activities that potentially change groundwater quality **following Closure**: ▪ storage of waste rock in the WRSAs	**Seepage from the WRSAs after Closure:** ▪ Seepage from the WRSAs to Patterson Lake may adversely affect groundwater, surface water, and sediment quality after Closure	▪ Use **engineered cemented paste backfill and tailings** to control source concentrations ▪ Include **engineered source control** layering in the PAG WRSA ▪ Install **engineered cover system** on PAG and NPAG material during reclamation ▪ Develop and implement a **Detailed Decommissioning and Reclamation Plan** to decommission and transfer the site to the province under the Institutional Control Program	Primary pathway
HG-04	Project components/activities that potentially change groundwater quality **following Closure**: ▪ storage of cemented paste tailings in the UGTMF and cemented paste backfill in the mined stopes	**Seepage from the UGTMF and backfilled production stopes after Closure:** ▪ Seepage from the UGTMF and backfilled production stopes to Patterson Lake may adversely affect groundwater, surface water, and sediment quality after Closure	▪ **Apply binder** to reduce permeability in cemented paste backfill and tailings ▪ **Engineer the tailings geochemistry** to control source concentrations	Primary pathway

Bolded text represents the key topic of the environmental design features and mitigation.
WRSA = waste rock storage area; UGTMF = underground tailings management facility; PAG = potentially acid generating; NPAG = non-potentially acid generating.

8.4.1 No Pathways

No Project interactions were predicted to result in no pathways to hydrogeology.

8.4.2 Secondary Pathways

No Project interactions were predicted to result in secondary pathways to hydrogeology.

8.4.3 Primary Pathways

The following Project interactions were predicted to be primary pathways for hydrogeology and were advanced for further assessment of residual effects (Section 8.5):

HG-01: Groundwater inflow to underground mine:

- Groundwater inflow may affect surface water elevations and flow rates.

HG-02: Seepage from the WRSAs during Construction, Operations and Closure:

- Seepage from the WRSAs may cause changes and alter groundwater, surface water, and sediment quality in Patterson Lake.

HG-03: Seepage from the WRSAs after Closure:

- Groundwater seepage from the WRSAs to Patterson Lake may adversely affect groundwater, surface water, and sediment quality after Closure.

HG-04: Seepage from the UGTMF and backfilled production stopes after Closure:

- Groundwater seepage from the UGTMF and backfilled production stopes to Patterson Lake may adversely affect groundwater, surface water, and sediment quality after Closure.

8.5 Residual Effects Analysis

8.5.1 Application Case

8.5.1.1 Groundwater Quantity

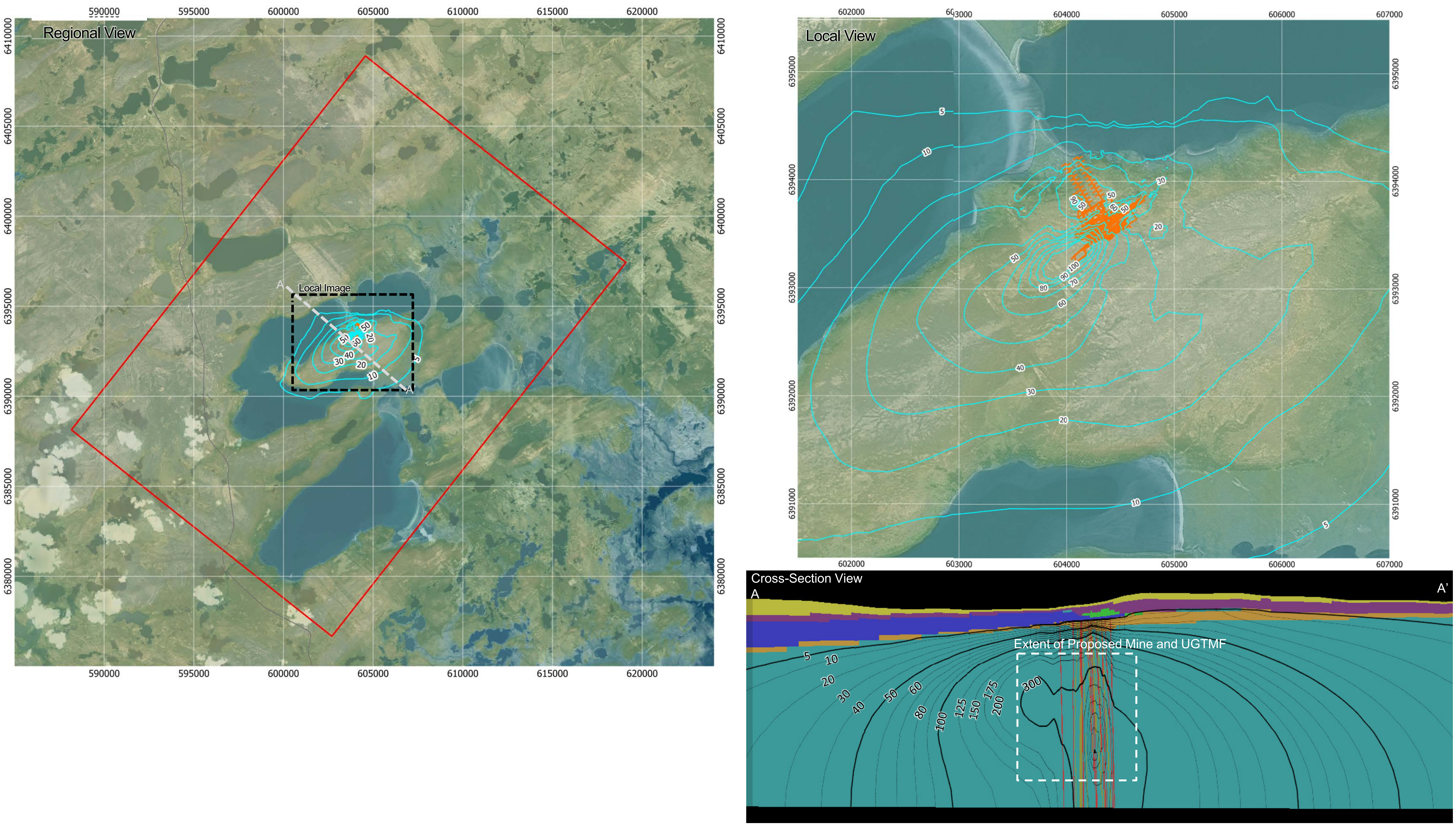
Groundwater quantity is inclusive of groundwater elevations, and groundwater flow patterns and rate measurement indicators.

The main objectives of the predictive modelling with respect to groundwater quantity were to estimate the groundwater inflows to the underground development, extent of depressurization, and the resulting potential influence of this depressurization on groundwater discharge to surface water features during Operations. The groundwater flow model was configured to represent Operations and used to estimate groundwater inflows to the mine, groundwater drawdown, and changes to baseflow.

For the far-future projection, the model was used to delineate groundwater flow pathways and flow rates through the various source areas.

8.5.1.1.1 Groundwater Elevation

During Operations, seepage to the mine would result in depressurization of the surrounding bedrock, which would be observed as a reduction in groundwater elevation at monitoring locations (i.e., groundwater drawdown). The extent of the simulated groundwater drawdown in bedrock resulting from the mine dewatering at approximately the upper horizon of the mine and at the end of Operations is illustrated in Figure 8.5-1. The simulated drawdown extends approximately 2 km to the north, 4 km to the south, and 3.5 km in both the east and west directions, based on the 5 m drawdown contour. Vertically, the extent of depressurization is generally limited to the basement rock, as the overlying sandstone aquifer is considerably more transmissive. The maximum simulated drawdown within the sandstone was estimated to be less than 5 m in the immediate area of the mine workings. Based on the results of the assessment it is anticipated that reduction in groundwater elevation would be limited to the bedrock units.



LEGEND

- MODEL DOMAIN
- PROPOSED UNDERGROUND WORKINGS
- SIMULATED GROUNDWATER DRAWDOWN CONTOUR (m)

Notes:

1) Masl = metres above sea level
2) UGTMF – underground tailings management facility
3) Groundwater drawdown shown for basement rock at elevation 330 masl, approximately 200 m below ground surface.

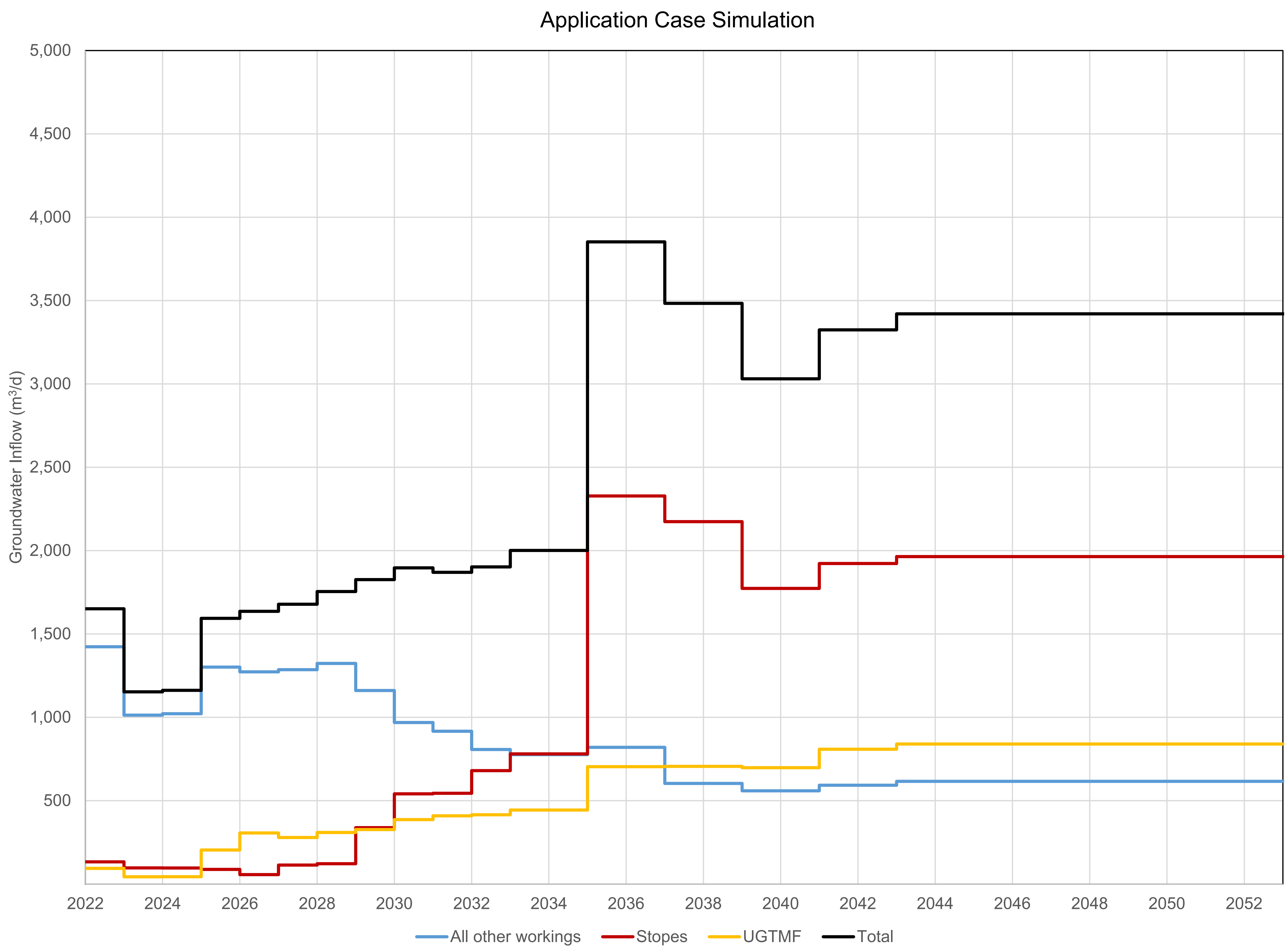
CLIENT	NexGen Energy Ltd.	PROJECT	ROOK I PROJECT
CONSULTANT	wsp	TITLE	SIMULATED GROUNDWATER DRAWDOWN AT THE END OF MINING (APPLICATION CASE)
YYYY-MM-DD	2023-02-27		
PREPARED	NB		
DESIGN	NB		
REVIEW	SD		
APPROVED	MT		

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	0	8.5-1

8.5.1.1.2 Groundwater Flow Patterns and Rates

Groundwater Seepage to the Mine

Figure 8.5-2 provides the simulated groundwater inflow rates to the underground development during Construction and Operations. For the Application Case simulation during the period from 2022 (Year -4) to 2035 (Year 10), the groundwater inflows to the underground development were predicted to range from a total of approximately 1,200 m^3/d, to 2,000 m^3/d, with the greatest portion of inflow occurring at the other workings (i.e., any underground opening not associated with the UGTMF or production stope backfilling). In 2035 (Year 10), the total groundwater inflows increased to approximately 3,900 m^3/d, corresponding to the opening of additional stopes. After 2041 (Year 16), the groundwater inflows are relatively stable at approximately 3,500 m^3/d total inflow, with approximately 60% of inflows derived from stopes and 20% derived from each of the UGTMF and additional workings areas.



Year	Annual Average (m^3/d)
	Application Case
2022	1,651
2023	1,153
2024	1,162
2025	1,594
2026	1,636
2027	1,679
2028	1,755
2029	1,826
2030	1,897
2031	1,870
2032	1,903
2033	2,001
2035	3,852
2037	3,483
2039	3,031
2041	3,325
2043	3,420

CLIENT
NexGen Energy Ltd.

CONSULTANT
wsp

YYYY-MM-DD	2021-07-24
PREPARED	NB
DESIGN	NB
REVIEW	SD
APPROVED	MT

PROJECT
ROOK I PROJECT

TITLE
SIMULATED GROUNDWATER INFLOW RATES TO THE MINE – APPLICATION CASE

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	0	8.5-2

Baseflow

During Operations, the groundwater seepage collected from the underground mine would be treated and, after monitoring to confirm discharge limits are met, discharged to Patterson Lake. Assuming that all groundwater seepage collected at the underground mine originates as surface infiltration from the Patterson Lake catchment, the resulting net change to the overall water balance in the surface water system is zero.

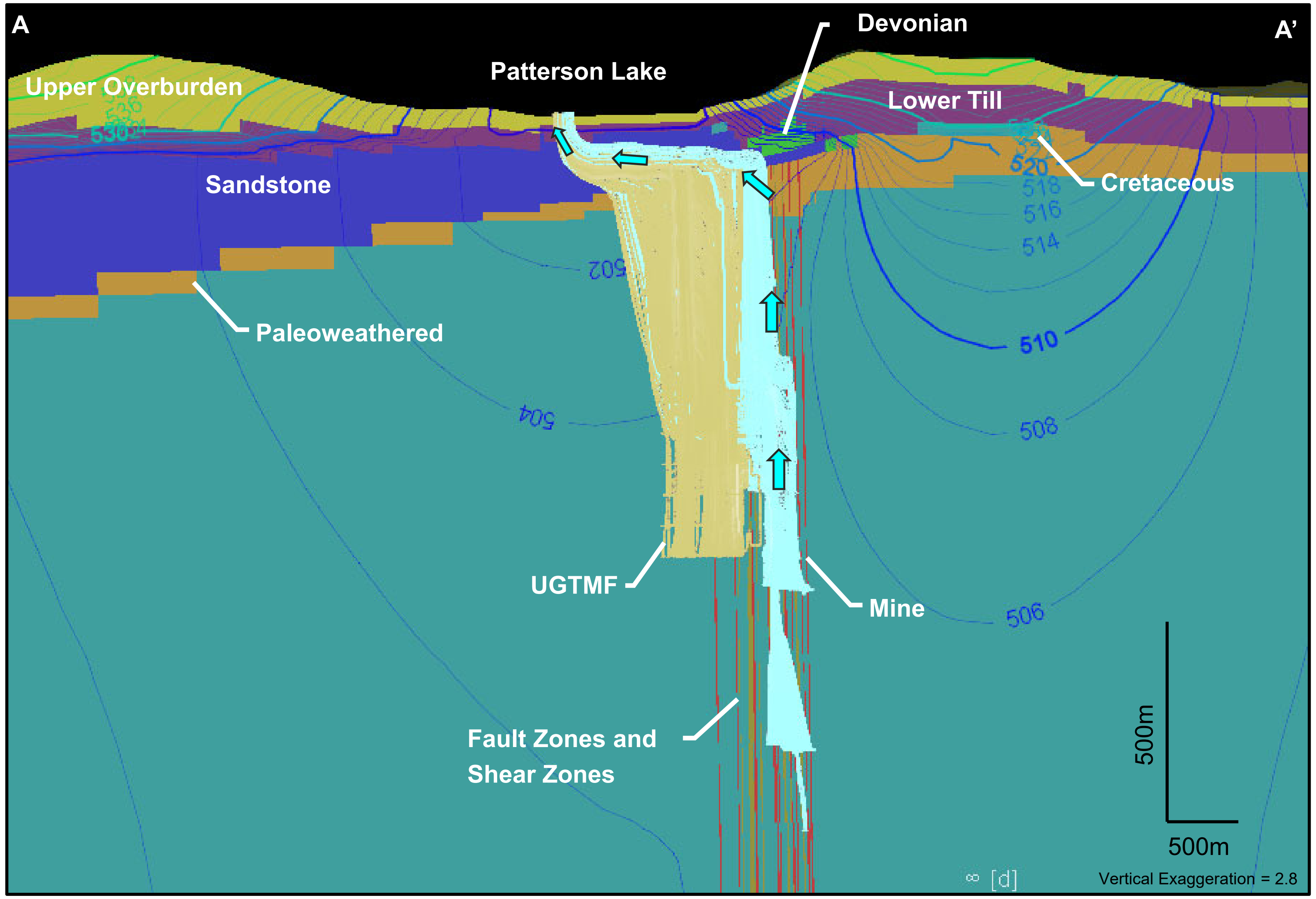
The results of the groundwater flow model were reviewed to evaluate the relative magnitude of simulated groundwater inflow rates to surface water baseflows. Under existing conditions, the estimated groundwater discharge to the Patterson Lake watershed is approximately 68,300 m^3/d, based on the simulated groundwater discharge to surface water boundaries. As described in Section 8.5.1.1.1, Groundwater Elevation, peak groundwater inflows to the mine during Operations are approximately 3,900 m^3/d, representing approximately 6% of the simulated groundwater discharge to surface water boundaries.

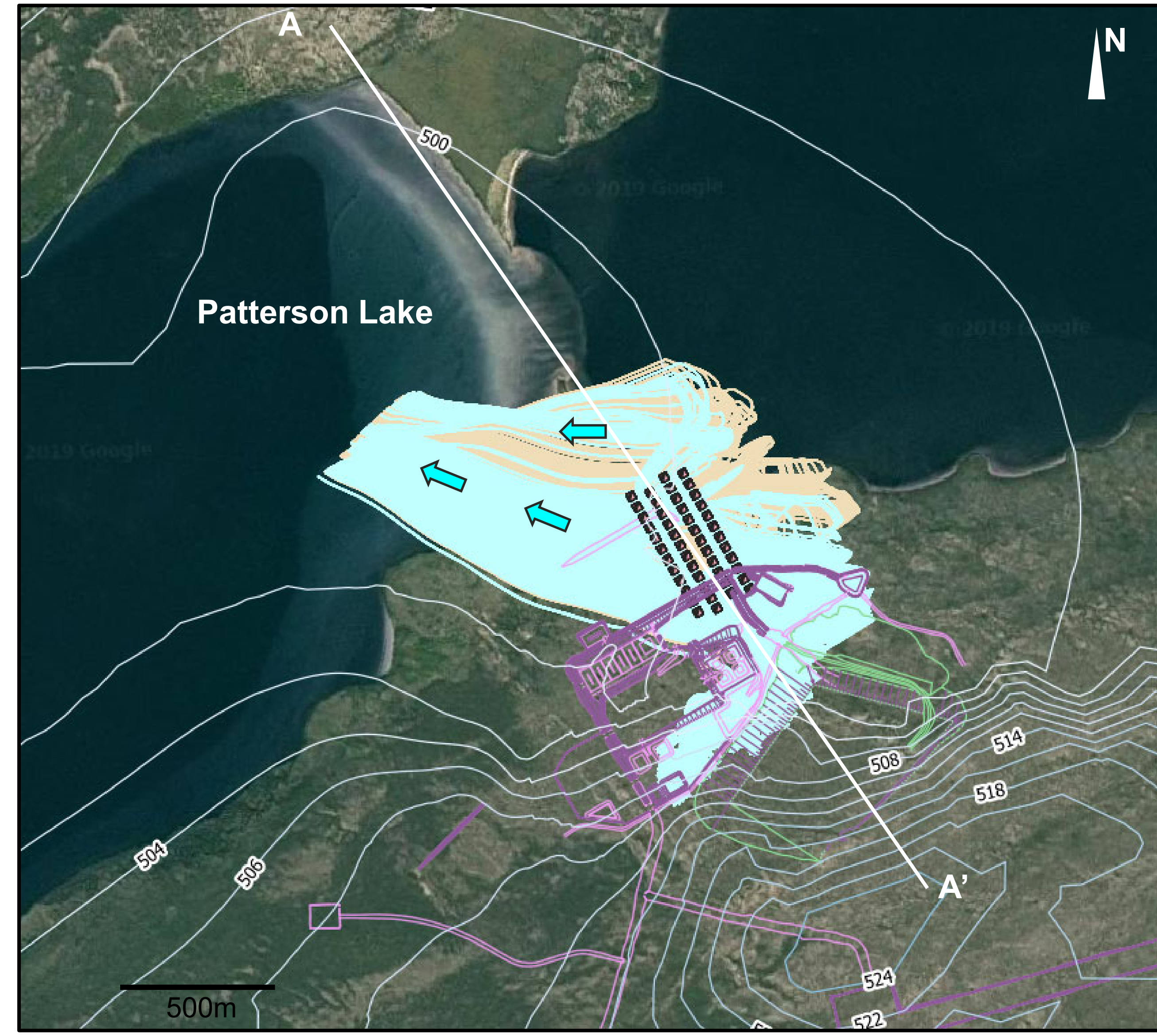
Groundwater Flow Paths and Travel Times

During Construction and Operations, groundwater seepage from the PAG WRSA would be captured and managed with contact waters that would be treated in the effluent treatment plant prior to discharge. These waters have been accounted for in Section 10, Surface Water Quality and Sediment Quality. Therefore, potential effects on surface waters from groundwater seepage would be limited to the Closure period.

The groundwater flow pathways for the long-term conditions following Closure are illustrated in Figure 8.5-3 for underground sources and Figure 8.5-4 for above-ground sources (i.e., the WRSAs). Based on the particle tracking analysis, groundwater originating at the UGTMF and production stope backfill source areas migrates vertically upward primarily through the fault and shear zones, then laterally through the sandstone, before discharging within Patterson Lake (i.e., the receptor). The total vertical length of the flow pathway for the underground sources is approximately 260 m, as measured from the top of the mine (i.e., 180 masl) to the top of the paleoweathered rock unit (i.e., 440 masl). The cross-sectional area through the fault zones was estimated to be 34,400 m^2 based on the number of fault zones intersected by the mine workings (i.e., 10) and the average length of faults intersected by the source areas (i.e., 344 m), with an assumed width of 10 m per fault zone. The total horizontal length through the sandstone is approximately 1,000 m, with a flow pathway width of 350 m and height of 20 m, estimated based on the particle pathway dimensions.

Based on the hydraulic gradients, hydraulic conductivity values, pathway dimensions, and effective porosity values applied to the pathways (i.e., 0.015 for the fault zone and 0.098 for the sandstone), the approximate advective groundwater travel time from the upper horizon of the mine to the discharge location at Patterson Lake is estimated to be approximately 1,000 years. For the groundwater flow pathways in the overburden, the approximate advective groundwater travel time from the WRSAs to Patterson Lake was 43 years to the north and 77 years to the south.





LEGEND

- SIMULATED GROUNDWATER HEAD CONTOUR – SECTION VIEW (m)
- SIMULATED GROUNDWATER HEAD CONTOUR – PLAN VIEW (m)
- SIMULATED GROUNDWATER FLOW PATHWAY (UGTMF)
- SIMULATED GROUNDWATER FLOW PATHWAY (BACKFILL)
- BASEMENT ROCK
- PALEOWEATHERED BASEMENT ROCK
- SANDSTONE
- DEVONIAN ROCK
- CRETACEOUS ROCK
- LOWER OVERBURDEN (TILL)
- UPPER OVERBURDEN

Notes:
1) Arrows indicate direction of groundwater flow pathway
2) Simulated groundwater head contours reflect long-term post-closure conditions.
3) UGTMF = underground tailings management facility

CLIENT
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CONSULTANT
wsp

YYYY-MM-DD	2021-07-24
PREPARED	NB
DESIGN	NB
REVIEW	SD
APPROVED	MT

PROJECT
ROOK I PROJECT

TITLE
PARTICLE TRACKING ANALYSIS – GROUNDWATER FLOW PATHWAYS FOR UNDERGROUND SOURCES

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	0	8.5-3

LEGEND

- SIMULATED GROUNDWATER FLOW CONTOUR – PLAN VIEW (m)
- SIMULATED GROUNDWATER FLOW PATHWAY
- SURFACE WASTE FACILITIES (SOURCE AREA)
- SURFACE MINE INFRASTRUCTURE

Notes:
1) Arrows indicate direction of groundwater flow pathway
2) Simulated groundwater head contours reflect long-term post-closure conditions.

CLIENT
NexGen Energy Ltd.

CONSULTANT
wsp

YYYY-MM-DD	2024-11-07
PREPARED	AC
DESIGN	NB
REVIEW	JL
APPROVED	JL

PROJECT
NEXGEN ENERGY LTD.
ROOK I PROJECT

TITLE
PARTICLE TRACKING ANALYSIS – GROUNDWATER FLOW PATHWAYS FOR ABOVE GROUND SOURCES

PROJECT No.	PHASE	Rev.	FIGURE
CA00226400.3030		0	8.5-4

8.5.1.2 Groundwater Quality

The main objective of the hydrogeology assessment with respect to groundwater quality was to estimate the solute mass loading rates from WRSAs and cemented paste tailings and backfill to downgradient receptors during Operations and in the long term following Closure. During Operations, waste stored in the UGTMF and underground mine workings would be under hydraulic containment as a result of mine depressurization and, as such, release to the groundwater environment would be limited to seepage from the surface waste sources (i.e., waste rock) and transport through the overburden groundwater flow path.

Results from the groundwater modelling were used as input for the surface water quality modelling and assessment (Section 10).

The protection of water from Project effects is extremely important to Indigenous Groups and LPA communities (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; BNDN-JWG 2019, BRDN-JWG 2019a; MN-S-JWG 2019b; NexGen 2019a; 2021 trapper's workshop). Indigenous Groups have expressed concerns regarding potential Project effects on water quality, and have indicated that they are experiencing adverse effects from industrial developments, including mineral exploration activities and the Cluff Lake Mine, which they believe has affected the health of the land and resources (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; BNDN-JWG 2019; BRDN-JWG 2020; BRDN-JWG- 2021a; BRDN-JWG 2021b; CRDN-JWG 2020a; BRDN-JWG 2021b; CRDN-JWG 2021; MN-S-JWG 2019a; MN-S-JWG 2019b). For example, the MN-S commented on the decommissioning process for the Cluff Lake Mine tailings pond and expressed concerns about the method used and whether there is radioactive contamination on the surface of waste rock (TSD IV: MN-S). Similarly, the CRDN and BRDN understand that waste and tailings were left behind or buried underground at the Cluff Lake Mine site and avoid harvesting activities in the vicinity of the site as a result (TSD V.2: CRDN; BRDN-JWG 2021a).

Indigenous Groups expressed concerns related to the effects of mine waste and tailings on surface and underground water quality, and risks to environmental and human health (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; BNDN-JWG 2019; BNDN-JWG 2020; BNDN-JWG 2021a; BRDN-JWG 2021b; CRDN-JWG 2020a; CRDN-JWG 2021; MN-S-JWG 2019a). The MN-S highlighted the importance of properly managing and containing tailings (TSD IV: MN-S). Members of LPA communities also commented on the safety of storing tailings underground, whether there would be any seepage, and potential effects to groundwater, surface water, and the environment in general (NexGen 2019a). Examples of received comments are as follows:

> [Tailings] that's of course – one of our concerns in the north right now, with the new mining, right. But we don't know about the buried ore or waste. I don't think nobody really does. It could be worse than the contamination. Not above ground; underground, where we don't see. (TSD V.2: CRDN)
>
> They said they're going to bury their waste. When they bury their waste, it'll go back in the water. And that's the thing about it. Why don't they take their waste out of there and go put it where they're living, see if they like it? They can put it in barrels and take it out of there if they [want] to keep our land safe . . . . We don't need it being dumped back in the ground or something to destroy the land and lake and that after they're gone. (TSD II: BNDN)

The CRDN also raised concerns about potential effects to ground stability from disturbance of bedrock containing uranium (TSD V.2: CRDN).

NexGen understands the concerns raised by Indigenous Groups and recognizes the importance of designing the UGTMF and the PAG WRSA in a manner that minimizes potential effects to groundwater. Placement of cemented paste tailings within the UGTMF reduces the risks associated with shallow groundwater effects and surface infrastructure stability compared to placement as conventional tailings in an above-ground facility. The UGTMF would be located in competent crystalline basement rock that provides increased geotechnical stability and reduced hydraulic conductivity compared to the Athabasca Sandstone. Cemented paste tailings, which provides reduced hydraulic conductivity compared to conventional tailings, would be deposited in the UGTMF to provide additional stability. Engineered source control would be included the PAG WRSA design to minimize constituent of potential concern loadings in seepage to the shallow groundwater. The assessment of groundwater seepage from the underground mine to the receiving environment is addressed in Section 8.5.1.1.2 (in terms of the rates and flow pathways), and in Section 8.5.1.2.1, Solute Mass Loading Rates to Patterson Lake (in terms of the groundwater quality of the seepage). The assessment of human health following exposure to radiation from air, water, soil, and sediment (i.e., through a potential exposure pathway from drilling) is detailed in Section 15, Human Health.

8.5.1.2.1 Solute Mass Loading Rates to Patterson Lake

The simulated peak solute mass loading rates for the Application Case are provided in Table 8.5-1. The total simulated mass loading rates from groundwater pathways arriving at Patterson Lake are plotted for selected solutes in Figure 8.5-5. Based on a review of the model output, including a comparison of mass loading rates from individual source areas, it was determined that peak mass loadings are driven primarily by WRSAs and reflooded mine workings. This is evident in the plots of in Figure 8.5-5 for copper, uranium, and radium, where solute mass arrives at the receptor (i.e., Patterson Lake) early in the simulation (i.e., approximately 100 years in model time; decades following Closure); the loading rate is maintained throughout the duration of the simulation due to the assumption that the source is infinite.

For some solutes, the arrival of mass loading from the reflooded mine workings is visible in the loading curves (e.g., for uranium, this occurs at approximately 10,000 years). For a minority of solutes, the relative portions of mass from underground backfill and waste rock sources is more balanced (i.e., for sulphate, calcium, and strontium). Solutes with peak mass loading rates that are driven by underground sources include molybdenum, sodium, and, to a lesser extent, vanadium.

Note that Table 8.5-1 includes results from the sensitivity simulations, as detailed in Section 8.5.1.2.2, Additional Model Simulations.

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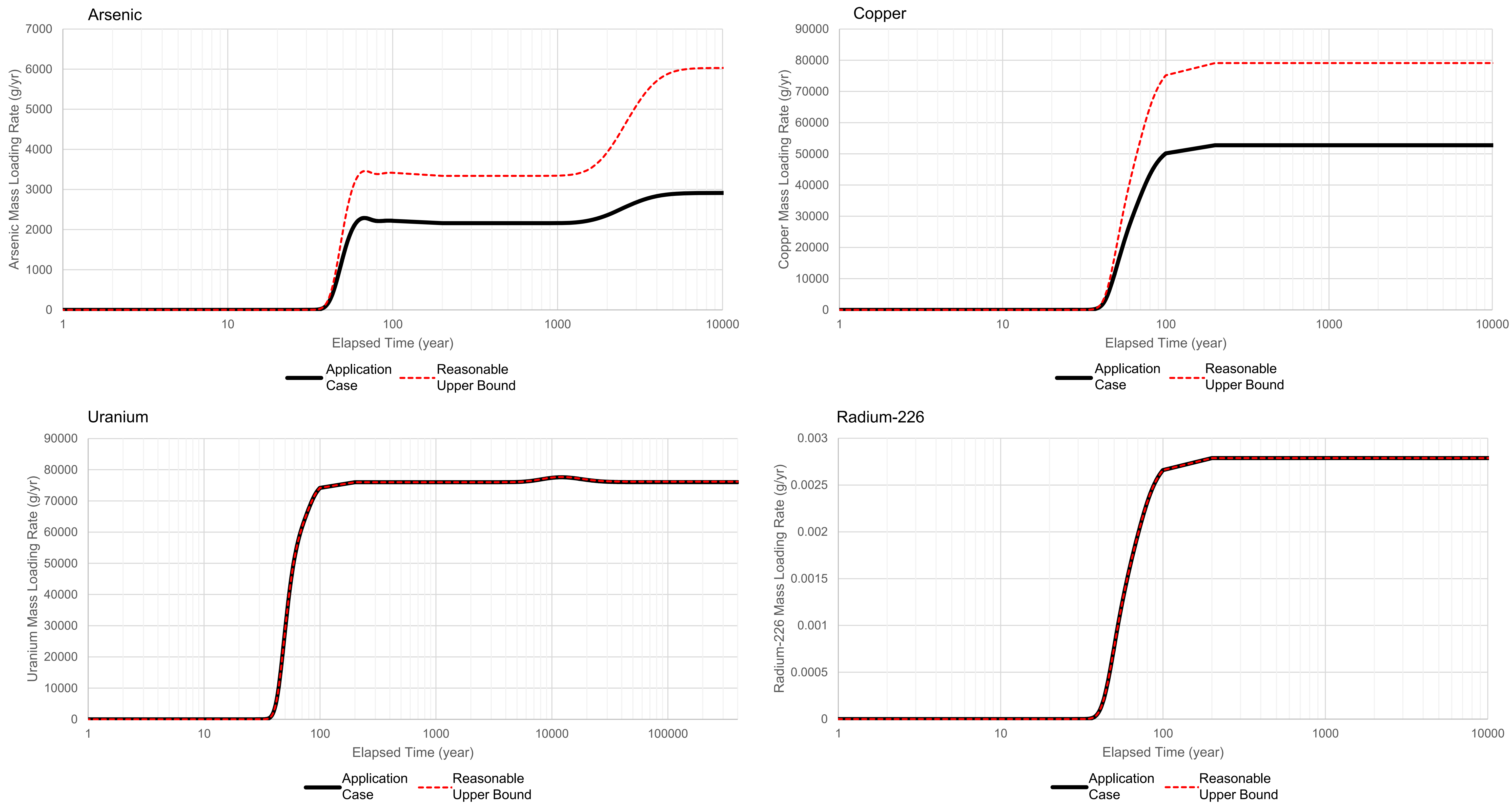
Table 8.5-1: Simulated Peak Solute Mass Loading Rates – Application Case

		Solute																	
		Silver	Aluminum	Arsenic	Boron	Calcium	Cadmium	Chlorine	Cobalt	Chromium	Copper	Fluorine	Iron	Mercury	Magnesium	Manganese	Molybdenum	Sodium	Ammonia
Application Case Peak Mass Loading Rate (g/yr)		210.6	812,669	2,918	20,756	5,376,000	89.78	13,030,000	32,209	472	52,879	163,880	604,519	38.93	2,362,000	48,220	175,901	2,463,000	115,559
Percent change relative to Base Case	SR1 – Bedrock K	0.90%	0.00%	3.00%	2.80%	1.10%	0.10%	-1.50%	0.00%	0.20%	0.00%	-1.50%	0.20%	0.00%	0.00%	0.00%	2.80%	2.60%	-1.50%
	SR2 – Fault zone K	2.20%	0.10%	6.20%	8.40%	7.10%	0.60%	-1.40%	0.00%	1.70%	0.10%	-1.80%	0.40%	0.00%	0.00%	0.00%	25.30%	23.90%	-1.90%
	SR3 – UGTMF tailings K	0.10%	0.00%	11.20%	0.30%	10.10%	0.30%	0.40%	0.00%	1.00%	0.10%	0.40%	0.00%	0.00%	0.00%	0.00%	14.60%	13.50%	0.40%
	SR4 – Backfill K	0.80%	0.10%	7.10%	0.50%	12.90%	1.00%	1.50%	0.00%	2.90%	0.10%	1.00%	0.00%	0.00%	0.00%	0.00%	42.60%	40.30%	0.80%
	SR5 – Fracture zone area	3.10%	0.00%	0.00%	11.30%	-2.90%	0.00%	-2.80%	0.00%	0.30%	0.00%	-2.90%	0.60%	0.00%	0.00%	0.00%	0.00%	0.00%	-3.00%
	SR6 – Upper bound UGTMF source	0.30%	0.10%	17.10%	0.10%	0.20%	0.80%	0.00%	0.00%	37.90%	0.10%	0.00%	0.00%	0.00%	0.00%	0.10%	15.30%	8.70%	0.00%
	SR7 – Upper bound backfill source	1.60%	1.70%	10.40%	0.10%	3.70%	1.30%	0.20%	0.00%	24.20%	0.10%	0.30%	0.10%	0.00%	0.00%	0.00%	130%	8.00%	0.10%
	SR8 – Upper bound waste rock source	47.00%	48.00%	40.40%	38.10%	27.20%	51.60%	46.40%	53.10%	46.60%	49.80%	46.90%	49.60%	48.90%	47.80%	51.00%	0.50%	2.90%	47.10%
	SR9 – All upper bound sources	52.30%	51.00%	107.10%	39.10%	57.40%	56.30%	48.70%	53.20%	160%	50.30%	48.70%	49.80%	48.90%	47.90%	51.30%	284%	85.20%	48.40%

		Solute																	
		Nickel	Nitrite	Nitrate	Phosphorus	Lead	Lead-210	Polonium-210	Radium-226	Radium-228	Selenium	Sulphate	Strontium	Thorium-228	Thorium-230	Uranium-234	Uranium-238	Vanadium	Zinc
Application Case Peak Mass Loading Rate (g/yr)		28,441	1,066	1,023	1,171	638.8	3.081×10^{-05}	5.24×10^{-07}	0.002796	2.38×10^{-09}	2,779	34,200,000	28,880	1.18×10^{-09}	0.03176	4.191	77,582	3,082	22,544
Percent change relative to Base Case	SR1 – Bedrock K	0.00%	-1.50%	-1.50%	-1.50%	0.20%	0.00%	0.00%	0.00%	0.00%	0.60%	1.10%	3.80%	0.00%	0.00%	0.50%	0.50%	4.00%	0.00%
	SR2 – Fault zone K	0.00%	-2.10%	-2.10%	-2.00%	3.10%	0.10%	0.10%	0.00%	0.00%	7.20%	7.30%	6.50%	0.00%	0.00%	1.10%	1.10%	6.80%	0.00%
	SR3 – UGTMF tailings K	0.00%	0.40%	0.40%	0.30%	1.20%	0.00%	0.00%	0.00%	0.00%	3.50%	5.20%	0.10%	0.00%	0.00%	0.00%	0.00%	0.60%	0.10%
	SR4 – Backfill K	0.00%	0.60%	0.50%	0.60%	5.40%	0.00%	0.00%	0.00%	0.00%	12.50%	11.80%	0.20%	0.00%	0.00%	0.00%	0.00%	0.50%	0.10%
	SR5 – Fracture zone area	0.00%	-3.00%	-3.00%	-3.10%	0.00%	0.10%	0.10%	0.10%	0.00%	0.00%	0.00%	8.70%	0.00%	0.00%	1.90%	1.90%	8.80%	0.00%
	SR6 – Upper bound UGTMF source	0.20%	0.00%	0.00%	0.00%	185.40%	0.00%	0.10%	0.00%	0.00%	0.80%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.40%
	SR7 – Upper bound backfill source	0.10%	0.00%	0.00%	0.00%	119.60%	0.20%	0.20%	0.10%	0.00%	12.00%	3.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.20%
	SR8 – Upper bound waste rock source	53.50%	47.20%	47.30%	47.10%	10.90%	0.00%	0.00%	0.00%	0.00%	32.40%	36.00%	35.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.10%
	SR9 – All upper bound sources	54.10%	48.30%	48.30%	48.20%	556%	0.40%	0.50%	0.30%	0.00%	67.80%	58.00%	35.00%	0.00%	0.00%	0.10%	0.10%	1.30%	51.40%

Shading indicates range in values:
minimum (-3.1%) maximum (556%).
UGTMF = underground tailings management facility; K = hydraulic conductivity.



Note:
“RFD” refers to reasonably foreseeable development

CLIENT
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CONSULTANT
wsp

YYYY-MM-DD	2021-07-24
PREPARED	NB
DESIGN	NB
REVIEW	SD
APPROVED	MT

PROJECT
ROOK I PROJECT

TITLE
SIMULATED MASS LOADING RATES TO PATTERSON LAKE – PLOTS FOR SELECT SOLUTES

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	**8.5-5**

8.5.1.2.2 Additional Model Simulations

To address the uncertainty associated with model input parameters and assumptions, a sensitivity analysis was completed. This involved completing nine additional simulations with varied inputs and comparing their output, in terms of peak mass loading rates to receptors, with the Application Case results. The additional simulations are detailed in TSD XIV. The sensitivity simulation that resulted in the highest overall peak mass loading rates to Patterson Lake (referred to as SR9 in TSD XIV and Table 8.5-1) was selected as the reasonable upper bound scenario for assessment of residual effects. This simulation involved inclusion of upper bound source terms for the UGTMF tailings, production stope backfill, and waste rock TSD XIV).

8.5.1.2.3 Climate and Natural Disturbance Factors

Throughout the EIS, assessment scenarios have also been added, where applicable, to consider how climate change (e.g., changes in precipitation and temperature, and associated effects) may interact with the Project and other developments to affect VCs and intermediate components (Section 6.5.3). Indigenous Groups expressed concerns about climate change (TSD V1: CRDN, TSD II: BNDN, TSD III: BRDN, TSD IV: MN-S). As there is no RFD Case for hydrogeology, potential changes from disturbance factors and climate change are qualitatively discussed in the Application Case.

Atmospheric interaction with hydrogeology is related to infiltration of precipitation, which recharges the groundwater system. Infiltration rates are controlled by precipitation, runoff, and evapotranspiration. Climate change is expected to result in atmospheric warming, which would cause greater rates of evapotranspiration, and greater amounts of precipitation. In terms of infiltration, greater evapotranspiration acts to buffer the potential effects of greater precipitation. Although changes in infiltration rates over time may affect groundwater levels, resulting in greater or lesser hydraulic gradients along flow paths, currently observed overall groundwater flow patterns would remain.

The potential effects of climate change are anticipated to have a limited influence on the deep groundwater flow pathways, which are confined by the upper hydrostratigraphic units. For the shallow groundwater flow pathways (i.e., those that apply to the WRSAs), the potential effects of climate change are limited to changes in flow rates through the transport pathway. Additionally, hydraulic properties of hydrostratigraphic units, which primarily control groundwater seepage would be unaffected by climate change. Because the modelled sources were assumed to be infinite and release of solutes would be governed by the seepage from the base of the WRSAs and through the UGTMF and mine workings, changes to the rate of groundwater transport through the pathway would result in negligible change to the predicted mass loadings to receptors.

8.5.2 Residual Effects Classification

Residual effects are classified in Table 8.5-1 and Table 8.5-2 for groundwater quantity and groundwater quality, respectively. Residual effects were also assessed for two time periods: Operations and Closure of the Project, and the far-future projection that encompasses the long-term effects to groundwater that may occur following Closure. The residual effects on groundwater quantity and groundwater quality are summarized according to direction, magnitude, geographic extent, duration/reversibility, frequency, and probability of occurrence following the methods described in Section 8.2.9, Residual Effects Classification (Table 8.2-3). Residual effects classification considered the implementation of mitigation outlined in Section 8.4, Project Interactions and Mitigations, to reduce the magnitude and duration of residual effects on groundwater quantity and quality. Key mitigations include the following:

- isolation of mine workings from groundwater inflows that could occur through high permeability strata with a hydrostatic liner in shaft;

- segregation and separate storage of PAG material and NPAG material;
- inclusion of engineered source control laying the PAG WRSA;
- construct an engineered cover system over the PAG WRSA landform;
- use of engineered containment and diversion of PAG waste rock runoff and seepage to effluent treatment plant;
- use of engineered cemented paste tailings and backfill to control source concentrations;
- design, maintenance, and monitoring of the mine dewatering system to manage the flow of groundwater inflow;
- application of a binder to reduce permeability in cemented past backfill and tailings;
- use of engineered tailings geochemistry to control source concentrations; and
- implementation of Project-specific management plans (e.g., Mine Waste Management Plan, Environmental Monitoring Plan), monitoring programs (e.g., Environmental Protection Program), and a Detailed Decommissioning and Reclamation Plan.

8.5.2.1 Groundwater Quantity

Residual Project-related changes on hydrogeology for the Application Case are anticipated to be in a negative direction for the measurement indicator of groundwater elevation (Table 8.5-2). Vertically, the drawdown is generally limited to the basement rock, with less than 5 m estimated in the overlying sandstone. The effect is considered local as it is confined to the basement rock (i.e., would not affect Patterson Lake water levels), and certain. The frequency of the effect is anticipated to be continuous as the effects on groundwater elevations occur continuously during Project Operations (i.e., medium-term duration) but would be reversible following Operations.

For the measurement indicator of groundwater flow directions and rates, Project effects on hydrogeology are considered neutral (i.e., result in net balance to hydrogeology) and local in geographic extent. For seepage to the mine and baseflow, the effects would be continuous, certain, and reversible following Project Operations (i.e., medium-term duration). For the groundwater flow pathways under the far-future projection, the effects would be certain and extend well beyond Closure (i.e., permanent).

Changes to groundwater quantity that affect surface water quantity in the receiving environment are subsequently considered in the hydrology assessment (Section 9).

8.5.2.2 Groundwater Quality

Residual Project-related changes on hydrogeology for the Application Case are anticipated to be in a negative direction for the measurement indicator of groundwater quality (Table 8.5-3), which considers solute mass loading rates from groundwater to receptors (e.g., Patterson Lake). Based on groundwater modelling, the magnitude of the effects is variable and solute-specific, and ranges from negligible changes beyond background values to multiple orders of magnitude above background values (Section 8.5.1.2.1). The geographic extent is considered local (i.e., groundwater discharge within Patterson Lake). The duration spans a period from the late stages of Operations into the far future following Closure (i.e., permanent). Effects would be continuous and certain.

Changes to groundwater quality that affect surface water quality in the receiving environment are subsequently considered in the water and sediment quality assessment (Section 10).

Table 8.5-2: Classification of Residual Effects on Groundwater Quantity Measurement Indicators for the Application Case During Operations

Measurement Indicator	Criterion	Rating / Effect Size
		Application Case
Groundwater elevations	Direction	Negative
	Magnitude	▪ 5 m of drawdown in basement rock ▪ Vertically, the drawdown is generally limited to the basement rock, with less than 5 m estimated in the overlying sandstone
	Geographic extent	Local: within the basement rock up to 4 km from the Project
	Duration	Medium-term: during Operations (24 years)
	Reversibility	Reversible
	Frequency	Continuous
	Probability of occurrence	Certain
Groundwater flow directions and rates (seepage to the mine)	Direction	Neutral
	Magnitude	Up to approximately 3,900 m^3/d sustained groundwater inflows
	Geographic extent	Local: within underground mine workings
	Duration	Medium-term: during Operations (24 years)
	Reversibility	Reversible
	Frequency	Continuous
	Probability of occurrence	Certain
Groundwater flow directions and rates (baseflow)	Direction	Neutral
	Magnitude	▪ Treated effluent discharge to Patterson Lake would offset reduction in baseflow resulting from mine dewatering ▪ Simulated mine inflow rates represent a maximum of approximately 6% of the simulated baseflow value to Patterson Lake watershed
	Geographic extent	Local: within the Patterson Lake watershed and the LSA
	Duration	Medium-term: during Operations (24 years)
	Reversibility	Reversible
	Frequency	Continuous
	Probability of occurrence	Certain
Groundwater flow directions and rates (groundwater flow pathways)	Direction	Neutral
	Magnitude	Groundwater flow pathway from the mine horizon to Patterson Lake through fault and shear zones and sandstone, with travel times of approximately 1,000 years
	Geographic extent	Local: between mine horizon and Patterson Lake
	Duration	Permanent: into far-future following Closure
	Reversibility	Irreversible
	Frequency	Continuous
	Probability of occurrence	Certain

LSA = local study area.

Table 8.5-3: Classification of Long-Term Residual Effects on Groundwater Quality Measurement Indicators for the Application Case

Measurement Indicator	Criterion	Rating / Effect Size
		Application Case
Groundwater quality (solute mass loading rates from groundwater to receptors)	Direction	Negative
	Magnitude	▪ Variable and solute specific ▪ Ranges from negligible effects beyond background values to multiple orders of magnitude above background values (Section 8.5.1.2.1)
	Geographic extent	Local: groundwater discharge within Patterson Lake
	Duration	Permanent: Spanning a period from the late stages of Operations and into far future following Closure
	Reversibility	Irreversible
	Frequency	Continuous with varying solute discharge rates
	Probability of occurrence	Certain

8.6 Prediction Confidence and Uncertainty

The purpose of the assessment is to predict future conditions for regional hydrogeology with the Project. The methods adopted for this assessment included baseline studies and quantitative modelling and allowed for a quantitative assessment of Project effects. As with any predictions of future conditions, the predictions made in this assessment embody a moderate degree of uncertainty. There is uncertainty associated with the groundwater flow and solute transport model development and the resulting predictive simulations. This uncertainty stems from limitations in the available subsurface information (e.g., the location and orientation of bedrock units determined from drilling and logging) and can be related to variability in the soil and bedrock properties (e.g., a range in values was determined from hydraulic response testing of faults and shear zones, hydraulic conductivity, and porosity) or uncertainties with the conceptual model (e.g., location of flow boundaries, recharge rates, continuity in aquitards and direction of groundwater flow, simplification of fracture flow systems).

The available data is considered sufficient for the purposes assessing the residual effects for groundwater. However, to gain an understanding of the potential influence of this uncertainty in the simulations, a sensitivity analysis was completed using a deterministic approach, where individual input parameters were adjusted, and the model output was compared to the Application Case results. This approach was adopted to assess the potential variability in the simulated results as a function of both conceptual model uncertainty (i.e., alternative model scenarios) and general uncertainty in the model input parameters. A total of nine additional simulations were completed, which involved the following:

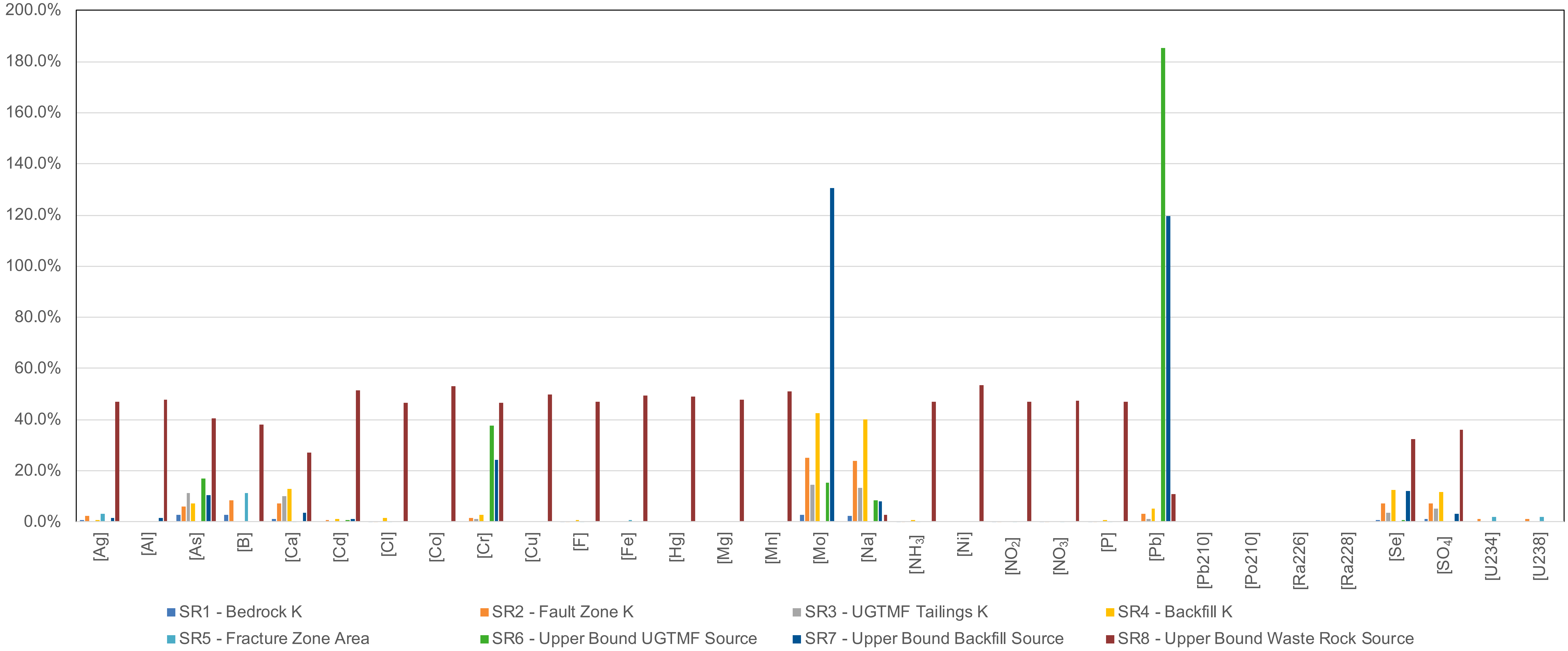
- increasing the hydraulic conductivity of the geological pathways (bedrock and fault zone) and source materials (i.e., tailings in the UGTMF and production stope backfill);
- reducing the geological pathway (i.e., fracture zone) cross-sectional flow area; and
- using upper-bound concentrations for all sources (i.e., tailings, backfill, and waste rock).

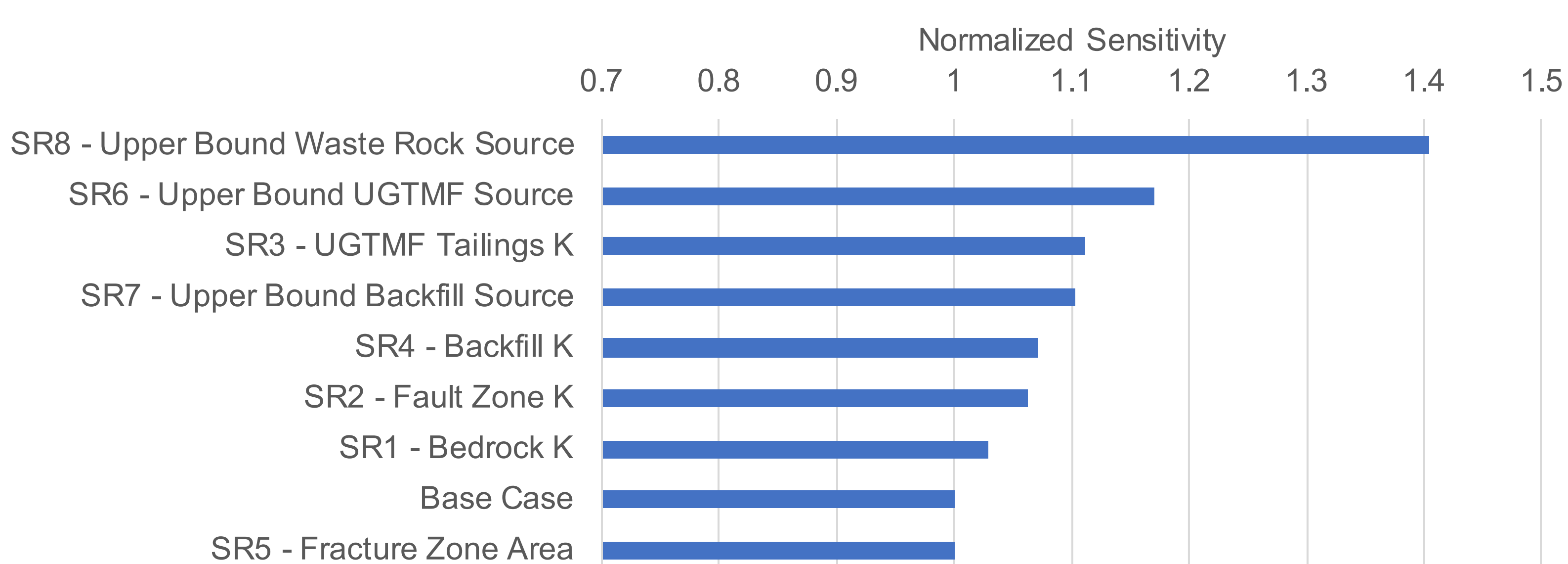
Additional details of the sensitivity simulations are provided in TSD XIV.

The results of the sensitivity simulations are provided in Table 8.5-1 and Figure 8.6-1 in terms of the change to peak mass loading rates. A review of the results led to the following observations:

- Because the surface waste rock loadings represent a large portion of the overall mass loadings (refer to Section 8.5.1.2.1), the results were generally most sensitive to the upper bound waste rock source term.
- The overall highest peak mass loading rates occurred when all upper bound sources were combined.
- The solute loadings were also sensitive to the source terms for backfill (cemented paste tailings and cemented paste backfill) and the UGTMF tailings for solutes where the upper bound source value was much greater than the Application Case value (e.g., lead for the UGTMF source).
- In general, model results were not sensitive (i.e., less than 5% difference) for simulations in which adjustments were made to the hydraulic conductivities of the groundwater flow pathways and backfill materials and the cross-sectional area of the fracture zone.

In summary, the sensitivity analysis showed that reduction in the uncertainty of the source terms for the WRSAs, and to a lesser degree, the underground reflooded mine, would result in greater robustness of the model predictions.





CLIENT
NexGen Energy Ltd.

CONSULTANT
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YYYY-MM-DD	2023-02-09
PREPARED	NB
DESIGN	NB
REVIEW	SD
APPROVED	MT

PROJECT
NEXGEN ENERGY LTD.
ROOK I - HYDROGEOLOGICAL MODELLING

TITLE
SOLUTE TRANSPORT MODEL – RESULTS OF SENSITIVITY SIMULATIONS

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	1	8.6-1

8.7 Monitoring, Follow-Up, and Adaptive Management

This subsection presents a summary of monitoring and follow-up programs required to confirm effects predictions and address uncertainty identified in Section 8.6.

Specifically, follow-up and monitoring programs would be used to:

- compare operational conditions with effect predictions and address uncertainty;
- monitor for changes in groundwater water quality and quantity, including continued monitoring of background wells located upgradient of the Project footprint;
- evaluate the effectiveness of reclamation and other mitigation actions, and modify or enhance as necessary through monitoring and developing updated mitigation measures, if needed;
- identify unanticipated negative effects, including possible accidents and malfunctions; and
- contribute to the overall continual improvement of the Project.

The plan for monitoring groundwater quantity and quality as a part of the Project would be detailed in the Environmental Monitoring Plan. The groundwater focus of this plan is establishment of monitoring systems to evaluate the effectiveness of groundwater protection controls. Groundwater monitoring targets were selected under the plan to achieve the monitoring objectives detailed above. These targets include monitoring of groundwater elevations and quality in the bedrock and overburden to monitor the effects of the following:

- dewatering during construction and development of the shaft, underground mine, and UGTMF;
- seepage from the WRSAs;
- seepage from the process and mine terrace areas, including the fuel and reagent storage areas and equipment such as diesel fuel generators (i.e., in the event of a spill and non-routine events); and
- seepage from the area of the effluent treatment ponds (in the event of leakage).

Constituents of potential concern for the groundwater monitoring were based on an evaluation of the conceptual site model (e.g., hydrogeology, risk of effects from the Project) and the objectives of the groundwater monitoring. Details would be provided in the Environmental Monitoring Plan.

In addition, Environmental Committees (i.e., one per primary Indigenous Group) composed of two NexGen and two Indigenous Group representatives would be established to act in an oversight manner to monitor the environmental performance of the Project and verify the parties are implementing the regulatory and environmental commitments made in respect of the Project.

Indigenous Groups have made recommendations related to mitigating the effects of the Project on the environment, including community-led long-term environmental testing and monitoring during Construction and Operations of the Project (TSD IV: MN-S; TSD V.2: CRDN; YNLRO 2019). NexGen has committed to provide funding for the lifespan of the Project for a full-time independent Indigenous Monitor chosen by each primary Indigenous Group; this Indigenous Monitor would have access to conduct environmental sampling for the Project, subject to the Indigenous Monitor complying with appropriate health and safety and other reasonable site-specific policies. The Indigenous Monitor would be able to report openly and without restriction to the Environmental Committee and Indigenous Group's community members on the performance of the Project. The Indigenous Monitor would also provide regular reports to the Environmental Committee.

8.8 Key Findings

The potential residual effects of the Project on hydrogeology, or groundwater quantity and quality, were characterized through an evaluation of baseline data and hydrogeological modelling. The Project has the potential to cause adverse effects on hydrogeology through the inflow of groundwater to the underground mine during Construction and Operations. Seepage from the WRSAs has the potential to affect groundwater quality in the shallow overburden aquifer. Following Closure of the mine, groundwater elevations would re-establish to static levels and groundwater would be in contact with the backfilled materials. Therefore, the Project has the potential to cause adverse effects on groundwater quality in the bedrock aquifer, and along the groundwater flow path to its ultimate discharge location.

A summary of the key findings from this assessment is provided as follows:

- During Operations, seepage to the mine would result in a depressurization of the surrounding bedrock, which would be observed as a reduction in groundwater elevation at monitoring locations (i.e., groundwater drawdown). The extent of the simulated groundwater drawdown in bedrock resulting from the mine dewatering at the end of Operations extends approximately 2 km to the north, 4 km to the south, and 3.5 km in both the east and west directions, based on the 5 m drawdown contour. Vertically, the extent of depressurization is generally limited to the basement rock, as the overlying sandstone aquifer is considerably more transmissive. The maximum simulated drawdown within the sandstone was estimated to be less than 5 m in the immediate area of the mine workings.
- For the Application Case simulation, between 2022 and 2035, the groundwater inflows to the underground development were predicted to range from a total of approximately 1,200 m^3/d to 2,000 m^3/d, with the greatest portion of inflow occurring at the underground openings not associated with the UGTMF or stope excavations. At year 2035, the total groundwater inflows increased to approximately 3,900 m^3/d, corresponding to the opening of additional stopes. After year 2041 and until Closure, the groundwater inflows are relatively stable at approximately 3,500 m^3/d total inflow, with approximately 60% of inflows derived from stopes and 20% derived from each of the UGTMF and additional workings areas.
- During Operations, the groundwater seepage collected from the underground mine would be treated, monitored, and discharged to Patterson Lake. Assuming that all groundwater seepage collected at the underground mine originates as surface infiltration from the Patterson Lake catchment, the resulting long-term net change to the overall water balance of in the surface water system is zero.
- Based on the particle tracking analysis, groundwater originating at the UGTMF and production stope backfill source areas would migrate vertically upward primarily through the fault and shear zones, then laterally through the sandstone, before discharging within Patterson Lake. The total vertical length of the flow pathway for the underground sources would be approximately 260 m, as measured from the top of the mine (i.e., 180 masl) to the top of the paleoweathered rock unit (i.e., 440 masl). The approximate advective groundwater travel time from the upper horizon of the mine to the discharge location at Patterson Lake is estimated to be approximately 1,000 years.
- Seepage from beneath the WRSAs was predicted to infiltrate vertically to the water table, then laterally towards Patterson Lake in both the northerly and southerly directions. For the overburden groundwater flow paths, the approximate advective groundwater travel time from the piles to Patterson Lake was 43 years to the north and 77 years to the south.

- Based on a review of the solute transport model output, including a comparison of mass loading rates from individual source areas, it was determined that peak mass loadings would be driven primarily by waste rock and reflooded mine workings for most solutes. For a minority of solutes (i.e., sulphate, calcium, and strontium), the relative portions of mass from underground backfill (i.e., cemented paste tailings and backfill) and waste rock sources would be more balanced. Solutes with peak mass loading rates that would be driven by underground sources include molybdenum, sodium, and, to a lesser extent, vanadium.
- The model sensitivity analysis indicated that because the surface waste rock loadings would represent a large portion of the overall mass loadings, the results were generally most sensitive to the upper bound waste rock source term. The loadings to Patterson Lake were also sensitive to the source terms for backfill and the UGTMF tailings for solutes where the upper bound source value was much greater than the Application Case value (e.g., lead for the UGTMF).
- In general, model results were not sensitive (i.e., less than 5% difference) for simulations in which adjustments were made to the hydraulic conductivities of the groundwater flow pathways and backfill materials, and the cross-sectional area of the fracture zone.

Results from the hydrogeological modelling and assessment were provided to the hydrology (Section 9) and surface water quality (Section 10) components for the assessment of how changes to groundwater may affect the receiving environment.

8.9 References

Literature Cited

ACFN (Athabasca Chipewyan First Nation). 2019. NexGen Energy Ltd. Rook 1 Project. July 2019.

BBOP (Business and Biodiversity Offset Programme). 2021. Key Concepts: The Mitigation Hierarchy. Washington, D.C. Accessed September 2021. Available at https://www.forest-trends.org/bbop/bbop-key-concepts/mitigation-hierarchy/.

Beanlands G, Duinker P. 1983. An ecological framework for environmental impact assessment in Canada. Halifax Nova Scotia: Institute for Resources and Environmental Studies, Dalhousie University 132 p.

BGC (BGC Engineering Inc.). 2017. NexGen Energy Ltd., Snowbird Prefeasibility Study 2017 Site Investigation Report – DRAFT. Appendix H – Slug Testing Results.

BNDN-JWG (Birch Narrows Dene Nation-Joint Working Group). 2019. Meeting Notes. Meeting #2. 4 December 2019.

BNDN-JWG. 2020. Meeting Notes. Meeting #4. 2 March 2020.

BNDN-JWG. 2021a. Meeting Notes. Meeting #8. 24 February 2021.

BNDN-JWG. 2021b. Meeting Notes. Meeting #10. 22 April 2021.

Bouwer H, Rice CR. 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Bosman SA, Ramaekers P. 2015. Athabasca Group + Martin Group = Athabasca Supergroup? Athabasca Basin multiparameter drill log compilation and interpretation, with updated geological map; in Summary of Investigations 2015, Volume 2, Saskatchewan Geological Survey, Saskatchewan Ministry of the Economy, Miscellaneous Report 2015-4.2, Paper A-5, 13p. https://pubsaskdev.blob.core.windows.net/pubsask-prod/92005/92005-A-5_Bosman_and_Ramaekers.pdf.

BRDN-JWG (Buffalo River Dene Nation-Joint Working Group). 2019a. Meeting Notes. Meeting #1. 1 November 2019.

BRDN-JWG. 2019b. Meeting Notes. Meeting #2. 5 December 2019.

BRDN-JWG. 2020. Meeting Notes. Meeting #4. 21 February 2020.

BRDN-JWG. 2021a. Meeting Notes. Meeting #9. 31 March 2021.

BRDN-JWG. 2021b. Meeting Notes. Meeting #11. 23 June 2021.

Campbell JE. 2007. Quaternary geology of the Eastern Athabasca Basin, Saskatchewan: EXTECH IV: geology and uranium EXploration TECHnology of the Proterozoic Athabasca Basin, Saskatchewan and Alberta, Jefferson CW, Delane G. (editors), Geological Survey of Canada Bulletin 588, 2007. p. 211-228.

CEA Agency (Canadian Environmental Assessment Agency). 2018. Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Interim Technical Guidance. March 2018 Version 2. Available at http://publications.gc.ca/collections/collection_2018/acee-ceaa/En106-204-2018-eng.pdf.

CNSC (Canadian Nuclear Safety Commission). 2019. Disposition Table of Public and Indigenous Groups' Comments on Project Description – Rook I Project. E-Doc: 6001783. Submitted 12 December 2019. Available at https://iaac-aeic.gc.ca/050/evaluations/proj/80171/contributions/id/35239.

CNSC. 2021. Generic Guidelines for the Preparation of an Environmental Impact Statement – Pursuant to the *Canadian Environmental Assessment Act*, *2012*. Available at https://www.cnsc-ccsn.gc.ca/eng/resources/environmental-protection/ceaa-2012-generic-eis-guidelines/.

CRDN (Clearwater River Dene Nation). 2019a. Comments in Respect License Renewal for Orano Canada Inc. Cluff Lake Project. Canadian Nuclear Safety Commission. CMD 19-H3.12. File 6.01.07.

CRDN. 2019b. Clearwater River Dene Nation Comments on Project Description NexGen Energy Ltd.'s Rook I Project. 31 May 2019.

CRDN-JWG (Clearwater River Dene Nation-Joint Working Group). 2020a. Meeting Notes. Meeting #2. 19 February 2020.

CRDN-JWG. 2020b. Meeting Notes. Meeting #3. 10 March 2020.

CRDN-JWG. 2021. Meeting Notes. Meeting #4. 24 March 2021.

Fission (Fission Uranium Corp.). 2019. Technical Report on the Pre-Feasibility Study of the Patterson Lake South Property using Underground Mining Methods, Northern Saskatchewan, Canada. NI 43-101 Report. Prepared by Roscoe Postle Associates Inc. for Fission Uranium Corp. November 2019.

Fission. 2021. Fission Project Description. Prepared by Clifton Engineering Group Inc. and Canada North Environmental Services Limited Partnership for Fission Energy Corp. 22 November 2021.

Hegmann G, Cocklin C, Creasey R, Dupuis S, Kennedy A, Kingsley L, Ross W, Spalling H, Stalker D, AXYS Environmental Consulting Ltd. 1999. Cumulative Effects Practitioners Guide. Prepared for: Canadian Environmental Assessment Agency.

MN-S (Métis Nation – Saskatchewan). 2019. Comments concerning the NexGen Energy Ltd. Rook I Project Description. Submission to the Canadian Nuclear Safety Commission and Saskatchewan Ministry of the Environment re: NexGen Rook 1 Project. April 2019.

MN-S-JWG (Métis Nation – Saskatchewan-Joint Working Group). 2019a. Meeting Notes. Meeting #1. 29 October 2019.

MN-S-JWG. 2019b. Meeting Notes. Meeting #2. 10 December 2019.

MN-S-JWG. 2020. Meeting Notes. Meeting #4. 27 February 2020.

NexGen (NexGen Energy Ltd.). 2019a. Community Information Session. Round One-June 2019. Submitted to Saskatchewan Ministry of Environment- Environmental Assessment Branch Canadian Nuclear Safety Commission (CNSC).

NexGen. 2019b. Hydrogeology of Upper Sandy-Bouldery Drift (Sandy Till) of the Overburden Sediments above the Arrow U-Deposit. 31 May 2019.

NexGen. 2019c. GAR-19-035 Westbay Purge Tracking.xlsx. 22 November 2019.

NexGen. 2019d. Athabasca Group Sandstone. Presentation provided by NexGen, 31 May 2019.

NexGen. 2019e. Presentation on Elk Point Group (Devonian) Carbonate-Cemented Sandstones and Siltstones. Presentation provided by NexGen, 31 May 2019.

NexGen. 2019f. Manville Group (Cretaceous) Sandstones, Mudstones, Siltstones, with Coaly Horizons. Presentation provided by NexGen, 31 May 2019.

Paterson DF, Kendall AC, Christopher JE. 1978. The Sedimentary Geology of the La Loche Area, Saskatchewan. Saskatchewan Mineral Resources, Report 201, 38p.

Rainbird RH, Stern RA, Jefferson CW. 2002. Summary of detrital zircon geochronology of the Athabasca Group, northern Saskatchewan and Alberta; in Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Sask. Industry Resources, Misc. Rep. 2002-4.2, CD-ROM, Paper D-17, 3p.

SRK (SRK Consulting (Canada) Inc.). 2018. Rook I Pilot Hole Characterization Report – FINAL. Appendix H – Injection Packer Testing Results.

YNLRO (Ya'thi Néné Lands and Resources Office). 2019. Comments concerning the NexGen Energy Ltd. Rook I Project Description. Written Submission from the Ya'thi Néné Lands and Resources Office In the Matter of; NexGen Energy Ltd. Rook I Project Description. May 2019.

Appendix 8A Geology Supplement

Abbreviations and Units of Measure

Abbreviation	Definition
CPB	cemented paste backfill
CNSC	Canadian Nuclear Safety Commission
CPT	cemented paste tailings
EIS	Environmental Impact Statement
LSA	local study area
NBCC	National Building Code of Canada
NexGen	NexGen Energy Ltd.
NRCC	National Research Council of Canada
Project	Rook I Project
RFD	reasonably foreseeable development
RSA	regional study area
U_3O_8	triuranium octoxide
UGTMF	underground tailings management facility
VC	valued component
WRSA	waste rock storage area

Unit	Definition
%	percent
<	less than
g	a value that quantifies the seismic loading on a structure relative to its own weight
Ga	giga annum or billions of years
ha	hectare
H:V	horizontal to vertical
km	kilometre
kt	kilotonne
m	metre
m^3/d	cubic metres per day
masl	metres above sea level
Mlb	million pounds
MPa	megapascal

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8A1 INTRODUCTION

Geology represents a key feature of the physical environment, and potential changes to the geological environment as a result of a project's activities represent important considerations within the assessment of effects. For the NexGen Energy Ltd. (NexGen) Rook I Project (Project), geology has potential linkages to certain valued components and intermediate components assessed in the Environmental Impact Statement (EIS), and in this regard, geology has been appropriately considered to verify that potential effects of the Project are properly understood. To demonstrate how geology has been considered within Project design and the EIS, this Geology Supplement has been developed as Appendix 8A to support EIS Section 8, Hydrogeology.

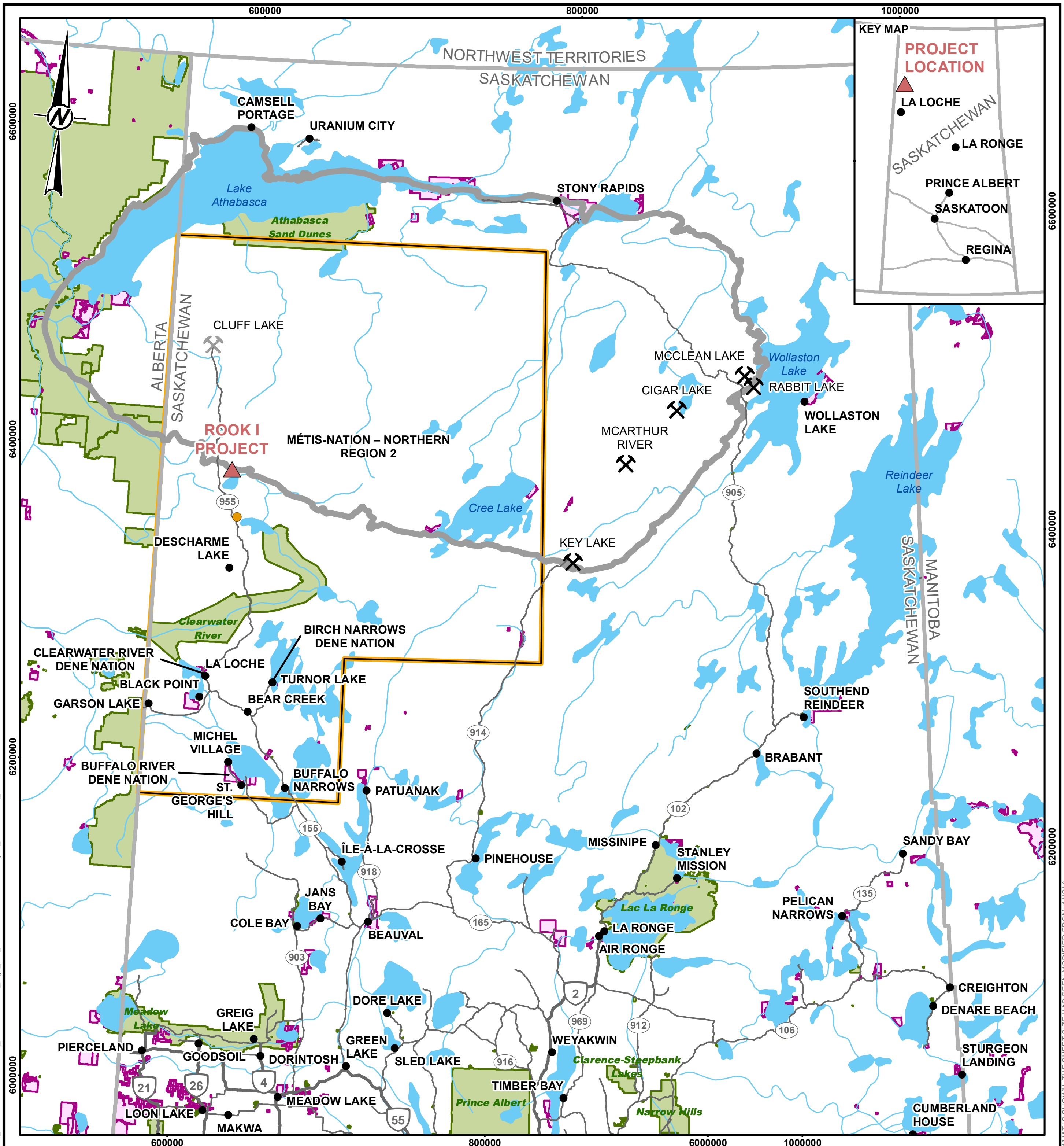
The Geology Supplement includes information on geology and geomorphology existing conditions, geotechnical conditions, an overview of seismicity at the Project location, and assessment of potential Project effects to sediment transport, hydrogeology, and terrain and soils. Where applicable, the content contained within this Geology Supplement include EIS section references where additional details are available.

8A1.1 Geology Baseline

The geology baseline report for the Project is provided in EIS Annex XI. The geology baseline study was completed to describe the existing geologic setting prior to potential development of the Project. The geology baseline includes a characterization of the geological composition of host rocks, alteration, and ore resources of the Arrow deposit, as well as the structural geology of the Arrow deposit, including geometry and characteristics of major faults and shear zones.

The proposed Project site is located in a sub-Arctic climactic region typical of mid-latitude continental areas, with elevations ranging from 583 metres above sea level (masl) on drumlins to 480 masl in lowland lakes (Figure 8A-1). The local topography around the Project site is variable with drumlins and lakes/wetlands dominating the northwest and southeast portion of the area, respectively. Lowland lakes, rivers, and muskegs dominate the central part of the study area.

The Arrow deposit is rooted in the Paleoproterozoic basement rocks of the Taltson Domain along the Patterson Lake corridor, east of the Clearwater River Domain and west of the Virgin River Domain. The bedrock geology is composed of variably silicified and metasomatized intermediate to mafic orthogneisses (Figure 8A-2). Local mafic-rich amphibolite and pyroxenite, ultrabasic and syenitic dykes, and porphyroblastic feldspar- and quartz-rich pegmatites intrude the gneissic granulite facies rocks. The main fabrics and contacts of crystalline basement rocks in the Arrow deposit area are all steeply dipping, dominantly southeast, with a northeast-southwest strike. Basement rocks are unconformably overlain by late Paleoproterozoic to Mesoproterozoic Athabasca Supergroup sandstones of variable thickness, rarely exceeding 50 m. Devonian and/or Cretaceous sedimentary rocks overlie the Athabasca sandstones, with Quaternary glacial deposits capping the geologic sequence and forming the present-day topography.



PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\Introduction\8_5x11\20144150_Fig1_2-1_Location-of-the-RookI-Project_NoTitleblock_Rev0.mxd PRINTED ON: 2023-02-06 AT: 3:27:30 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

25mm

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
- PRESTON LAKE WILDLIFE REFUGE
- 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

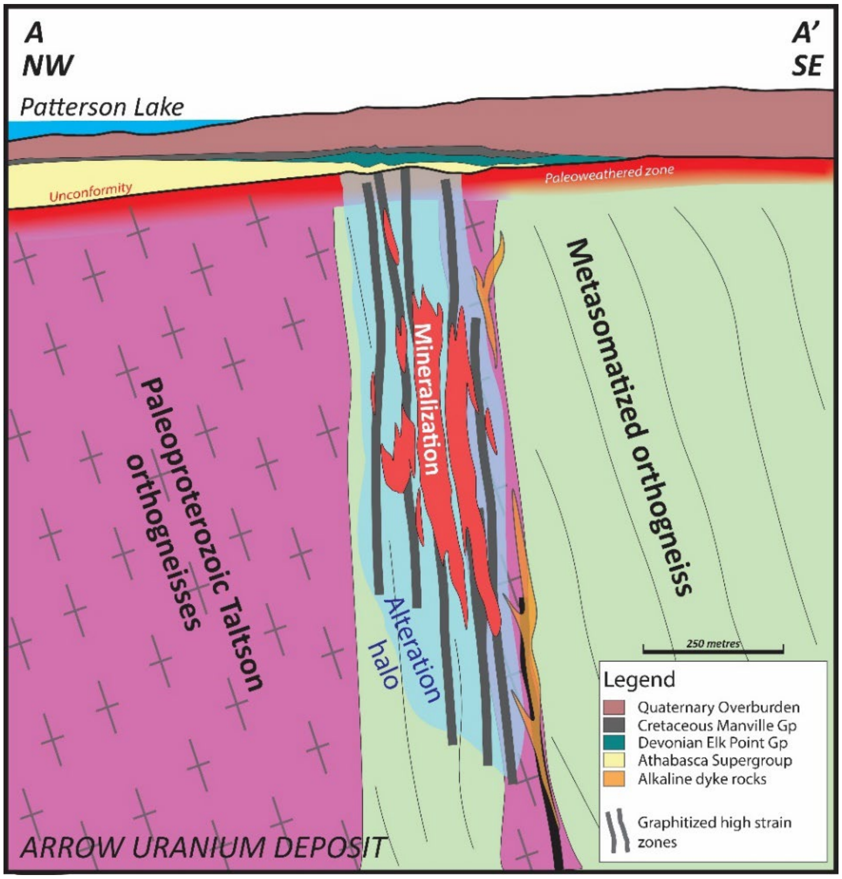
CONSULTANT

wsp

PROJECT	20144150	SCALE AS SHOWN	REV. 0

FIGURE 8A-1

Figure 8A-2: Schematic Northwest-Southeast Cross-Section through the Arrow Deposit showing Local Study Area Geology, Structure, and Zones of Uranium Mineralization



The rocks hosting the Arrow deposit display evidence of episodic structural reactivation and exhumation (i.e., rising towards surface or surface exposure) at progressively shallower crustal levels, related to the protracted tectonic evolution of the Precambrian shield in this region spanning from the Taltson-Thelon to Hudsonian orogenic events circa 1.94 billion years (Ga) to <1.84 Ga. Structural analysis along the ore-hosting portion of the Patterson Lake corridor at the Arrow deposit indicates a sequential development of early ductile and brittle-ductile, to late brittle episodes of movement along the southeast limb of a regional northeast plunging fold complex (Hillacre et al. 2020). Structural and metamorphic relationships suggest that mylonitization was initiated in a ductile environment during D_3 deformation circa 1.92 Ga to 1.90 Ga, with subsequent overprinting by brittle-ductile and brittle faulting involving widespread cataclasis and brecciation, reflecting the progressive unroofing of the high strain zones to shallower lithospheric levels over time (Hillacre et al. 2020).

The structural system at the Arrow deposit has been interpreted to have originally developed along near vertical dipping northeast-southwest-trending brittle-ductile high strain zones (A0 to A5 shears). The stacked high strain zones at the Arrow deposit are nearly parallel and are grouped into a deformation zone approximately 200 m wide, with ore shoots defining an overall plunge to the south-southwest. The heterogeneous high strain zones hosting the Arrow deposit further evolved through episodic reactivation events creating various small-scale brittle fault linkages oblique to and connecting the main fault zone. Primary formation of the uranium veins at the Arrow deposit is related to this episodic reactivation and reuse of pre-existing structures, which formed during the late phases of orogenic events affecting the area circa 1.8 Ga and younger. Fluid flow and reactivation of mineralized structures then further concentrated, remobilized, and altered ore within previously established and newly formed subsidiary fractures, cataclasis zones, and shear and mylonite zones. Multiple phases of uranium mineralization have been identified and classified based on mineral chemistry and textural relationships (Hillacre et al. 2020). Two groups of uraniferous phases have been identified; the first comprising early euhedral, brecciated, and remobilized uraninite, and the second composed of late uranium silicates and hydroxides/oxyhydroxides, such as coffinite and uranophane.

The Arrow deposit has Measured Mineral Resources of 209.6 million pounds (Mlb) of triuranium octoxide (U_3O_8) contained in 2,183 kilotonnes (kt) grading 4.35% U_3O_8, Indicated Mineral Resources of 47.1 Mlb of U_3O_8 contained in 1,572 kt grading 1.36% U_3O_8, and Inferred Mineral Resources of 80.7 Mlb of U_3O_8 contained in 4,399 kt grading 0.83% U_3O_8 (NexGen 2021). The mineralized area is 315 m wide with an overall strike of 980 m. Mineralization occurs 100 m below surface and extends to a depth of 950 m. The individual shear zones vary in thickness from 2 m to 60 m.

The geology baseline provided characterization information that was used in Project design with regards to geotechnical conditions, as well as the assessment of hydrogeology, both of which are summarized in Section 8A1.2 and Section 8A1.5, respectively.

8A1.2 Geotechnical Conditions and Design Considerations

Geotechnical Conditions

The geotechnical conditions in the area of the Project are favourable to crown pillar stability. Geotechnical conditions are generally characterized by up to 75 m of dense to very dense sedimentary layers underlain by very competent basement rock extending to below the Arrow deposit. Overlying materials generally have a higher level of hydraulic conductivity, allowing water to flow, while basement rock has very low hydraulic conductivity, with the exception of well-understood shear or fault zones, which can be conduits for water movement.

An understanding of basement rock mass conditions is required to reliably predict rock mass responses and conditions in the Arrow deposit, which allows the appropriate design of underground development and infrastructure, and ultimately, performance of mining activities. Generally, the basement rock in which proposed Project underground infrastructure would be developed is competent ground suitable for mine development and long-term tailings storage.

Rock mass classification systems have been used to classify rock mass quality in basement rock and assess the range in anticipated rock quality in the primary areas of interest associated with the Project (e.g., mining and underground tailings management facility [UGTMF] zones). In addition to rock quality, other geotechnical parameters associated with the material types were spatially interpreted to develop geotechnical domain (i.e., units representing different material types) models to relate the geotechnical conditions to the mine plan.

Several interpreted basement shears and faults align with, and are close to, mineralization (i.e., the uranium ore body). Shear zones are closely related to the strength of the overall rock mass. Lab-measured unconfined compressive strengths at the Arrow deposit range from 10 megapascals (MPa) to nearly 250 MPa.

Further information regarding surface and underground geotechnical conditions at the Project site are provided in EIS Section 5.3.3.2, Geotechnical Conditions.

Design Considerations

NexGen would develop and operate all Project infrastructure, facilities, and systems in accordance with design standards relevant to the Project, which are based on regulatory guidance, applicable building code requirements, and best management practices as developed by applicable industry and trade associations and standards organizations (EIS Section 5.3.1, Design Standards).

The underground workings would be safely developed through appropriate consideration of geotechnical conditions (EIS Section 5.4.3.3, Underground Tailings Storage). Openings in the mine workings would include ground support and reinforcement in the roof to mitigate potential instabilities. The UGTMF would be a purpose-built underground facility with chambers dedicated to the permanent disposal of tailings. The UGTMF would be located on the north side of the Arrow deposit, and the UGTMF chamber size requirements and development schedule would be derived from, and adapted to, the ore processing schedule to provide sufficient storage for tailings. The UGTMF chambers would be developed using long hole stoping mining methods. Geomechanical modelling has confirmed that chambers with approximately 25 m by 25 m openings and 15 m wide rock pillars between chambers would create stable excavations that would remain open until they are backfilled with the cemented paste tailings (CPT).

Regarding the stability of crown pillars, or the vertical distance between the unconformity and the uppermost production and UGTMF stopes, empirical stability assessments using the scaled span method (Carter 2008; Carter 2014) were conducted. The uppermost underground production stope crown pillars are rated as either Class F (0.5% to 1.5% chance of failure; public access allowed) or Class G (<0.5% chance of failure; free public access). Probability of failure of the crown pillars above the production stopes would be further reduced as the stopes would be backfilled with cemented paste backfill (CPB), which would consist of neutralized leached residue, water, and binder mixed in various ratios to meet appropriate geotechnical strength requirements (EIS Section 5.4.3.1, Paste Plant). The UGTMF stopes would be rated as Class G as a result of the existing geotechnical conditions of the surrounding basement rock; these stopes would be backfilled with the CPB and CPT, which, as with CPB, would contain a binder to promote structural strength (EIS Section 5.5.2.3, Tailings Management). Overall, potential subsidence is not expected due to the combination of low failure probabilities and the backfilling of both underground production and UGTMF stopes, which would facilitate long-term geotechnical stability.

With respect to Project surface features, as described in EIS Section 5.5.2.4, Mine Rock Management, both the potentially acid generating waste rock storage area (WRSA) and non-potentially acid generating WRSA would be constructed with side slopes of 4H:1V, which would facilitate long-term geotechnical stability.

8A1.3 Seismicity and Design Considerations

Seismicity

Seismic activity, such as earthquakes, can trigger natural hazards including ground vibrations, landslides, liquefaction of saturated sediments, and surface rupture. These natural hazards can affect underground mine workings and surface-engineered structures such as water diversions and WRSAs. Seismic activity can also result in work delays while stability is reassessed for the safety of the employees and continued production. Detailed information on earthquakes that have occurred in Canada is contained in publications of Earthquakes Canada of Natural Resources Canada and their predecessor organizations. A seismic zoning map for Canada has been developed on the basis of these studies and is used in the National Building Code of Canada (NBCC; NRCC 2020) to help design and construct buildings that are appropriately earthquake proof for a given region.

The potential for seismic events at the Project were evaluated in a risk assessment presented in EIS Section 22.6.7, Seismic Events.

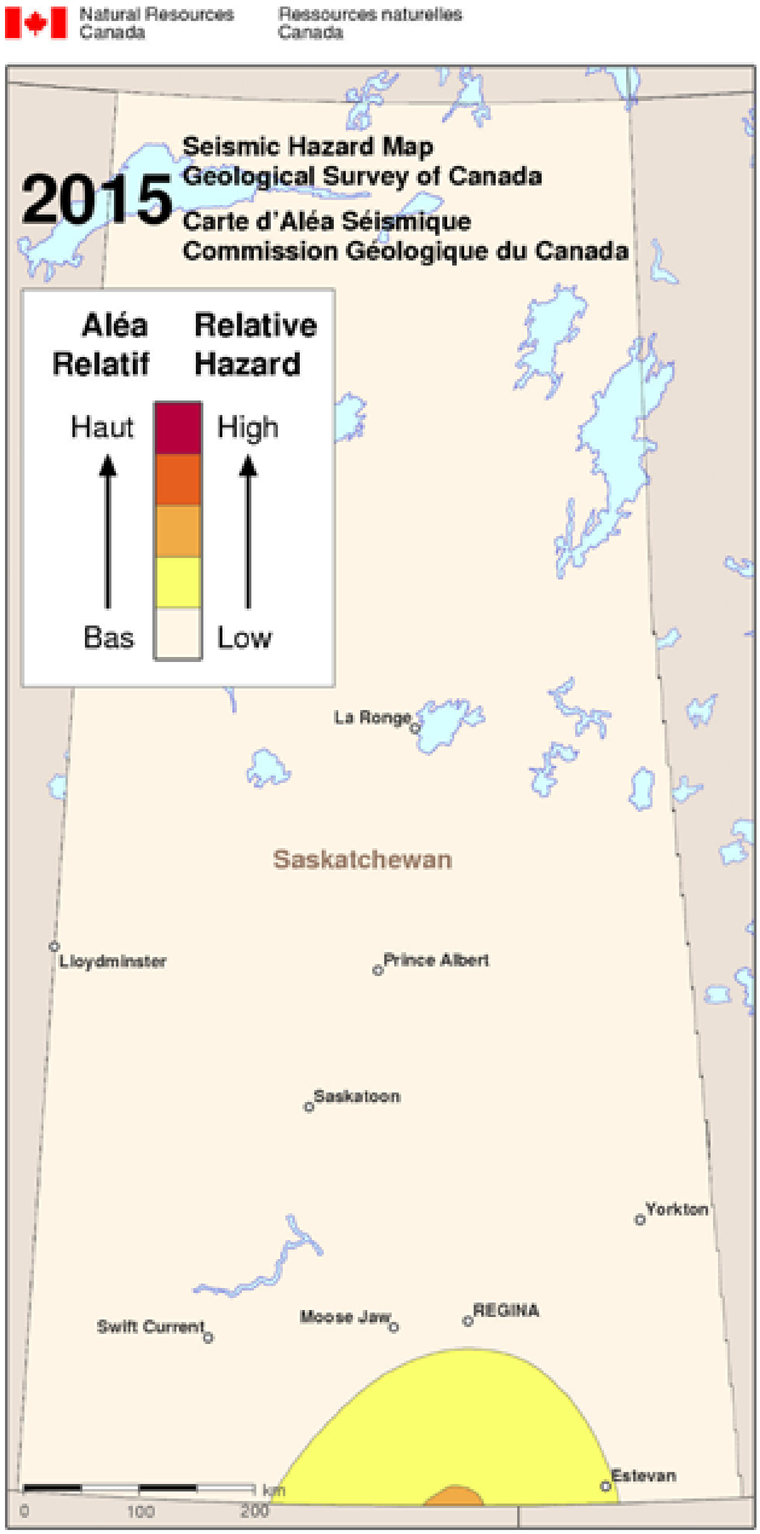
According to the Government of Canada (2021a), the seismic hazard for northern Saskatchewan is rated as low (i.e., less than 1% chance significant damage will occur in 50 years) (Figure 8A-3). The Project is located in a region of the lowest seismic activity in Canada. Moreover, in the past 400 years, there have been no earthquakes recorded with a magnitude greater than 3 in northern Saskatchewan (Government of Canada 2021b).

The Athabasca Basin is seismically inactive according to the NBCC. Numerical modelling has been completed for the Project, which included assessing the susceptibility of mine excavations and infrastructure to mine-induced stress over the Project lifespan. The estimated peak ground acceleration with a return period of 2,475 years is less than 0.036g at a probability of 2% over 50 years. The risk of naturally occurring seismic events is low. The mining would be at low to moderate depths; depths below surface range from 350 m to 710 m. Seismic events due to mining have been evaluated and are considered highly unlikely.

Design Considerations

The Project would incorporate seismic event risks into the design and operation of the mine. Project infrastructure would be designed to withstand extreme environmental conditions that pose risks to its integrity. All buildings on site would be designed according to the NBCC (NRCC 2020). The NBCC incorporates technical requirements so that buildings are protected against earthquakes based on local seismic conditions. The underground mine development, WRSAs, and UGTMF design considered geotechnical stability.

Figure 8A-3: Saskatchewan Seismic Hazard Map



8A1.4 Geomorphology Baseline and Fluvial Sediment Transport Assessment

The geomorphology characterization report for the Project is provided in EIS Annex IV.3. The geomorphology characterization report was completed as part of the hydrology program to characterize existing geomorphology of Patterson Lake's shorelines and the Clearwater River channel downstream of the Patterson Lake outlet and to identify areas that may be vulnerable to increased erosion due to proposed Project activities.

Field surveys completed for the geomorphology study included observations of landforms, shoreline slopes, bank and bed materials, and vegetation, as well as photographic documentation. Information collected during the field surveys was used to classify erosion susceptibility at the field survey sites. Erosion susceptibility at other portions of the Patterson Lake shoreline was assessed using a combination of field survey, geospatial data, and aerial imagery. Channel erosion susceptibility in the Clearwater River below Patterson Lake was also assessed based on field observations.

The results from the baseline characterization of Patterson Lake showed that several shoreline segments along Patterson Lake were observed to be subject to modification by ongoing sediment transport processes. These processes include accretion (i.e., gradual build-up of sediment) resulting from longshore drift, with historical shoreline alignments different than current shoreline locations visible in the aerial imagery, as well as likely ice thrust modification of sedimentary shorelines. The active sediment transport areas are expected to be most sensitive to possible changes in the lake hydrologic regime. The localized bank erosion sites observed along the lake shoreline in sections with ice-thrust berms were also identified as sensitive areas.

The corresponding results from the baseline characterization of Clearwater River identified a single channel upstream and multiple meandering channels farther downstream, with typical channel cross-section geometries (i.e., deep banks on the outside of the meander) and fluvial morphology (i.e., point bars). The river has an active sediment transport regime, capable of transporting mostly small size materials (i.e., fine to medium sand), as indicated by the delta feature at its mouth into Forrest Lake.

This information was applied to the assessment of fluvial sediment transport, which is a measurement indicator for hydrology (EIS Section 9.3.7, Fluvial Sediment Transport). The residual effects analysis (EIS Section 9.6.1.4, Fluvial Sediment Transport) considered predicted increases in flow downstream of the Project, which are small and not expected to result in a measurable change in the fluvial sediment transport regime under both the Application Case and Reasonably Foreseeable Development (RFD) Case. The classification of residual effects to fluvial sediment transport (Table 8A-1) is reproduced below from Table 9.7-1 of EIS Section 9.7, Residual Effects Classification.

Table 8A-1: Classification of Residual Effects for the Clearwater River Hydrology Nodes

Measurement Indicator	Criterion	Rating / Effect Size			
		Application Case	RFD Case Scenarios		
			RFD Case	Climate Change	Total (i.e., RFD Case [including Climate Change])
Fluvial sediment transport at mean annual flood	Direction	Neutral	Neutral	Neutral	Neutral
	Magnitude	Negligible	Negligible	Negligible	Negligible
	Geographic extent	Local	Local	Beyond regional	Regional[b]
	Duration[a]	Long-term: 43 years (2025 to 2068)	Medium-term: Maximum of 15 years (nominally modelled as 2025 to 2039) of temporal overlap between the Project and the Fission Patterson Lake South Property. Effect on water quantity primarily during construction and operations period of nine years (nominally modelled as 2025 to 2033)	Permanent	Permanent
	Reversibility	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Irreversible	Irreversible
	Frequency	Continuous	Continuous	Continuous/periodic	Continuous/periodic
	Probability of occurrence	Certain	Probable	Probable	Probable

a) For the purpose of ease of reference in modelling, construction of the Project and Fission Patterson Lake South Property were assumed to start in 2025. This assumption is conservative as it assumes effects from construction of Project and Fission Patterson Lake South Property occur at the same time.
b) The geographic extent for total change under RFD Case (including climate change) is regional to represent the cumulative effect of developments rather than global climate change effects, which would have a beyond regional geographic extent.
RFD = reasonably foreseeable development.

8A1.5 Hydrogeology Assessment

The hydrogeology baseline report for the Project is provided in EIS Annex III, and the assessment of hydrogeology is provided in EIS Section 8.

The Arrow deposit consists of several high-grade uranium veins and is hosted in Paleoproterozoic basement rocks. The basement rock in the regional study area (RSA) is predominantly composed of granite or gneiss. Athabasca Supergroup sandstones of variable thickness overlie the basement rocks unconformably. Sedimentary rocks overlie the Athabasca sandstones, with glacial drift deposits (i.e., materials such as gravel, sand, silt, and clay) capping the geologic sequence and forming the present-day topography. Hydrostratigraphic units were defined based primarily on the geological units that exhibit similar hydraulic properties and structures. The basement rock was identified to have relatively low porosity and permeability, and the primary hydraulic pathways are anticipated to be fractures, faults, and shear zones. These enhanced conductivity features defined the overall hydraulic conditions of the basement rock. The layers of the overlying Athabasca sandstone bedrock are the dominant areas in which groundwater flow occurs and are considered to be the primary aquifer. Interbedded zones of clay-rich cementation act as an aquitard within the Athabasca Supergroup, inhibiting the vertical movement of water. Therefore, the vertical hydraulic conductivity in this layer is considered to be lower than the horizontal hydraulic conductivity. The overlying, unconsolidated glacial drift deposits are present throughout the RSA. Based on the relatively coarse-grained nature of the unconsolidated glacial drift deposits within the vicinity of the Project, the unit is considered to be an unconfined aquifer.

The predominant deep groundwater west to east flow direction is controlled by regional topography. Local to the proposed underground mine, deep groundwater flows north and upward towards Patterson Lake.

Shallow groundwater flow patterns mimic local topography, infiltrating in highlands and discharging in low lying water bodies and drainages. At the peninsula where the Project would be located, a shallow groundwater flow divide exists south of the proposed mine. Shallow groundwater within glacial drift flows north and south from the divide, discharging to Patterson Lake in both directions.

During baseline assessments, representative groundwater samples were collected and analysed for water chemistry. Based on the interpreted bedrock groundwater type, it was considered likely that the groundwater in bedrock is “older” and indicative of groundwater moving along a flow path as it transitions from calcium- to sodium- type with increasing depth and age of the geologic formation. In contrast, the glacial drift groundwater type was considered “young” based on calcium-type and indicative of geologically recent recharge from the surface. Limited mixing likely occurs with older water from the geologic formation below.

This understanding of the hydrogeological existing conditions provided a basis for the residual effects assessment of Project effects to hydrogeology, which is detailed in EIS Section 8. The assessment considered three measurement indicators:

- groundwater elevations;
- groundwater flow directions and rates; and
- groundwater quality.

To support the hydrogeology assessment, a 3D numerical groundwater flow model was developed and calibrated based on target groundwater elevations and baseflow (i.e., the portion of streamflow sustained between precipitation events) information. The calibrated model was used to predict the Project effects through all phases (Construction, Operations, and Closure) on groundwater inflows and the extent and magnitude of groundwater depressurization, as well as to delineate groundwater flow pathways from mine waste source areas to Patterson Lake.

The residual effects analysis measured and described the effects of the Project on hydrogeology relative to existing conditions. Residual effects are described for each of the measurement indicators for the primary pathways identified for hydrogeology (i.e., groundwater elevations, groundwater flow directions and rates, and groundwater quality) in the local study area (LSA). An RFD Case was not required as there are little to no potential for cumulative effects on hydrogeology from the Project and RFDs.

Groundwater Quantity

The main objectives of the predictive modelling with respect to groundwater quantity were to estimate the groundwater inflows to the underground development, the extent of depressurization, and the resulting potential influence on groundwater discharge to surface water features during Operations. For the far-future projection, the model was used to delineate groundwater flow pathways and flow rates through the various source areas to surface water receptors.

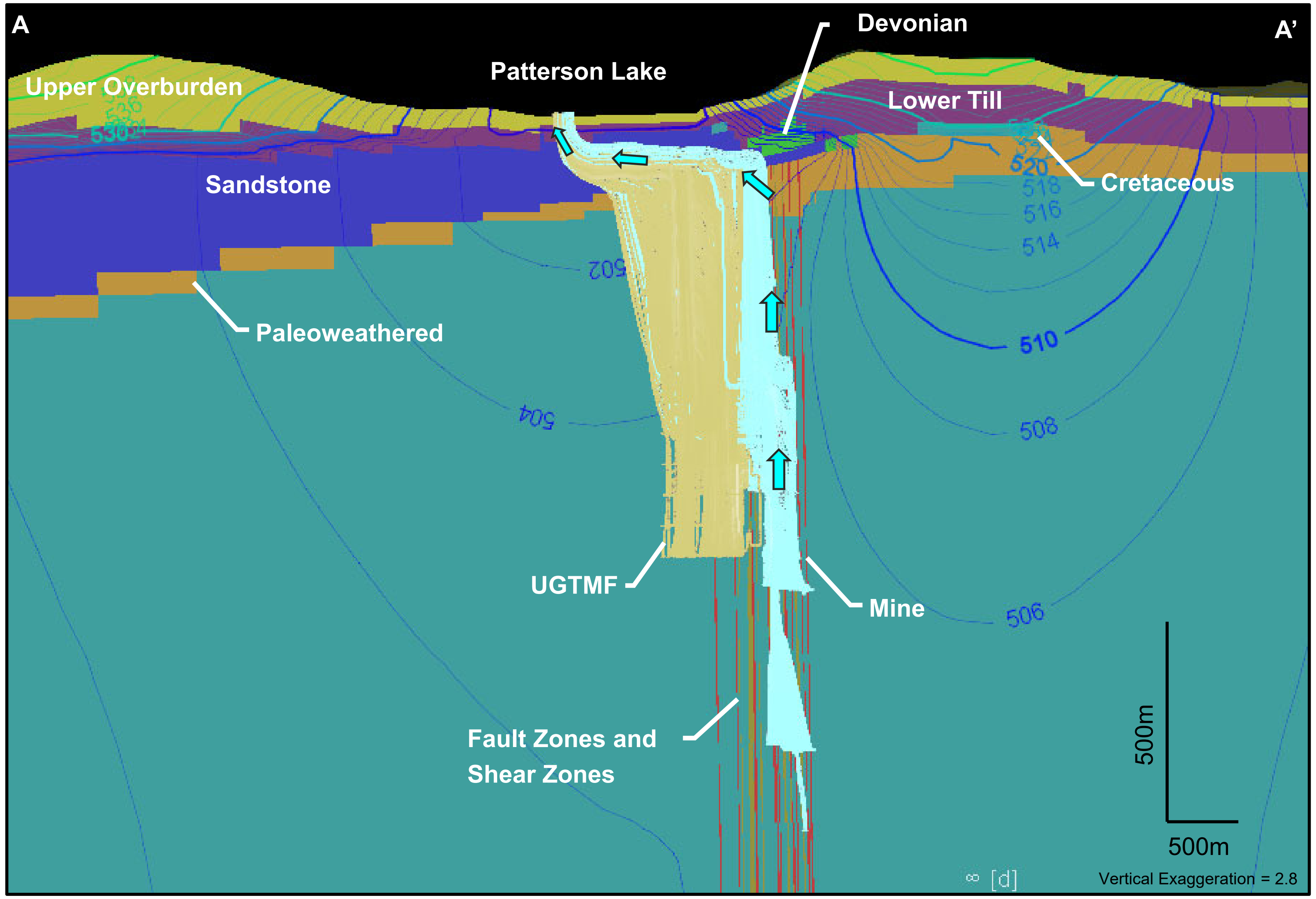
During Operations, seepage to the underground mine would result in a depressurization of the surrounding bedrock, which would be observed as a reduction in groundwater elevation at monitoring locations. The extent of the simulated groundwater drawdown in bedrock resulting from the mine dewatering at the end of Operations extends approximately 2 km to the north, 4 km to the south, and 3.5 km in both the east and west directions. Vertically, the extent of depressurization was generally limited to the basement rock, as the overlying sandstone aquifer had greater hydraulic conductivity. The maximum simulated drawdown within the sandstone was estimated to be less than 5 m in the immediate area of the mine workings.

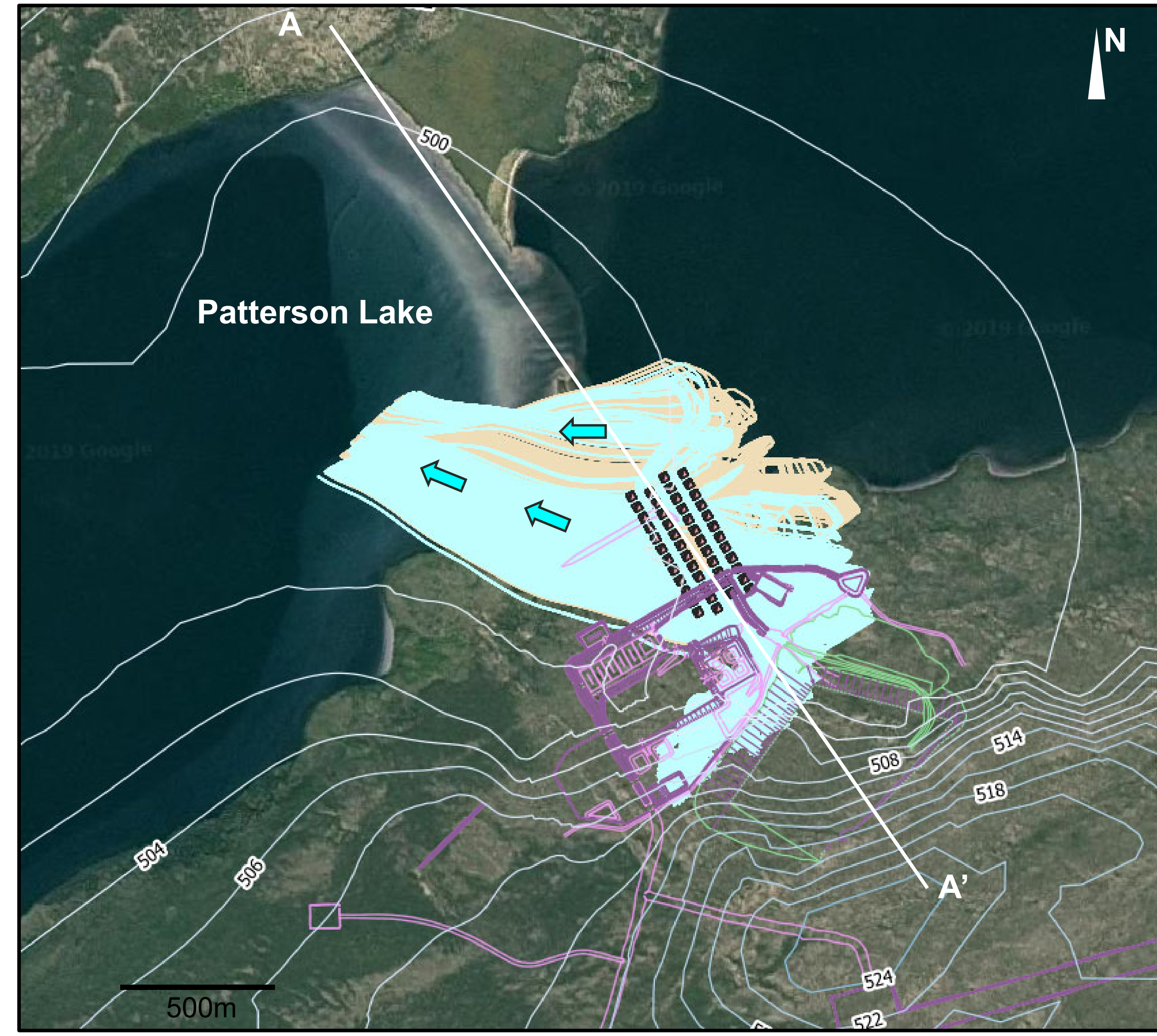
During Construction and Operations, groundwater inflows to the underground development are predicted to range from approximately 1,200 cubic metres per day (m^3/d) to 3,900 m^3/d. These conservatively assessed inflow values were used in the surface water modelling for the Project.

During Operations, the groundwater seepage collected from the underground mine would be treated, monitored, and discharged to Patterson Lake. Assuming that all groundwater seepage collected at the underground mine originates as surface infiltration from the Patterson Lake catchment, the resulting long-term net change to the overall water balance of the surface water system was identified to be negligible.

Based on the particle tracking modelling, groundwater originating at the UGTMF and production stope backfill source areas is predicted to migrate vertically upward primarily through the fault and shear zones, then laterally through the sandstone, before discharging within Patterson Lake (Figure 8A-4). The approximate advective groundwater travel time from the upper horizon of the mine to the discharge location at Patterson Lake is estimated to be approximately 1,000 years.

Seepage from beneath the WRSAs was predicted to infiltrate vertically to the water table, then laterally towards Patterson Lake in both the northernly and southernly directions (Figure 8A-5). For the overburden groundwater flow paths, the approximate advective groundwater travel time from the WRSAs to Patterson Lake was 43 years to the north and 77 years to the south.





LEGEND

- SIMULATED GROUNDWATER HEAD CONTOUR – SECTION VIEW (m)
- SIMULATED GROUNDWATER HEAD CONTOUR – PLAN VIEW (m)
- SIMULATED GROUNDWATER FLOW PATHWAY (UGTMF)
- SIMULATED GROUNDWATER FLOW PATHWAY (BACKFILL)
- BASEMENT ROCK
- PALEOWEATHERED BASEMENT ROCK
- SANDSTONE
- DEVONIAN ROCK
- CRETACEOUS ROCK
- LOWER OVERBURDEN (TILL)
- UPPER OVERBURDEN

Notes:
1) Arrows indicate direction of groundwater flow pathway
2) Simulated groundwater head contours reflect long-term post-closure conditions.
3) UGTMF = underground tailings management facility

CLIENT
NexGen Energy Ltd.

CONSULTANT
wsp

YYYY-MM-DD	2021-07-24
PREPARED	NB
DESIGN	NB
REVIEW	SD
APPROVED	MT

PROJECT
ROOK I PROJECT

TITLE
PARTICLE TRACKING ANALYSIS – GROUNDWATER FLOW PATHWAYS FOR UNDERGROUND SOURCES

PROJECT No.	PHASE	Rev.	FIGURE
20144150	3104	0	8A-4

LEGEND

- SIMULATED GROUNDWATER FLOW CONTOUR – PLAN VIEW (m)
- SIMULATED GROUNDWATER FLOW PATHWAY
- SURFACE WASTE FACILITIES (SOURCE AREA)
- SURFACE MINE INFRASTRUCTURE

Notes:

1) Arrows indicate direction of groundwater flow pathway
2) Simulated groundwater head contours reflect long-term post-closure conditions.

CLIENT
NexGen Energy Ltd.

CONSULTANT
wsp

YYYY-MM-DD	2024-11-07
PREPARED	AC
DESIGN	NB
REVIEW	JL
APPROVED	JL

PROJECT
NEXGEN ENERGY LTD.
ROOK I PROJECT

TITLE
PARTICLE TRACKING ANALYSIS – GROUNDWATER FLOW PATHWAYS FOR ABOVE GROUND SOURCES

PROJECT No.	PHASE	Rev.	FIGURE
CA00226400.3030		0	8A-5

Groundwater Quality

The main objective of the predictive modelling with respect to groundwater quality was to estimate the solute mass loading rates from waste rock and CPT and backfill to surface receptors during Operations and in the long-term following Closure.

Based on modelling of groundwater quality, the magnitude of the effects was variable and specific to the solute being modelled. Solute-specific effects ranged from negligible effects beyond background values to multiple orders of magnitude above background values. Spatially, these effects were predicted to be limited to the groundwater discharge within Patterson Lake. The temporal scale of these effects was long term, spanning a period from the late stages of Operations to long-term following Closure (i.e., permanent).

The classifications of residual effects to groundwater quantity (Table 8A-2) and groundwater quality (Table 8A-3) are reproduced below from Table 8.5-2 and Table 8.5-3, respectively, of EIS Section 8.5.2.2, Groundwater Quality.

Table 8A-2: Classification of Residual Effects on Groundwater Quantity Measurement Indicators for the Application Case During Operations

Measurement Indicator	Criterion	Rating / Effect Size
		Application Case
Groundwater elevations	Direction	Negative
	Magnitude	▪ 5 m of drawdown in basement rock ▪ Vertically, the drawdown is generally limited to the basement rock, with less than 5 m estimated in the overlying sandstone
	Geographic extent	Local: within the basement rock up to 4 km from the Project
	Duration	Medium-term: during Operations (24 years)
	Reversibility	Reversible
	Frequency	Continuous
	Probability of occurrence	Certain
Groundwater flow directions and rates (seepage to the mine)	Direction	Neutral
	Magnitude	Up to approximately 3,900 m^3/d sustained groundwater inflows
	Geographic extent	Local: within underground mine workings
	Duration	Medium-term: during Operations (24 years)
	Reversibility	Reversible
	Frequency	Continuous
	Probability of occurrence	Certain
Groundwater flow directions and rates (baseflow)	Direction	Neutral
	Magnitude	▪ Treated effluent discharge to Patterson Lake would offset reduction in baseflow resulting from mine dewatering ▪ Simulated mine inflow rates represent a maximum of approximately 6% of the simulated baseflow value to Patterson Lake watershed
	Geographic extent	Local: within the Patterson Lake watershed and the LSA
	Duration	Medium-term: during Operations (24 years)
	Reversibility	Reversible
	Frequency	Continuous
	Probability of occurrence	Certain

Table 8A-2: Classification of Residual Effects on Groundwater Quantity Measurement Indicators for the Application Case During Operations

Measurement Indicator	Criterion	Rating / Effect Size
		Application Case
Groundwater flow directions and rates (groundwater flow pathways)	Direction	Neutral
	Magnitude	Groundwater flow pathway from the mine horizon to Patterson Lake through fault and shear zones and sandstone, with travel times of approximately 1,000 years
	Geographic extent	Local: between mine horizon and Patterson Lake
	Duration	Permanent: into far-future following Closure
	Reversibility	Irreversible
	Frequency	Continuous
	Probability of occurrence	Certain

LSA = local study area; m^3/day = cubic metres per day.

Table 8A-3: Classification of Long-Term Residual Effects on Groundwater Quality Measurement Indicators for the Application Case

Measurement Indicator	Criterion	Rating / Effect Size
		Application Case
Groundwater quality (solute mass loading rates from groundwater to receptors)	Direction	Negative
	Magnitude	▪ Variable and solute specific ▪ Ranges from negligible effects beyond background values to multiple orders of magnitude above background values (EIS Section 8.5.1.2.1)
	Geographic extent	Local: groundwater discharge within Patterson Lake
	Duration	Permanent: Spanning a period from the late stages of Operations and into far future following Closure
	Reversibility	Irreversible
	Frequency	Continuous with varying solute discharge rates
	Probability of occurrence	Certain

8A1.6 Terrain and Soils

Potential changes to surficial geology due to the Project were assessed in EIS Section 12, Terrain and Soils.

Terrain in the LSA is primarily undulating to hummocky upland landscape. The slope of the local terrain ranges from relatively level to slopes of 25% or greater, with an average slope of about 7%. The LSA is composed of four terrain units, which are approximately distributed as follows:

- 79% glaciofluvial deposits;
- 14% water;
- 4% fen peat (i.e., Organic); and
- 4% anthropogenic (i.e., human-derived) disturbance.

For the soil-covered areas within the LSA, mineral soils are dominant, with some Organic soils also present. Mineral soil map units consist almost entirely of Brunisols, with small amounts of Gleysols and Mesisols also present. Organic soil map units consist almost entirely of Mesisols, with small amounts of Gleysols and Brunisols also present.

A residual effects analysis was conducted to determine the potential effects of the Project on terrain and soils. The residual effects analysis considered three measurement indicators:

- quantity and distribution of terrain units;
- quantity and distribution of soil map units; and
- soil quality, which focused on soil suitability for reclamation.

Effects on terrain and soil map units covered with permanent facilities of the Project (e.g., waste rock storage areas) would be irreversible. The effects from disturbance on terrain and soil map units not covered by permanent facilities would be reversible over a long-term duration. During Operations, the Project would be progressively reclaimed. During the Active Closure Stage, non-permanent facilities and infrastructure would be fully decommissioned and reclaimed. Permanent facilities would be reclaimed to the extent possible. Reclamation is predicted to reverse effects on disturbed terrain and soils and would support the establishment and succession of vegetation communities that have a similar function to natural ecosystems. This objective would be achieved by applying best practices for soil salvage, storage, and placement. The establishment of reclaimed terrain, soils, and associated vegetation ecosystems would extend well beyond Closure (i.e., more than 60 years). A summary of residual effects to terrain and soils (Table 8A-4) is reproduced below from Table 12.5-3 of EIS Section 12.5.3, Residual Effects Classification.

Table 8A-4: Classification of Residual Effects on Terrain and Soils Measurement Indicators for the Application Case

Measurement Indicator	Criterion	Rating / Effect Size
Quantity and distribution of terrain units	Direction	▪ Negative
	Magnitude	▪ 897.8 ha of natural terrain units under existing conditions converted to the disturbance map unit (i.e., high magnitude) ▪ 82.2 ha of the disturbance map unit remain in the maximum disturbance area
	Geographic extent	▪ Maximum disturbance area
	Duration	▪ Permanent: natural terrain units covered by permanent features (e.g., WRSAs) ▪ Long-term: for reclaimed terrain units, 33 years (start of Construction to end of Active Closure Stage) or earlier with progressive reclamation, and extending well beyond Closure
	Reversibility	▪ Irreversible: natural terrain units covered by permanent features (e.g., WRSAs) ▪ Reversible: for reclaimed terrain units
	Frequency	▪ Continuous
	Probability of occurrence	▪ Certain
Quantity and distribution of soil map units	Direction	▪ Negative
	Magnitude	▪ 897.8 ha of soil map units under existing conditions converted to the disturbance map unit (i.e., high magnitude) ▪ 82.2 ha of the disturbance map unit remain in the maximum disturbance area
	Geographic extent	▪ Maximum disturbance area
	Duration	▪ Permanent: for natural soil map units covered by permanent features (e.g., WRSAs) ▪ Long-term: for disturbed soil map units, 33 years (start of Construction to end of Active Closure Stage), or earlier with progressive reclamation, and extending well beyond Closure
	Reversibility	▪ Irreversible: natural soil map units covered by permanent features (e.g., WRSAs) ▪ Reversible: for reclaimed soil map units
	Frequency	▪ Continuous
	Probability of occurrence	▪ Certain

Table 8A-4: Classification of Residual Effects on Terrain and Soils Measurement Indicators for the Application Case

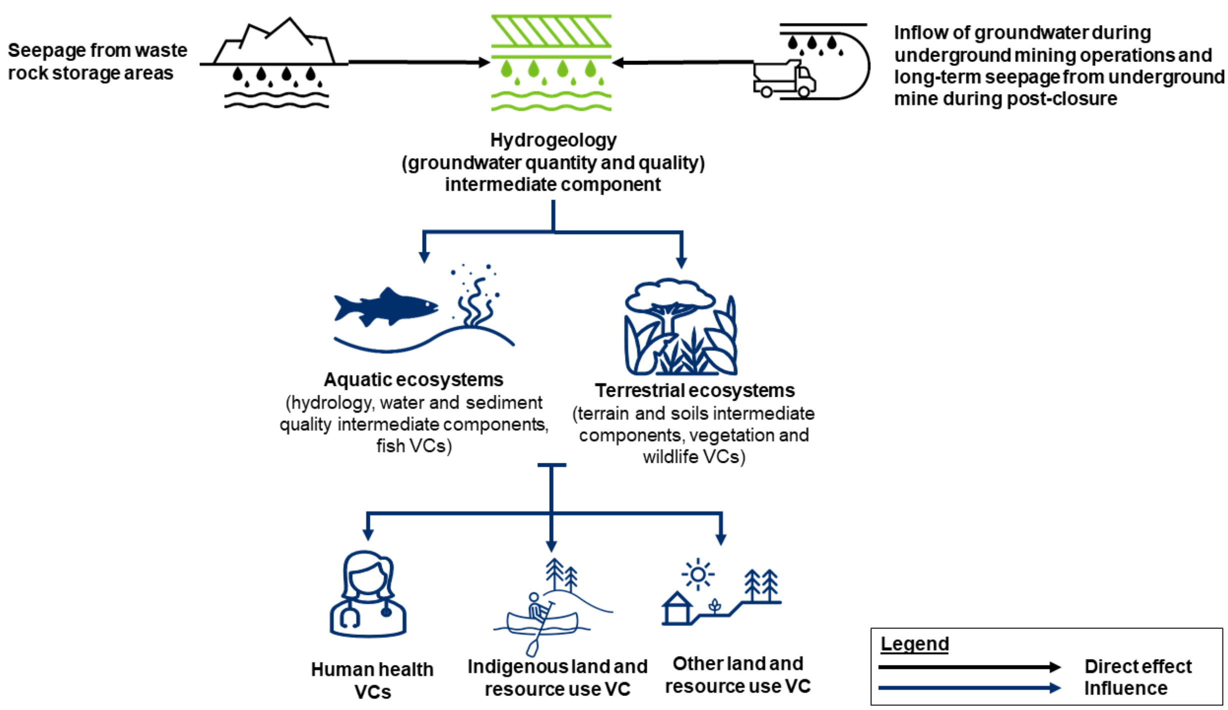
Measurement Indicator	Criterion	Rating / Effect Size
Soil quality (i.e., productivity)	Direction	▪ Negative
	Magnitude	▪ 897.8 ha of soil map units under existing conditions converted to the disturbance map unit (i.e., high magnitude) ▪ 82.2 ha of the disturbance map unit remain in the maximum disturbance area
	Geographic extent	▪ Maximum disturbance area
	Duration	▪ Long-term: for disturbed soil map units, 33 years (start of Construction to end of Active Closure Stage), or earlier with progressive reclamation, and extending well beyond Closure
	Reversibility	▪ Reversible
	Frequency	▪ Continuous
	Probability of occurrence	▪ Certain

ha = hectare; WRSAs = waste rock storage areas.

8A1.7 Linkages to Valued Components

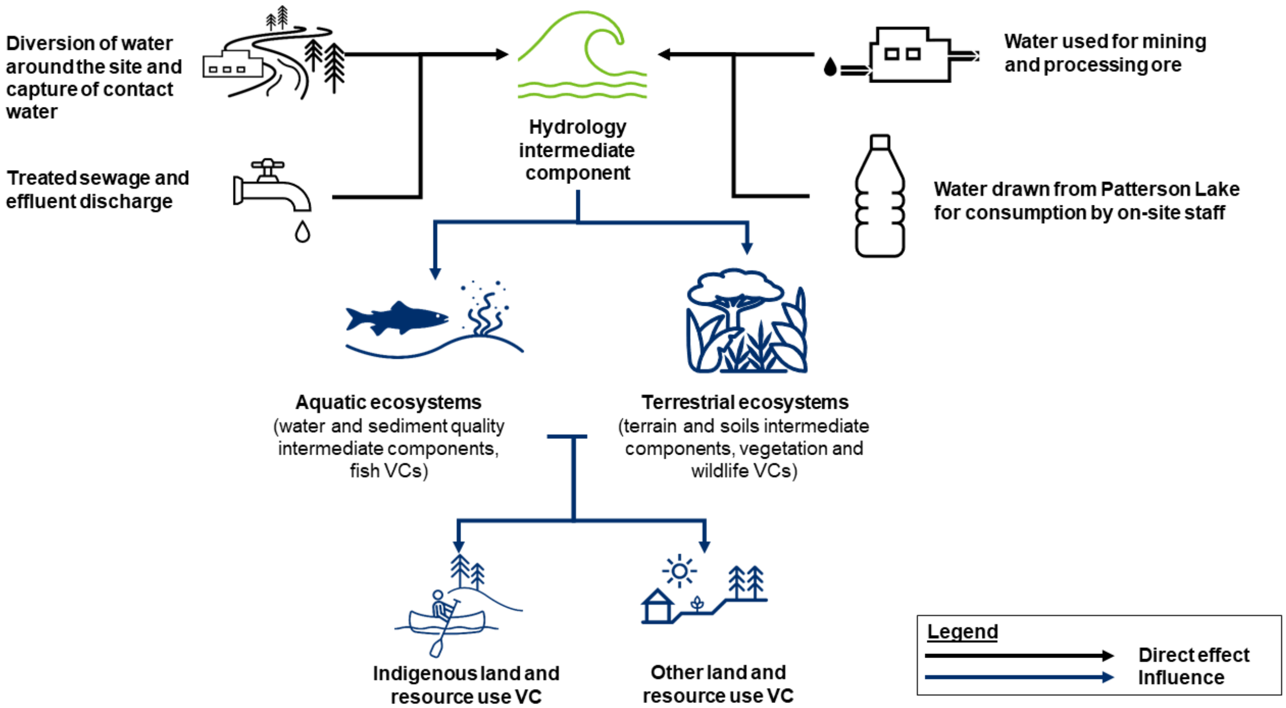
The geologically focused information used for the assessment of intermediate components listed above were linked to valued components and other intermediate components that assessed ecological and human aspects in the EIS. Linkage diagrams illustrating these relationships are reproduced below for hydrogeology (Figure 8A-6) from Figure 8.1-3 of EIS Section 8.1, Introduction; hydrology (Figure 8A-7) from Figure 9.1-3 of EIS Section 9.1, Introduction; and for terrain and soils (Figure 8A-8) from Figure 12.1-3 of EIS Section 12.1, Introduction. As these figures illustrate, the aspects of geology that could potentially result in effects to valued components (i.e., chemical loadings to the environment from the UGTMF and WRSAs, permanent changes to surficial geology, and other aspects of the geologic environment) have been assessed throughout the EIS.

Figure 8A-6: Linkage Diagram of Project Effects on Hydrogeology and Influenced Valued Components



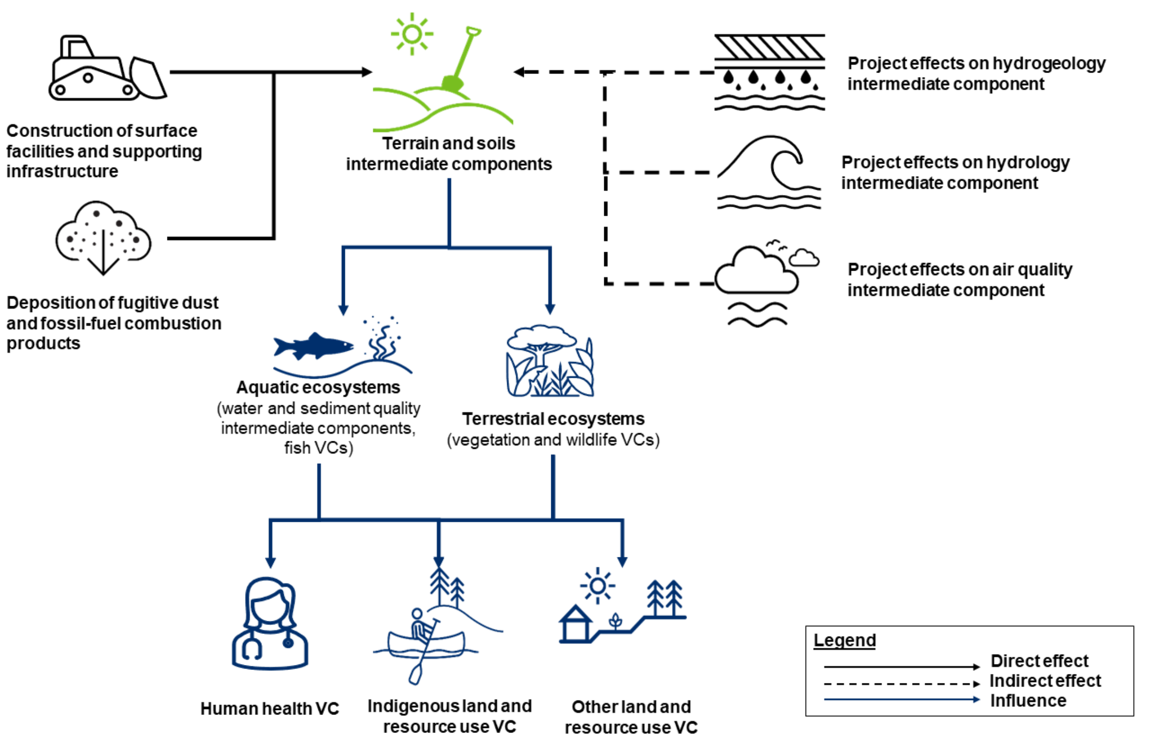
VC = valued component.

Figure 8A-7: Linkage Diagram of Project Effects on Hydrology and Influenced Valued Components



VC = valued component.

Figure 8A-8: Linkage Diagram of Project Effects on Terrain and Soils and Influenced Valued Components



VC = valued component.

8A1.8 Monitoring

As previously noted, NexGen would develop and operate all Project infrastructure, facilities, and systems in accordance with design standards relevant to the Project, which are based on regulatory guidance, applicable building code requirements, and best management practices as developed by applicable industry and trade associations and standards organizations. All Project phases from Construction through Closure would be required to satisfy licence and permitting requirements from the CNSC, Saskatchewan Ministry of Environment, and other federal and provincial regulatory bodies, and would follow NexGen management systems.

For all predicted residual effects, follow-up and monitoring programs would be used to:

- compare operational conditions with effect predictions and address uncertainty;
- monitor for changes in measurement indicators;
- evaluate the effectiveness of reclamation and other mitigation actions, and modify or enhance as necessary through monitoring and developing updated mitigation measures, if needed;
- identify unanticipated negative effects, including possible accidents and malfunctions; and
- contribute to the overall continual improvement of the Project.

With respect to geotechnical conditions, ground control measures such as observational monitoring, instrumentation installation and operation, and quality assurance and control processes for design elements would be implemented to monitor the stability of mine openings. Instrumentation would be installed to monitor water inflow, ground movement and displacement, and cemented paste performance. Instrumentation would also be used to validate and calibrate 3D numerical stress models to confirm designs (e.g., during initial development of the UGTMF, instrumentation would be used in the chamber back [i.e., roof] and pillars to monitor rock mass response to confirm design assumptions). Quality control and assurance of design components (e.g., blasting practices, ground support and reinforcement, shotcrete, backfill, instrumentation) would be complemented by observational monitoring conducted by trained and qualified operations and technical personnel. NexGen has identified proactive mitigation options to apply if rock mass conditions are locally poorer than anticipated, rock structure impacts wall/pillar stability, and/or pillar stresses are higher than anticipated (e.g., additional cable bolt support, decreasing chamber dimensions, increasing pillar thickness).

Fluvial sediment transport would be monitored as part of the hydrometric monitoring program. This continued data collection would extend the baseline monitoring period and data available. Selected hydrometric stations would also be monitored during the Project phases using remotely operated telemetry stations, which could be used to verify the receiving environment predictions of minimal changes in flows and water levels during the proposed Project duration and in the future. Proposed remotely operated stations being considered include the following:

- Clearwater River below Patterson Lake;
- Clearwater River below Beet Lake;
- Clearwater River below Naomi Lake;
- Clearwater River above the confluence with the Mirror River; and
- Clearwater River below Broach Lake.

The plan for monitoring groundwater quantity and quality for the Project would be detailed in the Environmental Monitoring Plan. The groundwater focus of this plan is the establishment of monitoring systems to evaluate the effectiveness of groundwater protection controls. Groundwater monitoring targets were selected under the plan to achieve the monitoring objectives detailed above. These targets include monitoring of groundwater elevations and quality in the bedrock and overburden to monitor the effects of the following:

- dewatering during construction and development of the shaft, underground mine, and UGTMF;
- seepage from the WRSAs;
- seepage from the process and mine terrace areas, including the fuel and reagent storage areas and equipment such as diesel fuel generators (i.e., in the event of a spill and non-routine events); and
- seepage from the area of the effluent treatment ponds (in the event of leakage).

Constituents of potential concern for the groundwater monitoring were based on an evaluation of the conceptual site model (e.g., hydrogeology, risk of effects from the Project) and the objectives of the groundwater monitoring. Details would be provided in the Environmental Monitoring Plan.

The Environmental Protection Program would be implemented to mitigate effects on terrain and soils and apply adaptive management, where necessary. Examples of monitoring activities for terrain and soils are outlined below.

For terrain stability:

- Monitor slope stability during land clearing, site preparation, and construction of facilities.
- Perform routine inspection and maintenance of containment and conveyance structures (i.e., roadside ditches and culverts) to limit the risk of road wash-out or sediment release to the environment.

For soil quality and quantity:

- Monitor site clearing, contouring, and excavation activities for signs of admixing, compaction, and erosion.
- Monitor soil transport and stockpiling activities for signs of erosion.
- Monitor dust deposition.
- Monitor soil chemistry.

The Preliminary Decommissioning and Reclamation Plan, along with monitoring, would assist in revising or adding mitigation measures to facilitate successful long-term reclamation of terrain and soils to support the establishment of vegetation communities and provide functional wildlife habitat.

In addition, Environmental Committees (i.e., one per primary Indigenous Group identified for the Project) composed of two NexGen and two Indigenous Group representatives would be established to act in an oversight manner to monitor the environmental performance of the Project and verify the parties are implementing the regulatory and environmental commitments made in respect of the Project.

The primary Indigenous Groups have made recommendations related to mitigating the effects of the Project on the environment, including community-led long-term environmental testing and monitoring during Construction and Operations of the Project. NexGen has committed to provide funding for the lifespan of the Project for a full-time independent Indigenous Monitor chosen by each primary Indigenous Group; this Indigenous Monitor would have access to conduct environmental sampling for the Project, subject to the Indigenous Monitor complying with appropriate health and safety and other reasonable site-specific policies. The Indigenous Monitor would be able to report openly and without restriction to the Environmental Committee and Indigenous Group's community members on the performance of the Project. The Indigenous Monitor would also provide regular reports to the Environmental Committee.

Further details regarding the proposed monitoring programs for the Project are presented in EIS Section 23, Summary of Mitigation, Monitoring, and Follow-up Programs.

8A1.9 Conclusions

As demonstrated in this Geology Supplement, geology represents an important feature of the physical environment that has been considered within existing conditions, Project design, valued components, intermediate components, and measurement indicators described and/or assessed within the EIS. Key aspects of geology that were presented in the EIS include the surface and subsurface geology in the area of the Project, geotechnical and seismicity conditions of the proposed mining area and how these conditions influenced Project design, fluvial sediment transport, and assessments of Project effects on terrain, soils, and hydrogeology, including both groundwater quantity and groundwater quality. In summary, geology has been appropriately considered within the EIS to verify that potential effects of the Project are properly understood, and follow-up and monitoring programs have been identified to allow for future comparison of operating conditions with effects predictions.

REFERENCES

Literature Cited

Carter TG, Cottrell BJ, Carvalho JL, Steed CM. 2008. Logistic regression improvements to the scaled span method for dimensioning surface crown pillars over civil or mining openings. Proceedings from the 42nd US Rock Mechanics Symposium, San Francisco.

Carter T. 2014. An update on the scaled span concept for dimensioning surface crown pillars for new or abandoned mine workings. Environmental Science.

Government of Canada. 2021a. Simplified Seismic Hazard Map for Canada, the Provinces and Territories. Maps provided by Natural Resources Canada 2015. Accessed October 2021. Available at https://seismescanada.rncan.gc.ca/hazard-alea/simphaz-en.php.

Government of Canada. 2021b. Earthquake map of Canada, Natural Resources Canada, Earthquakes Canada. Accessed October 2021. Available at https://earthquakescanada.nrcan.gc.ca/historic-historique/caneqmap-en.php.

Hillacre S, Ansdell K, McEwan B. 2020. Structural analysis and paragenesis of the Arrow uranium deposit, western Athabasca Basin, Saskatchewan, Canada: Implications for the development of the Patterson Lake corridor: Economic Geology.

NexGen (NexGen Energy Ltd.). 2021. Feasibility Study Report, Revision 0. Document No. 0000-BA00-RPT-001. Prepared for NexGen by Stantec - Mining. 28 April 2021.

NRCC (National Research Council of Canada). 2020. National Building Code of Canada, Volume 1. Canadian Commission on Building and Fire Codes. ISBN 978-0-660-37912-8.

Rook I Project

Environmental Impact Statement

Section 9 Hydrology

Submitted to:
Canadian Nuclear Safety Commission
Saskatchewan Ministry of Environment

Submitted by:
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November 2024

Executive Summary

Section Purpose

Section 9 of the Environmental Impact Statement (EIS) provides a comprehensive assessment of potential effects of the Rook I Project (Project) on hydrology. Hydrology is the study of the distribution and circulation of water in the environment. This assessment included consideration of both potential effects from the Project and cumulative effects from the Project and other reasonably foreseeable developments (RFDs). The hydrology assessment used widely accepted scientific practices and incorporated Indigenous and Local Knowledge.

Hydrology represented an intermediate component in the Environmental Assessment (EA); the selection was based on water being the basis of healthy, functioning, and resilient aquatic and terrestrial ecosystems and a conduit for transportation. The hydrology assessment provided information that was used to support valued component (VC) assessments such as fish and fish habitat, vegetation, wildlife and wildlife habitat, as well as the assessments of other intermediate components such as surface water quality, sediment quality, and terrain and soils. Intermediate components, such as hydrology, were not assessed for significance.

Setting

At a regional scale, the Project would be located within the southern Athabasca Basin adjacent to Patterson Lake, along the upper Clearwater River system, approximately 40 km east of the Saskatchewan-Alberta border and 640 km northwest of the city of Saskatoon.

The hydrology assessment focused on a local study area (LSA), which is in the area of the proposed Project where direct environmental effects would be most likely to occur, and a regional study area (RSA), where cumulative effects may occur. The LSA is the portion of the Clearwater River watershed extending from its headwaters to the outlet of Naomi Lake, representing a surface area of 685 km^2. The RSA includes the LSA and is defined by the portion of the Clearwater River watershed extending from its headwaters to its confluence with the Mirror River, representing a surface area of 1,076 km^2. Broach Lake is located in the northwest corner of both study areas and is considered to be the headwaters of the Clearwater River. The Clearwater River flows through a series of lakes including Patterson Lake to Naomi Lake. From Naomi Lake, the Clearwater River flows another 20 km southeast before reaching the Mirror River confluence. The LSA and RSA used for the assessment of hydrology are the same spatial boundaries as those used for other aquatic environment components (e.g., surface water quality and sediment quality, fish and fish habitat).

The waterbodies in the LSA and RSA are used by humans for navigation, recreation, and fishing, and the river is an important aspect of culture and heritage. Upstream of Patterson Lake, the channel is wide but relatively shallow, and it has a lower gradient downstream of Patterson Lake. In general, boat navigation upstream of Patterson Lake is more difficult than navigation downstream.

Existing Conditions (Section 9.3)

In general, the ground surface in the RSA is highly permeable, and water typically infiltrates the ground and moves via subsurface pathways to waterbodies (i.e., lakes, ponds, or wetlands) or watercourses (i.e., streams, creeks, or rivers). The RSA has an abundance of waterbodies from small wetlands to larger lakes; however, because of the ground permeability, there are relatively few watercourses on the landscape.

Hydrology within the RSA is typical of colder regions in Canada where water primarily enters the system as snowfall or rainfall, with some groundwater contributions. Waterbodies and watercourses in these regions usually show a common seasonal pattern with higher water levels and flows during spring freshet (i.e., a thaw of accumulated annual snow and ice), and lower water levels and flows during the remainder of the year. The RSA is dominated by lakes, so the seasonal variability of water level and flow is low compared to river-dominated systems.

Surface water flows vary over the course of a year due to fluctuations of hydrological processes, driven mainly by changes in precipitation and air temperature, as well as from energy inputs from solar radiation. Existing flow conditions were modelled, and results show that monthly and annual flow rates increase with watershed area; therefore, the Clearwater River flows increase in a downstream direction as tributary inflows increase.

Climate change is expected to result in wetter and warmer conditions in the RSA, with shorter winters and a generally earlier spring freshet.

Potential Effects and Proposed Mitigations (Section 9.5)

An analysis was completed to evaluate Project components and activities and associated effects pathways that could potentially affect hydrology. The evaluation also considered similar combined effects from the Fission Patterson Lake South Property, the identified RFD for the hydrology assessment.

Project activities that would have the potential to affect hydrology during the Project lifespan include:

- land clearing;
- site preparation;
- construction of facilities and infrastructure;
- handling of ore and waste rock;
- discharge of treated effluent and treated sewage;
- underground operations; and
- removal of infrastructure during decommissioning and reclamation activities.

Similar activities that could affect hydrology would be expected to occur for the Fission Patterson Lake South Property.

As part of the pathways analysis, proposed environmental design features and mitigation measures were considered to determine whether effects on the environment could be avoided or reduced to negligible levels, thereby removing the pathway. Project environmental design features such as the underground tailings management facility and site road alignment were designed to minimize the Project's effects on hydrology. In addition, the Project footprint has been optimized and would be limited to the extent practicable to minimize disturbance to waterbodies and watercourses surrounding the Project. Proposed mitigation measures, such as the use of erosion control, ground contouring of disturbed and restored areas, and the implementation of progressive reclamation and revegetation of disturbed areas, would reduce effects on hydrology. These mitigations have been used extensively within the mining sector and have been proven effective. Similar mitigation and adaptive management practices would also be expected to be implemented by the Fission Patterson Lake South Property.

After mitigation measures were considered, the pathways screening analysis determined that some of the potential pathways from the Project to the environment could be removed from the assessment. However, it was identified that the Project could still adversely affect hydrology from the following pathways:

- diversion of site runoff from its natural course and change in drainage areas during Construction, Operations, and Closure;
- activities may affect on basin yields, and in turn, affect waterbody water surface elevations (WSEs) and watercourse flows through changes in water balance and hydrological processes in the upstream contributing area during Construction, Operations, and Closure; and
- changes in watercourse flows during Construction and Operations that may cause erosion downstream, alter stream channel sediment transport and stream channel parameters, and affect shoreline integrity.

Therefore, these pathways were carried forward into the residual effects analysis.

Residual Effects Analysis (Section 9.6)

A residual effects analysis was conducted to determine the potential effects on hydrology under two assessment cases: effects of the Project (i.e., Application Case), and combined effects of the Project and the Fission Patterson Lake South Property (i.e., RFD Case). The residual effects analysis considered four measurement indicators:

- waterbody WSE;
- watercourse flow rate;
- stream channel parameters; and
- fluvial sediment transport.

In the Application Case, the Project would result in a net discharge of water to Patterson Lake from Construction through the Active Closure Stage, which is predicted to result in small but undetectable increases in WSEs and watercourse flow rates in the receiving environment. The increase in flows would propagate downstream but diminish in magnitude as the watershed area and ambient flows increase. The magnitude of changes to WSEs and flows along the Clearwater River are predicted to be well within the range of natural seasonal and annual variability and are not expected to affect navigation.

In the RFD Case, increases are expected in WSEs and in watercourse flow rates on the Clearwater River downstream of Patterson Lake. As with the Application Case, the magnitude of these effects is expected to be well within the range of seasonal and annual variability. The increases in WSEs predicted for the RFD Case are expected to increase further under climate change scenarios.

Small changes in stream channel parameters are anticipated in both the Application Case and the RFD Case due to the increased mean annual daily flow downstream of the Project. Changes in stream channel parameters would be negligible (i.e., likely undetectable) as a result of the Project and the Fission Patterson Lake South Property. However, in the RFD Case, there is predicted to be an increase in width and depth for the Clearwater River below Patterson Lake; this increase is also expected to be larger under climate change scenarios. In all scenarios, these changes are within the range of natural variation and are not expected to be large enough in magnitude to change how the watercourses are used by humans for navigation.

For both the Application Case and the RFD Case, increases to watercourse flow rates are predicted to result in both increased erosion at the upstream reach and increased sedimentation at downstream reaches. However, all assessment cases resulted in negligible changes in net transport of sediment for the Clearwater River reach between Patterson and Forrest Lake, compared to existing conditions.

Prediction Confidence and Uncertainty (Section 9.8)

Overall, there was a high degree of confidence in predictions related to the hydrology assessment. Uncertainty was primarily and appropriately addressed by making assumptions that conservatively overestimated rather than underestimated potential effects (i.e., a precautionary assessment).

Monitoring and Follow-Up (Section 9.9)

The Environmental Protection Program and Environmental Monitoring Plan and associated environmental monitoring would be implemented to manage effects on hydrology and verify the effectiveness of mitigation. Monitoring is also proposed to address residual uncertainty; this monitoring would follow on from baseline data collected, and hydrometric stations would also be monitored to verify the assessment's prediction of minimal changes in flows and water levels during the Project phases.

Abbreviations and Units of Measure

Abbreviation	Definition
1-D	one-dimensional
CNSC	Canadian Nuclear Safety Commission
EA	Environmental Assessment
EIS	Environmental Impact Statement
ENV	Saskatchewan Ministry of Environment
GPS	Global Positioning System
HEC-RAS	Hydrologic Engineering Center – River Analysis System
JWG	Joint Working Group
LSA	local study area
NexGen	NexGen Energy Ltd.
RFD	reasonably foreseeable development
RSA	regional study area
VC	valued component
WSE	water surface elevation

Unit	Definition
%	percent
°C	degrees Celsius
±	plus or minus
masl	metres above sea level
mg/L	milligrams per litre
mm	millimetre
m	metre
m^2	square metre
km	kilometre
km^2	square kilometre
m^3/s	cubic metres per second
Mm^3	million cubic metre
t/yr	tonnes per year

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Appendix 9B Hydraulic and Sediment Transport Modelling Summary Report

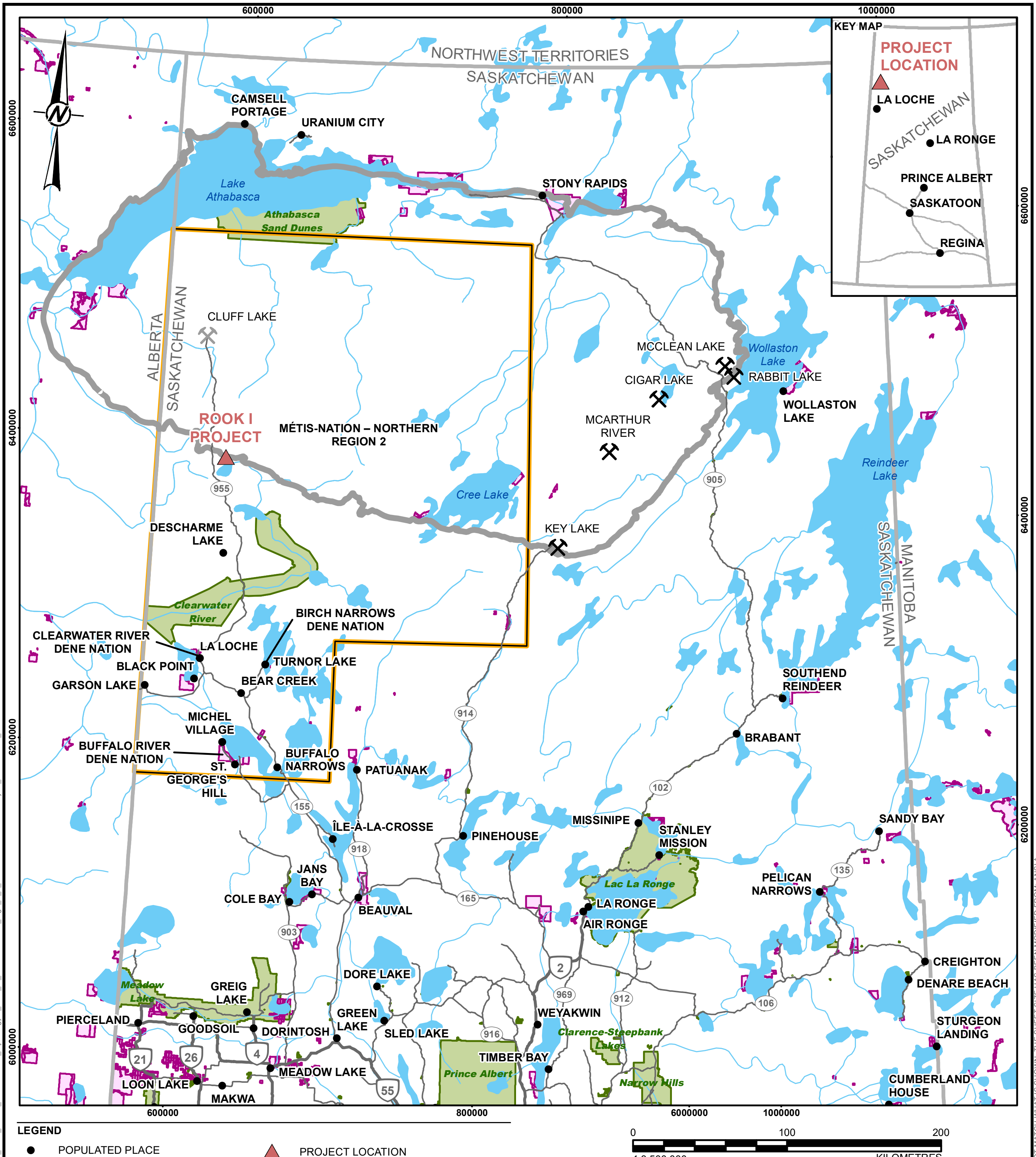
9 HYDROLOGY

9.1 Introduction

NexGen Energy Ltd. (NexGen) is proposing to develop a new uranium mining and milling operation in northwestern Saskatchewan, called the Rook I Project (Project). The Project would be located approximately 40 km east of the Saskatchewan-Alberta border, 130 km north of the Northern Village of La Loche, and 640 km northwest of the city of Saskatoon (Figure 9.1-1). 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 9.1-2), with on-site worker accommodation serviced by fly-in/fly-out access.

Section 9, Hydrology, of the Environmental Impact Statement (EIS) characterizes the potential residual effects of the Project on hydrology, which is an attribute or component of the aquatic environment. Hydrology represents an intermediate component for the Environmental Assessment (EA). The Project has the potential to cause adverse effects on hydrology through various pathways. The diversion of non-contact water around the site, which is intended to prevent water from contacting Project components and avoid changes in water quality, can affect surface water flows and levels in adjacent lakes, rivers, and streams. Water that contacts surface facilities would be captured, monitored, and treated if necessary to meet discharge criteria before being discharged to the receiving environment; this discharge can also change hydrological conditions in adjacent lakes, rivers, and streams. The water used for mining and processing ore, including water required to support these activities (e.g., use of water by those working at the site for drinking, showering), can also alter surface water flows and levels. The quantity and quality (Section 10, Surface Water Quality and Sediment Quality) of water is important to culture; it is a conduit for transportation and the basis of healthy, functioning, and resilient aquatic and terrestrial ecosystems.

Changes in hydrology could alter aquatic and terrestrial ecosystems and affect the people that use natural resources. For these reasons, the hydrology assessment provides information that is used to support the assessments of other valued components (VCs); specifically, fish and fish habitat (Section 11, Fish and Fish Habitat), vegetation (Section 13, Vegetation), wildlife and wildlife habitat (Section 14, Wildlife and Wildlife Habitat), Indigenous land and resource use (Section 16, Cultural and Heritage Resources and Indigenous Land and Resource Use), and other land and resource use (Section 17, Other Land and Resource Use), as well as other intermediate components such as surface water and sediment quality (Section 10, Surface Water Quality and Sediment Quality) and terrain and soils (Section 12, Terrain and Soils). A simplified linkage diagram, Figure 9.1-3, illustrates how proposed Project activities could result in a direct or indirect effect on hydrology, and the VCs that could be influenced through changes to hydrology.



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

wsp

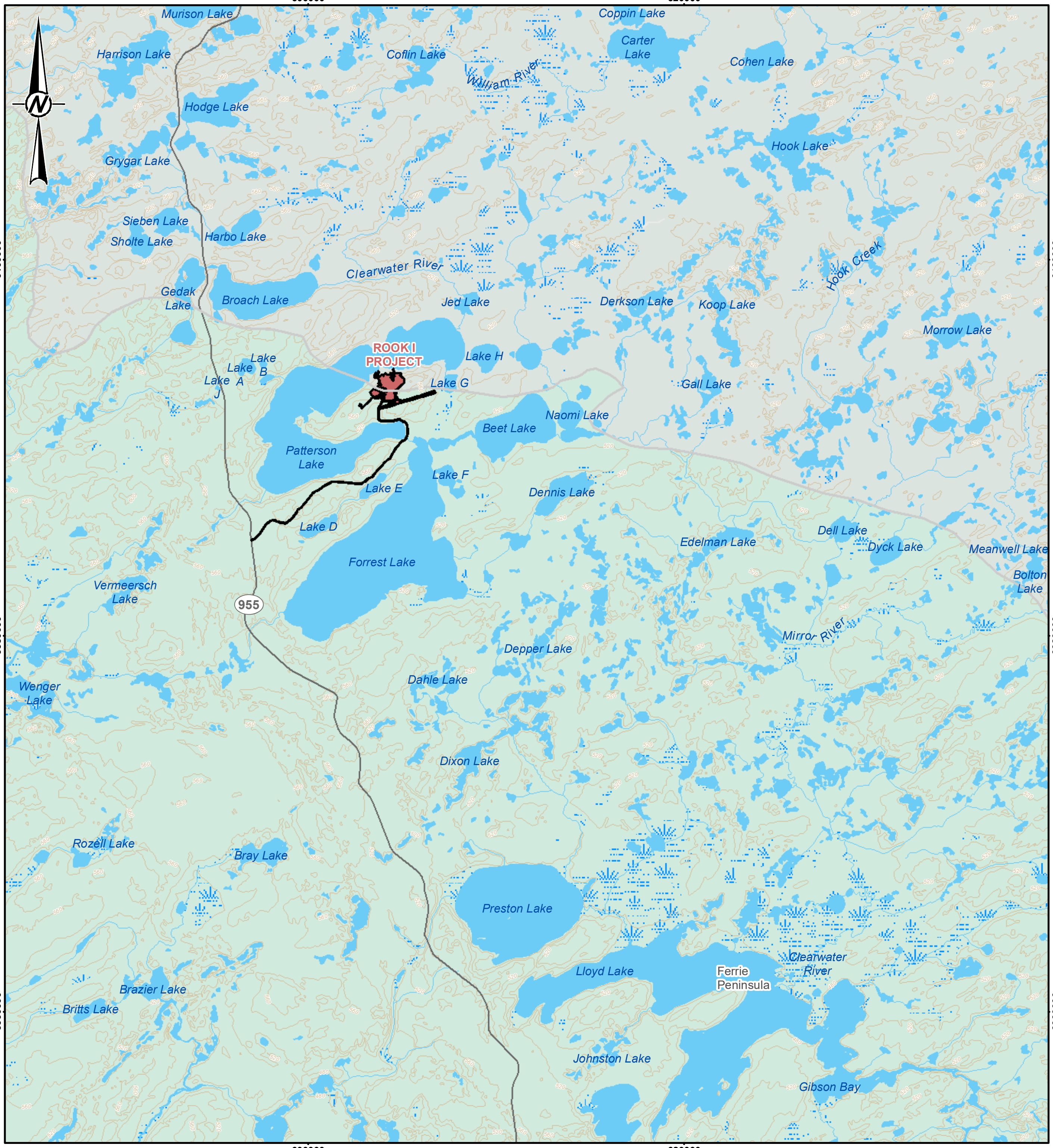
PROJECT	20144150	SCALE AS SHOWN	REV. 0

FIGURE 9.1-1

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\09_Hydrology\8_5x11\8_5x11\20144150_Fig9_1_1_Location-of-the-RookI-Project_NoTitleblock_Rev0.mxd PRINTED ON: 2023-02-10 AT: 10:05:14 AM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

25mm



LEGEND

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

0 5 10
1:300,000 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.

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	SCALE AS SHOWN	REV. 0

FIGURE 9.1-2

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\09_Hydrology\8_5x11\8_5x11\20144150_Fig9_1_2_Regional-Area_Rook_I_Project_NoTitleblock_Rev0.mxd PRINTED ON: 2023-02-10 AT: 10:05:38 AM

25mm
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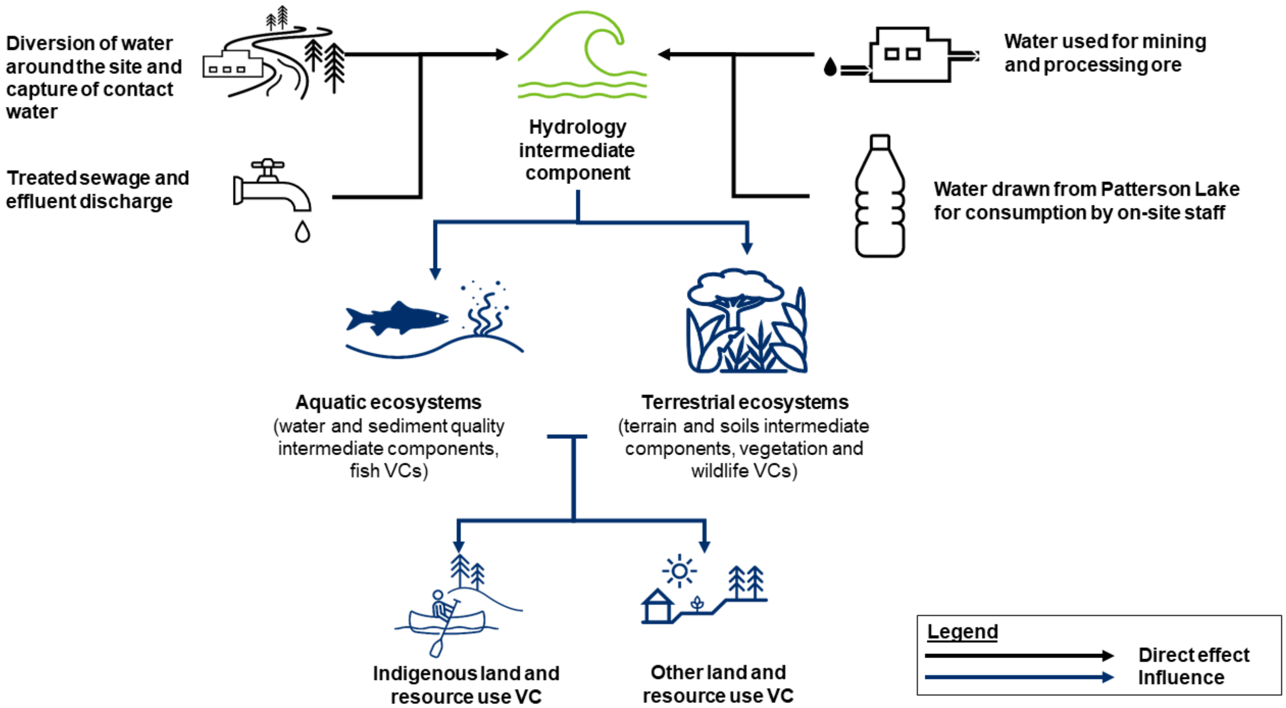
Figure 9.1-3: Linkage Diagram of Project Effects on Hydrology and Influenced Valued Components



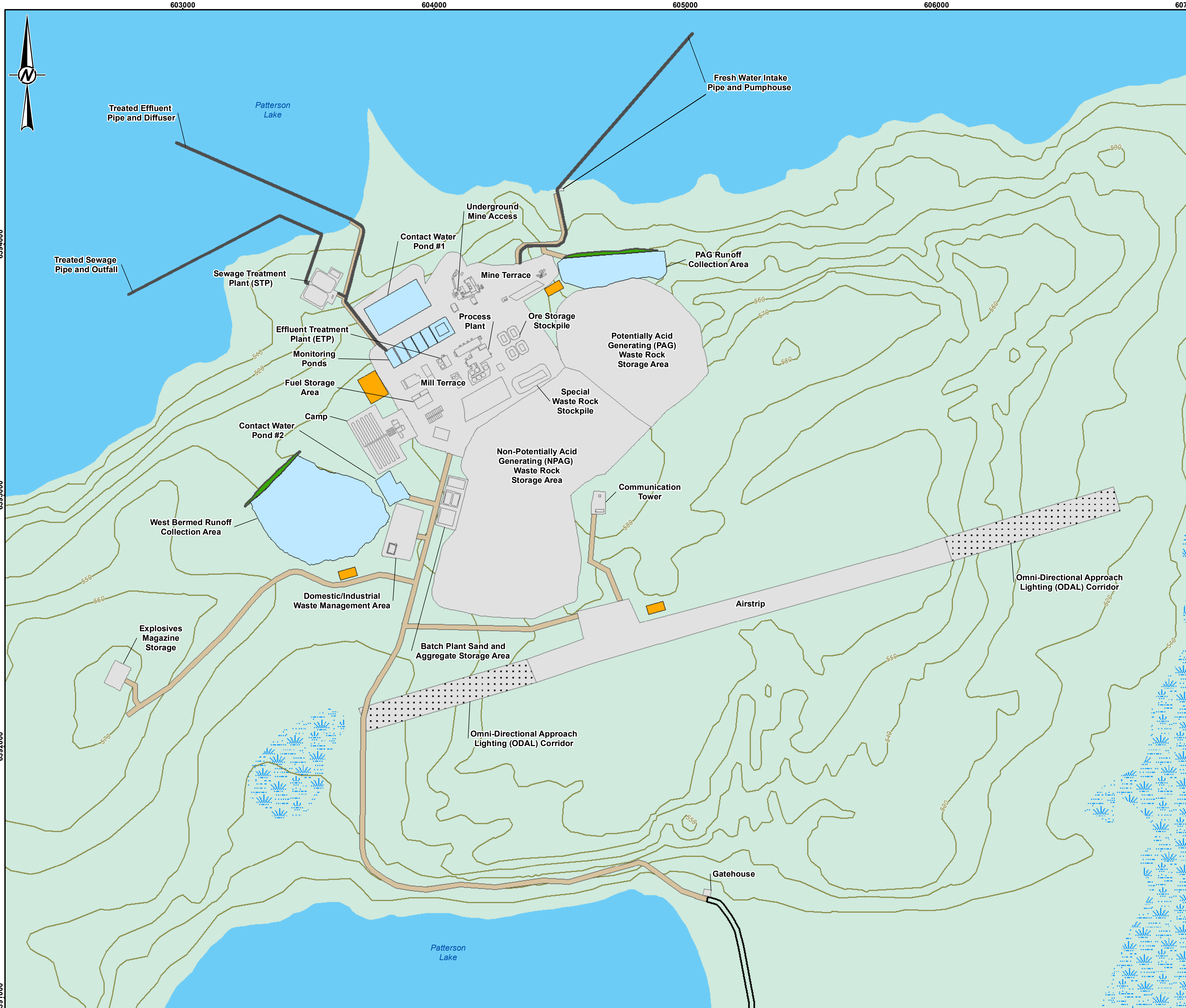
VC = valued component

9.1.1 Project Summary

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 9.1-4):

- underground mine development;
- process plant buildings, including uranium concentrate packaging facilities;
- paste tailings distribution system;
- underground tailings management facility;
- potentially acid generating waste rock storage area;
- non-potentially acid generating waste rock storage area;
- special waste rock[1] and ore storage stockpiles;
- surface and underground water management infrastructure, including water management ponds, effluent treatment plant, 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

- 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 SCALE AS SHOWN REV. 0

FIGURE 9.1-4

9.1.2 Purpose and Approach to the Assessment

The purpose of Section 9 is to provide a detailed and comprehensive assessment of all potential Project-specific effects and cumulative effects from the Project and other previous, existing, and reasonably foreseeable developments (RFDs), if applicable, on hydrology. This section meets the Terms of Reference for the Project submitted to the Saskatchewan Ministry of Environment (ENV) and the Canadian Nuclear Safety Commission (CNSC) *Generic Guidelines for the Preparation of an Environmental Impact Statement – Pursuant to the Canadian Environmental Assessment Act, 2012* (Appendix 1A, Concordance Tables). The assessment of hydrology followed the overall EA approach and methods (Section 6, Environmental Assessment Approach and Methods) and includes the following primary steps:

Step 1 – Define component-specific methods (Section 9.2): presents the specific approaches and methods used to measure and assess the effects of the Project on hydrology as well as cumulative effects from the Project, other previous and existing projects and activities, and RFDs, if applicable.

Step 2 – Characterize existing conditions (Section 9.3): describes and characterizes existing conditions to provide both context and a basis for evaluating potential changes to hydrology caused by the Project. The anticipated changes to existing conditions due to climate change within the Project lifespan are characterized in Section 9.4, Climate Change Scenario.

Step 3 – Evaluate Project interactions and mitigations (Section 9.5): identifies Project components and/or activities with the potential to affect hydrology and provides environmental design features and mitigation policies and actions committed to NexGen to avoid or minimize potential adverse effects. A pathways analysis was used to focus further assessment on key interactions between the Project and hydrology by evaluating the different effects pathways to determine if, after incorporation of mitigation, there is still potential to cause residual adverse effects. Primary pathways anticipated to result in residual adverse effects after incorporation of mitigation are carried forward to Step 4 for further analysis. Where potential adverse effects are adequately mitigated and are not forwarded for further analysis (i.e., where mitigation results in a negligible effect or avoids the pathway altogether), the reasons for concluding the assessment at this stage are provided.

Step 4 – Analyze and classify residual effects (Section 9.6; Section 9.7): evaluates and describes the potential Project effects on hydrology that are anticipated to occur through the primary pathways. The residual effects analysis is presented as an integrated narrative that describes the effects of the Project over time and highlights predicted effects at the point when adverse effects of the Project are expected to be greatest. This step also includes an analysis of residual cumulative effects from the Project, other previous and existing projects and activities, and RFDs. Residual effects are classified and tabulated using criteria direction, magnitude, geographic extent, duration, reversibility, and frequency to provide structure and comparability across all VCs and intermediate components in the EA.

Step 5 – Describe uncertainty and define prediction confidence (Section 9.8): identifies key uncertainties and explains how these uncertainties have been addressed to achieve a conservative, precautionary assessment. The implications of the approaches used to address uncertainties and the level of confidence in the residual effects analysis are discussed.

Step 6 – Identify monitoring and follow-up (Section 9.9): outlines the proposed actions to verify predicted residual effects. The purpose of these actions is to evaluate the effectiveness of planned mitigation designs, policies, and practices, and address key sources of uncertainty.

Understanding changes to hydrology is fundamental to understanding the total effects of the Project on the biophysical, cultural, and socio-economic environments.

9.2 Component Methods

9.2.1 Incorporation of Indigenous and Local Knowledge

Indigenous and Local Knowledge included in the assessment of hydrology was shared by potentially affected First Nations and Métis Groups (collectively referred to as Indigenous Groups) and local priority area (LPA)[2] community members through the Project engagement process. The overall approach and methods for the incorporation of Indigenous and Local Knowledge into the EA is discussed in detail in Section 3, Indigenous and Local Knowledge. Issues and concerns related to hydrology raised by Indigenous Groups and LPA community members, and how these comments were addressed, are summarized in Appendix 2B, Summary of Issues and Concerns Identified by Indigenous Groups, and identified and addressed in this assessment, where applicable.

A key source of Indigenous and Local Knowledge is the Project-specific studies completed by Indigenous Groups, including Traditional Land Use and Occupancy studies, Traditional Knowledge and Use studies, and Indigenous Rights and Knowledge studies (henceforth referred to collectively as Indigenous Knowledge and Traditional Land Use Studies). The Indigenous Knowledge and Traditional Land Use Studies that were reviewed and referenced in the EIS as technical support documents (TSDs) are listed below:

- TSD II (BNDN), Birch Narrows Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD III (BRDN), Buffalo River Dene Nation Traditional Knowledge and Use Study Specific to NexGen Energy Limited's Proposed Rook I Project;
- TSD IV (MN-S), Métis Nation – Saskatchewan Northern Region 2 Traditional Land Use & Diet Study for the NexGen Rook I Project;
- TSD V.1 (CRDN), Preliminary Identification of Issues and Concerns Related to the Proposed NexGen Energy Ltd. Rook I Project in the Patterson Lake Area; A Review; Clearwater River Dene Nation; Traditional Land Use and Occupancy Mapping Interviews; 2010 – 2016;
- TSD V.2 (CRDN), Clearwater River Dene Nation Indigenous Rights and Knowledge Survey related to the proposed NexGen Energy Ltd. Rook 1 Project in the Patterson Lake Area;
- TSD V.3 (CRDN), Socio-economic and Harvest Study; Clearwater River Dene Nation; NexGen Rook 1 Project; and
- TSD VI (YNLR), Provision of Athabasca Denesųłiné Traditional Knowledge, Land Use and Occupancy Information for the NexGen Rook I Project Environmental Assessment.

[2] The LPA consists of the local communities closest to the Project that would experience most of the Project effects and for which NexGen would prioritize local training, employment, and business opportunities for the Project. These communities are located along, or accessed via, Highways 155 and 955 north of the intersection of Highways 155 and 925.

Another key source of Indigenous and Local Knowledge was information shared by Indigenous Group representatives during Joint Working Group (JWG) meetings. The JWGs represent an agreed-upon primary engagement mechanism as outlined in the Study Agreements signed by each Indigenous Group and NexGen. More details regarding the JWGs can be found in Section 2, Indigenous, Regulatory, and Public Engagement and Section 3, Indigenous and Local Knowledge. There are four JWGs with the Project's primary Indigenous Groups (Section 2.4.1, Identification of Indigenous Groups for Engagement):

- Clearwater River Dene Nation (CRDN) JWG;
- Métis Nation – Saskatchewan (MN-S) JWG representing MN-S Northern Region 2 (NR2);
- Birch Narrows Dene Nation (BNDN) JWG; and
- Buffalo River Dene Nation (BRDN) JWG.

The leadership of each Indigenous Group selected their JWG participants with consideration of group diversity; where possible, members included Elders, youth, different genders, a range of ages, and land users around Patterson Lake.

In addition to the Indigenous Knowledge and Traditional Land Use Studies and JWGs, Indigenous and Local Knowledge shared during specific engagement activities undertaken through the EA development process was incorporated into the assessment, where appropriate. These engagement activities included, but were not limited to:

- community information sessions held in four locations in 2019 (NexGen 2019);
- site tours;
- comments from the CRDN (2019b) on the Cluff Lake Mine licence renewal;
- other formal and informal meetings;
- workshops with specific groups (e.g., Fur Block N-19 trapper's workshop); and
- environmental and socio-economic baseline data collection.

Comments submitted by Indigenous Groups on the Project Description (CRDN 2019a; MN-S 2019; YNLRO 2019; ACFN 2019; CNSC 2019) were also reviewed for applicable Indigenous and Local Knowledge.

Indigenous and Local Knowledge related to hydrology was incorporated into the assessment by viewing the information as complementary and influential alongside scientific information. Where possible, knowledge from each potentially affected Indigenous Group or LPA community member was described separately and cited accordingly. Where information is described for multiple potentially affected Indigenous Groups, they are collectively referred to as "Indigenous Groups" throughout the assessment.

Indigenous and Local Knowledge was included in the hydrology assessment in the following ways:

- **Component Methods – Valued Components and Intermediate Components:** Indigenous and Local Knowledge was considered in the selection of the valued component of hydrology and reflects the importance of water for supporting traditional land use activities including habitation, harvesting and transportation, and to community wellbeing and health. Physical features on the landscape, including water, contribute to a sense of place, which is an important cultural value tied to identify. Water features on the landscape (e.g., lakes and river valleys) are often used for travel to access traditional use areas and as navigational landmarks. The importance of water was also reflected in the holistic perspective related to the interconnectedness of rivers, lakes and to other environmental components (Section 9.2.2.1).

- **Component Methods – Spatial Boundaries:** The approach used to select spatial boundaries (i.e., the Clearwater River watershed), which includes a portion of the Clearwater River system and connecting waterbodies, was supported by Indigenous and Local Knowledge which has highlighted the interconnectedness of the region's waterways, and the Clearwater River as a holistic river system with many large lakes that are connected and integral to the river and cannot be viewed in isolation (Section 9.2.3).
- **Existing Conditions – Hydrographic Setting and Surface Water Uses:** Indigenous and Local Knowledge was shared about the Clearwater River, Patterson Lake and other large waterbodies in the local study area (LSA), particularly related to the interconnectedness of these waterways and their importance to Indigenous Groups and LPA communities for fishing and other harvesting activities, recreation and travel (Section 9.3.2 and Section 9.3.3).
- **Project Interactions and Mitigation:** Indigenous and Local Knowledge helped to inform the scoping of Project interactions, pathway analysis, and consideration of mitigation measures (Section 9.5). Specifically, the effects of Project activities on flows and stream channel parameters to the Clearwater River were considered in the context of changes to navigation which were assessed in Section 9.6.1.3 (Stream Channel Parameters).
- **Monitoring, Follow-Up, and Management:** Feedback provided by Indigenous Groups during engagement, including recommendations, was considered in the development of monitoring and follow-up activities (Section 9.9). In addition, it is planned that ongoing feedback from Indigenous Groups on the effectiveness of mitigations would be considered when updating monitoring programs and management plans. Independent Indigenous Monitors chosen by each primary Indigenous Group would have opportunities to participate in environmental monitoring programs for the proposed Project.

Specific references to Indigenous and Local Knowledge, and Project comments and concerns related to hydrology raised by Indigenous Groups and LPA community members, are included in the applicable subsections of this assessment.

9.2.2 Valued Components, Intermediate Components, and Measurement Indicators

9.2.2.1 Valued Components and Intermediate Components

Valued components are aspects of the biophysical, cultural, and socio-economic environments that are considered to have scientific, social, cultural, economic, historical, archaeological, or aesthetic importance (Beanlands and Duinker 1983; CNSC 2021). Intermediate components include physical attributes of the biophysical environment or media upon which VCs rely, such as air quality, terrain and soils, hydrogeology, and hydrology (Section 6.3.3, Intermediate Components). Valued components and intermediate components are assessed using the same steps; however, unlike VCs, intermediate components do not have assessment endpoints or significance criteria. Instead, the significance of changes in intermediate components is evaluated in the context of related influences to VCs, which are the ultimate receptors.

Hydrology was selected as an intermediate component based on the connection to human use, fish and fish habitat, and healthy and functioning aquatic and terrestrial ecosystems (Table 9.2-1). Indigenous Groups shared Indigenous and Local Knowledge of the hydrological system (TSD V.2: CRDN) with commentary on the seasonal and interannual changes (i.e., changes from year to year) in hydrology (BNDN-JWG 2019), the importance of atmospheric losses such as evaporation (TSD V.2: CRDN), potential implications of climate change to hydrology (TSD V.2: CRDN) and reference to subsurface runoff pathways that are dominant in the area (TSD III: BRDN).

Indigenous Groups have described the fundamental importance of water for all forms of life and supporting traditional land use activities, including movement across traditional lands. For the CRDN, "respect for water is at the core of Denesųłiné teachings and practices because clean water is the fundamental requirement for all life . . . . Clean water is therefore inextricably connected to CRDN livelihoods, practices, customs and spirituality" (TSD V.2: CRDN). The YNLR commented on the importance of water to the community "I want this for the future generations. Water should be monitored, it should be kept clean, water is sacred for us" (TSD VI: YNLR). The BNDN noted that "Water is the most important thing, vital to life" (BNDN-JWG 2019). Water is central to BNDN and BRDN culture, community well-being and health (TSD II: BNDN; TSD III: BRDN).

Indigenous Groups have highlighted the interconnectedness of the region's waterways both above and below ground, and how rivers and lakes cannot be viewed in isolation (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.2; BRDN-JWG 2019; BRDN-JWG 2020; BNDN-JWG 2021; CRDN-JWG 2021).

> But Mother Earth is just like a sponge. It collects everything. And also, water flows. It goes wherever. It goes where – it connects all over the place. (TSD III: BRDN)

> But everything works, like, in a circle . . . . And what annoys the heck out of me is that people just think one lake operates in isolation. It has veins everywhere. It has veins going everywhere. If you're going to [speaking Dene] take all the water out from here, you're not only stopping the flow of water that comes from Clearwater. It goes all the way over here. You're stopping the flow of all kinds of veins that come around here. You're going to dry up all these things. (TSD V.2: CRDN)

The Clearwater River is described by the CRDN as a holistic river system and Patterson, Forrest, Beet, Preston and Lloyd lakes are intrinsically connected to and integral to the river (TSD V.2: CRDN). Likewise, Patterson Lake and other lakes are viewed as connected to the network of waterbodies and water travel routes in the area, rather than as discrete and separate waterbodies. The MN-S described the importance of Patterson Lake because it is central to the river system for the entire area and feeds the lakes to the south, affecting all the waterways (TSD IV: MN-S).

Occupancy, travel, and harvesting activities are often centered around water, where cabins and camp sites serve as base camps from which traditional activities extend and waterways are utilized for travel in the summer by boat or the winter by snowmobile. The CRDN have described their core occupancy and traditional lands within eleven different watersheds, and concentrated in the Clearwater River watershed where members are intimately familiar with the lands and water (TSD V.2: CRDN).

Travel routes used by Indigenous Groups to access traditional use areas in the past and today contribute to sense of place, which is based on ancestral connections and familiarity with the land and waterways (TSD III: BRDN). Travel routes used in the past by Indigenous Peoples were often selected based on the terrain and its physical features, including waterways, where frozen lakes and river valleys facilitated travel; these water features are still used for travel today. The importance of waterbodies and watercourses for travel was noted by a member of the BRDN:

> I hear a little bit of a talk, I mean, like from the elders. They're all gone now. People used to travel between Buffalo River, Cold Lake, Black Lake. We had our own, mostly water systems. And probably trails too. So, people – not as much as today, but you know, people still travelled in between those places . . . . But usually the main rivers like Clearwater . . . . (TSD III: BRDN)

The MN-S described boating from Patterson Lake to Preston Lake, all the way to Lake Athabasca and also down the Clearwater River (TSD IV: MN-S). Members of the CRDN described the upper segment of Clearwater River to Big Hills/Lloyd Lake as an ancestral water route and harvesting loop that continues to be well travelled today (TSD V.1: CRDN). The Clearwater River is part of an extensive travel network utilized by the ancestors and current members of Indigenous Groups and part of this travel network is a trail system in the Patterson Lake area that includes Patterson, Forrest, Beet, Preston and Lloyd lakes (TSD IV: MN-S; TSD V.2: CRDN).

Indigenous and Local Knowledge clearly links the importance of water flow (hydrology) to local community members. This affirms the necessity to include hydrology as an intermediate component in the EA, which is used to inform assessments for water and sediment quality, and subsequently, fish and fish habitat, vegetation, wildlife and wildlife habitat, Indigenous land and resource use, and other land and resource use VCs.

9.2.2.2 Measurement Indicators

Measurement indicators are used to characterize changes to attributes of the environment from the Project, other human developments, and natural factors. The changes in measurement indicators are used to predict overall effects on VCs and intermediate components (Section 6.3.2, Assessment Endpoints and Measurement Indicators). Four measurement indicators were identified and used for the hydrology assessment (Table 9.2-1):

- **Waterbody water surface elevation (WSE):** Waterbody WSE is a measure of surface water elevation or levels relative to a local or geodetic vertical datum (i.e., the vertical elevation of a point relative to a vertical control network) at each hydrometric station or assessment location. In the hydrology assessment, waterbodies refer to lakes, ponds, or wetlands. However, water elevation or water level may also be discussed in terms of total water depth in a waterbody or watercourse as well as variations in total water depth if, or when, this is relevant to the assessment. The standard units used to describe water level or WSE are metres (m) or metres above sea level (masl). In this assessment, the Canadian Geodetic Vertical Datum (CGVD2013) was used for most hydrometric stations, and arbitrary local datums were adopted at more remote locations. Waterbody WSE values are presented to the nearest millimetre rather than three significant figures, as is adopted for other measurement indicators, because it is possible to measure waterbody WSE to the millimetre assuming calm conditions.
- **Watercourse flow rate:** Watercourse flow rate is a measure of the volume of surface water passing a location within a defined channel over a specified time period. The term flow rate is interchangeable with streamflow or discharge. In this subsection, watercourse refers to streams, creeks, or rivers. Flow rates vary naturally through a drainage system and over time. The standard unit used to describe flow rate is cubic metres per second (m^3/s).

- **Stream channel parameters:** The fluctuation of stream flows results in changes to open-channel hydraulic characteristics according to the physical constraints of stream channel geometry, roughness, and slope. Water depth, wetted area, wetted width, and wetted perimeter are important hydraulic characteristics, all of which fluctuate in response to changing stream flow. Wetted area, wetted width, and wetted perimeter all refer to the geometry of the stream channel filled with water. Changes to stream channel parameters influence the amount and type of habitat available for aquatic organisms and use of the river for navigation. Standard units used to describe channel parameters are metre for length or depth, and square metre (m^2) for area.
- **Fluvial sediment transport:** Flowing water transports sediment as it moves downstream. Fluctuation of stream flow results in changes to the rate and nature of sediment transport. Sediment is transported in the water column through the wash load (i.e., fine sediments including clay, silt and fine sand that move in suspension above the bed), suspended load (i.e., sediment that is transported in suspension in the water column), and along or near the bed as bed load. Standard units used to describe fluvial sediment transport are milligrams per litre (mg/L) for concentration and tonnes per year (t/yr) for mass flow rate.

Table 9.2-1: Intermediate Component, Rationale, and Measurement Indicators

Intermediate Component	Rationale	Measurement Indicators
Hydrology	▪ Important to human use ▪ Indigenous and other land users may use local waterbodies and watercourses for navigation and recreational or cultural practices ▪ Key attribute of healthy and functioning aquatic and terrestrial ecosystems ▪ Link to fish and fish habitat	▪ Waterbody WSE ▪ Watercourse flow rates ▪ Stream channel parameters (e.g., wetted area) ▪ Fluvial sediment transport

WSE = water surface elevation.

9.2.3 Spatial Boundaries

The regional study area (RSA) for hydrology is defined by the Clearwater River watershed boundary upstream of the Mirror River confluence, which represents a surface area of 1,076 km^2 (Figure 9.2-1). The RSA is the largest scale at which data were collected, compiled, and analyzed, and includes the area where indirect effects that extend beyond the LSA may occur (CEA Agency 2018). The RSA is considered large enough to provide an ecologically relevant and confident assessment of the direct and indirect effects on hydrology from the Project, and the cumulative effects from the Project, as well as previous, existing, and RFDs and natural factors. The RSA for hydrology is consistent with the RSA used by other water-related assessments in the EIS (i.e., surface water quality, fish and fish habitat). The rationale for selecting the Mirror River confluence as the downstream point defining the hydrology RSA is that the potential cumulative hydrological changes from the Project and RFDs would not be detectable downstream of this confluence due to the three-fold increase in drainage area and flows.

Within the RSA, the LSA includes waters where direct changes to the physical-chemical environment as a result of the Project would be expected and likely to be detectable (e.g., the mid-basin area of Patterson Lake, where a diffuser/intake may be installed, and the Patterson Lake outflow [i.e., Clearwater River]). The LSA for hydrology is defined by the Clearwater River watershed boundary up to the Naomi Lake outlet (Figure 9.2-1), which covers a surface area of 685 km^2. There are five larger lakes in the LSA including Broach, Patterson, Forrest, Beet, and Naomi lakes, as well as several smaller waterbodies including Lake G, Lake H, and wetlands. The rationale for selecting the extent of the LSA was that it includes waterbodies and watercourses where direct Project-related changes would be expected and likely to be measurable (i.e., the receiving environment). The LSA for hydrology is consistent with the LSA used by other water-related assessments in the EIS (i.e., surface water quality and fish and fish habitat).

The approach used to select spatial boundaries is supported by Indigenous and Local Knowledge shared by Indigenous Groups about the interconnectedness of the region's waterways, and how rivers and lakes cannot be viewed in isolation (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.2: CRDN; BNDN-JWG 2021; BRDN-JWG 2019; BRDN-JWG 2020).

The larger lakes in the LSA, including Patterson Lake and Forrest Lake, and the Clearwater River have been documented as culturally important to Indigenous Groups and LPA communities and have been used for harvesting activities and travel for generations (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S, TSD V.1: CRDN; TSD V.2: CRDN; TSD VI: YNLR; MN-S 2019; CRDN 2019a; 2019b; YNLRO 2019).

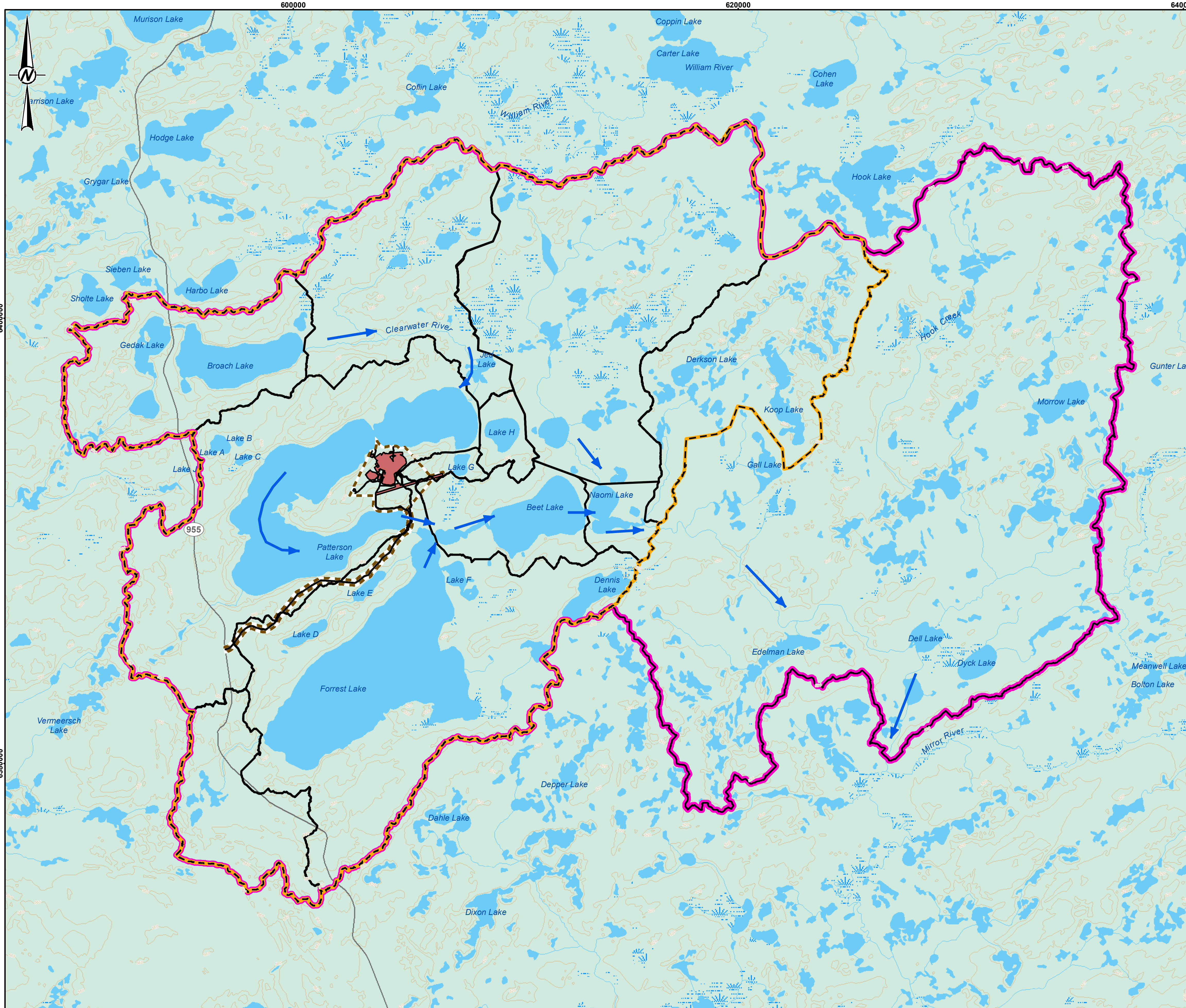
9.2.4 Temporal Boundaries

The temporal scope of the assessment focuses on the 43-year period from initial Construction to the end of Decommissioning and Reclamation (i.e., Closure) as defined by the following Project phases (Section 6.4.2, Temporal Boundaries):

- **Construction Phase (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. The duration of Construction is expected to be four years.
- **Operations Phase (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. The duration of Operations is expected to be 24 years.
- **Decommissioning and Reclamation Phase (Closure):** includes two stages expected to occur over 15 years:
  - **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 and 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. The duration of the Active Closure Stage is expected to be five years.

- **Transitional Monitoring Stage:** includes monitoring and reporting activities that occur post-Active Closure that 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 back under Provincial management through the Institutional Control Program. The duration of the Transitional Monitoring Stage is nominally 10 years; however, NexGen acknowledges this duration would be dependent on the achievement of performance criteria.

The temporal boundaries applied to cumulative effects assessments included the duration of residual effects from previous and existing developments that overlap with residual effects from the Project, and the period during which the residual effects from RFDs overlap with the Project, if applicable.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 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

HYDROLOGY STUDY AREAS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	LB/NO	2023-02-10	**FIGURE 9.2-1**	
CHECK	RWP	2023-02-10		
REVIEW	NPS	2023-02-10		

9.2.5 Assessment Cases

The concept of assessment cases was applied to the hydrology assessment to estimate the incremental and cumulative effects from the Project and other developments (Section 6.5, Assessment Cases). The approach incorporated temporal boundaries for analyzing the potential effects from previous, existing, and approved projects and RFDs before, during, and after the anticipated lifespan of the Project. There are no known approved (but not yet constructed) projects in the LSA and RSA for hydrology. Assessment cases for the Project included a Base Case, Application Case, and RFD Case.

Base Case for hydrology is represented by existing conditions. The Base Case describes the existing environment in the LSA and RSA before development of the proposed Project to provide an understanding of the current conditions that may be influenced by the Project. The temporal boundary of the Base Case includes the combined effects from previous and existing human disturbances and natural factors (e.g., fire, floods, drought) on the environment and hydrology. As such, existing conditions represent the cumulative effects of historical and current environmental pressures that have influenced the observed condition and patterns of hydrology (CEA Agency 2018).

Application Case for hydrology represents predictions of the combined effects of the previous and existing projects/activities and natural factors in the Base Case plus the potential effects from the proposed Project. This case was also used to identify and assess incremental, Project-specific changes that are predicted to occur to hydrology.

Reasonably Foreseeable Development (RFD) Case for hydrology represents predictions of the combined effects of the Base Case, Application Case, and RFDs that have not yet been approved, as well as considerations for climate change. Reasonably foreseeable developments are defined as projects and activities that fit any of the first three, and both of the last two criteria from the list below:

- are currently under regulatory review or have officially entered a formal regulatory application process;
- have been publicly disclosed by other proponents;
- may be induced by the Project;
- have the potential to change the Project or the effects predictions; and
- occur in the spatial assessment boundary defined for hydrology.

A key criterion for selecting other projects to include in the RFD Case was that the projects must cause similar effects to hydrology influenced by the Project (Hegmann et al. 1999). The Fission Patterson Lake South Property, which is planned by Fission Uranium Corp. (Fission 2019, 2021), was included in the RFD Case (Figure 9.2-2). Public information describes a projected three-year construction period and seven-year operating period (production and processing) (Fission 2019, 2021). The anticipated start of construction and duration of active decommissioning at the Fission Patterson Lake South Property were not publicly available at the time this assessment was completed. For the assessment, it was assumed that the duration of active decommissioning for the Fission Patterson Lake South Property would be similar to the Active Closure Stage for the Project (i.e., five years; Section 6.5.3, Reasonably Foreseeable Development Case).

The CRDN and MN-S specifically mentioned the risk of cumulative effects from the Project and the nearby proposed Fission Patterson Lake South Property (CRDN 2019a; MN-S-JWG 2020; CRDN-JWG 2021).

As a scenario within the RFD Case (where applicable), potential effects from climate change, including how natural factors (e.g., fire and insects) may be altered resulting from climate change, was considered within the assessment. Indigenous Groups indicated concerns about cumulative effects from human development, policies, and climate change (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN).

The assessment of the RFD Case was analyzed and classified based on the following scenarios:

- **Reasonably Foreseeable Development Case:** includes the Application Case plus the Fission Patterson Lake South Property (Section 9.6.2, Reasonably Foreseeable Development Case). The RFD Case includes the Base Case, Application Case, and Fission Patterson Lake South Property effects under historical climate conditions.
- **Climate Change Scenario:** includes the effect of climate change as discussed in Section 9.4 without the inclusion of Project or Fission Patterson Lake South Property effects. The climate change scenario used in the RFD Case (including climate change) represents projected climate change for the 2050s.
- **Reasonably Foreseeable Development Case (including climate change):** includes the combined effects of the RFD Case and climate change scenarios (Section 9.6.3, Reasonably Foreseeable Development Case [including Climate Change]).

The hydrology assessment includes a quantitative and qualitative analysis of predicted changes on measurement indicators and associated effects from the Fission Patterson Lake South Property on hydrology. In addition, potential changes from natural disturbance factors and climate change are qualitatively discussed for hydrology.

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA

REFERENCE(S)

1. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
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

DEVELOPMENTS INCLUDED IN THE REASONABLY FORESEEABLE DEVELOPMENT CASE

CONSULTANT

WSP

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2023-02-10	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-10		
CHECK	RWP	2023-02-10	FIGURE 9.2-2	
REVIEW	NPS	2023-02-10		

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25mm

9.2.6 Existing Conditions

The approach to characterizing existing hydrological conditions is summarized in this subsection with a focus on LSA and RSA hydrology (Figure 9.2-1). In a general sense, the characterization of existing conditions incorporated Indigenous and Local Knowledge as well as detailed monitoring results to develop a fulsome understanding of the existing hydrological system.

Baseline monitoring and desktop studies were conducted to characterize the hydrology, geomorphology, stream channel parameters, stream hydraulics, and fluvial sediment transport of the Clearwater River and its tributaries in the RSA. Extensive field baseline monitoring programs were completed over the period of August 2018 to September 2020 to collect detailed measurements representative of conditions at that time. The baseline monitoring program is summarized in Section 9.2.6.1, Baseline Hydrology Monitoring and Studies, and Annex IV, Hydrology Baseline Road Map.

The numerical models developed to characterize existing conditions were the regional hydrological model and the fluvial sediment transport model for the Clearwater River below (i.e., downstream of) Patterson Lake. Both models were developed and calibrated based on measured data collected during baseline studies (Annex IV). The models were used to broaden the range of conditions compared to what could be measured over the baseline monitoring period to include a longer period and greater range of conditions, including extreme conditions such as drought and floods. The methods and results of the regional hydrological model are summarized in Section 9.2.6.2, Hydrological Modelling of Water Surface Elevation and Flow Rates, and Appendix 9A, Hydrological Modelling Summary Report.

The methods and results of the fluvial sediment transport model, including the associated hydraulic model, are summarized in Section 9.2.6.4, Fluvial Sediment Transport, and Appendix 9B, Hydraulic and Sediment Transport Modelling Summary Report. This model was used to characterize the reach of the Clearwater River between Patterson Lake and the north end of Forrest Lake (Section 9.2.6.4 and Appendix 9B).

9.2.6.1 Baseline Hydrology Monitoring and Studies

The characterization of existing hydrological conditions in the RSA was based on information from field-based studies, community engagement, and desktop analyses, including numerical modelling. Several hydrological baseline reports were prepared as part of the comprehensive hydrology baseline program that documents different aspects of the natural environment in the area of the proposed Project:

- Annex IV.1: Regional Meteorological and Hydrological Characterization Report;
- Annex IV.2: Hydrometric Monitoring Characterization Report;
- Annex IV.3: Geomorphology Characterization Report;
- Annex IV.4: Patterson Lake Currents Assessment Report; and
- Annex IV.5: Forrest Lake Mixing Study Report.

The hydrometric monitoring program was carried out at numerous locations within the RSA and is summarized in Table 9.2-2 and Figure 9.2-3. Monitoring was conducted at the following locations:

- six waterbodies in the RSA;
- one reference waterbody outside the RSA (i.e., Hodge Lake);
- nine watercourses in the RSA, consisting of six along the Clearwater River mainstem and three tributaries;

- one reference watercourse outside the RSA (i.e., Hodge Lake outlet); and
- three watercourses far downstream of the RSA along the Clearwater River.

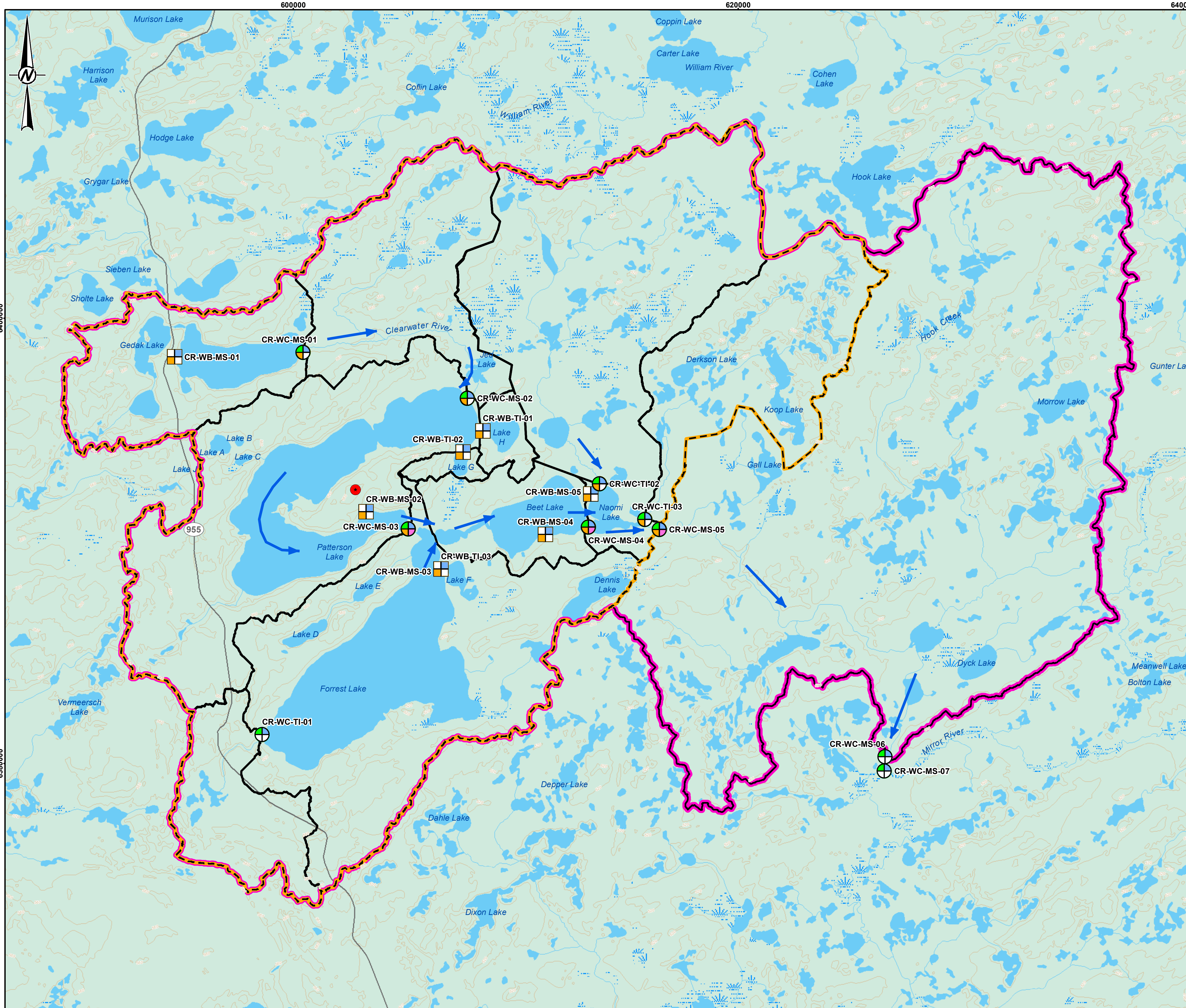
Table 9.2-2: Baseline Hydrometric Station Locations (2018 to 2020)

Hydrometric Station ID	Hydrometric Station Name	Location (UTM NAD83 Z12)	Watershed Area (km^2)[(a)]	Period of Record	Parameters Measured[(b)]
Waterbodies					
HL-WB-MS-01	Hodge Lake	6407639 N 593182 E	52.6	2020	WSE, WT
CR-WB-MS-01	Broach Lake	6398271 N 594670 E	56.4	2018-2020	WSE, WT
CR-WB-TI-01	Lake H	6394933 N 608527 E	7.36	2018-2020	WSE, WT
CR-WB-TI-02	Lake G	6393993 N 607640 E	3.75	2018-2020	WSE, WT
CR-WB-MS-02	Patterson Lake	6391308 N 603277 E	264	2018-2020	WSE, WT
CR-WB-MS-03	Forrest Lake	6388735 N 606636 E	445	2018-2020	WSE, WT
CR-WB-MS-04	Beet Lake	6390290 N 611334 E	473	2018-2020	WSE, WT
CR-WB-MS-05	Naomi Lake	6392110 N 613375 E	685	2018-2020	WSE, WT
Watercourses					
HL-WC-MS-01	Hodge Lake outflow	6407639 N 593182 E	52.6	2020	WSE, WT, Q
CR-WC-MS-01	Clearwater River below Broach Lake	6398465 N 600437 E	56.4	2018-2020	WSE, WT, Q
CR-WC-MS-02	Clearwater River above Patterson Lake	6396408 N 607825 E	121	2018-2020	WSE, WT, Q
CR-WC-MS-03	Clearwater River below Patterson Lake	6390535 N 605166 E	264	2018-2020	WSE, WT, Q, CH, S
CR-WC-MS-04	Clearwater River below Beet Lake	6390617 N 613269 E	473	2018-2020	WSE, WT, Q, CH, S
CR-WC-MS-05	Clearwater River below Naomi Lake	6390517 N 616451 E	685	2018-2020	WSE, WT, Q, CH, S
CR-WC-MS-06	Clearwater River above Mirror River confluence	6380305 N 626600 E	1,076[(c)]	2018-2020	WSE, WT, Q, CH
CR-WC-MS-07	Clearwater River below Mirror River confluence	6379687 N 626541 E	3,300	2018-2020	WSE, WT, Q
CR-WC-MS-08	Clearwater River at the Lloyd Lake Outlet	6356667 N 634720 E	4,370	2018-2020	WSE, WT, Q
CR-WC-MS-09	Clearwater River at Warner Rapids	6307938 N 623078 E	9,590	2018-2020	WSE, WT, Q
CR-WC-TI-01	Tributary Inflow above Forrest Lake	6381301 N 598609 E	34.8	2018-2019	WSE, WT, Q
CR-WC-TI-02	Tributary Inflow to Naomi Lake	6392567 N 613764 E	134	2018-2020	WSE, WT, Q
CR-WC-TI-03	Tributary Inflow downstream of Naomi Lake	6390967 N 615802 E	67.5	2018-2020	WSE, WT, Q

Note: All coordinates referenced are in Universal Transverse Mercator (UTM) Zone 12 and North American Datum 1983 (NAD83).
a) Methods for delineation of watershed boundaries are described in Appendix 9A.
b) Details of measurement methods are provided in Annex IV.2.
c) The area provided for the Clearwater River above the Mirror River Confluence is provided to the square kilometre for consistency with use in other sections.
WSE = water surface elevation; WT = water temperature; Q = discharge; CH = geomorphic stream channel parameters; S = suspended bed load sediment measurements.

The Clearwater River below Forrest Lake is a broad channel with two constriction points that are routinely backwatered by Beet Lake (i.e., the downstream lake level may often control water levels in Forrest Lake as well). As a result, this section of the Clearwater was not conducive to installing and operating a hydrometric station.

Physical characteristics of lakes (i.e., lake morphometry) influence how water is stored and routed through the drainage network. Bathymetric mapping of lake depth contours was completed for Patterson Lake (NexGen 2016), Broach Lake, Lake G, Lake H, and Beet Lake (Annex V.1 Aquatic Environment Baseline Report), and Naomi Lake Bathymetry Report (Annex V.3). Baseline digital bathymetry data were used to generate bathymetric maps and establish WSE-volume relationships for Broach Lake, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake as well as Lake G and Lake H.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED
- METEOROLOGICAL STATION

WATERBODY HYDROMETRIC STATIONS

- DISCHARGE
- SURVEYED BENCHMARK (GEODETIC DATUM)
- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- DISCHARGE
- SURVEYED BENCHMARK (GEODETIC DATUM)
- TOTAL SUSPENDED SOLIDS AND BEDLOAD
- WATER SURFACE ELEVATION

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 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

BASELINE HYDROMETRIC MONITORING WITHIN THE REGIONAL STUDY AREA

CONSULTANT

wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-10		
CHECK	RWP	2023-02-10	**FIGURE 9.2-3**	
REVIEW	NPS	2023-02-10		

9.2.6.2 Hydrological Modelling of Water Surface Elevation and Flow Rates

Quantitative modelling of existing conditions over an extended period provides an understanding of the hydrological system and context for natural variability and responses to climate. Hydrological models were developed using the GoldSim modelling platform to characterize existing conditions and predict Project effects on the hydrological regime. GoldSim is an object-oriented computer program that is commonly used in industry to dynamically model complex systems (GoldSim 2018). A model was first developed for existing conditions, and as described in Section 9.2.10.1, this model also forms the basis for the quantitative effects assessment by simulating Project development scenarios.

Details of the hydrological modelling completed in support of the EA, including model scenarios, structure, setup, and results, are provided in Appendix 9A, with a summary provided in Section 9.2.6.2.1, Model Spatial and Temporal Domains to Section 9.2.6.2.6, Model Calibration and Validation.

9.2.6.2.1 Model Spatial and Temporal Domains

The regional hydrological model was set up to cover the RSA as defined by the watershed boundary for the Clearwater River above (i.e., upstream of) the Mirror River confluence (Figure 9.2-1) for existing conditions as well as for all other scenarios (Section 9.2.9, Residual Effects Analysis).

The temporal domain representing existing conditions spanned the timeframe from August 2025 to December 2068 (Table 9.2-3). The timeframe is an arbitrary point chosen for ease of reference by starting on a five-year increment; the actual start date may deviate from what was assumed for modelling. Different temporal domains were used for model calibration and model validation, and were influenced by data availability and the purpose of the model application. Different time periods were used for model calibration and model validation so that the model validation could be an objective test of the calibrated model.

9.2.6.2.2 Model Software

The software selected for the hydrological model was GoldSim®. The processes related to atmospheric losses, including sublimation (i.e., transition of water from solid ice or snow to water vapour), lake evaporation (i.e., transition of water from liquid form to water vapour), and evapotranspiration (i.e., evaporation that is the movement of water to the air from surfaces as well as transpiration that releases water vapour from plants) were modelled using different software called MATLAB®, due to computational and model complexity constraints. The MATLAB software is used for programming data, statistical analysis, and graphics (The Mathworks Inc. 2021). Atmospheric loss outputs from MATLAB were then input into the Regional Hydrological Model in GoldSim.

9.2.6.2.3 Model Structure and Configuration

The GoldSim model is a representation of the physical properties of the model spatial domain within the RSA watershed. The spatial domain of the regional hydrological model extends from the headwaters of the Clearwater River to its confluence with the Mirror River at the hydrometric monitoring station, CR-WC-MS-06, as shown in Figure 9.2-3. A single watershed model was run throughout the year to better enable continuous simulation over longer periods of time. The main waterbodies along the Clearwater River mainstem include Broach Lake, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake. Runoff from land drains directly into these waterbodies or the Clearwater River mainstem, or is carried by tributary streams to the mainstem.

The sub-watersheds constituting the spatial domain of the regional hydrological model are shown in Figure 9.2-1. The key evaluation nodes within the spatial domain are at baseline hydrometric monitoring stations (i.e., stations that were established for the Project's baseline studies). The watercourses and associated surface water routing are shown in Figure 9.2-3.

A sensitivity analysis was completed prior to calibrating the model to identify the parameters that were more influential on discharge. The model was calibrated from August 2018 to August 2020 by optimizing comparisons of modelled hydrograph volume and peak flow to observations at hydrometric stations throughout the model domain. The calibrated model was then validated using regional data over a much longer period (i.e., 1979 to 2018) in which the optimized parameters were used in the model runs, and the model performance was again checked against historical observations.

9.2.6.2.4 Input Data

The key input data for the regional hydrological model included the following:

- watershed and landcover characteristics (e.g., drainage network, basin areas, distribution of wetlands landcover, terrestrial landcover, and lake areas);
- lake morphometry;
- hydrometric monitoring data;
- historical meteorological data (i.e., air temperature, precipitation, and atmospheric losses);
- climate trends;
- climate change predictions (Appendix 22A, Climate Change Dataset Summary Report); and
- existing water management infrastructure.

9.2.6.2.5 Parameterization

The regional hydrological model incorporated necessary hydrological processes, including the following main parameters described in detail in Appendix 9A:

- snowmelt estimated using a temperature-index method;
- forest canopy storage represented as a storage reservoir (i.e., the amount of precipitation intercepted and temporarily stored in the canopy until it evaporates);
- surface or subsurface storage and flow;
- groundwater exchange (i.e., the difference between groundwater recharge in terrestrial or wetland areas and discharge in waterbodies or watercourses), calculated for each sub-watershed; and
- lake outflow rating curves calculated for each waterbody based on baseline hydrometric monitoring results, with correction factors to account for backwater from ice during winter periods.

9.2.6.2.6 Model Calibration and Validation

The regional hydrological model calibration used daily values of water level and discharge measured in the RSA between August 2018 and August 2020. The model calibration and evaluation nodes within the RSA are provided in Table 9.2-3 and the locations coincide with the baseline hydrology monitoring stations in Figure 9.2-3. A key modelling assumption was that parameters and processes inferred from the calibration at several hydrometric station locations for a short period of record (i.e., two years) could be effectively and accurately applied to a longer period (i.e.,43 years) at the same locations, as well as other ungauged (i.e., unmeasured) locations. As meteorological and hydrological conditions were variable during the calibration period, with both low and high flow periods, and as ungauged locations are in similar terrain as the gauged sub-watersheds, this assumption is reasonable.

Table 9.2-3: Model Calibration and Evaluation Nodes within the Regional Study Area Model Domain

Type	Locations	Station ID	Cumulative Area (km²)	Calibration Point	Evaluation Point
Watercourses	Clearwater River below Broach Lake	CR-WC-MS-01	56.4	✓	✓
	Clearwater River above Patterson Lake	CR-WC-MS-02	121	✓	✓
	Clearwater River below Patterson Lake	CR-WC-MS-03	264	✓	✓
	Clearwater River below Beet Lake	CR-WC-MS-04	473	✓	✓
	Tributary Inflow to Naomi Lake	CR-WC-TI-02	607	✓	×
	Tributary Inflow Downstream of Naomi Lake	CR-WC-TI-03	685	✓	×
	Clearwater River above the Mirror River confluence	CR-WC-MS-06	1,076	✓	×
Waterbodies	Broach Lake	CR-WB-MS-01	56.4	✓	×
	Patterson Lake	CR-WB-MS-02	264	✓	×
	Forrest Lake	CR-WB-MS-03	445	✓	×
	Beet Lake	CR-WB-MS-04	473	✓	×
	Naomi Lake	CR-WB-MS-05	685	✓	×
	Lake H	CR-WB-TI-01	7.36	✓	×
	Lake G	CR-WB-TI-02	3.75	✓	×

× = location not used; ✓ = location used.

The calibration was completed using daily values, and since a continuous record was required for the modelling, gaps in the observations were filled to extend the record over periods when observations were not available (e.g., during the ice-covered period at some locations). The calibration period covered a range of conditions including dry (e.g., 2018) and wet (e.g., 2020) years. The supporting data are presented in the hydrology modelling report (Appendix 9A).

9.2.6.3 Stream Channel Parameters

The fluctuation of discharge within a watercourse results in changes to open-channel hydraulic characteristics according to the physical constraints of stream channel geometry, roughness, and slope. Water depth, channel wetted area, top width, and wetted perimeter are important hydraulic characteristics, all of which fluctuate in response to changing surface water flows and influence the amount and type of habitat available for aquatic organisms and navigability.

Stream channel parameters, including mean water depth, channel wetted area, top width, and wetted perimeter, were measured (or calculated from field measurements) during numerous field visits whenever discharge was measured at the hydrometric stations. Stream channel parameter results were plotted against the corresponding measured discharge values at each site to develop the relationship of each parameter with discharge for each location.

The existing relationship between discharge and wetted area had the most robust correlation among the stream channel parameters measured as part of baseline monitoring. This relationship was evaluated at the following four hydrometric stations:

- Clearwater River below Patterson Lake (CR-WC-MS-03);
- Clearwater River below Beet Lake (CR-WC-MS-04);
- Clearwater River below Naomi Lake (CR-WC-MS-05); and
- Clearwater River above the Mirror River confluence (CR-WC-MS-06).

9.2.6.4 Fluvial Sediment Transport

As water is conveyed downstream by a watercourse, a portion of its energy is expended on moving and rearranging material from the bed and banks. Over time, there is ongoing inflow and outflow of sediment in each watercourse reach, and this sediment transport can be broadly broken down into three stages: the initiation of motion; downstream transport; and deposition. To initiate sediment motion, a critical energy level must be reached. Once in motion, sediment is transported downstream and deposited when the stream no longer has the energy to transport it. Deposition generally occurs when the energy available in the stream for transporting the sediment decreases or the sediment load drastically increases.

Fluvial sediment transport (i.e., the movement of particles by water) can be broadly divided into two classes: suspended load (i.e., particles suspended in the water column) and bed load (including wash load[3]), where moving particles sustain intermittent contact with the streambed (i.e., sediment rolls, slides, and bounces along the bottom of a waterway). In general, sediment transport is directly proportional to a stream's discharge and is typically highest during flood periods.

The following information sources were used to quantify fluvial sediment transport in the receiving environment:

- Baseline sediment monitoring and sampling completed at three hydrometric monitoring locations downstream of Patterson Lake; details are provided in Annex IV.2.
- Field data collected in the study area in fall 2018, which included a real-time kinematic GPS survey at numerous cross-sections along surveyed reaches as well as water level surveys, flow measurement, total suspended solids water sampling, and geomorphology observations.
- A one-dimensional (1-D) open-channel hydraulic and fluvial sediment transport model developed using the Hydrologic Engineering Center – River Analysis System version 5.0.7 (HEC-RAS) modelling platform to characterize hydraulic and sediment transport mechanisms for existing conditions.

9.2.6.4.1 Baseline Fluvial Sediment Monitoring and Sampling

As part of the hydrological baseline monitoring program, suspended and bed load sampling was conducted at key locations in the RSA during the 2018 to 2020 open-water season field visits. Measurement and sampling sites were situated at the hydrometric stations installed along the Clearwater River mainstem below Patterson, Beet, and Naomi lakes, as these are the closest reaches downstream of the Project (Table 9.2-2; Figure 9.2-3). These locations had relatively uniform depths and sand-sized substrates; uniform bedforms were visible across the channel. Stream bed substrate grain size was measured in fall 2018 at the same locations that suspended

[3] Wash load is defined as smaller sediments up to fine sand in size that are readily carried in suspension by the stream (Gordon et al. 2004).

sediment and bed load were measured to characterize sediment sizes and inform sediment transport modelling. Detailed methods and results are provided in Annex IV.2.

9.2.6.4.2 Fluvial Sediment Transport Model

A 1-D hydraulic model was developed using HEC-RAS version 5.0.7 (USACE 2019) to characterize the existing fluvial sediment transport regime for the Clearwater River reach between Patterson Lake and Forrest Lake over a range of climatic conditions. Details of hydraulic and sediment transport modelling completed in support of the EA, including model scenarios, structure setup, and results, are provided in Appendix 9B.

The key components of HEC-RAS models are the geometry data, which represent the physical geometry and characteristics of the spatial domain, and the flow data, which can be static (i.e., steady state) or dynamic (i.e., unsteady or quasi-unsteady state). ArcGIS mapping software (ESRI 2018) was also used to create the channel geometry files required for the HEC-RAS model. The model geometry was based on channel surveys completed using real-time kinematic GPS survey equipment in fall 2018. Channel geometry was used to define the Upper Reach of this portion of the Clearwater River as being within the reach of the single channel, with an estimated length of 565 m starting downstream of Patterson Lake to the channel division (Appendix 9B).

The model was used for developing 1-D steady state (i.e., instantaneous) and quasi-unsteady state time series flow models for hydraulic and sediment transport analysis of the study reach. The steady state model runs were used to evaluate projected water levels in the channel under different (i.e., high and low) flow conditions. The quasi-unsteady state model runs were used to simulate fluvial sediment transport and had a temporal domain of 1 year at a daily time step using flood hydrographs with return periods of 2, 5, 10, 20, 50, and 100 years.

The existing conditions model was calibrated for discharge based on measurements collected on 2 October 2018 and 3 October 2018. The performance of the hydraulic model, including calibration results, are described in Appendix 9B.

9.2.7 Climate Change

Climate change is probable during the Project period. Site-specific future climate projections were developed for the Project based on results from a multi-model ensemble representing different levels of greenhouse gas emissions. The 2050s (i.e., this includes the years 2041 to 2070) represent a reasonable upper bound in terms of climate change during the Project lifespan. Appendix 6A, Climate Change Road Map, summarizes how climate change was incorporated into applicable discipline effect assessments (i.e., Sections 7 to 19).

The anticipated effect of climate change on hydrology relative to the Base Case was assessed independently from the effects of the Project and other developments. The mean projected monthly changes in air temperature and precipitation for the 2050s relative to a historical climate period of 1981 to 2020 were incorporated into the hydrological model. The climate change scenario consisted of a daily time series with the model run in deterministic mode (i.e., simulating one scenario at a time). In the mean climate change scenario, temperature, precipitation, lake evaporation, and evapotranspiration are all projected to increase, while sublimation would decrease due to a shorter snow-covered period.

Four sensitivity scenarios were also modelled to understand uncertainty in climate change projections and quantify sensitivity of the model to the range of potential climate change outcomes. Results from the four sensitivity scenarios are provided in Appendix 9A.

The climate change scenario was not incorporated in the Application Case to improve certainty in the estimation of changes to hydrology expected from the Project alone. However, the climate change scenario was combined with the Fission Patterson Lake South Property in the regional hydrological model in the RFD Case (Section 9.6.2). As the assumed construction of the Fission Patterson Lake South Property would begin in 2025 and operation would span the period from 2028 to 2033, the RFD Case (Fission 2019), combined with climate change projections from the 2050s, provides more conservative results than using climate change projections from the 2020s.

9.2.8 Project Interactions and Mitigations

Interactions (i.e., linkages) between Project components or activities, and the corresponding potential changes to measurement indicators, were identified by a pathway analysis that was then used to inform the residual effects analysis for the hydrology (Section 6.7, Pathways Analysis). The first part of the analysis was to identify all potential effects pathways for all phases of the Project (Section 6.7.1, Identification of Project Interactions). Each pathway was initially assumed to have a linkage to potential effects on hydrology.

Potential pathways from Project activities on hydrology were identified using the following:

- review of the Project description (Section 5) and potential effects scoping by the project development, environmental, and socio-economic teams for the Project;
- input from Indigenous, regulatory, and public engagement (Section 2) and Indigenous and Local Knowledge (Section 3);
- scientific knowledge;
- previous experience with mining projects; and
- consideration of potential effects identified from the Terms of Reference (Section 1, Appendix 1A).

Potential adverse effects of the Project were then identified, and practicable mitigation was applied to avoid, minimize, and/or rehabilitate effects on hydrology (Section 6.7.2, Identification of Mitigation). Avoidance and minimization are widely recognized as the most important approach for biodiversity conservation (BBOP 2021). Avoidance designs and actions integrated into the Project were developed iteratively by the Project's environmental and project development teams. Minimization techniques and technology were also identified collaboratively between Project teams.

Each potential effect pathway was evaluated using proposed mitigation to predict whether the pathway had the potential to cause residual adverse effects (Section 6.7.3, Pathway Screening). A screening-level assessment was applied using Indigenous and Local Knowledge, scientific knowledge, logic, experience with similar developments, and an understanding of the effectiveness of mitigation (i.e., level of certainty that mitigation would work) to assign each pathway to one of the following categories:

- **No pathway:** Analysis reveals that the pathway could be removed (i.e., the effect is avoided) by mitigation so that the Project would result in no measurable environmental change relative to existing conditions or guideline values and, therefore, would have no residual effect on hydrology.
- **Secondary pathway:** The pathway could result in a measurable but minor environmental change relative to existing conditions or guideline values, but this change would be sufficiently small that it would have a negligible residual effect on hydrology. Therefore, the pathway is not expected to contribute to effects of RFDs to cause a significant effect.
- **Primary pathway:** The pathway is likely to result in an environmental change relative to existing conditions or guideline values and could cause a greater than negligible effect on hydrology.

Project interactions determined as no pathway or secondary pathways were not carried forward for further assessment (Section 6.7.3). Primary pathways that could result in changes to the environment with one or more associated measurement indicator and have the potential to cause a greater than negligible effect to hydrology were carried forward to the residual effects analysis and residual effects classification (Section 9.5).

9.2.9 Residual Effects Analysis

The residual effects analysis measures and describes the effects of the proposed Project on hydrology relative to existing conditions. The residual effects analysis was conducted using the spatial boundaries (Section 9.2.3, Spatial Boundaries) and temporal boundaries (Section 9.2.4, Temporal Boundaries) identified for the assessment. Residual effects are described for each of the measurement indicators for the primary pathways identified for hydrology in the LSA and RSA (Section 9.5.3, Primary Pathways). The residual effects analysis was completed for the Application Case and the RFD Case (Section 6.8, Residual Effects Analysis) and was supported by hydrological and hydraulic models for the Base Case conditions, modified to account for the identified primary pathways.

9.2.10 Residual Effects Classification

The residual effects were classified for the LSA and RSA waterbodies and outflow channel watercourses that are expected to be affected by the Project and RFDs. The residual effects analysis focused on the Clearwater River from Patterson Lake to above the Mirror River confluence.

The residual effects analysis for hydrology used quantitative analysis and logical reasoning to describe anticipated changes to each measurement indicator caused by the Project and RFDs. The description of predicted effects was integrated into the residual effects analysis to determine the net effects of the primary pathways during the Application Case and RFD Case. Residual effects were then summarized or classified in tabular form for each of the cases to provide structure and comparability across other intermediate components and VCs.

Residual effects were described for each of the measurement indicators identified in Section 9.2.2 for the primary pathways identified for hydrology (Section 9.5.3, Primary Pathways) as follows:

- **Waterbody WSE**: Changes in characteristic waterbody WSE were estimated numerically by calculating the differences in the mean annual daily WSE between the Base Case, Application Case, and RFD Case.
- **Watercourse flow rate:** Changes in characteristic watercourse flow rate were estimated numerically by calculating the differences in the mean annual daily low flow, mean annual daily mean flow, and mean annual daily peak flow between the Base Case, Application Case, and RFD Case.
- **Stream channel parameters:** Changes to wetted area were estimated numerically using relationships between discharge and wetted area developed using baseline monitoring data and mean annual discharge between the Base Case, Application Case, and RFD Case.
- **Fluvial sediment transport:** Changes to fluvial sediment transport were quantified numerically by calculating the differences in the daily sediment load between the Base Case, Application Case, and RFD Case using a HEC-RAS sediment transport model. Potential changes to flows from the Project, climate change scenario, and cumulative effects scenario were included in the model to predict changes to the fluvial sediment transport regime.

The residual effects analysis used a reasoned narrative to describe anticipated changes to each measurement indicator caused by the Project and other projects (if applicable) and subsequent effects to hydrology. The narrative description of anticipated effects is the foundation for the residual effects classification. Residual effects are summarized or classified in tabular form using effects criteria, which is intended to provide structure and comparability across VCs and intermediate components assessed for the Project (Section 6.9.1, Residual Effects Classification).

The residual effects classification used direction, magnitude, geographic extent, duration, reversibility, frequency, and probability of occurrence as criteria. The approach to classify each residual effect criterion is provided in Table 9.2-4.

Table 9.2-4: Definitions Applied to Effects Criteria Classifications for the Assessment of Hydrology

Criterion	Rating	Definition
Direction	Increase	Increase in magnitude of measurement indicator
	Decrease	Decrease in magnitude of measurement indicator
Magnitude	Qualitative narrative or numeric quantification	Change in measurement indicator is described by effect size (e.g., flow). A categorical classification of low (less than 10%), moderate (10% to 30%), and high (greater than 30%) is also provided for context
Geographic extent	Project footprint	Change in measurement indicator is confined to the Project footprint
	Local	Change in measurement indicator extends outside the Project footprint but within the LSA
	Regional	Change in measurement indicator extends beyond the LSA but is confined to the RSA
	Beyond regional	Change in measurement indicator extends beyond the RSA
Duration	Qualitative narrative or numeric quantification	Change in measurement indicator is described by effect duration (e.g., months, years, decades, or permanent)
Reversibility	Reversible	Change in measurement indicator is reversible within a clearly defined time period
	Irreversible	Change in measurement indicator is predicted to influence the component indefinitely
Frequency	Occasional	Change in measurement indicator is expected to occur rarely (e.g., once or a few times)
	Periodic	Change in measurement indicator is expected to occur consistently at regular intervals or associated with temporal events (e.g., during dry summers)
	Continuous	Change in measurement indicator is expected to occur all the time
Probability of occurrence	Unlikely	Change in measurement indicator is not expected to occur, but not impossible
	Possible	Change in measurement indicator may occur, but is not likely
	Probable	Change in measurement indicator is likely to occur, but is uncertain
	Certain	Change in measurement indicator will occur

RSA = regional study area; LSA = local study area.

While most criteria could be assigned categorical ratings for hydrology, predicted effect sizes were provided in specific terms (i.e., narrative or numeric quantification) in the residual effects characterization (Table 9.2-4). Similarly, duration was described in specific terms (e.g., years). Applying a category rating to a criterion such as magnitude might lead to confusion or misinterpretation of the effects assessment, or result in the criterion not being easily categorized in a meaningful way. Characterizing magnitude solely using an ordinal scale (i.e., low, moderate, or high) in a manner meaningful for hydrology is often not appropriate as additional context is required to properly characterize the effects. Universal effect size boundaries, such as a 20% change in a measurement indicator at the RSA or LSA scale used to define a high magnitude effect, work poorly because these size boundaries fail to consider context. For example, a 20% change in one measurement indicator from existing conditions in the study area may be required to cause a high magnitude effect on one intermediate component or VC, whereas for other measurement indicators a 20% change may result in a low magnitude effect on another intermediate component or VC (Section 6.9.1).

Specific to the hydrology effects classification, direction was referred to as increase, neutral, or decrease, as the changes to a physical measurement indicator are not easily classified as positive or negative. The determination of whether the change was positive or negative was addressed in the residual effects analysis for the relevant measurement indicator. For example, a 10% increase or decrease in flows or water levels may be positive or negative with respect to fish and fish habitat, but not to hydrology itself. The magnitude of the change was expressed as a percentage of the measurement indicator value in the Base Case.

9.2.10.1 Hydrological Modelling of Water Surface Elevation and Flow Rates

The regional hydrological model for the Application Case included the combined effects of the Base Case and Project effects predicted to occur on hydrology. The temporal period that was represented in the hydrological model included all Project phases as follows:

- The Project activities included in the Application Case are quantitative outputs from the site-wide water balance and water quality model (i.e., an internal model for within the spatial and temporal boundaries of the Project); the details of the site-wide water balance and water quality model are documented in TSD XVIII, Site-Wide Water Balance and Water Quality Modelling Report.
- Variable state Project effects were incorporated into the regional hydrological model, including simulated fresh water demand, which would vary according to Project activities, camp population, and mining production over time. The daily rate of treated effluent release would vary through the Project lifespan based on Project activities, and the treated sewage release rate would vary due to camp population. Surface runoff (e.g., both contact and non-contact water) releases would also vary over time due to Project activities and phases.
- A model simulation start year (i.e., Construction) of 2025 was adopted for ease of reference and to align with a five-year increment.
- The 43-year simulation period consists of Construction (4 years), Operations (24 years), and Closure (15 years), which is divided into two stages: Active Closure (5 years) and Transitional Monitoring (10 years).

For the RFD Case (including climate change), a similar approach was used in predictive modelling as in the Application Case, except that this modelled case also considered how natural factors and climate change may interact with the Project (i.e., Climate Change Scenario) and other developments to affect hydrology (i.e., cumulative developments). The mean projected climate change for the 2050s (i.e., 2041 to 2070) relative to the period from 1981 to 2010 was applied to the historical climate record (Section 9.2.7). Other developments, including the Fission Patterson Lake South Property, were also assumed to begin in 2025 with operations from 2028 to 2033 and their effects on hydrology were incorporated as a variable time series.

9.2.10.2 Fluvial Sediment Transport Model

Potential changes to fluvial sediment transport for the Application Case and RFD Case were modelled in the same way as the Base Case (Section 9.2.6.4), except that the potential changes accounted for predicted changes in flood flows in the Clearwater River between Patterson and Forrest lakes. The temporal domain for the quasi-unsteady state model was 1 year with a daily time step, and the simulation used flood hydrographs with return periods of 2, 5, 10, 20, 50, and 100 years.

9.2.11 Prediction Confidence and Uncertainty

The purpose of the assessment is to predict the future conditions for hydrology with the addition of the Project and the Fission Patterson Lake South Property and climate change. As with all predictions of future conditions, the predictions made in this assessment embody some degree of uncertainty. The assessment applied a precautionary (i.e., conservative) approach to address uncertainty by identifying the greatest magnitude, duration, and geographic extent of potential adverse effects when a range of outcomes were possible. Consequently, uncertainty was addressed in a manner that increased the level of confidence that residual effects were conservatively estimated. The key uncertainties for hydrology and the way they were addressed are presented as part of this assessment (Section 9.6).

9.2.12 Monitoring, Follow-Up, and Adaptive Management

Monitoring programs are proposed to address the uncertainties associated with the effects predictions and to evaluate the performance of mitigation. In general, monitoring is used to verify the effects predictions. Monitoring is also used to identify any unanticipated effects and to support the implementation of adaptive management to limit these effects.

Typically, monitoring includes one or both of the following categories that may be applied during the Project lifespan:

- **Regulatory compliance monitoring:** monitoring activities, procedures, and programs undertaken to confirm the implementation of approved design standards, mitigation and conditions of approval, and company commitments (e.g., inspecting the installation of a silt fence or monitoring the quality of water discharge from the Project).
- **Follow-up monitoring:** programs designed to test the accuracy of effects predictions, reduce or address uncertainties, determine the effectiveness of mitigation, or provide appropriate feedback to operations for modifying or adopting new mitigation designs, policies, and practices (e.g., implementation of adaptive management). Results from these programs can be used to increase the certainty of effect predictions in future EAs.

Where relevant, conceptual monitoring programs would be proposed to confirm predictions and to address the uncertainties associated with the effects predictions and mitigation, and upon Project approval, would be included in the Integrated Management System.

The implementation of robust, long-term environmental testing and monitoring has also been requested by Indigenous Groups to verify protection of the environment, including community-led monitoring during Construction and Operations of the Project (TSD IV: MN-S; TSD V.2: CRDN; TSD VI: YNLR).

In addition to environmental monitoring programs typically implemented for projects (i.e., as noted above), NexGen is working with local Indigenous Groups to implement independent environmental monitoring. In combination with standard Project monitoring processes, independent Indigenous monitoring would be used to verify Project performance and to determine if mitigations and controls are effective in protecting the receiving environment.

Adaptive management measures may also be proposed to address the uncertainties associated with the effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

9.3 Existing Conditions

This subsection provides a summary of existing hydrological conditions in the RSA. The existing conditions for hydrology form the Base Case against which Project effects, and Project effects combined with effects from RFDs, were evaluated.

9.3.1 Hydrology of the Regional Study Area

Water primarily enters the RSA as snowfall or rainfall, with some groundwater contributions. A small amount of snowfall is intercepted in the forest canopy before reaching the ground surface. Snow that reaches the ground surface is accumulated and stored in the snowpack during winter months, with a small amount lost to the atmosphere as sublimation. In spring, the accumulated snowpack melts and either runs off directly into waterbodies (surface runoff) or infiltrates the ground surface. The ground surface is highly permeable and excess water at the ground surface infiltrates the ground surface and reports to waterbodies and watercourses located in low lying areas through primarily sub-surface flow pathways. Figure 9.3-1 shows the hydrological inputs, water storage, and water losses that occur at the scale of a waterbody or watershed.

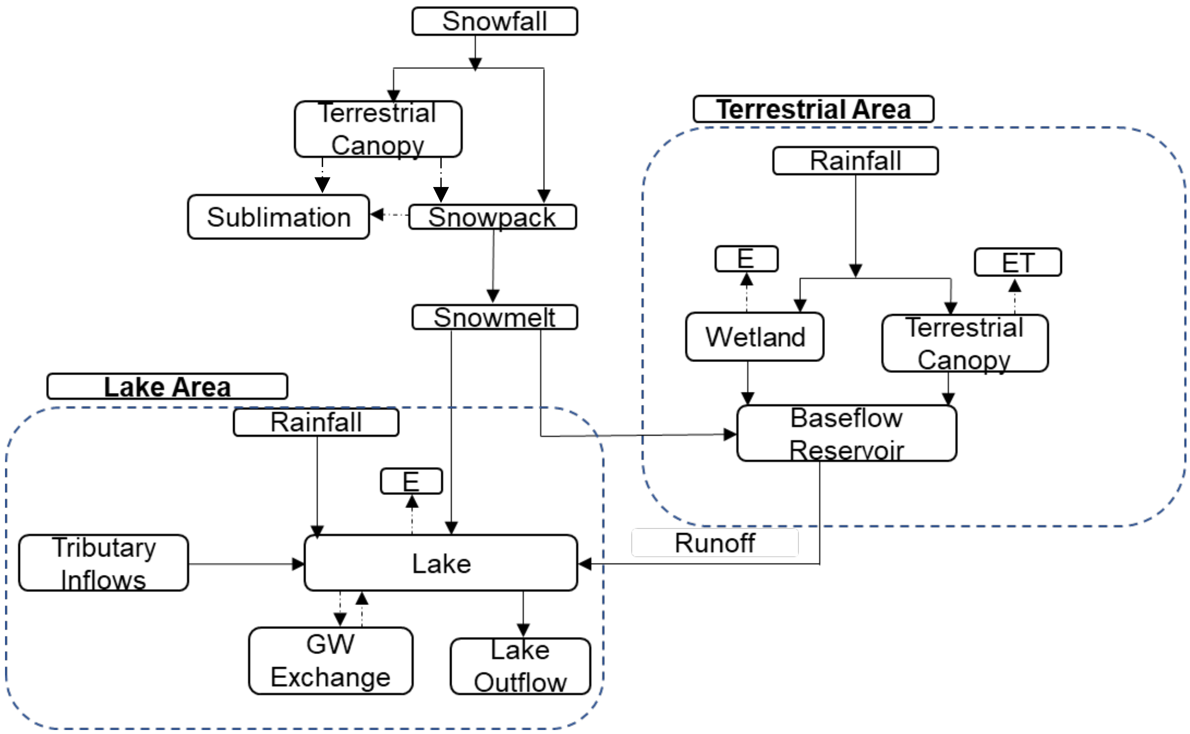
In cold regions of Canada that experience snow accumulation over the winter, including the RSA, waterbodies and watercourses usually show a common seasonal pattern with higher WSEs and flows during spring freshet and lower WSEs and flows during the remainder of the year. Snowmelt, which usually starts in March or April and continues through early June, and rainfall in the spring months contribute to the higher runoff reporting to waterbodies and watercourses during these times of the year. Rainfall may occur in any month of the year; however, higher rainfall amounts occur in the months of May through October. Fall and winter air temperatures below freezing lead to ice formation on waterbodies, and ice accumulates over the winter months. Recession of water levels occurs throughout the winter (i.e., November to March) and minimum annual levels tend to occur in late winter prior to the spring thaw (i.e., March and April).

Interannual (i.e., year-to-year) variability of WSEs and flows occurs mainly due to differences in snowfall and rainfall each year. Less variation occurs due to differences in meteorological conditions that affect losses, including the amount of evaporation, evapotranspiration from water and soil or vegetation, and blowing snow and sublimation losses from the snowpack. Infiltration and deep percolation losses to groundwater may occur as well as movement of deeper groundwater towards the ground surface or to waterbodies; these losses are generally smaller components of the water balance that do not vary greatly from year to year.

High WSEs and flows are commonly referred to as flood events even if they do not always exceed the top of the watercourse banks. On a hydrograph, a flood event consists of a rising limb, the peak or highest point, and the falling or receding limb. The annual daily mean peak in each year of the long-term simulated record is used to calculate the magnitude and frequency of floods, which provides a statistical basis for comparing locations. In Section 9.3.5, the mean annual maximum daily flow was calculated, which is the average of all the simulated annual peaks, with the highest single flood peak from each year used in the calculation.

Droughts are extended periods of drier-than-normal conditions. Droughts are typically characterized in terms of severity as well as duration (Dingman 2002). For this assessment, the duration of short-term drought is on the order of one year, and long-term drought is on the order of four years or more, consistent with normal climate cycles; a moderate drought event is defined as exceeding one year and less than four years in duration. Persistent meteorological drought (i.e., deficit of precipitation) can lead to hydrological drought over time (i.e., deficit of water on the landscape) with moisture regimes, water levels, and stream flows in the surrounding watershed being lower than normal.

Figure 9.3-1: General Schematic of Hydrological Processes in the Regional Hydrological Model for Existing Conditions



GW = groundwater; E = evaporation; ET = evapotranspiration.

9.3.2 Hydrographic Setting

Hydrography is the arrangement and connectivity of waterbodies and watercourses and provides important context for the Project location and how the Project interacts with the receiving environment. The proposed Project would be located adjacent to Patterson Lake within the Clearwater River watershed. Patterson Lake is located near the headwaters of the Clearwater River watershed at Broach Lake (CHRS 2021). The headwaters of the Clearwater River are situated north of Patterson Lake, and the Clearwater River flows south and west through the CRDN's traditional lands and primary harvesting areas (TSD V.2: CRDN). The CRDN noted that the Clearwater River starts underground, north of Patterson Lake and east of Broach Lake, as noted by a CRDN member "I asked my grandpa where this whole river system starts and he said, it's underground" (TSD V.2: CRDN).

The Clearwater River flows from Broach Lake through a series of lakes including Patterson, Forrest, Beet, and Naomi lakes, in order from upstream to downstream.

The Clearwater River (within the LSA) from Broach Lake to Naomi Lake is dominated by glaciolacustrine terrain (Annex IV.3), and the main stem is made up mainly of waterbodies separated by short channel sections (except for the relatively long, steeper reach downstream of Broach Lake). From Naomi Lake, the Clearwater River flows another 20 km southeast before reaching the Mirror River confluence. Below the Mirror River confluence, the Clearwater River deepens with the higher flow volumes from the Mirror River, and the channel form changes to meandering within a well-defined river valley.

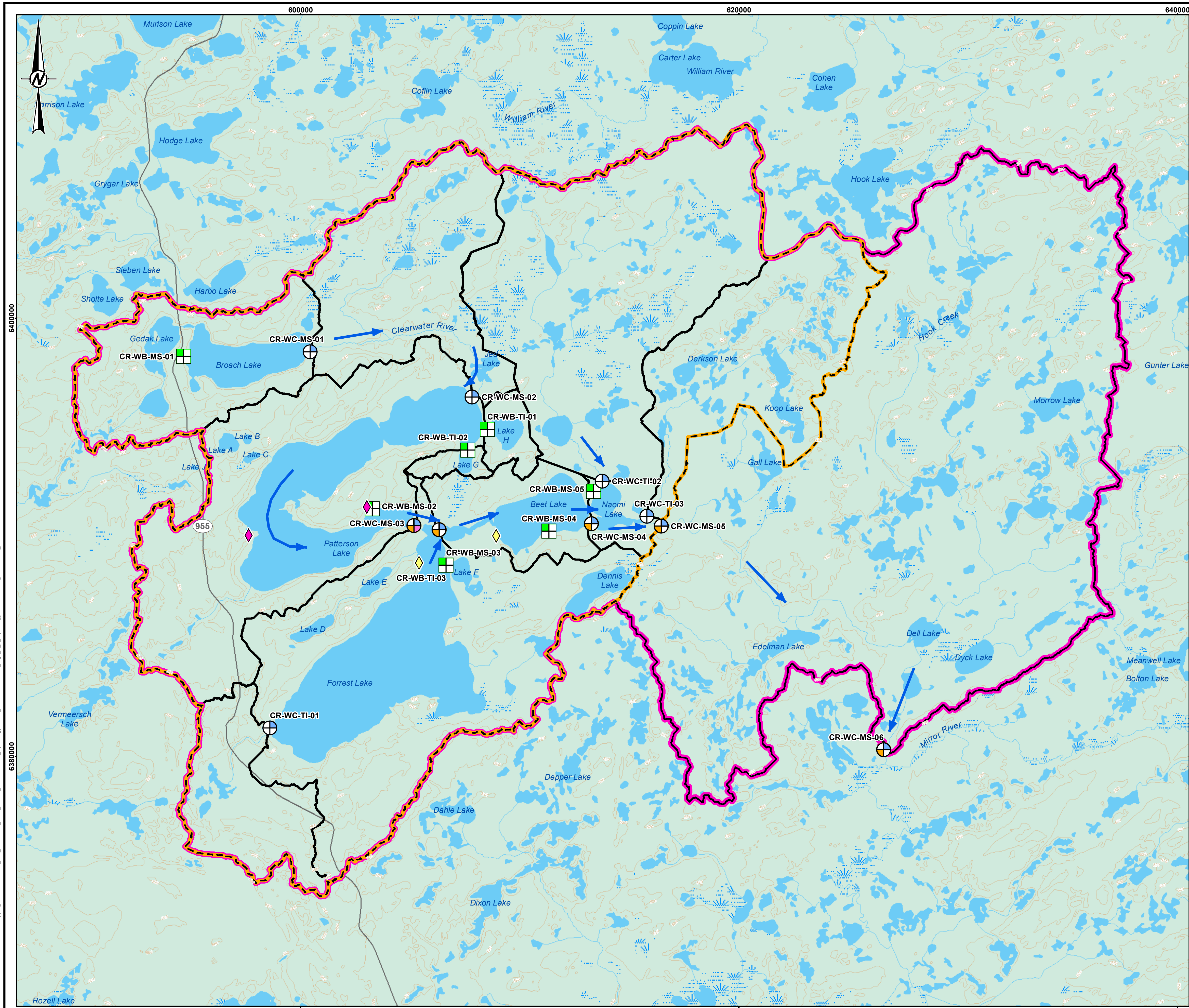
Farther downstream, the Clearwater River flows through Lloyd Lake, which is upstream of the Clearwater River Provincial Park; the downstream end of the park is at the Saskatchewan-Alberta border. The Clearwater River flows into the Athabasca River at Fort McMurray, Alberta, which flows north into the west end of Lake Athabasca through the Peace-Athabasca delta, where the MN-S reported being able to travel to by boat from Patterson Lake and Preston Lake (TSD IV: MN-S). Water from the Clearwater River ultimately flows to the Arctic Ocean through the Mackenzie River.

Indigenous Groups have highlighted the interconnectedness of the various watercourses and waterbodies in the Patterson Lake area (TSD III: BRDN; TSD IV: MN-S; TSD V.2: CRDN). The Clearwater River is viewed by the CRDN as a holistic river system intrinsically connected to Patterson, Forrest, Beet, Preston, and Lloyd lakes (TSD V.2: CRDN). The MN-S have also noted the interconnectedness of the lakes in the RSA, and especially the importance of Patterson Lake because it is central to the river system for the entire area and feeds the lakes to the south, affecting all the waterways that members use (TSD IV: MN-S). Sub-watershed features within the RSA are described in Table 9.3-1 and presented on Figure 9.3-2. In general, the ground surface is highly permeable (i.e., water easily infiltrates the ground surface), and water typically infiltrates the ground and moves via subsurface pathways to watercourses or waterbodies. As a result, there are relatively few minor watercourses on the landscape.

Table 9.3-1: Regional Hydrological Model Sub-Watersheds

Sub-watershed Name	Description	Hydrometric Stations	Sub-Watershed Area (km^2)
Broach Lake	Clearwater River below Broach Lake	CR-WB-MS-01 and CR-WC-MS-01	56.4
Above Patterson Lake	Upstream of Patterson Lake excluding Broach Lake	CR-WC-MS-02	64.6
Lake H	Lake H	CR-WB-TI-01	7.36
Lake G	Lake G	CR-WB-TI-02	3.75
Patterson Lake	Clearwater River below Patterson Lake	CR-WC-MS-03 and CR-WB-MS-02	132
Forrest Lake	Forrest Lake	CR-WB-MS-03	181
Beet Lake	Clearwater River below Beet Lake	CR-WC-MS-04 and CR-WB-MS-04	29.0
Tributary to Naomi Lake	Tributary inflow to Naomi Lake	CR-WC-TI-02	134
Tributary downstream of Naomi Lake	Tributary inflow downstream of Naomi Lake	CR-WC-TI-03	67.5
Naomi Lake	Clearwater River below Naomi Lake	CR-WC-MS-05 and CR-WB-MS-05	10.5
Above the Mirror River confluence	Watershed below Naomi Lake above Mirror River confluence	CR-WC-MS-06	390
Total	Cumulative Watershed Area above Mirror River confluence	n/a	1,076

Source: Appendix 9A.
Note: Some numbers are rounded for presentation purposes. Therefore, it may appear that the totals do not equal the sum of the individual values.
n/a = not applicable because this row represents the total watershed area for Clearwater River above the Mirror River confluence.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED

WATER BODY HYDROMETRIC STATIONS

- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- STREAM CHANNEL PARAMETERS
- FLUVIAL SEDIMENT TRANSPORT
- WATERCOURSE FLOW RATE

LOCAL WATER USERS

- EXPLORATION CAMP
- OUTFITTERS CAMP

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 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

HYDROLOGY UNDER EXISTING CONDITIONS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-10		
CHECK	RWP	2023-02-10	**FIGURE 9.3-2**	
REVIEW	NPS	2023-02-10		

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9.3.2.1 Waterbodies

The RSA has an abundance of waterbodies from small wetlands to larger lakes (Figure 9.3-2). As described previously, the waterbodies along the Clearwater River mainstem include Broach, Patterson, Forrest, Beet, and Naomi lakes, and there are numerous other smaller named and unnamed lakes in the RSA. These waterbodies are culturally important to Indigenous Groups and used for harvesting, occupancy, and travel, and also used by LPA community members for fishing and recreation (NexGen 2019). Physical and hydrological characteristics of selected waterbodies within the LSA are provided in Table 9.3-2. Waterbodies are presented in upstream to downstream order in the Clearwater River watershed. Additional details, including bathymetry maps and tabular summaries of stage, storage, and area, are included in the subsections following Table 9.3-2.

Table 9.3-2: Morphometric and Hydrological Characteristics of Selected Waterbodies in the Hydrology Regional Study Area

Waterbody	Basin	Cumulative Watershed Area (km^2)	Average WSE (masl)	Volume(Mm^3)[a]	Surface Area (km^2)[a]	Maximum Depth (m)[a]	Mean Depth (m)[a]	Mean Annual Discharge (m^3/s)	Retention Time (yrs)[b]
Broach Lake	n/a	56.4	526.707	242	9.31	82.6	26.0	0.254	31.0
Lake H	n/a	7.36	499.914	2.60	1.68	8.2	1.4	0.038	2.17
Lake G	n/a	3.75	499.482	0.890	0.59	3.5	1.5	0.015	1.88
Patterson Lake	North Arm – East Basin	264	498.675	64.4	9.15	24.0	7.0	1.35	1.53
	North Arm – West Basin			233	12.4	52.7	18.8		5.56
	South Arm			234	15.9	49.5	14.8		5.58
	Total			532	37.4	52.7	14.2		12.7
Forrest Lake	North Basin	445	498.360	1.71	1.49	2.00	1.15	2.23	0.02
	South Basin			1,130	41.3	84.8	27.4		42.9
	Total			1,130	42.8	84.8	26.5		42.9
Beet Lake	n/a	473	498.303	95.6	8.83	33.8	10.8	2.40	1.27
Naomi Lake	n/a	685	498.303	3.83	2.27	8.30	1.75	3.07	0.04

Source: Annex IV.2; Annex V.1; Annex V.3.
a) Lake morphometry values presented in Table 9.3-2 are evaluated at average WSE.
b) Retention time was calculated based on the time required to turn over waterbody volume at the average WSE and mean annual discharge at each waterbody outflow (i.e., retention time = volume/discharge).
n/a = not applicable; masl = metres above sea level; Mm^3 = million cubic metres; WSE = water surface elevation.

Broach Lake

Broach Lake is located in the northwest corner of the RSA and is considered to be the headwaters of the Clearwater River. The lake is roughly rectangular and measures 5.8 km west to east and 1.8 km north to south. It has one main inflow along its west shoreline from Gedak Lake, and its outflow is at the southeast corner of the lake. Bathymetry and WSE area-volume data for Broach Lake are provided in Figure 9.3-3.

Lake H

Lake H is a small, circular waterbody located east of the Patterson Lake North Arm – East Basin. No surface inflows or outflows have been documented for Lake H, though its shoreline is only 50 m from the Patterson Lake shoreline. Bathymetry and the WSE area-volume data for Lake H are provided in Figure 9.3-4.

Lake G

Lake G is a small, circular waterbody located south of the Patterson Lake North Arm – East Basin. Lake G is drained by an outflow channel that flows northwest into the Patterson Lake North Arm – East Basin. Bathymetry and WSE area-volume data for Lake G are provided in Figure 9.3-5.

Patterson Lake

Patterson Lake is located along the Clearwater River mainstem downstream of Broach Lake and upstream of Forrest Lake. The Patterson Lake area is particularly significant to the CRDN as this area has sustained CRDN members for generations (TSD V.1: CRDN; TSD V.2: CRDN). For the MN-S, the Patterson Lake area is described as paramount to its members and their lifeblood (TSD IV: MN-S). The BRDN and BNDN have also reported practicing traditional activities in the Patterson Lake area (TSD II: BNDN; TSD III: BRDN).

Patterson Lake is a U-shaped lake oriented approximately southwest to northeast with a prominent peninsula that separates two distinct arms: the North Arm and South Arm. The North Arm can be further separated into the West Basin and East Basin by a narrow and shallow sandbar with spit formations extending from the south and north shorelines (Annex IV.3). Of the three basins, the Patterson Lake North Arm – East Basin is relatively shallow and has a lower volume than the other two basins. By comparison, the Patterson Lake North Arm – West Basin and Patterson Lake South Arm are both relatively deep and have higher volumes.

The Clearwater River is the main inflow to and outflow from Patterson Lake, and it has no other major tributaries. Sediment samples taken from lake bed cores were dominated by sand-sized particles at 10 locations (Annex V.1), and the major inflow and outflow are also dominated by sand. Bathymetry and WSE area-volume data for Patterson Lake are provided in Figure 9.3-6.

Forrest Lake

Forrest Lake is located along the Clearwater River mainstem between Patterson Lake and Beet Lake. As noted above, Indigenous Groups have reported using the Forrest Lake area for traditional activities (TSD II: BNDN; TSD IV: MN-S; TSD V.2: CRDN). Forrest Lake has two basins: a smaller, shallow North Basin located along the Clearwater River and a large South Basin with a few minor inflows. The Clearwater River flows through the Forrest Lake – North Basin from west to east. The Forrest Lake – North Basin is separated from the South Basin by a sand bar consisting of sandy material. Water depths over the sand bar are typically less than 1.0 m. The South Basin is by far the larger of the two basins; it comprises approximately 99.9% of the total lake volume and 97.5% of the lake's total surface area. In addition to inflows from the Clearwater River, Forrest Lake receives inflows from four smaller tributaries:

- E Creek, which flows into the west side of the Forrest Lake – North Basin and drains an area of 15 km^2;
- F Creek, which flows into the east side of Forrest Lake just south of the sand bar, which separates the Forrest Lake – North Basin and Forrest Lake – South Basin and drains an area of 13 km^2;
- an unnamed tributary, which flows into the southwest corner of Forrest Lake and drains an area of 35 km^2; and
- Dennis Creek, which flows into the east side of Forrest Lake and drains an area of 10.4 km^2, including Dennis Lake, which lies at its headwaters.

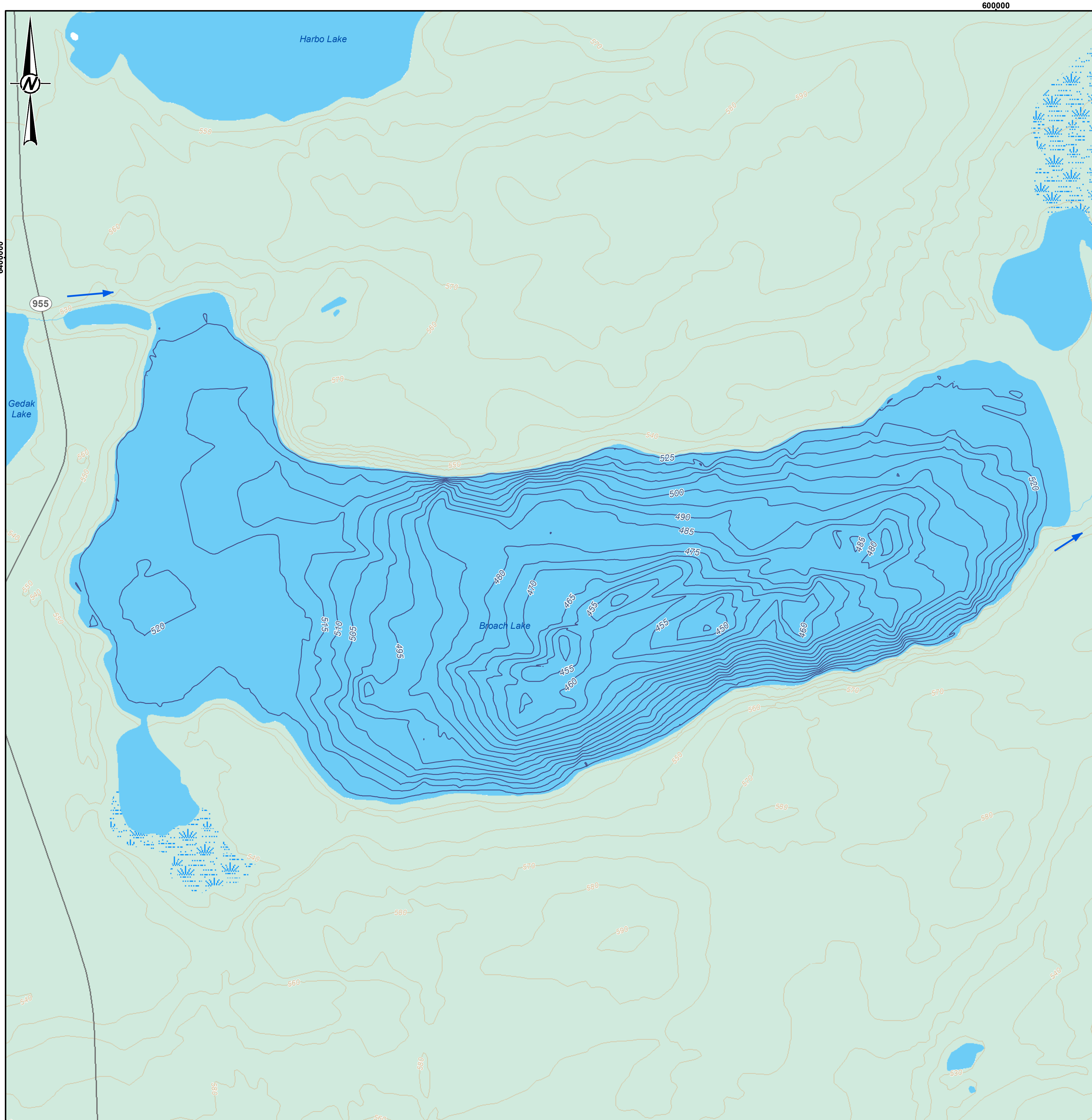
Sediment samples taken from Forrest Lake lake bed cores were dominated by coarse sand-sized particles at five locations (Annex V.1), and the lake's major inflow and outflow were also dominated by sand. Bathymetry and the WSE area-volume data for Forrest Lake are provided in Figure 9.3-7. A mixing study completed for Forrest Lake in October 2018 (Annex IV.5) did not observe mixing between the North Basin and South Basin.

Beet Lake

Beet Lake is located along the Clearwater River mainstem between Forrest and Naomi lakes. Beet Lake is roughly rectangular and measures 4.3 km west to east and 2.0 km north to south. The Clearwater River is its main inflow and outflow, and the lake has no other major tributaries. Bathymetry and the WSE area-volume data for Beet Lake are provided in Figure 9.3-8.

Naomi Lake

Naomi Lake is located downstream of Beet Lake, along the Clearwater River mainstem. Beet Lake has two basins divided by a relatively shallow narrows: the North Basin, which is round and roughly circular, and the South Basin, which is an elongated widening of the Clearwater River that passes into and out of the South Basin. A major tributary that drains a watershed lying to the east and northeast of the Project empties into the north end of the North Basin. Bathymetry and the WSE area-volume data for Naomi Lake are provided in Figure 9.3-9.



ELEVATION (m ASL)	VOLUME (m³)	AREA (m²)
445.65	1,616	3,268
447.15	12,609	12,143
448.65	41,610	28,227
450.15	101,666	52,338
451.65	200,003	79,597
453.15	345,374	116,107
454.65	553,787	164,456
456.15	848,552	232,358
457.65	1,259,552	317,877
459.15	1,809,499	416,864
460.65	2,513,417	522,361
462.15	3,378,392	628,597
463.65	4,388,448	716,806
465.15	5,526,316	800,416
466.65	6,790,896	887,276
468.15	8,201,801	1,003,812
469.65	9,777,973	1,094,773
471.15	11,484,313	1,180,477
472.65	13,320,623	1,267,598
474.15	15,288,405	1,356,146
475.65	17,390,598	1,447,959
477.15	19,636,549	1,547,755
478.65	22,038,610	1,656,390
480.15	24,612,644	1,780,309
481.65	27,424,017	1,982,912
483.15	30,588,110	2,239,553
484.65	34,102,307	2,431,531
486.15	37,861,712	2,579,008
487.65	41,840,095	2,726,190
489.15	46,044,505	2,880,270
490.65	50,490,054	3,052,494
492.15	55,211,594	3,242,638
493.65	60,212,558	3,424,130
495.15	65,476,727	3,593,834
496.65	70,989,566	3,753,969
498.15	76,737,075	3,908,327
499.65	82,712,754	4,062,996
501.15	88,930,945	4,227,361
502.65	95,392,438	4,388,901
504.15	102,098,804	4,551,511
505.65	109,047,054	4,709,791
507.15	116,219,068	4,851,743
508.65	123,600,490	4,989,794
510.15	131,188,951	5,128,704
511.65	138,983,885	5,265,750
513.15	147,008,655	5,438,820
514.65	155,314,577	5,640,972
516.15	163,941,407	5,861,861
517.65	172,908,863	6,105,113
519.15	182,320,207	6,462,810
520.65	192,354,130	6,977,668
522.15	203,394,512	7,697,200
523.65	215,341,686	8,239,046
525.15	228,140,345	8,842,605
526.65	241,756,813	9,304,436
528.15	255,755,877	9,343,368

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (5 m INTERVAL)
- WATERCOURSE
- FLOW DIRECTION
- WATERBODY
- WETLAND
- WOODED

0 500 1,000
1:25,000 METRES

NOTE(S)

1. WATER SURFACE ELEVATION DAILY AVERAGE ESTIMATED BASED ON MONITORING BY GOLDER TO BE 526.650 mASL ON OCTOBER 9-10, 2018.
2. LAKE VOLUME ON OCTOBER 9-10, 2018 = 241,756,813 m³.

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. BATHYMETRY WAS COLLECTED BY CANNORTH CONSULTING USING A HUMMINGBIRD 999CI HD SI DEPTH SOUNDER MOUNTED ON A ZODIAC PORTABLE BOAT.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
BROACH LAKE BATHYMETRY

CONSULTANT
wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-10		
CHECK	RWP	2023-02-10	**FIGURE 9.3-3**	
REVIEW	NPS	2023-02-10		

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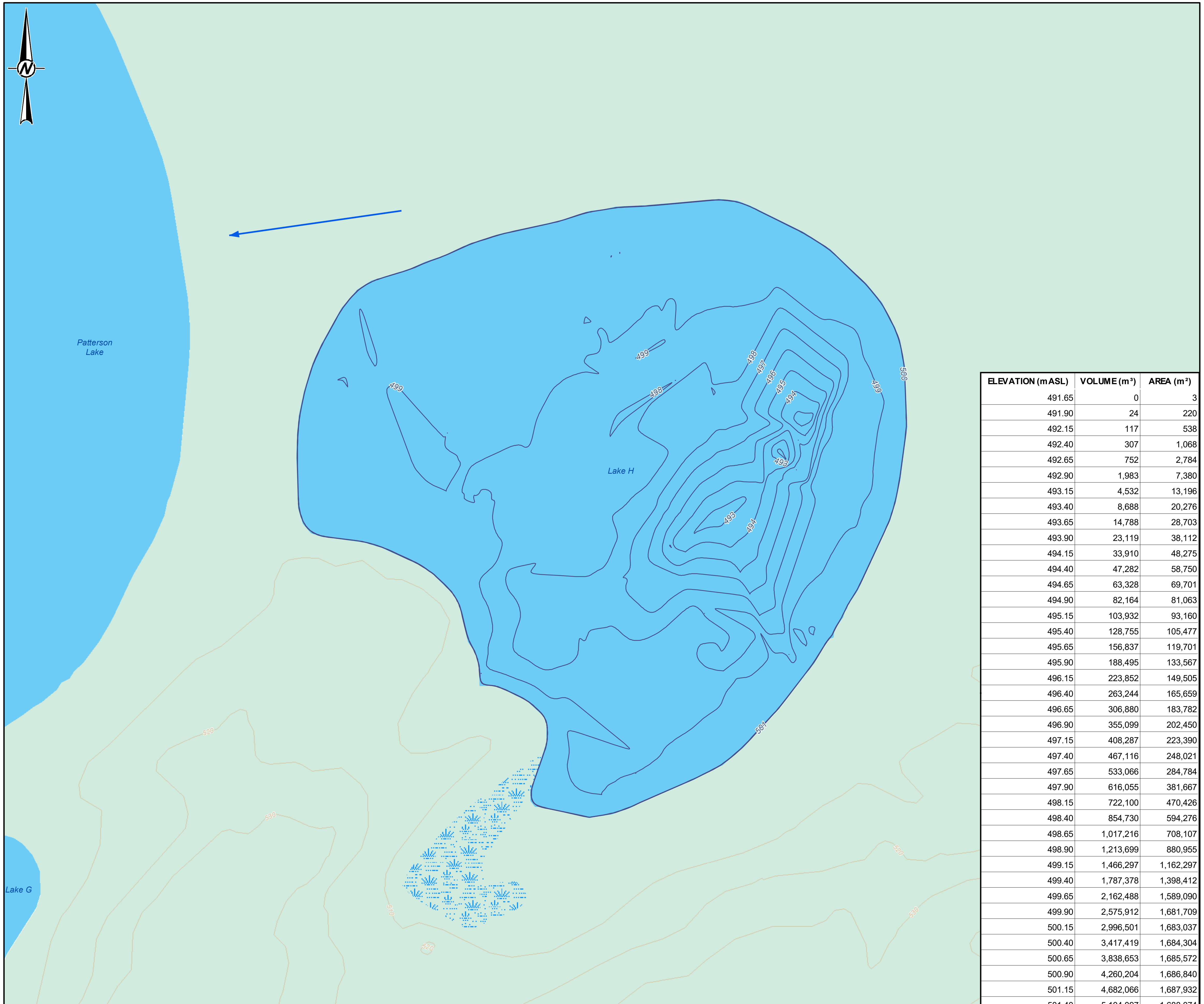

ELEVATION (m ASL)	VOLUME (m³)	AREA (m²)
491.65	0	3
491.90	24	220
492.15	117	538
492.40	307	1,068
492.65	752	2,784
492.90	1,983	7,380
493.15	4,532	13,196
493.40	8,688	20,276
493.65	14,788	28,703
493.90	23,119	38,112
494.15	33,910	48,275
494.40	47,282	58,750
494.65	63,328	69,701
494.90	82,164	81,063
495.15	103,932	93,160
495.40	128,755	105,477
495.65	156,837	119,701
495.90	188,495	133,567
496.15	223,852	149,505
496.40	263,244	165,659
496.65	306,880	183,782
496.90	355,099	202,450
497.15	408,287	223,390
497.40	467,116	248,021
497.65	533,066	284,784
497.90	616,055	381,667
498.15	722,100	470,426
498.40	854,730	594,276
498.65	1,017,216	708,107
498.90	1,213,699	880,955
499.15	1,466,297	1,162,297
499.40	1,787,378	1,398,412
499.65	2,162,488	1,589,090
499.90	2,575,912	1,681,709
500.15	2,996,501	1,683,037
500.40	3,417,419	1,684,304
500.65	3,838,653	1,685,572
500.90	4,260,204	1,686,840
501.15	4,682,066	1,687,932
501.40	5,104,097	1,688,074

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (1 m INTERVAL)
- WATERBODY
- FLOW DIRECTION
- WETLAND
- WOODED

0 200 400
1:10,000 METRES

NOTE(S)

1. WATER SURFACE ELEVATION DAILY AVERAGE COLLECTED BY GOLDER WAS 499.900 mASL ON AUGUST 5, 2018.
2. LAKE VOLUME ON AUGUST 5, 2018 = 2,575,912 m³.

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. BATHYMETRY WAS COLLECTED BY CANNORTH CONSULTING USING A HUMMINGBIRD 999CI HD SI DEPTH SOUNDER MOUNTED ON A ZODIAC PORTABLE BOAT.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
LAKE H BATHYMETRY

CONSULTANT
wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-10		
CHECK	RWP	2023-02-10	**FIGURE 9.3-4**	
REVIEW	NPS	2023-02-10		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
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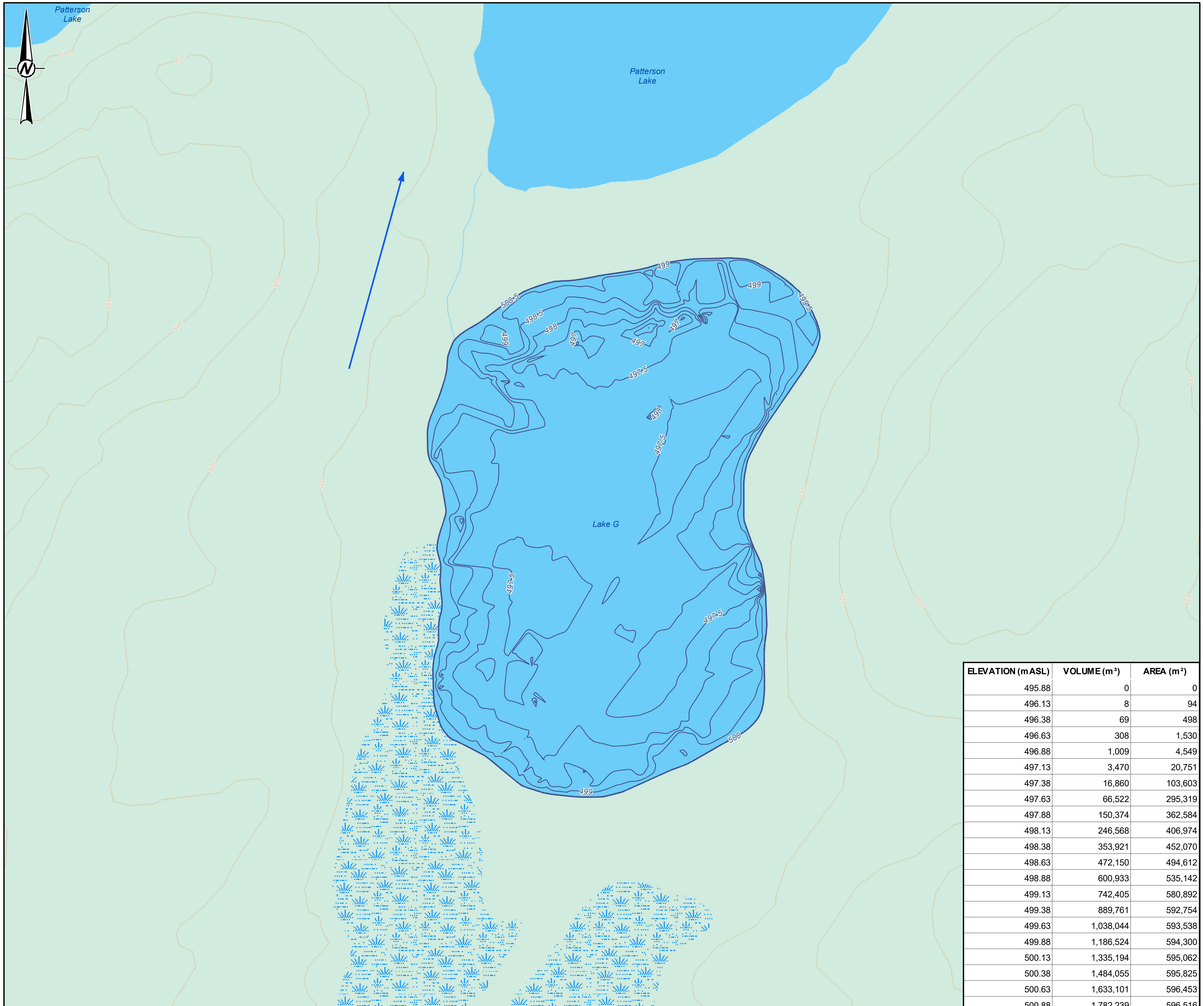


ELEVATION (m ASL)	VOLUME (m³)	AREA (m²)
495.88	0	0
496.13	8	94
496.38	69	498
496.63	308	1,530
496.88	1,009	4,549
497.13	3,470	20,751
497.38	16,860	103,603
497.63	66,522	295,319
497.88	150,374	362,584
498.13	246,568	406,974
498.38	353,921	452,070
498.63	472,150	494,612
498.88	600,933	535,142
499.13	742,405	580,892
499.38	889,761	592,754
499.63	1,038,044	593,538
499.88	1,186,524	594,300
500.13	1,335,194	595,062
500.38	1,484,055	595,825
500.63	1,633,101	596,453
500.88	1,782,239	596,516

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (0.5 m INTERVAL)
- WATERCOURSE
- FLOW DIRECTION
- WATERBODY
- WETLAND
- WOODED

0 150 300

1:7,500 METRES

NOTE(S)

1. WATER SURFACE ELEVATION DAILY AVERAGE COLLECTED BY GOLDER WAS 499.380 mASL ON AUGUST 7, 2018.
2. LAKE VOLUME ON AUGUST 7, 2018 = 889,761 m³.

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. BATHYMETRY WAS COLLECTED BY CANNORTH CONSULTING USING A HUMMINGBIRD 999CI HD SI DEPTH SOUNDER MOUNTED ON A ZODIAC PORTABLE BOAT.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

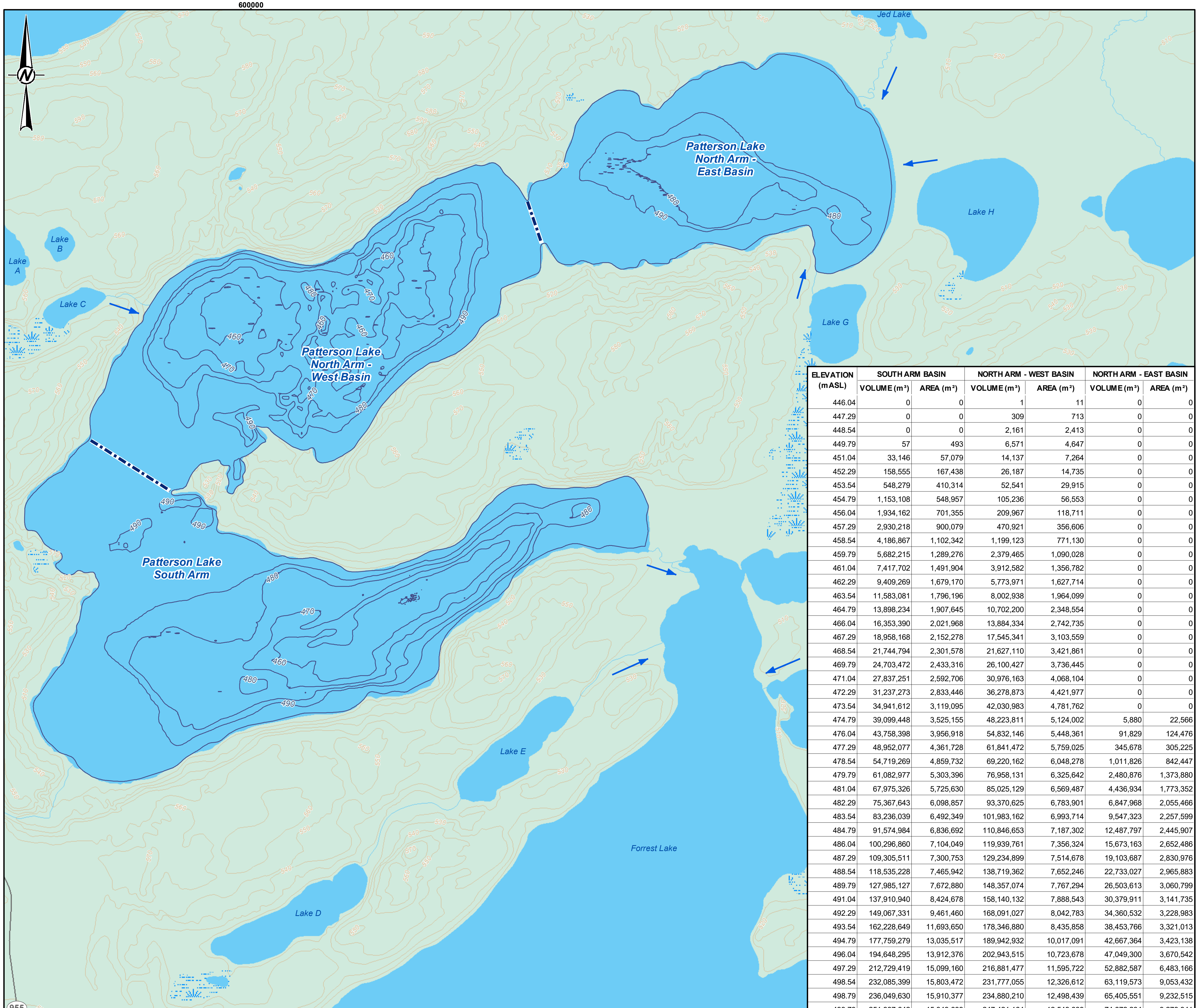
TITLE

LAKE G BATHYMETRY

CONSULTANT

wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-10		
CHECK	RWP	2023-02-10	**FIGURE 9.3-5**	
REVIEW	NPS	2023-02-10		



LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (10 m INTERVAL)
- LAKE BASIN DIVISION
- FLOW DIRECTION
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED

ELEVATION (mASL)	SOUTH ARM BASIN		NORTH ARM - WEST BASIN		NORTH ARM - EAST BASIN	
	VOLUME (m³)	AREA (m²)	VOLUME (m³)	AREA (m²)	VOLUME (m³)	AREA (m²)
446.04	0	0	1	11	0	0
447.29	0	0	309	713	0	0
448.54	0	0	2,161	2,413	0	0
449.79	57	493	6,571	4,647	0	0
451.04	33,146	57,079	14,137	7,264	0	0
452.29	158,555	167,438	26,187	14,735	0	0
453.54	548,279	410,314	52,541	29,915	0	0
454.79	1,153,108	548,957	105,236	56,553	0	0
456.04	1,934,162	701,355	209,967	118,711	0	0
457.29	2,930,218	900,079	470,921	356,606	0	0
458.54	4,186,867	1,102,342	1,199,123	771,130	0	0
459.79	5,682,215	1,289,276	2,379,465	1,090,028	0	0
461.04	7,417,702	1,491,904	3,912,582	1,356,782	0	0
462.29	9,409,269	1,679,170	5,773,971	1,627,714	0	0
463.54	11,583,081	1,796,196	8,002,938	1,964,099	0	0
464.79	13,898,234	1,907,645	10,702,200	2,348,554	0	0
466.04	16,353,390	2,021,968	13,884,334	2,742,735	0	0
467.29	18,958,168	2,152,278	17,545,341	3,103,559	0	0
468.54	21,744,794	2,301,578	21,627,110	3,421,861	0	0
469.79	24,703,472	2,433,316	26,100,427	3,736,445	0	0
471.04	27,837,251	2,592,706	30,976,163	4,068,104	0	0
472.29	31,237,273	2,833,446	36,278,873	4,421,977	0	0
473.54	34,941,612	3,119,095	42,030,983	4,781,762	0	0
474.79	39,099,448	3,525,155	48,223,811	5,124,002	5,880	22,566
476.04	43,758,398	3,956,918	54,832,146	5,448,361	91,829	124,476
477.29	48,952,077	4,361,728	61,841,472	5,759,025	345,678	305,225
478.54	54,719,269	4,859,732	69,220,162	6,048,278	1,011,826	842,447
479.79	61,082,977	5,303,396	76,958,131	6,325,642	2,480,876	1,373,880
481.04	67,975,326	5,725,630	85,025,129	6,569,487	4,436,934	1,773,352
482.29	75,367,643	6,098,857	93,370,625	6,783,901	6,847,968	2,055,466
483.54	83,236,039	6,492,349	101,983,162	6,993,714	9,547,323	2,257,599
484.79	91,574,984	6,836,692	110,846,653	7,187,302	12,487,797	2,445,907
486.04	100,296,860	7,104,049	119,939,761	7,356,324	15,673,163	2,652,486
487.29	109,305,511	7,300,753	129,234,899	7,514,678	19,103,687	2,830,976
488.54	118,535,228	7,465,942	138,719,362	7,652,246	22,733,027	2,965,883
489.79	127,985,127	7,672,880	148,357,074	7,767,294	26,503,613	3,060,799
491.04	137,910,940	8,424,678	158,140,132	7,888,543	30,379,911	3,141,735
492.29	149,067,331	9,461,460	168,091,027	8,042,783	34,360,532	3,228,983
493.54	162,228,649	11,693,650	178,346,880	8,435,858	38,453,766	3,321,013
494.79	177,759,279	13,035,517	189,942,932	10,017,091	42,667,364	3,423,138
496.04	194,648,295	13,912,376	202,943,515	10,723,678	47,049,300	3,670,542
497.29	212,729,419	15,099,160	216,881,477	11,595,722	52,882,587	6,483,166
498.54	232,085,399	15,803,472	231,777,055	12,326,612	63,119,573	9,053,432
498.79	236,049,630	15,910,377	234,880,210	12,498,439	65,405,551	9,232,515
499.79	251,987,642	15,949,639	247,421,164	12,549,839	74,672,234	9,273,941

0 1.5 3

1:50,000 KILOMETRES

NOTE(S)

1. WATER SURFACE ELEVATION ESTIMATED TO BE 498.79 mASL ASSOCIATED WITH MEAN ANNUAL FLOOD.
2. LAKE VOLUME ON JUNE 6-8, 1981:
- SOUTH ARM BASIN = 236,049,630 m^3
- NORTH ARM - WEST BASIN = 234,880,210 m^3
- NORTH ARM - EAST BASIN = 65,405,551 m^3

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. BATHYMETRY CONTOURS DERIVED FROM DATA COLLECTED BY NEXGEN, 2016.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

PATTERSON LAKE BATHYMETRY

CONSULTANT

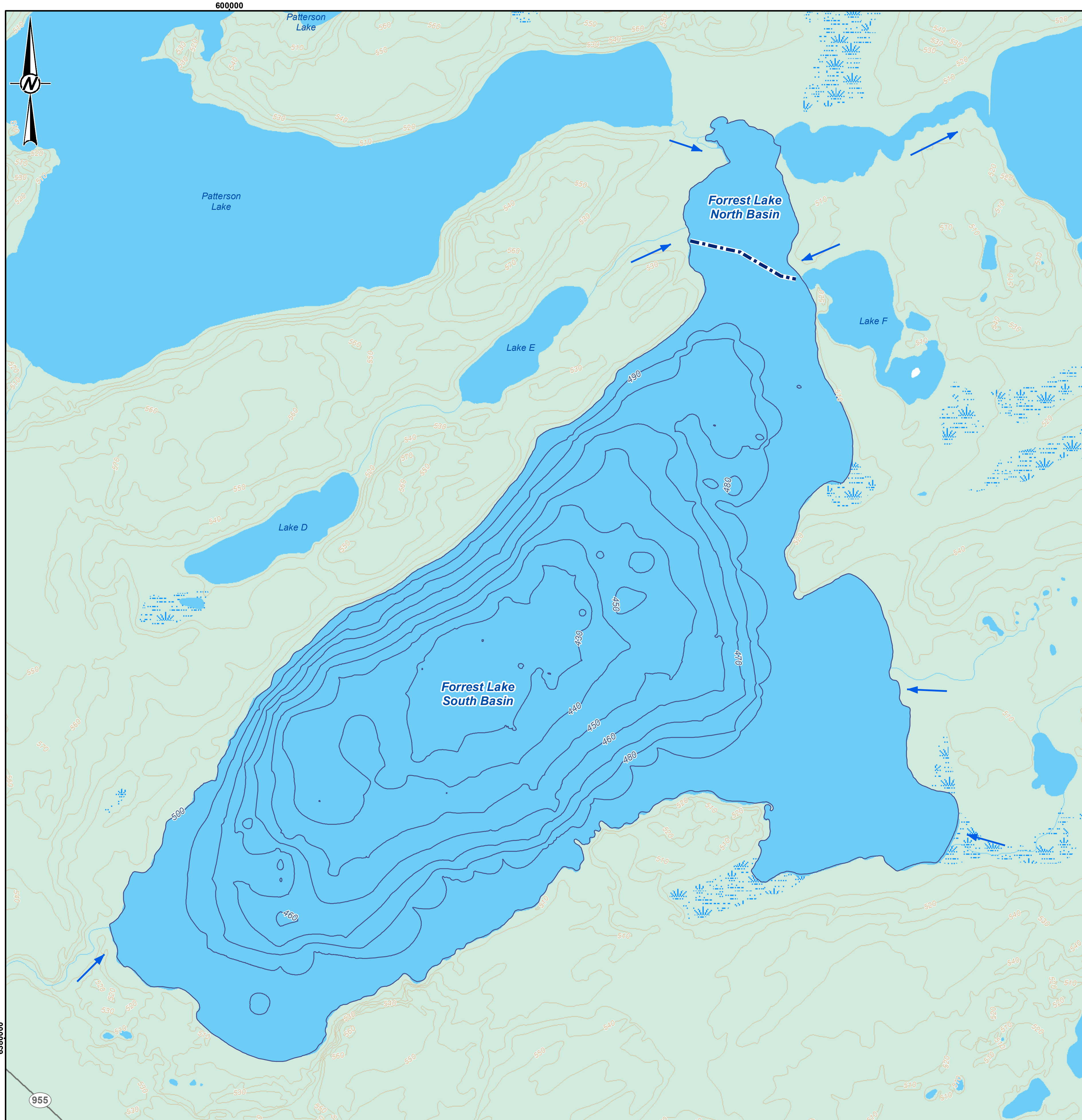
wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-10		
CHECK	RWP	2023-02-10	FIGURE 9.3-6	
REVIEW	NPS	2023-02-10		

25mm

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\09_Hydrology\11x17\11x17_20144150_Fig9_3_6_PattersonLake_Bathymetry_Rev0.mxd PRINTED ON: 2023-02-10 AT: 10:13:58 AM



ELEVATION (mASL)	SOUTH BASIN		NORTH BASIN	
	VOLUME (m³)	AREA (m²)	VOLUME (m³)	AREA (m²)
413.30	0	0	0	0
414.30	15	79	0	0
415.30	320	543	0	0
416.30	1,116	1,059	0	0
417.30	2,476	1,694	0	0
418.30	4,564	2,644	0	0
419.30	8,592	5,304	0	0
420.30	16,499	20,856	0	0
421.30	117,539	165,630	0	0
422.30	330,139	258,947	0	0
423.30	648,041	391,273	0	0
424.30	1,133,092	584,223	0	0
425.30	1,848,090	852,526	0	0
426.30	2,892,644	1,249,687	0	0
427.30	4,358,816	1,650,777	0	0
428.30	6,162,471	1,951,071	0	0
429.30	8,265,099	2,252,288	0	0
430.30	10,680,034	2,561,348	0	0
431.30	13,406,194	2,902,055	0	0
432.30	16,471,968	3,229,346	0	0
433.30	19,867,036	3,558,122	0	0
434.30	23,587,901	3,886,663	0	0
435.30	27,655,688	4,245,003	0	0
436.30	32,073,738	4,594,404	0	0
437.30	36,855,532	4,972,595	0	0
438.30	42,027,801	5,389,947	0	0
439.30	47,631,099	5,805,980	0	0
440.30	53,643,971	6,226,290	0	0
441.30	60,084,870	6,659,292	0	0
442.30	66,957,044	7,079,577	0	0
443.30	74,238,438	7,496,977	0	0
444.30	81,966,091	7,951,762	0	0
445.30	90,130,107	8,373,164	0	0
446.30	98,717,082	8,801,331	0	0
447.30	107,726,263	9,218,422	0	0
448.30	117,162,800	9,648,959	0	0
449.30	127,022,209	10,074,148	0	0
450.30	137,304,096	10,483,424	0	0
451.30	147,979,897	10,866,744	0	0
452.30	159,036,738	11,253,695	0	0
453.30	170,493,352	11,664,873	0	0
454.30	182,352,805	12,042,530	0	0
455.30	194,574,794	12,405,659	0	0
456.30	207,164,162	12,768,682	0	0
457.30	220,102,328	13,107,492	0	0
458.30	233,389,432	13,479,684	0	0
459.30	247,058,847	13,857,507	0	0
460.30	261,103,918	14,236,876	0	0
461.30	275,537,360	14,633,332	0	0
462.30	290,375,241	15,034,553	0	0
463.30	305,601,312	15,414,121	0	0
464.30	321,199,387	15,780,166	0	0
465.30	337,158,158	16,135,743	0	0
466.30	353,462,991	16,472,157	0	0
467.30	370,103,813	16,813,125	0	0
468.30	387,087,910	17,154,119	0	0
469.30	404,412,200	17,496,618	0	0
470.30	422,088,856	17,858,766	0	0
471.30	440,133,307	18,237,787	0	0
472.30	458,590,416	18,688,518	0	0
473.30	477,547,075	19,240,488	0	0
474.30	497,057,113	19,755,228	0	0
475.30	517,044,332	20,215,322	0	0
476.30	537,475,556	20,640,910	0	0
477.30	558,316,751	21,039,680	0	0
478.30	579,547,613	21,419,971	0	0
479.30	601,151,148	21,781,105	0	0
480.30	623,104,467	22,125,782	0	0
481.30	645,413,184	22,497,318	0	0
482.30	668,090,606	22,855,766	0	0
483.30	691,117,173	23,191,844	0	0
484.30	714,469,945	23,513,536	0	0
485.30	738,145,978	23,839,874	0	0
486.30	762,154,878	24,182,238	0	0
487.30	786,525,009	24,569,595	0	0
488.30	811,313,119	25,016,138	0	0
489.30	836,585,155	25,548,305	0	0
490.30	862,461,510	26,263,573	0	0
491.30	889,360,645	27,566,232	0	0
492.30	917,528,999	28,755,189	0	0
493.30	946,896,509	29,989,552	0	0
494.30	977,801,939	32,380,092	1	11
495.30	1,011,709,501	35,195,020	93	254
496.30	1,047,954,730	37,335,483	992	2,291
497.30	1,086,475,086	40,073,828	220,432	1,038,126
498.30	1,127,365,188	41,264,206	1,621,246	1,493,829
499.30	1,168,666,084	41,321,148	3,118,923	1,500,292
499.80	1,189,330,999	41,338,468	3,869,651	1,502,603

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (10 m INTERVAL)
- LAKE BASIN DIVISION
- FLOW DIRECTION
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED

0 1.5 3

1:50,000 KILOMETRES

NOTE(S)

1. WATER SURFACE ELEVATION ESTIMATED TO BE 498.303 mASL ON JUNE 11, 2019.
2. LAKE VOLUME ON JUNE 11, 2019:
- SOUTH BASIN = 1,127,365,188 m^3
- NORTH BASIN = 1,621,246 m^3

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. BATHYMETRY CONTOURS DERIVED FROM JUNE 2019 BATHYMETRY SURVEY DATA.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

FORREST LAKE BATHYMETRY

CONSULTANT

wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-10		
CHECK	RWP	2023-02-10	**FIGURE 9.3-7**	
REVIEW	NPS	2023-02-10		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B 25mm 0

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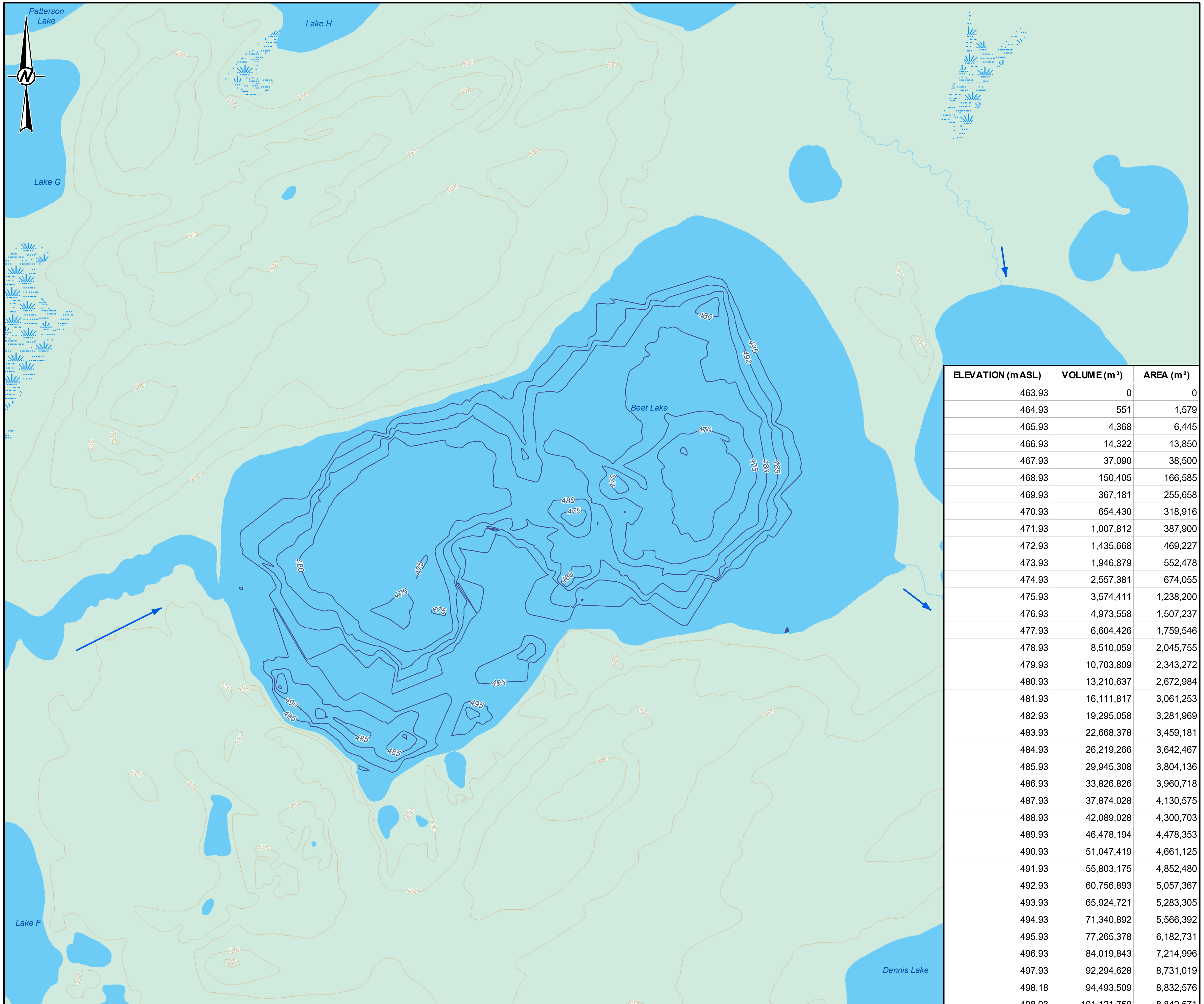


ELEVATION (m ASL)	VOLUME (m³)	AREA (m²)
463.93	0	0
464.93	551	1,579
465.93	4,368	6,445
466.93	14,322	13,850
467.93	37,090	38,500
468.93	150,405	166,585
469.93	367,181	255,658
470.93	654,430	318,916
471.93	1,007,812	387,900
472.93	1,435,668	469,227
473.93	1,946,879	552,478
474.93	2,557,381	674,055
475.93	3,574,411	1,238,200
476.93	4,973,558	1,507,237
477.93	6,604,426	1,759,546
478.93	8,510,059	2,045,755
479.93	10,703,809	2,343,272
480.93	13,210,637	2,672,984
481.93	16,111,817	3,061,253
482.93	19,295,058	3,281,969
483.93	22,668,378	3,459,181
484.93	26,219,266	3,642,467
485.93	29,945,308	3,804,136
486.93	33,826,826	3,960,718
487.93	37,874,028	4,130,575
488.93	42,089,028	4,300,703
489.93	46,478,194	4,478,353
490.93	51,047,419	4,661,125
491.93	55,803,175	4,852,480
492.93	60,756,893	5,057,367
493.93	65,924,721	5,283,305
494.93	71,340,892	5,566,392
495.93	77,265,378	6,182,731
496.93	84,019,843	7,214,996
497.93	92,294,628	8,731,019
498.18	94,493,509	8,832,576
498.93	101,121,750	8,842,571

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (5 m INTERVAL)
- WATERCOURSE
- FLOW DIRECTION
- WATERBODY
- WETLAND
- WOODED

0 0.5 1
1:25,000 KILOMETRES

NOTE(S)

1. WATER SURFACE ELEVATION DAILY AVERAGE COLLECTED BY GOLDER WAS 498.180 mASL ON OCTOBER 5-7, 2018.
2. LAKE VOLUME ON OCTOBER 5-7, 2018 = 94,493,509 m^3.

REFERENCE(S)

1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. BATHYMETRY WAS COLLECTED BY CANNORTH CONSULTING USING A HUMMINGBIRD 999CI HD SI DEPTH SOUND MOUNTED ON A ZODIAC PORTABLE BOAT.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

BEET LAKE BATHYMETRY

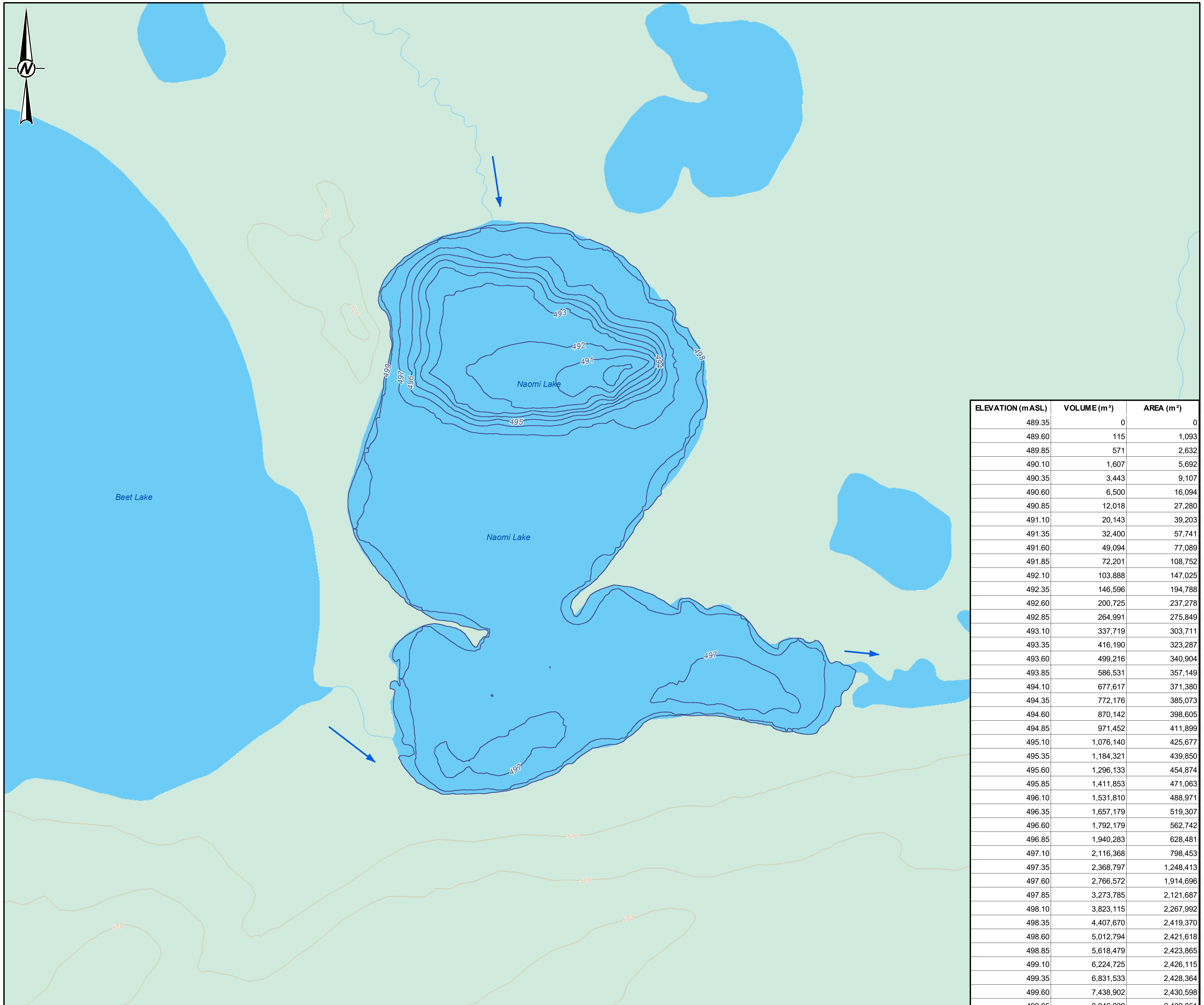
CONSULTANT

wsp

PROJECT	20144150		PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-10		
CHECK	RWP	2023-02-10		
REVIEW	NPS	2023-02-10		

FIGURE 9.3-8

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



ELEVATION (mASL)	VOLUME (m³)	AREA (m²)
489.35	0	0
489.60	115	1,093
489.85	571	2,632
490.10	1,607	5,692
490.35	3,443	9,107
490.60	6,500	16,094
490.85	12,018	27,280
491.10	20,143	39,203
491.35	32,400	57,741
491.60	49,094	77,089
491.85	72,201	108,752
492.10	103,888	147,025
492.35	146,596	194,788
492.60	200,725	237,278
492.85	264,991	275,849
493.10	337,719	303,711
493.35	416,190	323,287
493.60	499,216	340,904
493.85	586,531	357,149
494.10	677,617	371,380
494.35	772,176	385,073
494.60	870,142	398,605
494.85	971,452	411,899
495.10	1,076,140	425,677
495.35	1,184,321	439,850
495.60	1,296,133	454,874
495.85	1,411,853	471,063
496.10	1,531,810	488,971
496.35	1,657,179	519,307
496.60	1,792,179	562,742
496.85	1,940,283	628,481
497.10	2,116,368	798,453
497.35	2,368,797	1,248,413
497.60	2,766,572	1,914,696
497.85	3,273,785	2,121,687
498.10	3,823,115	2,267,992
498.35	4,407,670	2,419,370
498.60	5,012,794	2,421,618
498.85	5,618,479	2,423,865
499.10	6,224,725	2,426,115
499.35	6,831,533	2,428,364
499.60	7,438,902	2,430,598
499.85	8,046,239	2,432,851

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY
- WOODED
- BATHYMETRY CONTOUR ELEVATION (1 m INTERVAL)
- FLOW DIRECTION

0 0.5 1
1:15,000 KILOMETRES

NOTE(S)
1. WATER SURFACE ELEVATION ESTIMATED TO BE 498.35 mASL ON MARCH 23, 2019.
2. LAKE VOLUME ON MARCH 23, 2019 = 4,407,670 m^3.

REFERENCE(S)
1. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. BATHYMETRY CONTOURS CREATED FROM GROUND PENETRATING RADAR DATA COLLECTED IN 2019.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
NAOMI LAKE BATHYMETRY

CONSULTANT
wsp

PROJECT	20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN — REV. 0
GIS	AL/NO	2023-02-10	
CHECK	RWP	2023-02-10	
REVIEW	NPS	2023-02-10	

FIGURE 9.3-9

PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\09_Hydrology\17x11\20144150_Fig9_3_9_NaomiLake_Bathymetry_Rev0.mxd PRINTED ON: 2023-02-10 AT 10:15:09 AM

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9.3.2.2 Watercourses

The Clearwater River mainstem forms the central drainage corridor connecting the major waterbodies in the RSA (Figure 9.3-1; Annex IV.2). The Clearwater River flows south and then west to land users farther downstream, where it is used by Indigenous Groups and LPA community members for recreation, transportation, fishing, and drinking water (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). In the past, the major rivers in the region facilitated long-distance travel of Indigenous Groups to harvesting areas, other communities, and trade networks. The Clearwater River provides east-west access to CRDN's traditional lands within the Lower Athabasca and Upper Churchill watersheds, as well as north-south access to harvesting areas along Clearwater and Athabasca rivers, including access to smaller tributaries connected to these main watercourses (TSD V.2: CRDN).

The landscape in the RSA is highly permeable, resulting in relatively few small headwater watercourses. Most of the local watercourses have relatively low gradient channels and there are also some low-gradient channels that form at the lower end of fens (i.e., a peat accumulating wetland that receives drainage from surrounding areas). An exception is the higher gradient reach between Broach and Patterson lakes. Physical and hydrological characteristics of selected watercourses within the RSA are provided in Table 9.3-3. Additional details, including flow rates and stream channel parameters, are provided in the subsections following Table 9.3-3, as well as in Annex IV.2.

Table 9.3-3: Physical Characteristics of Regional Study Area Watercourses

Watercourse Reach	Boundaries	Mean Annual Flow (m^3/s)	Reach Length (km)	Channel Width (m)	Channel Depth (m)
Clearwater River below Broach Lake	Broach Lake to Jed Lake	0.248	10.2	3.35	0.31
Clearwater River above Patterson Lake	Jed Lake to Patterson Lake	0.564	1.40	10.1	0.42
Clearwater River below Patterson Lake	Patterson Lake to Forrest Lake	1.34	1.50	10.6	0.48
Clearwater River below Forrest Lake	Forrest Lake to Beet Lake	2.21	2.86	n/a	n/a
Clearwater River below Beet Lake	Beet Lake to Naomi Lake	2.38	0.356	22.6	0.64
Clearwater River below Naomi Lake	Naomi Lake to Dell Lake	3.06	20.1	26.7	0.52
Clearwater River above the Mirror River confluence	Dell Lake to Mirror River	5.72	7.09	53.1	0.64

Source: Mean annual flows from Appendix 9A.
Note: Reach length measured using CanVec watercourse layer; channel width and depth from Annex IV.2. Channel width and channel depth are not applicable to the Clearwater River below Forrest Lake because it is a short narrowing of the Clearwater River with a width of about 70 m that functions more like a waterbody than a river channel.
n/a = not applicable.

Clearwater River below Broach Lake

The Clearwater River below Broach Lake flows out of the southeast corner of Broach Lake and continues southeast to Jed Lake (Figure 9.3-2; Figure 9.3-3). The river bed consists of sand, gravel, and some cobbles. Riparian vegetation is a mixture of shrubs and coniferous trees.

Clearwater River above Patterson Lake

The Clearwater River above Patterson Lake flows out of the south end of Jed Lake and empties into the Patterson Lake North Arm – East Basin (Figure 9.3-2; Figure 9.3-6). The river bed is sandy, and the riparian vegetation consists primarily of shrubs.

Clearwater River below Patterson Lake

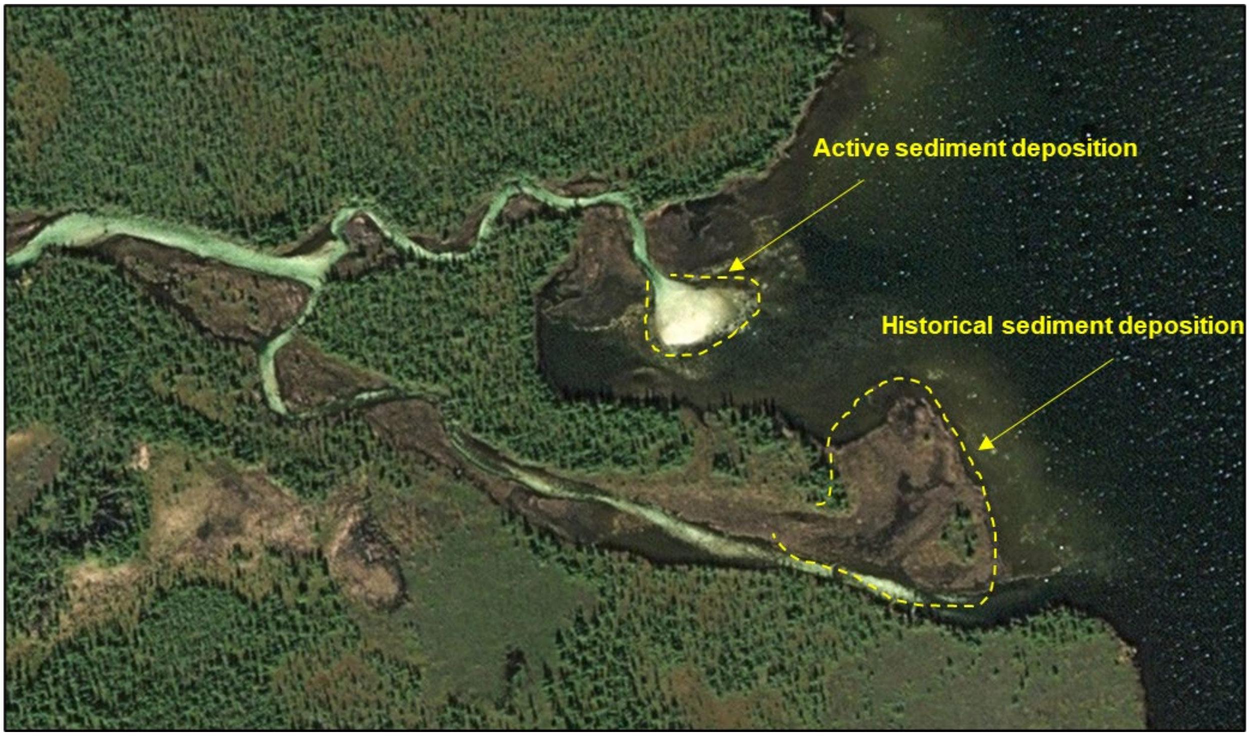
The Clearwater River below Patterson Lake originates at the eastern end of the Patterson Lake South Arm and conveys outflow from Patterson Lake approximately 1.5 km to the Forrest Lake – North Basin (Figure 9.3-6). The Upper Reach channel is meandering with a sinuosity coefficient of approximately 1.5. The river meanders show typical channel geometries, with steeper banks occurring on the outside of bends and with some erosion and deeper than average (i.e., 1.5 to 1.9 m) riverbed pools at the apex and downstream of the apex of the meanders. Approximately 580 m downstream of the Patterson Lake outflow (and 200 m upstream of Forrest Lake), the river channel separates into two smaller channels (i.e., North Channel and South Channel).

The Clearwater River flows through flat terrain, with surficial materials of hummocky, glaciofluvial deposits covered by predominantly black spruce or jack pine forests. Both banks of the channel have soils consisting of primarily organic materials fully covered by vegetation that is predominantly black spruce.

The river bed materials are primarily sand with sparse, large boulders. The channel banks were observed to be a mixture of soils and organic materials. In straight run reaches, the bed is characterized by a typical ripple bed form pattern. This observation is supported by the comparison of hydraulic characteristics to the bed form charts presented in Maidment (1993) that are associated with fine to medium sand.

Available remote sensing imagery suggests that the North Channel is the main active sediment transport pathway, with visible and recent sediment deposits at its mouth and the formation of a delta (Figure 9.3-10). Field observations for sediment transport indicate that the bulk of the sediment volume is delivered during the spring high flows, as sediment transport was often either very low or not measurable during low flow conditions (Annex IV.2). Sediment transport also occurs in the South Channel, but at a lower rate compared to the North Channel, with no recent sediments visible at its mouth. However, older delta deposits at the mouth of the South Channel were interpreted from aerial imagery to be similar in morphology to the active deposits at the mouth of the North Channel. The delta deposits imply that the river may switch between the North Channel and South Channel alignments in this section during flood events.

Figure 9.3-10: Clearwater River below Patterson Lake at Forrest Lake Inflow



Clearwater River below Forrest Lake

The outflow from Forrest Lake outflow is located at its northeast end. The outflow is a short narrowing of the Clearwater River with a width of about 70 m (Figure 9.3-7). Between the Forrest Lake outflow and the Beet Lake inflow, the river is more like a waterbody than a river channel, with a width ranging from about 100 m to 600 m. The Beet Lake inflow is about 2.5 km farther east of the Forrest Lake outflow. No hydrometric stations were installed at the Forrest Lake outflow due to the lack of a well-defined channel location.

Clearwater River below Beet Lake

The Clearwater River below Beet Lake is a single meandering channel with a sand substrate and accumulated organic debris in slack water areas formed at the margins (Figure 9.3-8). The river bed was observed to be uniform and composed of medium- to fine-grained sand (Annex IV.2).

Clearwater River below Naomi Lake

Below Naomi Lake, in the vicinity of hydrometric station CR-WC-MS-05, the Clearwater River is a single meandering channel and was observed to have a uniform bed composed of medium- to fine-grained sand (Annex IV.2). However, farther downstream, the reach transitions to intermittent braiding of multiple channels interrupted by occasional riffles and rapids. Additional tributaries flow into the Clearwater River between Naomi Lake and the Mirror River confluence, with the largest tributary being Hook Creek, which enters the river at Dell Lake (Figure 9.3-9).

Clearwater River above the Mirror River Confluence

Between Dell Lake and the Mirror River confluence, the Clearwater River is broad and shallow, with a sand substrate and emergent macrophyte (i.e., aquatic plants that have roots on streambeds or lake beds) vegetation. In addition to Dell Lake, there are two lakes located along the river along this reach (Figure 9.3-2).

9.3.3 Surface Water Uses

The Clearwater River and the waterbodies it connects with are used by people for navigation, recreation, fishing, and other harvesting activities (e.g., hunting, trapping, plant gathering); the river is an important aspect of culture and heritage. The Clearwater River is classified as a Canadian Heritage River in recognition of its exceptional importance to natural, cultural, and recreational heritage (CHRS 2021). The Clearwater River is also a key component in a healthy functioning aquatic and terrestrial ecosystem. Indigenous Groups have reported using Patterson and Forrest lakes for habitation (i.e., cabins and camp sites), fishing, hunting, trapping, and travel (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). Medicinal plants and berries are also gathered adjacent to both lakes (TSD II: BNDN; TSD IV: MN-S; TSD V.2: CRDN). The CRDN have identified cultural sites (i.e., Dene place names) on Patterson Lake and Forrest Lake (TSD V.1: CRDN; TSD V.2: CRDN) and the BNDN have also reported cultural sites on Patterson Lake (e.g., teaching site; TSD II: BNDN).

Patterson Lake and other lakes in the RSA are used for recreational and traditional fishing and as a transportation route for back country travel to camping, trapping, hunting, and fishing areas. Historic and contemporary cabins, and camp sites are also reported in the RSA at Patterson Lake, Forrest Lake, Beet Lake, Gedak Lake, Broach Lake, Dennis Lake, and Gall Lake (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN).

Patterson Lake is currently used as water supply for NexGen and other project's mining exploration activities. NexGen's existing exploration camp is located on the north side of the Patterson Lake South Arm and draws water from Patterson Lake for domestic uses and exploration activities. The Fission Patterson Lake South Property exploration camp is located on the west side of Patterson Lake and also draws water from Patterson Lake for domestic uses and exploration activities. No permanent surface water management infrastructure (e.g., dams, dikes, water intakes, or wastewater outfalls) is currently present within the RSA. There are no existing surface water works registered with the Province of Saskatchewan; however, Fission has three registered groundwater withdrawal projects in the vicinity of Patterson Lake (WSA 2021).

Forest Lake Outfitters operate a tourist fishing camp on the west side of Beet Lake (Forest Lake Outfitters 2021). Forest Lake Outfitters use Forrest Lake, Patterson Lake, Naomi Lake, Beet Lake, and the Clearwater River seasonally for recreational fishing and tourism purposes. This outfitter camp consists of a main camp on Beet Lake and an outpost camp on Forrest Lake.

Surface water users within the RSA are identified in Figure 9.3-2.

9.3.4 Waterbody Water Surface Elevations

Existing conditions for surface water levels were simulated at seven waterbodies using the regional hydrological model; detailed modelling results are provided in Appendix 9A. Mean monthly lake WSEs for existing conditions (i.e., Base Case) are provided in Table 9.3-4.

Table 9.3-4: Base Case Simulated Mean Monthly Waterbody Water Surface Elevations

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Broach Lake	526.656	526.644	526.650	526.737	526.825	526.781	526.733	526.701	526.691	526.694	526.695	526.671	526.706
Lake H	499.874	499.856	499.845	499.878	500.003	500.004	499.965	499.929	499.912	499.909	499.913	499.897	499.915
Lake G	499.441	499.426	499.421	499.465	499.581	499.554	499.516	499.489	499.481	499.485	499.490	499.469	499.485
Patterson Lake	498.632	498.602	498.581	498.618	498.774	498.792	498.762	498.720	498.696	498.687	498.688	498.666	498.685
Forrest Lake	498.314	498.286	498.270	498.306	498.448	498.469	498.443	498.409	498.393	498.389	498.382	498.350	498.372
Beet Lake	498.295	498.276	498.257	498.269	498.369	498.347	498.327	498.311	498.305	498.304	498.315	498.314	498.307
Naomi Lake	498.256	498.235	498.226	498.269	498.425	498.389	498.351	498.328	498.320	498.317	498.303	498.278	498.308

Source: Appendix 9A.
masl = metres above sea level; WSE = water surface elevation.

Summary statistics for Base Case waterbody WSEs are summarized in Table 9.3-5. The range of daily mean WSEs simulated from the model over the 43-year period varies for the waterbodies from about 0.39 m at Beet Lake to 0.88 m at Patterson Lake.

Table 9.3-5: Base Case Waterbody Water Surface Elevation Summary Statistics

Location	Waterbody WSEs			
	Mean (masl)	Maximum (masl)	Minimum (masl)	Range (m)
Broach Lake	526.708	526.933	526.523	0.410
Lake H	499.915	500.166	499.698	0.468
Lake G	499.485	499.685	499.267	0.418
Patterson Lake	498.685	499.160	498.282	0.878
Forrest Lake	498.372	498.716	498.016	0.700
Beet Lake	498.308	498.499	498.113	0.386
Naomi Lake	498.309	498.573	498.052	0.521

Source: Appendix 9A.
masl = metres above sea level; WSE = water surface elevation.

9.3.5 Watercourse Flow Rates

Surface water flows are the net result of hydrological processes active in the contributing watershed, including inputs of precipitation, snowmelt runoff, and groundwater discharge, as well as losses to evaporation, sublimation, and groundwater recharge. Surface water flows vary over the course of a year as a result of fluctuations of hydrological processes, primarily driven by changes in precipitation and air temperature, as well as energy inputs from solar radiation. Existing conditions (i.e., Base Case) were modelled using the regional hydrological model for nine hydrology nodes over a 43-year period for locations in the RSA. In the hydrological modelling, daily mean flows were used to characterize existing conditions. In particular, three statistics were calculated to summarize flows: mean annual minimum daily flow, mean annual flow, and mean annual maximum daily flow.

Mean monthly flows for existing conditions are provided in Table 9.3-6 and mean annual flow summary statistics are provided in Table 9.3-7. Flood and low flow magnitudes and frequencies are summarized in Table 9.3-8 and Table 9.3-9. Model results show that mean monthly flows and annual flow statistics increase with watershed area; therefore, these values increase in a downstream direction along the Clearwater River as tributary inflows increase. Lakes G and H have small watershed areas, and average flows are also predicted to be relatively small. Peak flows usually occur in the month of May during spring freshet and minimum flows usually occur in February.

Table 9.3-6: Base Case Simulated Mean Monthly Flows

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Broach Lake	0.134	0.119	0.132	0.286	0.540	0.430	0.315	0.246	0.230	0.230	0.211	0.171	0.254
Clearwater River above Patterson Lake	0.209	0.240	0.292	0.813	1.162	0.863	0.671	0.572	0.559	0.560	0.474	0.265	0.557
Lake H	0.027	0.024	0.025	0.034	0.061	0.058	0.049	0.041	0.040	0.039	0.034	0.029	0.038
Lake G	0.007	0.006	0.006	0.015	0.037	0.025	0.018	0.015	0.015	0.016	0.013	0.009	0.015
Clearwater River below Patterson Lake	1.08	1.03	1.05	1.24	1.68	1.73	1.64	1.52	1.46	1.41	1.25	1.15	1.35
Clearwater River below Forrest Lake	1.89	1.74	1.66	1.85	2.68	2.80	2.64	2.42	2.34	2.33	2.30	2.09	2.23
Clearwater River below Beet Lake	1.99	1.83	1.78	2.08	3.30	3.01	2.75	2.56	2.51	2.49	2.35	2.18	2.40
Clearwater River below Naomi Lake	2.45	2.23	2.13	2.58	4.58	4.04	3.53	3.25	3.19	3.18	3.00	2.71	3.07
Clearwater River above Mirror River confluence	3.52	3.48	3.52	6.03	9.97	7.99	6.64	6.03	6.00	6.01	5.35	3.96	5.71

Source: Appendix 9A.

Table 9.3-7: Base Case Summarized Flow Characteristics

Location	Mean Annual Minimum Daily Flow (m^3/s)	Mean Annual Minimum 7-Day Flow (m^3/s)	Mean Annual Flow (m^3/s)	Mean Annual Maximum Daily Flow (m^3/s)
Clearwater River below Broach Lake	0.082	0.083	0.257	0.633
Clearwater River above Patterson Lake	0.120	0.124	0.564	1.759
Lake H	0.019	0.019	0.039	0.074
Lake G	0.004	0.004	0.016	0.052
Clearwater River below Patterson Lake	0.864	0.870	1.36	1.90
Clearwater River below Forrest Lake	1.48	1.49	2.24	3.19
Clearwater River below Beet Lake	1.55	1.57	2.42	3.85
Clearwater River below Naomi Lake	1.84	1.86	3.10	5.38
Clearwater River above Mirror River confluence	2.71	2.74	5.77	12.8

Source: Appendix 9A.

Table 9.3-8: Base Case Frequency Analysis of Annual Maximum Daily Flow

Hydrological Condition	Average Return Period (yrs)	Estimated Annual Maximum Daily Flow (m^3/s)						
		Clearwater River below Broach Lake	Clearwater River above Patterson Lake	Clearwater River below Patterson Lake	Clearwater River below Forrest Lake	Clearwater River below Beet Lake	Clearwater River below Naomi Lake	Clearwater River above Mirror River Confluence
Wet	100	1.12	4.10	3.19	5.28	6.12	8.19	20.5
	75	1.10	3.93	3.14	5.20	6.04	8.10	20.2
	50	1.07	3.70	3.05	5.08	5.91	7.96	19.7
	35	1.04	3.50	2.98	4.96	5.79	7.82	19.2
	20	0.99	3.17	2.84	4.75	5.56	7.55	18.4
	10	0.91	2.75	2.63	4.43	5.21	7.14	17.2
	5	0.81	2.31	2.38	4.01	4.76	6.58	15.6
Average (mean)	n/a	0.63	1.76	1.90	3.19	3.85	5.38	12.8
Median	2	0.63	1.64	1.89	3.19	3.85	5.42	12.7
Dry	5	0.45	1.13	1.43	2.38	2.95	4.21	9.97
	10	0.37	0.92	1.20	1.97	2.49	3.58	8.63
	20	0.30	0.76	1.02	1.64	2.12	3.07	7.56
	35	0.25	0.65	0.90	1.41	1.86	2.71	6.83
	50	0.22	0.59	0.83	1.28	1.71	2.50	6.41
	75	0.20	0.53	0.75	1.14	1.55	2.28	5.97
	100	0.18	0.49	0.70	1.05	1.45	2.13	5.67

Source: Frequency analysis of Appendix 9A results.
Note: Extreme value distribution was used for frequency analysis.
n/a = not applicable.

Table 9.3-9: Base Case Frequency Analysis of Annual Minimum Daily Flow

Hydrological Condition	Average Return Period (yrs)	Estimated Annual Low Flow (m^3/s)						
		Clearwater River below Broach Lake	Clearwater River above Patterson Lake	Clearwater River below Patterson Lake	Clearwater River below Forrest Lake	Clearwater River below Beet Lake	Clearwater River below Naomi Lake	Clearwater River above Mirror River Confluence
Wet	100	0.229	0.447	1.53	2.53	2.62	3.20	5.31
	75	0.220	0.427	1.50	2.48	2.57	3.13	5.15
	50	0.207	0.399	1.45	2.40	2.49	3.03	4.93
	35	0.196	0.373	1.40	2.33	2.42	2.93	4.72
	20	0.177	0.330	1.32	2.21	2.30	2.77	4.39
	10	0.151	0.273	1.22	2.04	2.12	2.54	3.93
	5	0.122	0.210	1.09	1.83	1.92	2.27	3.41
Average (mean)	n/a	0.082	0.120	0.864	1.48	1.55	1.84	2.71
Median	2	0.074	0.109	0.846	1.45	1.53	1.79	2.56
Dry	5	0.038	0.038	0.631	1.11	1.17	1.38	1.93
	10	0.025	0.013	0.536	0.95	1.01	1.21	1.69
	20	0.016	0.000	0.469	0.84	0.90	1.09	1.55
	35	0.012	0.000	0.428	0.77	0.83	1.01	1.47
	50	0.010	0.000	0.407	0.74	0.79	0.98	1.43
	75	0.008	0.000	0.386	0.70	0.75	0.94	1.40
	100	0.007	0.000	0.374	0.68	0.73	0.92	1.38

Source: Frequency analysis of Appendix 9A results.
Note: Weibull distribution was used for frequency analysis.
n/a = not applicable.

Annual hydrographs showing the median, 25th, and 75th percentile flows for selected locations in the RSA are provided in Figure 9.3-11 to Figure 9.3-17. Results from the regional hydrological model represent existing conditions and are based on daily mean discharge values. Hydrograph shapes are similar for the different locations along the Clearwater River mainstem, with peak discharge usually occurring in May and lowest discharge usually occurring in the winter months (December through March).

Figure 9.3-11: Base Case Flows at the Clearwater River below Broach Lake (CR-WC-MS-01)

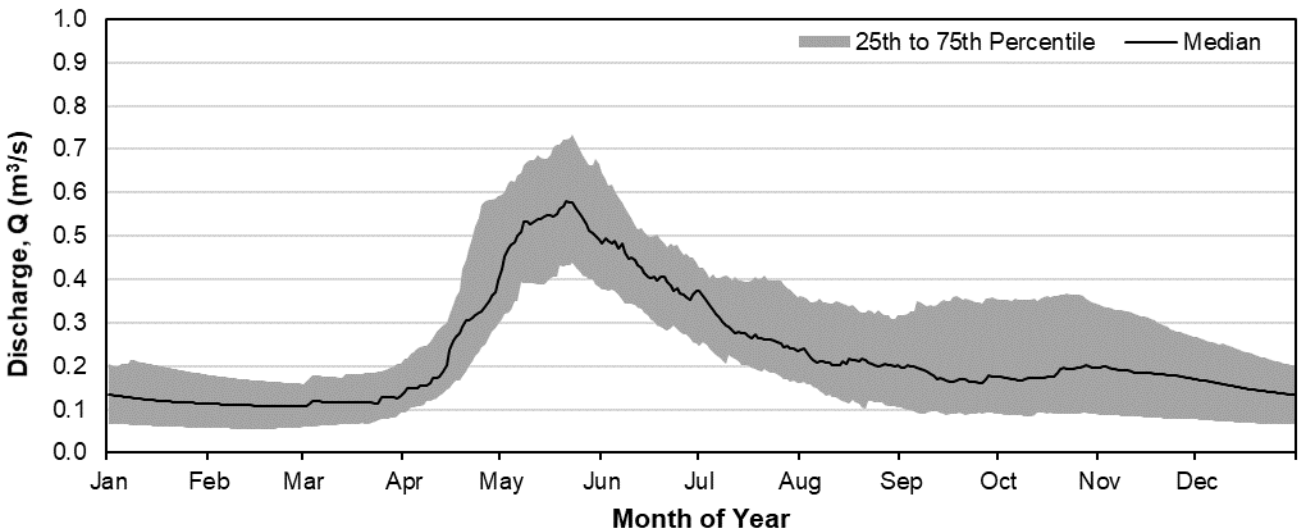


Figure 9.3-12: Base Case Flows at the Clearwater River above Patterson Lake (CR-WC-MS-02)

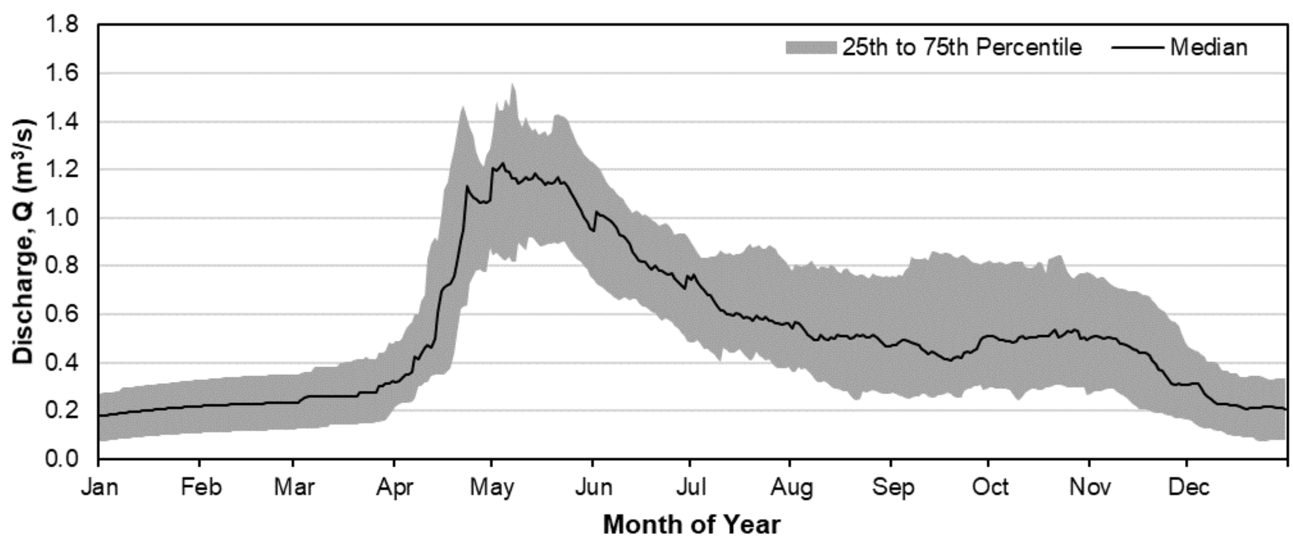


Figure 9.3-13: Base Case Flows at the Clearwater River below Patterson Lake (CR-WC-MS-03)

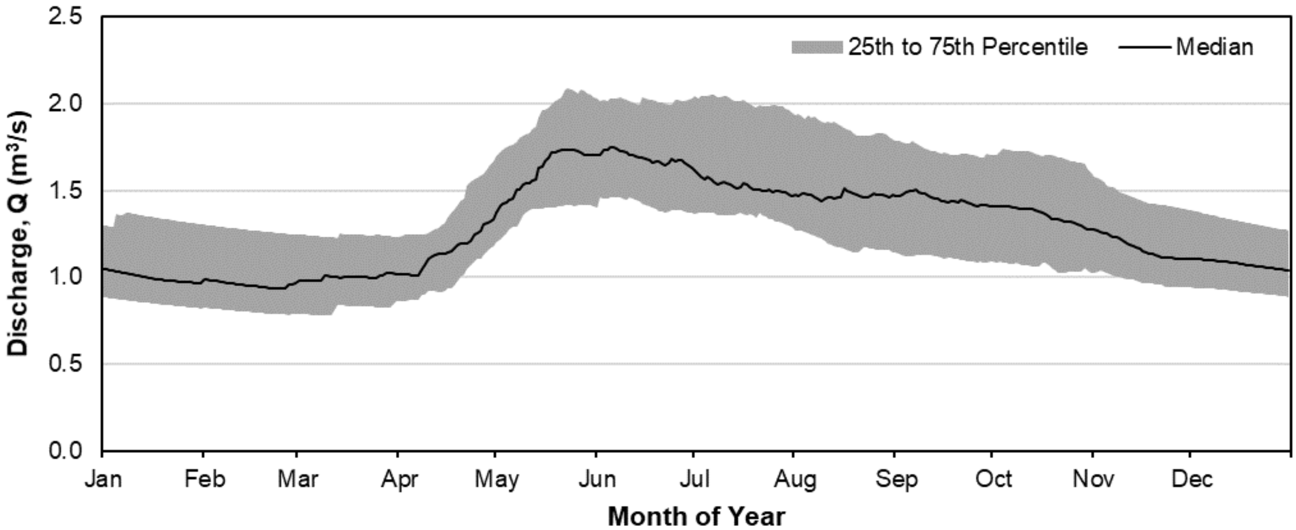


Figure 9.3-14: Base Case Flows at the Clearwater River below Forrest Lake

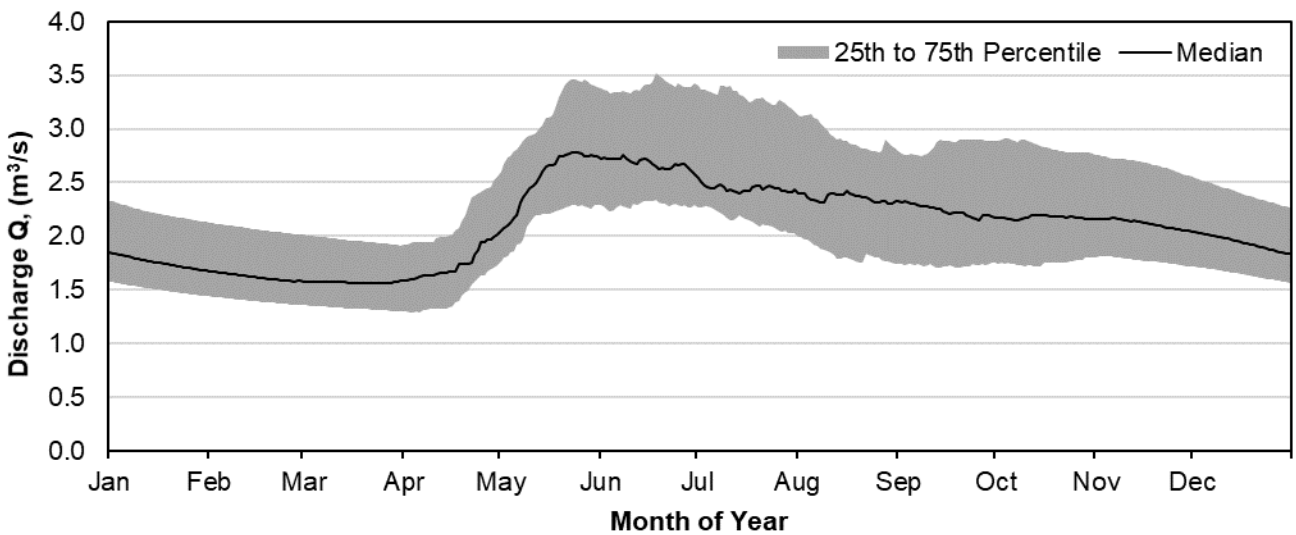


Figure 9.3-15: Base Case Flows at the Clearwater River below Beet Lake (CR-WC-MS-04)

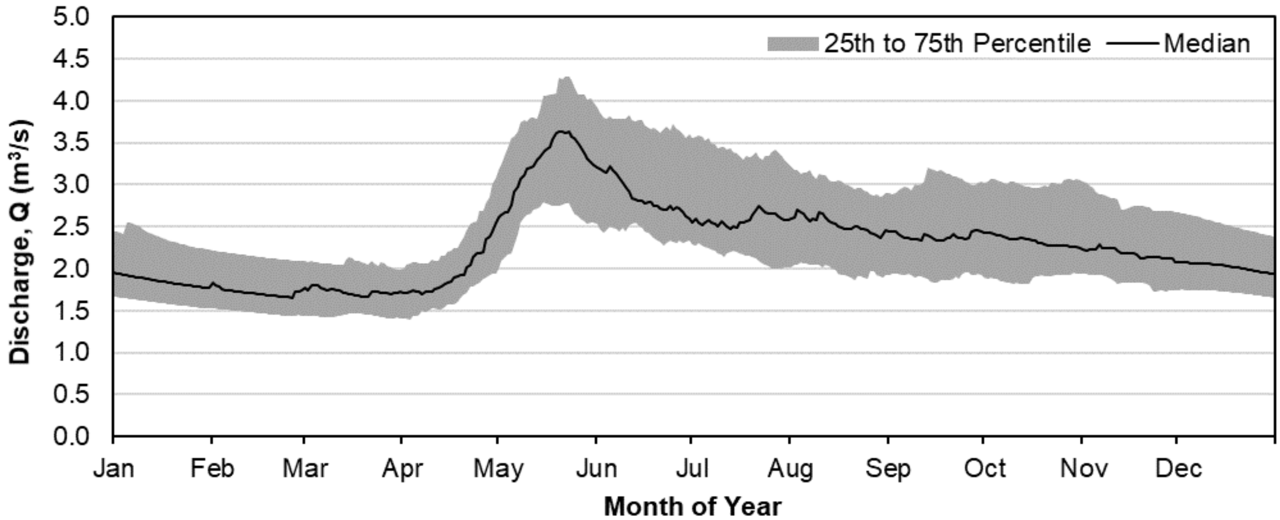


Figure 9.3-16: Base Case Flows at the Clearwater River below Naomi Lake (CR-WC-MS-05)

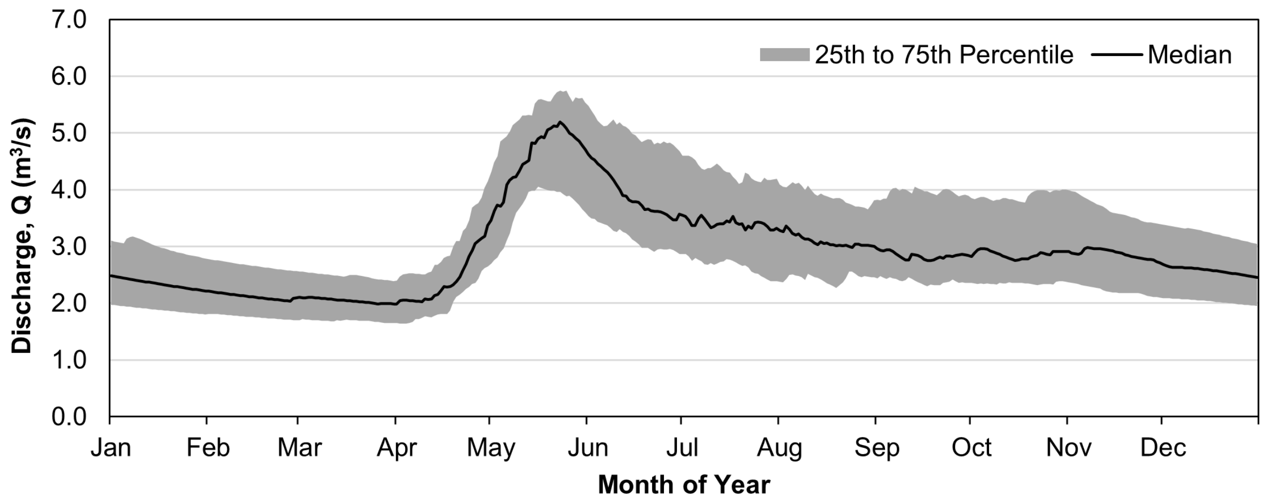
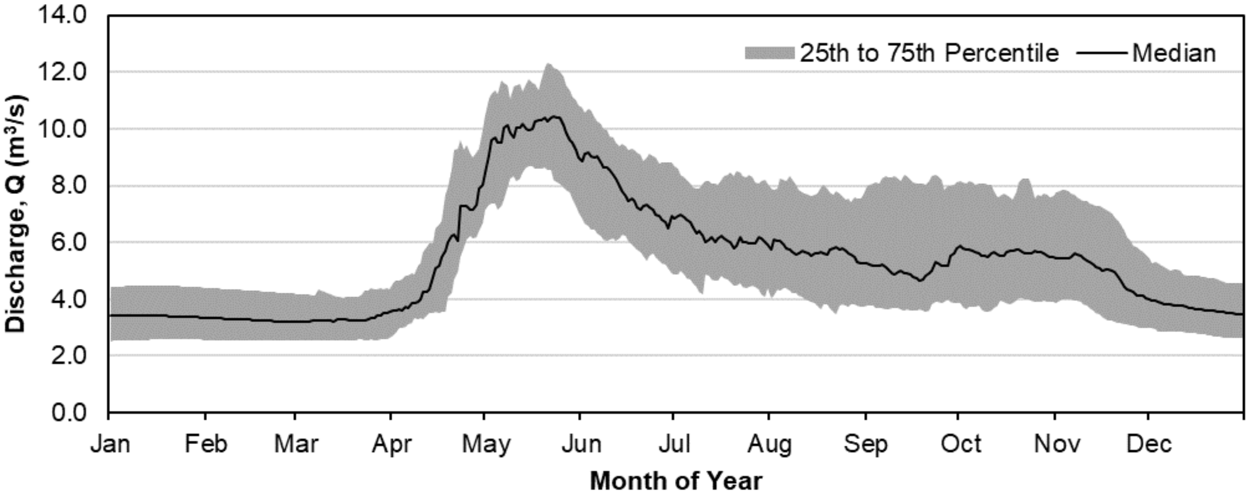


Figure 9.3-17: Base Case Flows at the Clearwater River above Mirror River Confluence (CR-WC-MS-06)



9.3.6 Stream Channel Parameters

Base Case stream channel parameters are summarized in Table 9.3-10. With increasing flows, the channel wetted area and widths tend to increase, while mean annual flow depth and velocity vary with channel morphology at the evaluation nodes, which are located at hydrometric stations. The stream channel parameters presented in Table 9.3-10 can help to support interpretation of navigability by boat. In general, boat navigation above Patterson Lake is more difficult than navigation downstream. Upstream of Patterson Lake, the channel is wide but relatively shallow such that it would be more difficult to navigate by motorboat during average flow conditions. The Clearwater River channel between Broach Lake and Jed Lake (i.e., the small waterbody upstream of Patterson Lake) has a higher gradient than downstream of Patterson Lake and is narrower, has rapids and steeper gradients in sections, and is not considered to be navigable by motorboat (although it may be navigable with non-motorized watercraft). Navigation downstream of Patterson Lake is generally easier than upstream of the lake as it has a lower gradient, although there are shallow areas and rocks to be avoided.

The CRDN have reported that seasonal water level changes affect river travel in general within their traditional lands (TSD V.2: CRDN). The CRDN have indicated that travel on the Clearwater River is very difficult and technically challenging for canoes because of the many rapids and need for portages (TSD V.2: CRDN). Although some members prefer to use white-water rafts because it reduces the number of portages, there are many reports of capsizing and damaged watercrafts because of the rough waters.

> People usually do it [Clearwater River] with canoes. It takes them about a week because they have to portage. There's lots of portages. Like from Virgin River on, it's just rapids, rapids, rapids, rapids, rapids. There's more rapids on there than you can write in here . . . Past here there's all just rapids. It's just work. Work, work, work. (TSD V.2: CRDN)

> These ones here. I fell in the water on this one time. I fell into the water on that one and that wasn't very fun. This one. This holds you in the water there because it goes – it drops off and it comes down . . . . So it holds you in there. And me and my buddy fell in there. And this one is a braided – and this is the one where [name] and lots of people rip their rafts or screw up their boats and stuff. (TSD V.2: CRDN)

Table 9.3-10: Base Case Stream Channel Parameters for Selected Locations in the Hydrology Regional Study Area

Evaluation Node	Mean Annual Flow (m^3/s)	Mean Annual Flow Wetted Area (m^2)	Mean Annual Flow Depth (m)	Mean Annual Flow Width (m)	Mean Annual Flow Velocity (m/s)
Clearwater River below Broach Lake	0.248	1.1	0.31	3.4	0.25
Clearwater River above Patterson Lake	0.564	4.1	0.42	10.1	0.16
Clearwater River below Patterson Lake	1.36	5.2	0.49	10.7	0.26
Clearwater River below Beet Lake	2.42	14.5	0.64	22.6	0.17
Clearwater River below Naomi Lake	3.10	14.0	0.52	26.7	0.23
Clearwater River above the Mirror River confluence	5.77	34.6	0.65	53.1	0.17

Source: Appendix 9A results and stream channel parameter relationships developed from Annex IV.2.

9.3.7 Fluvial Sediment Transport

Fluvial sediment transport was assessed for the Clearwater River between Patterson and Forrest lakes. The water surface along this reach remains within the channel for the two-year flood (i.e., the median annual maximum daily flow). Based on sediment transport model results, during higher flow conditions, there is net erosion or degradation in the Upper Reach (i.e., from the Patterson Lake outflow to the channel bifurcation, approximately 565 m from the lake outlet) and sediment deposition or aggradation in the lower reaches with relatively more deposition occurring in the South Channel than in the North Channel (Figure 9.3-9). The balance of sediment eroded from the Upper Reach that is not deposited in the Lower Reach is expected to be deposited into the Forrest Lake – North Basin, mostly at the mouth of the North Channel.

Sediment transport over time during existing conditions was assessed at one location in the Upper Reach and at one location in each of the North Channel and South Channel of the Lower Reach; results are provided in Table 9.3-11. Erosional losses are expected in the Upper Reach with increased flows; however, this loss is offset by sediment deposition expected in the Lower Reach channels. The net balance represents the amount of sediment deposited in Forrest Lake annually.

Table 9.3-11: Base Case Fluvial Sediment Transport in the Clearwater River below Patterson Lake

Assessment Case	Mean Annual Maximum Daily Flow (m^3/s)	Longitudinal Cumulative Mass Change (t/yr)			
		Upper Reach	Lower Reach		Net Balance
			North Channel	South Channel	
Base Case	1.89	-86	27	36	-23

Source: Appendix 9B.

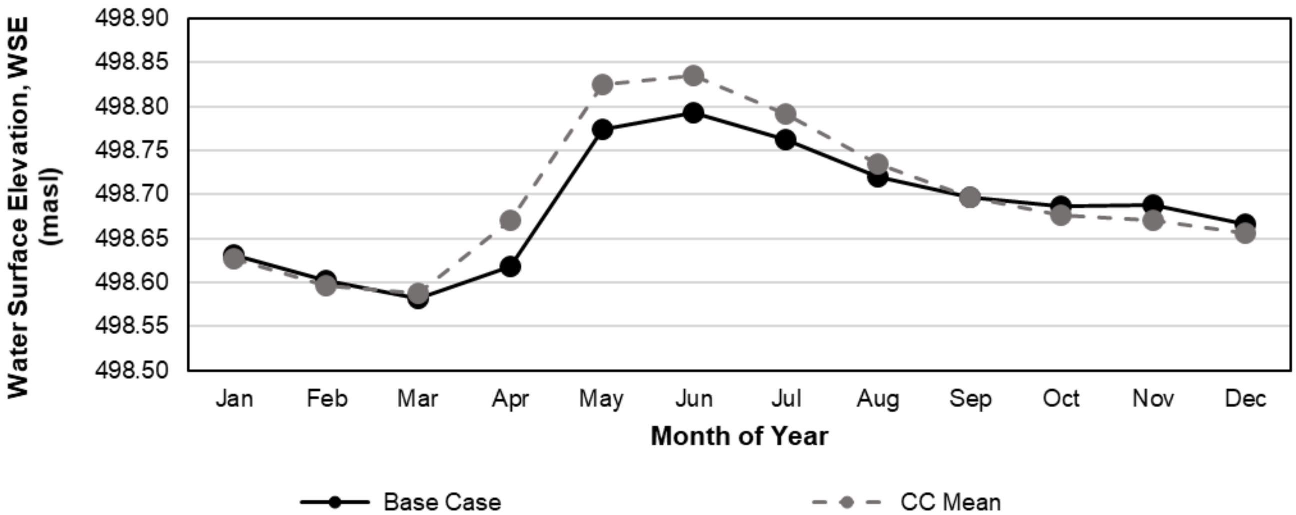
9.4 Climate Change Scenario

Climate change in the region of the Project and across the globe is anticipated to occur during the 43-year Project lifespan. The nature of the change to historical climate varies geographically and is dynamic over time. Site-specific future climate projections were developed for the Project through analysis of available projections from a multi-model ensemble (Appendix 22A, Climate Change Dataset Summary Report). The multi-model ensemble consisted of available regional scale projections from several climate models representing different future climate scenarios. Climate change scenarios were incorporated into the regional hydrological model to evaluate the effect of climate change on the proposed Project and are discussed in detail in Appendix 9A. The mean of climate change projections for 2041 to 2070 (i.e., change relative to the period of 1981 to 2010) was adopted as the most probable of the climate change scenarios. The 2050s (2041 to 2070) represent a reasonable upper bound in terms of climate change during the Project lifespan. Results from the mean of climate projections are referred to in this subsection as the climate change scenario. Additional sensitivity scenarios were also modelled with results provided in Appendix 9A.

9.4.1 Waterbody Water Surface Elevations

Mean monthly WSEs in Patterson Lake in the climate change scenario are plotted alongside the Base Case in Figure 9.4-1. The results show the seasonal distribution of predicted effects from climate change, with the highest increases projected for the spring and summer months from April to August. Decreases in water levels are predicted for the months of October through February.

Figure 9.4-1: Patterson Lake Mean Monthly Water Surface Elevation in the Climate Change Scenario and Base Case



CC = climate change; masl = metres above sea level.

Waterbody WSE results for the climate change scenario for the hydrology evaluation nodes are provided in Table 9.4-1. The absolute magnitude of changes relative to the Base Case are provided in Table 9.4-2 while percent changes relative to simulated WSE range for each waterbody are provided in Table 9.4-3. Mean monthly WSE increases are predicted to be the highest in the month of April, with the increases ranging from 0.029 m at Beet Lake to 0.076 m at Patterson Lake. On an annual basis, the largest change is at Patterson Lake with an increase in its mean WSE of 0.013 m. These increases in mean monthly WSEs are large enough that they may be detectable, though they are well within the range of natural variation provided for the Base Case in Table 9.3-4.

All waterbodies are predicted to experience small decreases in mean monthly WSEs in the late summer, fall, and winter months (Table 9.4-2). These changes would be difficult to differentiate from existing conditions.

Table 9.4-1: Climate Change Scenario Mean Monthly Lake Water Surface Elevation

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Broach Lake	526.655	526.647	526.675	526.785	526.836	526.783	526.725	526.684	526.668	526.668	526.674	526.666	526.706
Lake G	499.437	499.422	499.427	499.505	499.598	499.561	499.516	499.482	499.469	499.470	499.475	499.463	499.485
Lake H	499.862	499.846	499.844	499.911	500.034	500.023	499.971	499.922	499.897	499.888	499.889	499.881	499.914
Patterson Lake	498.627	498.594	498.590	498.694	498.833	498.831	498.785	498.728	498.694	498.675	498.669	498.654	498.698
Forrest Lake	498.306	498.283	498.278	498.351	498.493	498.503	498.464	498.415	498.386	498.372	498.362	498.337	498.379
Beet Lake	498.287	498.263	498.252	498.299	498.391	498.363	498.335	498.311	498.299	498.292	498.295	498.301	498.307
Naomi Lake	498.250	498.233	498.233	498.314	498.455	498.408	498.361	498.328	498.313	498.303	498.286	498.263	498.312

Source: Appendix 9A.
masl = metres above sea level; WSE = water surface elevation.

Table 9.4-2: Water Surface Elevation Change for the Climate Change Scenario Relative to the Base Case Water Surface Elevation Range

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Broach Lake	-0.002	0.003	0.025	0.049	0.011	0.003	-0.008	-0.017	-0.023	-0.025	-0.021	-0.006	-0.001
Lake G	-0.004	-0.004	0.006	0.040	0.017	0.007	-0.001	-0.007	-0.012	-0.015	-0.016	-0.006	0.000
Lake H	-0.011	-0.010	-0.001	0.033	0.031	0.019	0.006	-0.006	-0.015	-0.021	-0.024	-0.016	-0.001
Patterson Lake	-0.005	-0.008	0.009	0.076	0.059	0.039	0.023	0.008	-0.003	-0.012	-0.019	-0.012	0.013
Forrest Lake	-0.008	-0.004	0.009	0.045	0.045	0.034	0.020	0.005	-0.007	-0.016	-0.020	-0.013	0.008
Beet Lake	-0.008	-0.013	-0.005	0.029	0.023	0.015	0.009	0.001	-0.006	-0.012	-0.020	-0.012	0.000
Naomi Lake	-0.006	-0.002	0.007	0.045	0.030	0.018	0.009	-0.001	-0.008	-0.014	-0.018	-0.015	0.004

Source: Appendix 9A.
masl = metres above sea level; WSE = water surface elevation.

Table 9.4-3: Expected Percent Change in Mean Monthly Lake Water Surface Elevation due to the Climate Change Scenario Water Surface Elevation Range

Location	Change in Mean Monthly WSE (%)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Broach Lake	-0.7%	1.2%	9.2%	13.4%	2.5%	0.7%	-2.3%	-5.2%	-7.2%	-8.0%	-6.6%	-1.9%	-0.4%
Lake H	-0.8%	-1.0%	1.5%	8.6%	2.9%	1.2%	-0.1%	-1.5%	-2.6%	-3.0%	-3.2%	-1.3%	0.1%
Lake G	-1.3%	-1.2%	-0.1%	3.8%	3.1%	1.9%	0.6%	-0.7%	-1.6%	-2.3%	-2.7%	-1.8%	-0.2%
Patterson Lake	-0.6%	-1.1%	1.4%	10.4%	6.7%	4.3%	2.7%	1.0%	-0.3%	-1.5%	-2.3%	-1.6%	1.58%
Forrest Lake	-1.6%	-0.8%	1.8%	8.7%	6.8%	5.1%	3.1%	0.9%	-1.2%	-2.7%	-3.4%	-2.3%	1.21%
Beet Lake	-0.8%	-1.4%	-0.6%	3.2%	2.2%	1.5%	0.9%	0.1%	-0.6%	-1.3%	-2.0%	-1.3%	-0.01%
Naomi Lake	-0.6%	-0.2%	0.7%	4.4%	2.5%	1.6%	0.8%	-0.1%	-0.7%	-1.3%	-1.6%	-1.4%	0.33%

WSE = water surface elevation.

For the climate change scenario, the predicted range of Patterson Lake WSEs is 1.022 m, which is greater than the Base Case range of 0.878 m (Table 9.4-4). At all the waterbodies, maximum values are expected to increase and minimum values are expected to decrease from the values shown in Table 9.3-4. The range of WSEs (i.e., the variability) is also expected to increase with climate change for the other receiving environment waterbodies, though to a lesser extent than for Patterson Lake.

Table 9.4-4: Climate Change Scenario Waterbody Water Surface Elevation Statistics

Location	Waterbody WSEs			
	Mean (masl)	Maximum (masl)	Minimum (masl)	Range (m)
Broach Lake	526.707	526.956	526.482	0.474
Lake H	499.914	500.190	499.657	0.533
Lake G	499.485	499.695	499.215	0.480
Patterson Lake	498.698	499.238	498.216	1.022
Forrest Lake	498.380	498.768	497.949	0.819
Beet Lake	498.307	498.516	498.077	0.439
Naomi Lake	498.312	498.588	498.008	0.580

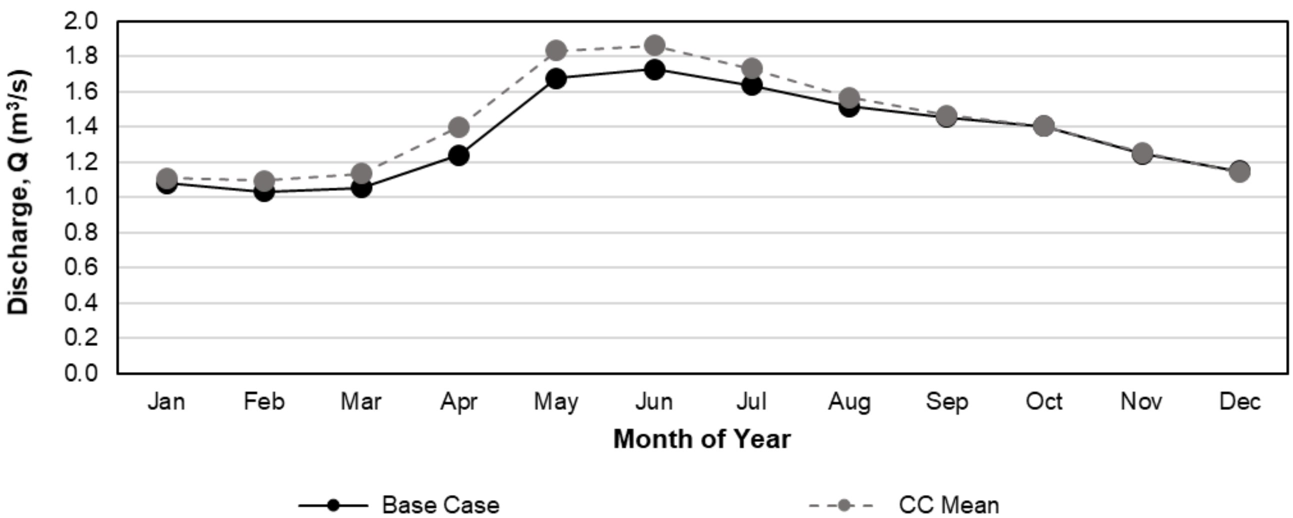
masl = metres above sea level; WSE = water surface elevation.

9.4.2 Watercourse Flow Rates

Results for watercourse flow rates for the climate change scenario are provided in Table 9.4-5, Table 9.4-6, and Figure 9.4-2. Changes relative to the Base Case are also provided in Table 9.4-7. Predicted changes in flows exhibit similar seasonal patterns as for the waterbodies, with increased flows from late winter through the summer months and the largest increases predicted for the months of March and April. Decreases in flows are predicted in the fall and early winter months from September to January. The largest variations from the Base Case are predicted for the Clearwater River headwaters (i.e., Clearwater River below Broach Lake and Clearwater River above Patterson Lake).

Increases in mean annual flows of between 3% and 9% are expected at the evaluation nodes; a 4.7% increase is expected at the Clearwater River below Patterson Lake. Mean annual maximum daily flows are also expected to increase at all locations, with a 6.6% increase expected at the Clearwater River below Patterson Lake. Mean annual minimum daily flows have more variable results at the evaluation nodes, with the Clearwater River below Patterson Lake having a slight decrease of 0.3% and all other locations having a negative change in minimum flows.

Figure 9.4-2: Clearwater River below Patterson Lake Mean Monthly Flows in the Expected Climate Change Scenario and Base Case



CC = climate change.

Table 9.4-5: Climate Change Scenario Mean Monthly Flows

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Broach Lake	0.146	0.138	0.181	0.412	0.587	0.444	0.306	0.224	0.201	0.203	0.194	0.174	0.268
Clearwater River above Patterson Lake	0.210	0.274	0.426	1.042	1.215	0.933	0.704	0.580	0.558	0.560	0.495	0.311	0.609
Lake H outlet	0.027	0.025	0.027	0.043	0.070	0.064	0.050	0.040	0.037	0.036	0.032	0.029	0.040
Lake G outlet	0.007	0.007	0.008	0.022	0.043	0.029	0.019	0.014	0.014	0.015	0.014	0.011	0.017
Clearwater River below Patterson Lake	1.109	1.095	1.137	1.401	1.835	1.863	1.734	1.567	1.467	1.405	1.256	1.141	1.42
Clearwater River below Forrest Lake	1.878	1.753	1.731	2.131	3.006	3.067	2.796	2.478	2.321	2.266	2.221	2.066	2.31
Clearwater River below Beet Lake	1.998	1.856	1.862	2.461	3.663	3.246	2.890	2.594	2.468	2.404	2.264	2.115	2.48
Clearwater River below Naomi Lake	2.436	2.253	2.240	3.161	5.109	4.348	3.702	3.285	3.139	3.070	2.873	2.616	3.19
Clearwater River above Mirror River confluence	3.436	3.569	4.063	7.464	10.817	8.697	7.047	6.205	6.077	6.005	5.392	4.086	6.07

Source: Appendix 9A.

Table 9.4-6: Changes in Mean Monthly Discharge in the Climate Change Scenario relative to the Base Case

Location	Percent (%) Change Relative to the Base Case												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Broach Lake	9.1%	15.7%	37.6%	44.1%	8.6%	3.2%	-2.7%	-9.0%	-12.7%	-11.4%	-8.3%	1.9%	6.4%
Clearwater River above Patterson Lake	0.7%	14.3%	46.0%	28.1%	4.5%	8.1%	4.8%	1.4%	-0.1%	-0.1%	4.5%	17.7%	10.8%
Lake H outlet	-0.1%	3.4%	8.7%	24.4%	14.6%	9.3%	3.1%	-2.5%	-6.0%	-5.7%	-5.0%	-2.6%	3.5%
Lake G outlet	0.1%	0.1%	0.2%	0.6%	0.6%	0.4%	0.2%	0.0%	-0.1%	-0.1%	0.1%	0.2%	0.2%
Clearwater River below Patterson Lake	2.7%	6.1%	7.9%	13.0%	9.3%	7.8%	5.8%	3.1%	0.7%	-0.1%	0.6%	-0.7%	4.7%
Clearwater River below Forrest Lake	-0.4%	0.8%	4.4%	15.3%	12.4%	9.4%	6.1%	2.3%	-0.8%	-2.8%	-3.3%	-1.3%	3.5%
Clearwater River below Beet Lake	0.6%	1.3%	4.5%	18.6%	10.9%	7.9%	5.1%	1.4%	-1.5%	-3.4%	-3.8%	-2.8%	3.2%

Table 9.4-6: Changes in Mean Monthly Discharge in the Climate Change Scenario relative to the Base Case

Location	Percent (%) Change Relative to the Base Case												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Naomi Lake	-0.5%	0.9%	5.0%	22.4%	11.5%	7.6%	4.8%	1.0%	-1.6%	-3.5%	-4.4%	-3.4%	3.3%
Clearwater River above Mirror River confluence	-2.5%	2.6%	15.5%	23.8%	8.5%	8.9%	6.2%	3.0%	1.3%	0.0%	0.7%	3.1%	5.9%

Source: Appendix 9A.

Table 9.4-7: Climate Change Scenario Summarized Flow Characteristics and Percent Change from the Base Case

Location	Mean Annual Minimum Daily Flow		Mean Annual Daily Flow		Mean Annual Maximum Daily Flow	
	(m^3/s)	% Change	(m^3/s)	% Change	(m^3/s)	% Change
Clearwater River below Broach Lake	0.077	-6.7%	0.270	5.1%	0.676	6.8%
Clearwater River above Patterson Lake	0.109	-9.1%	0.616	9.1%	1.78	1.0%
Clearwater River below Patterson Lake	0.862	-0.3%	1.42	4.7%	2.03	6.6%
Clearwater River below Forrest Lake	1.46	-1.0%	2.32	3.6%	3.45	8.0%
Clearwater River below Beet Lake	1.52	-2.3%	2.50	3.4%	4.11	6.8%
Clearwater River below Naomi Lake	1.81	-2.0%	3.21	3.5%	5.76	7.0%
Clearwater River above the Mirror River confluence	2.63	-3.1%	6.13	6.2%	13.2	3.2%

Source: Appendix 9A.

9.4.3 Stream Channel Parameters

Changes in stream channel parameters rely on predicted changes in flows in the RSA. Therefore, with increases in the mean annual flow, increases in wetted area are expected to be as high as 5.1% at the Clearwater River above the Mirror River confluence (Table 9.4-8). Wetted area at the confluence is expected to increase from 34.6 m^2, representing existing conditions, to 36.5 m^2 in the climate change scenario. The changes in channel dimensions are related to increased wetted width (i.e., 0.36 m) and only a small (i.e., 0.03 m) increase in water depth.

Table 9.4-8: Climate Change Scenario Stream Channel Parameters and Percent Change from the Base Case

Evaluation Node	Climate Change Scenario Mean Annual Flow (m^3/s)	Climate Change Scenario Mean Annual Flow Wetted Area	
		(m^2)	% Change from Base Case
Clearwater River below Patterson Lake	1.42	5.40	3.5%
Clearwater River below Beet Lake	2.50	14.7	1.2%
Clearwater River below Naomi Lake	3.21	14.1	1.1%
Clearwater River above the Mirror River confluence	6.13	36.5	5.1%

Source: Appendix 9A.
Note: Clearwater River below Forrest Lake not included in stream channel parameters as the channel is not conducive to hydrometric monitoring, as discussed in Section 9.2.6.

9.4.4 Fluvial Sediment Transport

Fluvial sediment transport was assessed for the Clearwater River below Patterson Lake along the reach from Patterson Lake to the north end of Forrest Lake. Changes in sediment transport relative to the Base Case were assessed at one location in the Upper Reach and in both North Channel and South Channel of the Lower Reach; these changes are provided in Table 9.4-9. Erosional losses are expected in the Upper Reach with increased flows; however, these losses are offset by sediment deposition in the lower reaches. The net balance for the entire reach was negative, which represents a net loss of sediment from the reach to downstream areas, but this negative net balance is predicted to be of a similar magnitude as the Base Case.

Table 9.4-9: Climate Change Scenario Fluvial Sediment Transport in the Clearwater River below Patterson Lake

Assessment Case or Scenario	Mean Annual Maximum Daily Flow (m^3/s)	Longitudinal Cumulative Mass Change (t/yr)					
		Upper Reach	% Change	Lower Reach			Net Balance
				North Channel	South Channel	% Change	
Base Case	1.89	-86	n/a	27	36	n/a	-23
Climate change scenario	2.00	-93	8%	31	40	13%	-23

Source: Appendix 9B.
n/a = not applicable.

9.5 Project Interactions and Mitigations

The pathways analysis identified potential adverse effects of the Project on hydrology, identified practicable mitigation for these potential effects, and determined whether potential effects could be sufficiently mitigated such that they are not expected to cause a residual adverse effect. As described in Section 9.2.8, the pathways analysis assigned each potential effect as:

- no pathway (i.e., mitigation results in no effect on hydrology);
- secondary pathway (i.e., mitigation results in a negligible effect on hydrology); or
- primary pathway (i.e., effect that is greater than negligible and carried forward for further assessment).

Guidelines relevant to the pathways screening for hydrology are included in Table 9.5-1. The quantitative approach adopted to support the effects assessment allowed for direct comparisons to thresholds and constraints laid out by the guidelines. In some cases, the guidelines listed below have been included because they require a quantitative assessment of pathways rather than being directly used to screen pathways.

Table 9.5-1: Relevant Guidelines considered in the Hydrology Pathways Screening

Guideline	Relevant Guideline Sections	Considerations for Pathways Screening
CNSC Generic Guidelines for the Preparation of an EIS pursuant to the Canadian *Environmental Assessment Act, 2012*	Sections 8 and 9	General guidance for effects assessment
CNSC REGDOC-2.9.1: Environmental Protection: Environmental Principles, Assessments and Protection Measures	Sections B.2 and C.2	To describe the effects of the facility or activity on the surface water environment during the life cycle of the facility or activity
ENV Guidelines for the Terms of Reference and Environmental Impact Statement	Sections 9.1 to 9.3	To satisfy EIS Additional Information Required

Table 9.5-1: Relevant Guidelines considered in the Hydrology Pathways Screening

Guideline	Relevant Guideline Sections	Considerations for Pathways Screening
EC 2009 Code of Practice for Metal Mines	Section 4.3.8	Potential impacts of climate change should be considered in planning all aspects of mine operations particularly water management
Fisheries and Oceans Canada Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada	All	Guidance on cumulative flow alterations to amplitude of the actual flow in the river relative to a “natural flow” regime

Source: DFO 2013; CNSC 2020; CNSC 2021; ENV 2021.
CNSC = Canadian Nuclear Safety Commission; EC = Environment Canada; ENV = Saskatchewan Ministry of Environment; EIS = Environmental Impact Statement.

The pathway analysis is summarized in Table 9.5-2. The subsections following the table provide the rationale used to assign potential effects to the no pathway and secondary pathway categories and list primary pathways. Each Project interaction identified as a primary pathway was carried forward for detailed assessment in Section 9.6. Effects pathways apply to all Project phases unless otherwise noted.

The environmental design features and mitigations in Table 9.5-2 represent the list of key actions used to inform the pathway analysis as part of preparing the EIS. In addition to this list of key actions, NexGen would implement the Environmental Protection Program, which would describe the processes required to monitor and characterize emissions from Project facilities and activities. This program would be used to periodically evaluate mitigation performance and identify additional mitigation, where required, and prompt potential adaptive management measures (Section 9.9, Monitoring, Follow-Up, and Adaptive Management). Where relevant, adaptive management measures may also be proposed to address uncertainties associated with effects predictions and mitigation. The process for determining when, how, and where to use adaptive management would be described within the Integrated Management System Manual.

Potential accidents and malfunctions that have the capability to influence biophysical or human environments are discussed in Section 21, Accidents and Malfunctions.

Table 9.5-2: Potential Effects Pathways for Hydrology

Pathway ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
H-01	Project components or activities that may divert water from its natural course and result in changes to contributing surface watershed area during **Construction and Operations**: ▪ land clearing, site preparation, and construction of facilities and infrastructure ▪ process plant operation ▪ handling and storage of waste rock, special waste rock, and ore ▪ additional infrastructure (e.g., roads, airstrip, camp, maintenance shop, and offices)	**Diversion of natural watercourses and drainage areas during Construction and Operations** ▪ Project activities and footprint may divert site runoff from its natural course and change drainage areas during Construction and Operations	▪ **Limit the Project footprint** to the extent practical using practices such as: o designing an efficient infrastructure footprint (i.e., buildings clustered together) o optimizing the use of cleared areas for Project activity o using existing road infrastructure, including existing access road and bridge crossing o storing tailings underground o divert water away from site facilities through design and the establishment of berms and grading ▪ Break drainage areas into **smaller catchment areas** to limit large areas of runoff and reduce the potential erosive energy ▪ Base **ditch geometry and erosion protection** on analysis of predicted peak flows and incorporate climate change effects so that the channels have sufficient capacity ▪ Use **engineered containment and conveyance of PAG waste rock runoff** and seepage to the PAG Runoff Collection Area ▪ As part of reclamation activities, complete **contouring of disturbed areas** to minimize erosion, re-establish drainage, and encourage the growth of vegetation ▪ Implement **sedimentation and erosion control** best practices and standard mitigation (e.g., temporary sediment ponds, silt curtains, sediment traps) during all Project phases ▪ Implement **progressive reclamation and revegetation** of disturbed areas no longer required ▪ Implement a Project-specific Environmental Protection Program and a Project-specific **Environmental Monitoring Plan** ▪ Implement a Project-specific **Mine Waste Management Plan**	Primary pathway
H-02	Project components or activities that may divert water from its natural course and result in changes to contributing surface watershed area during **Closure**: ▪ removal of infrastructure ▪ reclamation and revegetation of facilities and infrastructure	**Diversion of natural watercourses and drainage areas during Closure** ▪ Project activities and footprint may divert site runoff from its natural course and change drainage areas during Closure	▪ As part of reclamation activities, complete **contouring of disturbed areas** to minimize erosion, re-establish drainage, and encourage the growth of vegetation ▪ Implement **sedimentation and erosion control** best practices and standard mitigation (e.g., temporary sediment ponds, silt curtains, sediment traps) during all Project phases ▪ **Reclaim and revegetate areas** where non-permanent Project facilities have been decommissioned ▪ Develop and implement a **Detailed Decommissioning and Reclamation Plan** to decommission and transfer the site to the province under the Institutional Control Program	Primary pathway

Table 9.5-2: Potential Effects Pathways for Hydrology

Pathway ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
H-03	Project components or activities that influence hydrological processes and water balance in the upstream contributing area during **Construction and Operations**: ▪ land clearing, site preparation, and construction of facilities and infrastructure ▪ underground shaft and mine development ▪ process plant and underground operations ▪ handling and storage of waste rock, special waste rock, and ore ▪ effluent treatment plant and treated effluent discharge ▪ domestic wastewater discharge following treatment in sewage treatment plant ▪ additional infrastructure (e.g., roads, airstrip, camp, maintenance shop, and offices)	**Changes in water balance and hydrological processes during Construction and Operations** ▪ Activities may affect basin yields (i.e., the amount of surface runoff or subsurface water storage and movement) and in turn affect waterbody WSEs and watercourse flows through changes in water balance and hydrological processes in the upstream contributing area during Construction and Operations	▪ **Recycle and reuse of process water** to reduce fresh water intake and release to Patterson Lake, to the extent practical ▪ Adhere to guidance from regulators such as DFO as to the **allowable rate and timing of water withdrawals from the point of supply** ▪ Confirm discharge meets **water quality discharge criteria** prior to release to the environment ▪ Implement **progressive reclamation and revegetation** of disturbed areas no longer required ▪ **Reclaim and revegetate areas** where non-permanent Project facilities have been decommissioned ▪ **Monitor flows before and after Construction** at the outlet of Patterson Lake to quantify the change of flow and its effects to the aquatic environment ▪ Implement a Project-specific **Environmental Protection Program** and a Project-specific **Environmental Monitoring Plan** ▪ Implement a Project-specific **Mine Waste Management Plan**	Primary pathway
H-04	Project components or activities that influence hydrological processes and water balance in the upstream contributing area during **Closure**: ▪ removal of infrastructure ▪ effluent treatment plant and treated effluent discharge ▪ domestic wastewater discharge following treatment in sewage treatment plant ▪ reclamation and revegetation of facilities and infrastructure	**Changes in water balance and hydrological processes during Closure** ▪ Activities may affect basin yields (and in turn affect waterbody WSEs and watercourse flows) through changes in water balance and hydrological processes in the upstream contributing area and result in changes to runoff during Closure	▪ As part of reclamation activities, complete **contouring of disturbed areas** to minimize erosion, re-establish drainage, and encourage the growth of vegetation ▪ Implement **sedimentation and erosion control** best practices and standard mitigation (e.g., temporary sediment ponds, silt curtains, sediment traps) during all Project phases ▪ **Reclaim and revegetate areas** ▪ Develop and implement a **Detailed Decommissioning and Reclamation Plan** to decommission and transfer the site to the province under the Institutional Control Program	Primary pathway

Table 9.5-2: Potential Effects Pathways for Hydrology

Pathway ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
H-05	Project components or activities that influence surface water flows and may change stream channel parameters during **Construction and Operations**: ▪ land clearing, site preparation, and construction of facilities and infrastructure ▪ underground shaft and mine development ▪ process plant and underground operations ▪ handling and storage of waste rock, special waste rock, and ore ▪ effluent treatment plant and treated effluent discharge ▪ domestic wastewater discharge following treatment in sewage treatment plant ▪ additional infrastructure (e.g., roads, airstrip, camp, maintenance shop, and offices) ▪ removal of infrastructure	**Changes in flows during Construction and Operations** ▪ Changes in flows during Construction and Operations may cause erosion downstream, alter stream channel sediment transport and stream channel parameters, and affect shoreline integrity	▪ **Avoid placing soil stockpiles** near waterbodies (i.e., maintain a 150 m buffer from waterbodies and watercourses), and near natural drainage features, unless required for temporary storage ▪ **Minimize areas of vegetation clearing** and soil disturbance ▪ **Minimize steepness and length of slopes of disturbed areas** and stockpiled soils ▪ **Discharge water** to the watershed of origin, to the extent practical ▪ Adhere to guidance from regulators such as DFO as to the **allowable rate and timing of water withdrawals from the point of supply** ▪ Provide **adequate contact water storage capacity** to allow controlled rate of release during both routine and non-routine operation scenarios ▪ Use **erosion control measures** as required ▪ Implement **progressive reclamation and revegetation** of disturbed areas no longer required ▪ **Reclaim and revegetate areas** where non-permanent Project facilities have been decommissioned ▪ **Monitor flows before and after Construction** at the outlet of Patterson Lake to quantify the change of flow and its effects to the aquatic environment ▪ Perform routine inspection and maintenance of **water containment and conveyance structures** (i.e., roadside ditches and culverts) to limit the risk of road wash-out or sediment release to the environment ▪ Implement a Project-specific **Environmental Protection Program** and a Project-specific **Environmental Monitoring Plan** ▪ Implement a Project-specific **Mine Waste Management Plan**	Primary pathway
H-06	Project components or activities that may result in temporary changes to surface water flows during **Construction, Operations, and Closure**: ▪ site roads ▪ removal of infrastructure ▪ reclamation and revegetation of facilities and infrastructure	**Changes to culverts during Construction, Operations, and Closure** ▪ Construction, operation, and closure of culverts may affect surface water flows	▪ Design **cross-drainage structures** to provide a conveyance for the maximum instantaneous flow resulting from a 1:100 year 24 h storm event ▪ Inspect and maintain **road embankments, ditches, ponds, and cross-drainage structures** ▪ Implement a Project-specific **Environmental Protection Program** and a Project-specific **Environmental Monitoring Plan**	No pathway

Table 9.5-2: Potential Effects Pathways for Hydrology

Pathway ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
H-07	Project components or activities that influence surface water flows and may change stream channel parameters during **Closure**: ▪ removal of infrastructure ▪ reclamation and revegetation of facilities and infrastructure	**Changes in flows during Closure** ▪ Residual changes in flows during Closure may cause erosion downstream, alter stream channel sediment transport and stream channel parameters, and affect shoreline integrity	▪ As part of reclamation activities, complete **contouring of disturbed areas** to minimize erosion, re-establish drainage, and encourage the growth of vegetation ▪ Implement **sedimentation and erosion control** best practices and standard mitigation (e.g., temporary sediment ponds, silt curtains, sediment traps) during all Project phases ▪ **Reclaim and revegetate areas** ▪ Develop and implement a **Detailed Decommissioning and Reclamation Plan** to decommission and transfer the site to the province under the Institutional Control Program	No pathway

Bolded text represents the key topic of the environmental design features and mitigation.
PAG = potentially acid generating; WSE = water surface elevation; DFO = Fisheries and Oceans Canada.

9.5.1 No Pathways

The following Project interactions were predicted to result in no pathway to hydrology and were not carried forward in the assessment.

H-06: Changes to culverts during Construction, Operations, and Closure:

- Construction, operation, and closure of culverts may affect surface water flows.

Project activities would include upgrades to existing roads and construction of new on-site roads, some of which would require the installation of culverts. During Construction activities, a failure to properly maintain stream crossings and on-site roads could lead to temporary effects to surface water flows.

Existing road embankments and cross-drainage structures would be inspected and maintained. New cross-drainage structures (i.e., culverts) would be designed to allow unobstructed flows. The design of new cross-drainage structures would incorporate erosion protection and prevent localized erosion from high-velocity flows.

Bank erosion control measures, such as riprap armouring, would be installed as required at each culvert outlet. Adverse effects to surface water would also be mitigated by adhering to the sediment and erosion control procedures and by following best management practices for in-water construction work; such mitigations include working in dry conditions where possible, isolating the work area, and diverting flow to maintain downstream flows.

Maintenance or minor upgrades of the existing infrastructure is not expected to result in a measurable change in surface water flows. During Construction, Operations, and Closure, culverts may affect timing of natural flows by removing an attenuating effect during flood flows; however, the change is expected to be infrequent and measurable at a timescale of minutes or hours. The implementation of appropriate cross-drainage structures would likely result in no measurable change to flow paths, or lower velocity in the vicinity of the structures relative to existing conditions. Subsequently, the construction, upgrading, and use of on-site roads is predicted to have no effect on hydrology and this pathway was not carried forward for further assessment.

H-07: Changes in flows during Closure:

- Residual changes in flows during Closure may cause erosion downstream, alter stream channel sediment transport and stream channel parameters, and affect shoreline integrity.

Potential changes to flows above the Base Case during Closure were simulated using the regional hydrological model for all assessment cases and scenarios (Appendix 9A; Section 9.6). Residual changes from this pathway were not evaluated separately as they are predicted to be negligible; after reclamation activities are complete at the end of the Active Closure Stage, the Project activities that influence hydrology measurement indicators would cease and the quantity of water in the receiving environment is not expected to be affected. The removal of infrastructure, and reclamation and revegetation of facilities, would gradually return runoff from the Project footprint to its natural course; water intake and treated effluent discharge would cease. Potential erosion and sediment transport on site would be addressed through the Environmental Protection Program.

Following the Active Closure Stage, fluctuations in flow in the Clearwater River below Patterson Lake would not be influenced by Project activities, and as a result, no changes to stream channel sediment transport, stream channel parameters, or shoreline integrity are expected.

9.5.2 Secondary Pathways

No Project interactions were identified as secondary pathways for hydrology.

9.5.3 Primary Pathways

The following Project interactions were predicted to be primary pathways to potential effects on hydrology (Table 9.5-1) and were carried forward for further assessment in the residual effects analysis (Section 9.6):

H-01: Diversion of natural watercourses and drainage areas during Construction and Operations:

- Project activities and footprint may divert site runoff from its natural course and change drainage areas during Construction and Operations.

H-02: Diversion of natural watercourses and drainage areas during Closure:

- Project activities and footprint may divert site runoff from its natural course and change drainage areas during Closure.

H-03: Changes in water balance and hydrological processes during Construction and Operations:

- Activities may affect basin yields (i.e., and in turn affect waterbody WSEs and watercourse flows) through changes in water balance and hydrological processes in the upstream contributing area during Construction and Operations.

H-04: Changes in water balance and hydrological processes during Closure:

- Activities may affect basin yields (i.e., and in turn affect waterbody WSEs and watercourse flows) through changes in water balance and hydrological processes in the upstream contributing area and result in changes to water balance and hydrological processes during Closure.

H-05: Changes in flows during Construction and Operations:

- Changes in watercourse flows during Construction and Operations may cause erosion downstream, alter stream channel sediment transport and stream channel parameters, and affect shoreline integrity.

9.6 Residual Effects Analysis

This subsection assesses the predicted changes to receiving environment hydrology based on the primary pathways identified in Section 9.5.3. The residual effects analysis was completed to compare the Base Case conditions to the Application Case and RFD Case conditions. The residual effects analysis for each case is structured using separate subsections for each measurement indicator and follows the methods described in Section 9.2.9. Changes to measurement indicators are summarized for the key evaluation nodes on waterbodies and watercourses downstream of the Project. These nodes typically coincide with existing or planned hydrometric monitoring stations. Conditions related to the Application Case are presented in Figure 9.6-1 and Figure 9.6-2, and conditions related to the RFD Case are presented in Figure 9.6-5.

The effects of primary pathways on hydrology were calculated numerically by integrating these pathways into a hydrological model developed for each phase, as discussed in detail in Appendix 9A. The results presented for the measurement indicators are the net results of changes in the contributing watershed associated with the identified primary pathways. Project and cumulative effects are discussed in terms of changes to measurement indicators within the RSA, where direct and indirect effects to hydrology are likely to be detectable.

9.6.1 Application Case

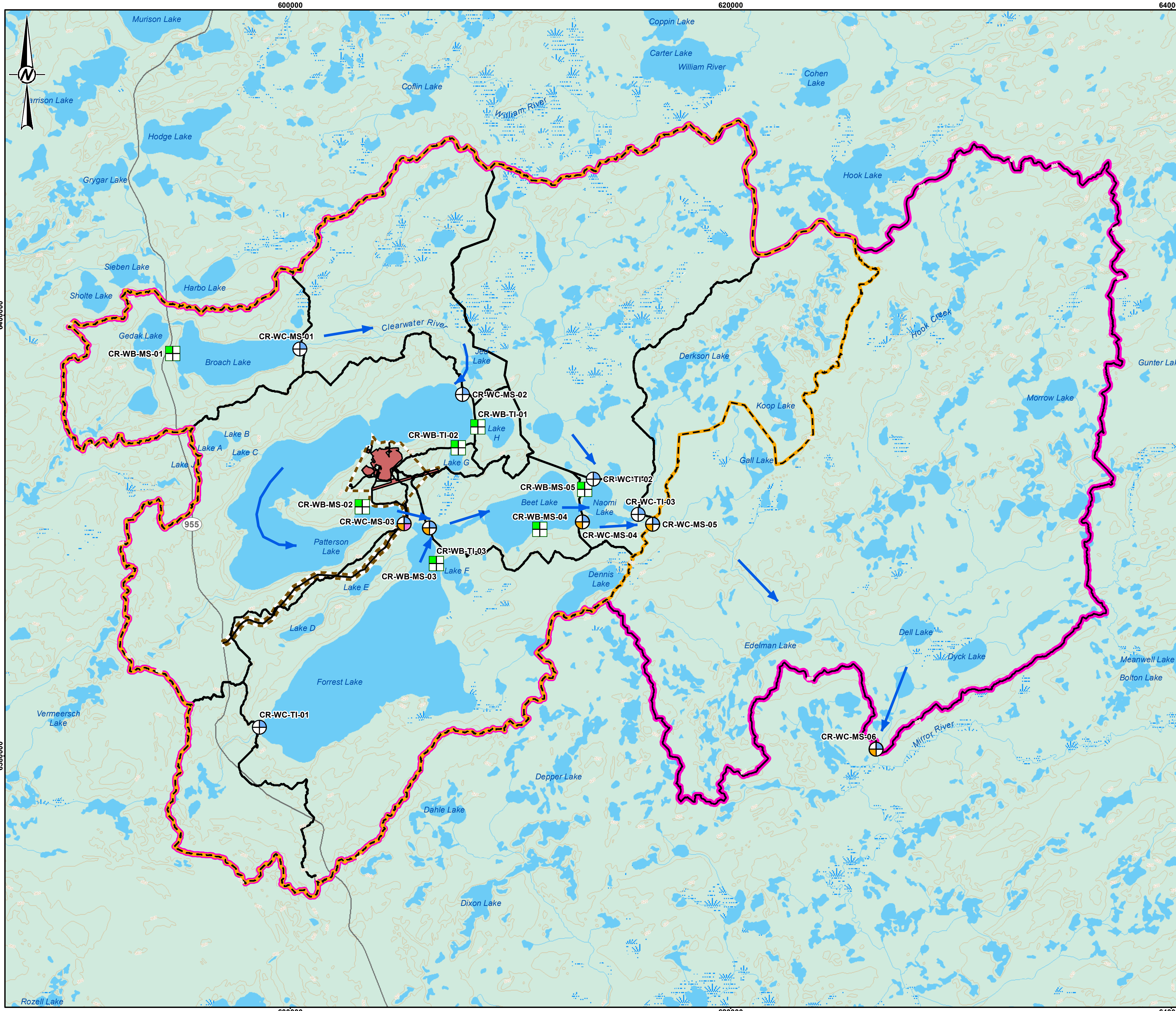
Project activities during Construction, Operations, and the Active Closure Stage would remove drainage area from the Patterson Lake watershed, include fresh water withdrawal from Patterson Lake, and release treated water to Patterson Lake, resulting in a net discharge of water to Patterson Lake. Mean monthly hydrograph figures are shown in this subsection specifically for Patterson Lake outflow, as predicted changes are the largest at this location compared to downstream locations. Application Case hydrology conditions in the RSA are summarized in Figure 9.6-1, with water management infrastructure during Operations shown in Figure 9.6-2.

Water management planning used a risk-based approach that considered both routine and non-routine Project conditions that would be periodically re-evaluated throughout the Project lifespan to adopt to best available technology and techniques; this process would include obtaining feedback through ongoing engagement with Indigenous Groups and local communities (TSD XVIII).

The site water management approach can be summarized by the following environmental protection design and development principles:

- Maximize diversion of non-contact surface runoff away from facilities and infrastructure.
- Minimize fresh-water intake withdrawals through water reuse and recycling wherever possible.
- Collect and treat mineralized contact water.
- Collect and test non-mineralized water:
    - If non-mineralized contact water is tested and it meets both regulated and established discharge criteria, it may be released without additional treatment.
    - If non-mineralized contact water is tested and does not meet environmental release targets, it would be treated.
- Consistently meet both regulated and established discharge criteria for release water.

The effects of Project interactions predicted to be primary pathways on hydrology have been mitigated by design of surface water management infrastructure and approach. In alignment with the principles listed above, potential effects on hydrology due to the Project footprint have been mitigated by the compact design of surface infrastructure that reduces changes to drainage areas and runoff pathways, which also reduces the amount of water that needs to be collected and treated. Also, the siting of the Project footprint and integration with natural topography makes it possible to divert non-contact surface runoff away from facilities and infrastructure, thereby reducing the amount of water that needs to be collected and treated. Surface grading and drainage would segregate different types of site water to keep clean water clean. Site water management facilities and systems have been designed in a manner that reduces closure activities where possible and minimizes Institutional Controls following decommissioning and reclamation.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED

WATER BODY HYDROMETRIC STATIONS

- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- STREAM CHANNEL PARAMETERS
- FLUVIAL SEDIMENT TRANSPORT
- WATERCOURSE FLOW RATE

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 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

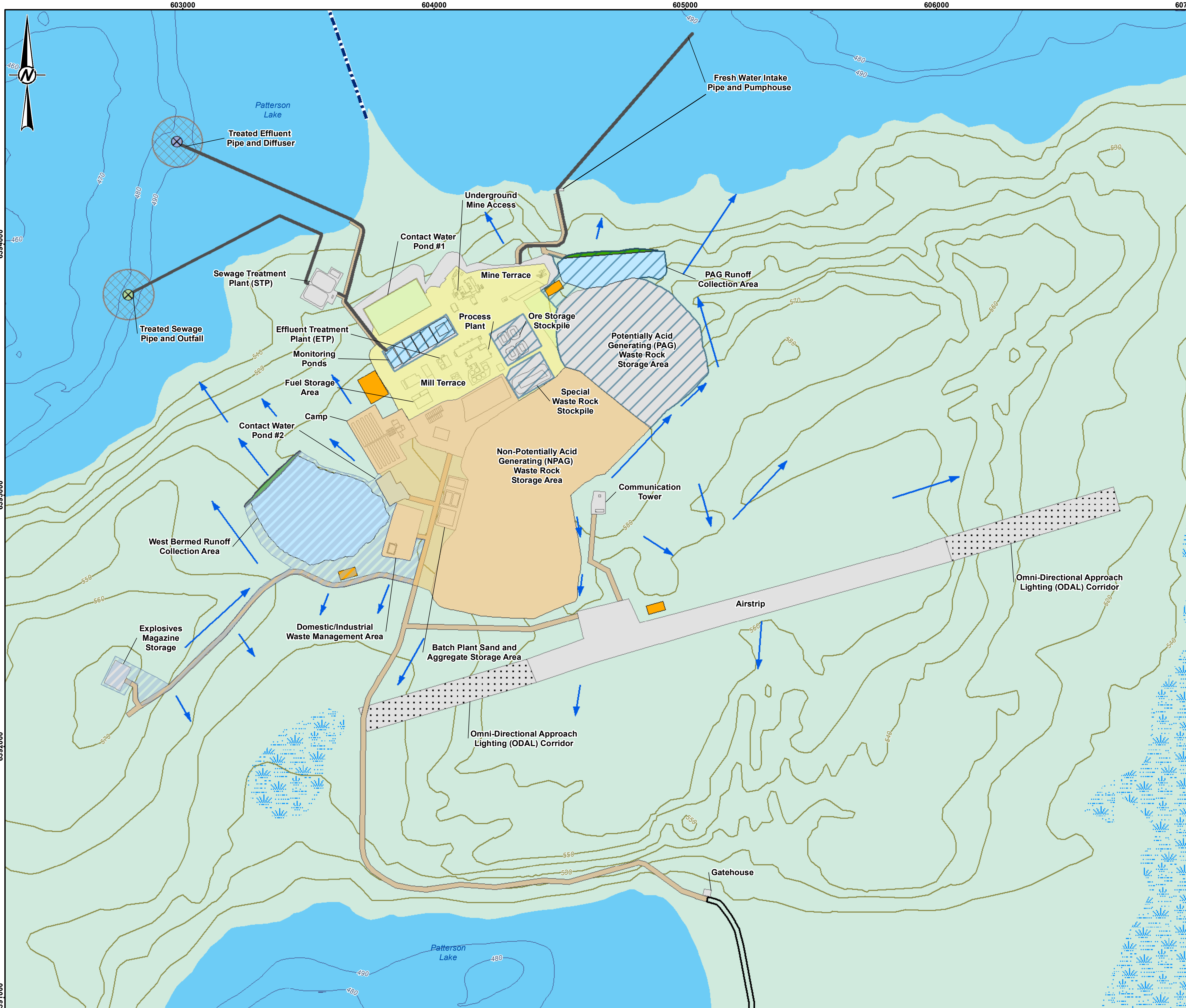
TITLE

HYDROLOGY APPLICATION CASE

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	LB/NO	2023-02-10		
CHECK	RWP	2023-02-10	**FIGURE 9.6-1**	
REVIEW	NPS	2023-02-10		



LEGEND

- BATHYMETRY CONTOUR ELEVATION (5 m INTERVAL)
- ELEVATION CONTOUR (10 m INTERVAL)
- GENERAL FLOW DIRECTION
- LAKE BASIN DIVISION
- 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
- EFFLUENT TREATED PIPE DIFFUSER
- SEWAGE TREATED PIPE OUTFALL
- PROPOSED REGULATED MIXING ZONE
- DRAINAGE TO SITE RUNOFF POND #1
- DRAINAGE TO SITE RUNOFF POND #2
- SELF CONTAINED
- TO WEST BERMED RUNOFF COLLECTION AREA

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.
3. BATHYMETRY CONTOURS DERIVED FROM DATA COLLECTED BY NEXGEN, 2016.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

OPERATIONS SURFACE WATER MANAGEMENT PROJECT INFRASTRUCTURE

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-10		
CHECK	RWP	2023-02-10	**FIGURE 9.6-2**	
REVIEW	NPS	2023-02-10		

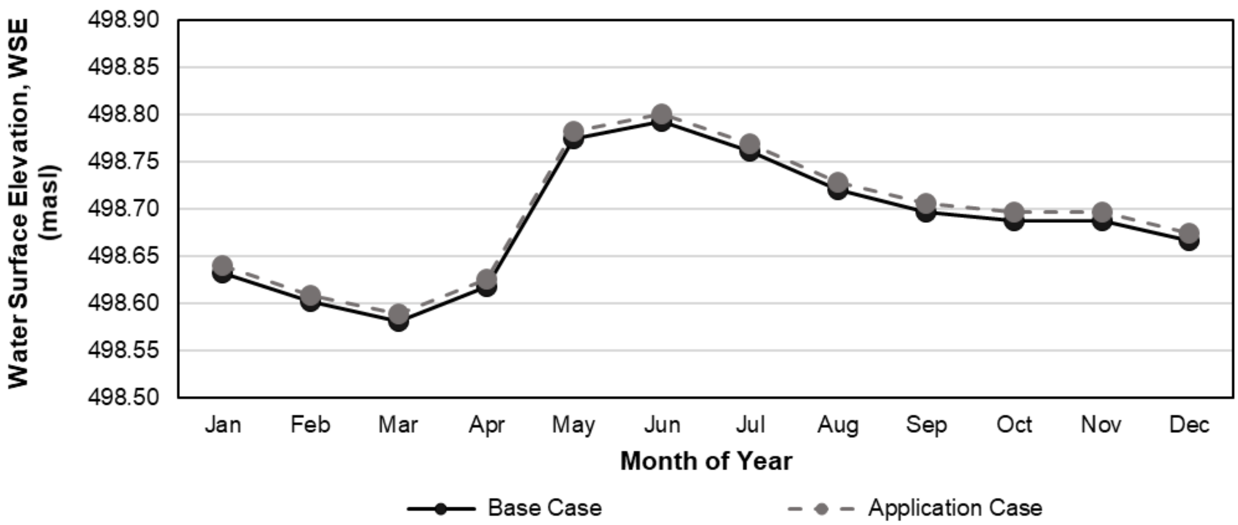
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

9.6.1.1 Waterbody Water Surface Elevation

Patterson Lake WSE is expected to increase in the Application Case, in response to a net discharge of water to the lake from Project activities during the Project lifespan. However, the magnitude of the Application Case change to WSE is expected to be small and unlikely to be measurable. Changes to WSE of less than five centimetres (0.05 m) are difficult to measure and distinguish from natural variability at daily and seasonal timescales. Predictions of mean monthly Patterson Lake WSE for the Application Case are less than 0.01 m higher than the Base Case in all months, as shown in Figure 9.6-3.

Predicted mean monthly WSE (Table 9.6-1) and changes in mean monthly values (Table 9.6-2) show that the changes in WSE are anticipated to decrease in magnitude as water moves from Patterson Lake to waterbodies farther downstream along the Clearwater River, including Forrest, Beet, and Naomi lakes. The predicted changes are unlikely to be detectable at any of these waterbodies. Patterson Lake is predicted to have a 1% increase in mean annual WSE for the Application Case above the Base Case, and increases are predicted to be less than 1% for the waterbodies farther downstream (Table 9.6-3). Predicted changes are variable during the Project lifespan and the effect on WSE are predicted to cease following the Active Closure Stage, as there would no longer be releases to, or water taken from, Patterson Lake.

Figure 9.6-3: Patterson Lake Mean Monthly Water Surface Elevation for the Base Case and Application Case



masl = metres above sea level.

Table 9.6-1: Predicted Application Case Mean Monthly Lake Water Surface Elevation

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	498.640	498.609	498.588	498.625	498.782	498.800	498.770	498.729	498.706	498.696	498.697	498.674	498.693
Forrest Lake	498.318	498.290	498.273	498.309	498.452	498.472	498.447	498.414	498.398	498.393	498.387	498.354	498.375
Beet Lake	498.297	498.278	498.259	498.271	498.370	498.349	498.329	498.313	498.307	498.306	498.317	498.316	498.309
Naomi Lake	498.259	498.237	498.227	498.271	498.427	498.391	498.353	498.331	498.323	498.320	498.306	498.281	498.311

Source: Appendix 9A.
masl = metres above sea level; WSE = water surface elevation.

Table 9.6-2: Changes in Mean Monthly Lake Water Surface Elevations for the Application Case relative to the Base Case

Location	Change in Monthly WSE (m)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	0.008	0.007	0.007	0.007	0.007	0.008	0.008	0.009	0.009	0.010	0.009	0.008	0.008
Forrest Lake	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004	0.004
Beet Lake	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Naomi Lake	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.002

Source: Appendix 9A.
WSE = water surface elevation.

Table 9.6-3: Percent Changes in Lake Water Surface Elevations for the Application Case relative to the Base Case

Location	Percent Change in Monthly WSE (%)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	1.0%	1.0%	1.0%	1.0%	0.8%	0.8%	0.9%	1.1%	1.2%	1.2%	1.1%	1.1%	1.0%
Forrest Lake	0.7%	0.7%	0.7%	0.6%	0.5%	0.6%	0.5%	0.7%	0.7%	0.8%	0.7%	0.7%	0.7%
Beet Lake	0.2%	0.2%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.2%	0.2%
Naomi Lake	0.2%	0.2%	0.2%	0.2%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%

WSE = water surface elevation.

In the Application Case, the predicted range of Patterson Lake WSE is 0.883 m based on 43 years of daily mean values (Table 9.6-4), which is similar to the Base Case range of 0.878 m (Table 9.4-4). These changes are not likely be differentiated from existing conditions indicated by field measurements.

Table 9.6-4: Application Case Waterbody Water Surface Elevation Statistics

Location	Waterbody WSE			
	Mean (masl)	Maximum (masl)	Minimum (masl)	Range (m)
Patterson Lake	498.693	499.164	498.281	0.883
Forrest Lake	498.376	498.718	498.017	0.701
Beet Lake	498.310	498.501	498.110	0.391
Naomi Lake	498.311	498.576	498.052	0.524

masl = metres above sea level; WSE = water surface elevation.

9.6.1.2 Watercourse Flow Rates

Flows in the Clearwater River below Patterson Lake are expected to increase during the Application Case in response to a net discharge of water to Patterson Lake from Project activities during Construction, Operations, and the Active Closure Stage. Predictions of mean monthly discharge in the Clearwater River below Patterson Lake for the Application Case are compared with the Base Case in Figure 9.6-4.

Predictions for mean monthly flows (Table 9.6-5) and changes in mean monthly values (Table 9.6-6) for watercourses downstream of Patterson Lake show that the change in flows is anticipated to decrease in magnitude moving in a downstream direction. Mean monthly flows at the Clearwater River below Patterson Lake are expected to increase between 1.3% to 1.9% and the annual mean increase is predicted to be 1.6%. For the evaluation nodes farther downstream, percent increases in annual mean flow are predicted to be less than 1.2% (Table 9.6-7). These changes would not be detectable at any of the hydrometric stations (i.e., difficult to distinguish from existing conditions). Changes to discharge of less than five percent are difficult to measure and differentiate from natural variability at daily and seasonal timescales and are within an acceptable margin of error for individual discharge measurements.

Predicted changes include simulation of the largest increase during the Project lifespan and are variable over time. The effect on flows would cease following the Active Closure Stage.

Figure 9.6-4: Clearwater River below Patterson Lake Monthly Flows for the Application Case and Base Case

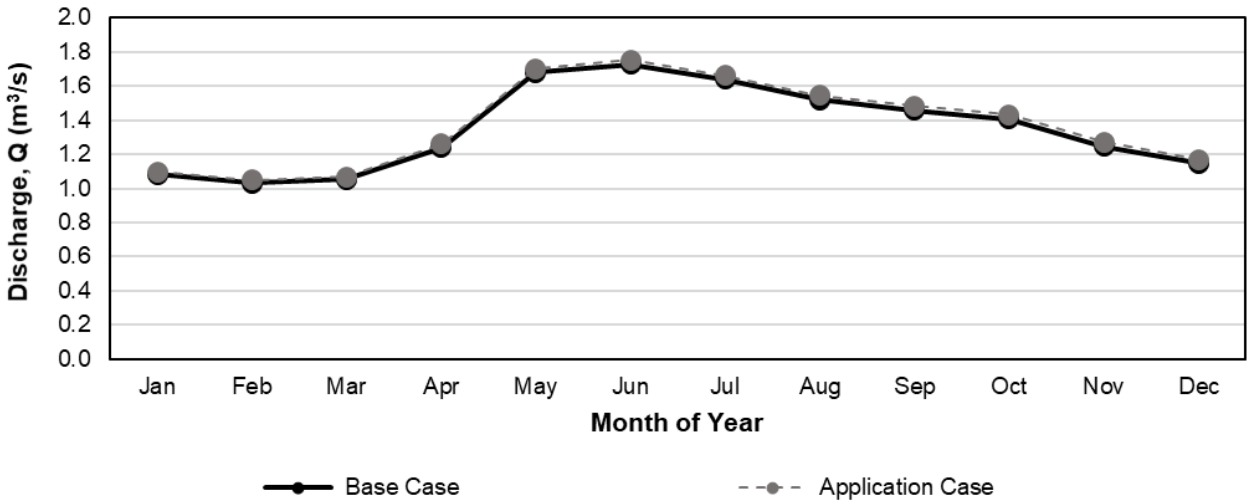


Table 9.6-5: Predicted Application Case Mean Monthly Discharges

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	1.10	1.05	1.07	1.26	1.70	1.75	1.66	1.55	1.48	1.43	1.27	1.17	1.37
Clearwater River below Forrest Lake	1.91	1.76	1.68	1.87	2.70	2.83	2.66	2.45	2.37	2.36	2.33	2.12	2.25
Clearwater River below Beet Lake	2.01	1.85	1.80	2.10	3.33	3.04	2.77	2.59	2.54	2.52	2.39	2.20	2.43
Clearwater River below Naomi Lake	2.48	2.26	2.15	2.61	4.61	4.07	3.56	3.29	3.23	3.22	3.04	2.74	3.11
Clearwater River above Mirror River confluence	3.56	3.51	3.54	6.05	10.0	8.04	6.67	6.09	6.07	6.08	5.41	4.00	5.75

Source: Appendix 9A.

Table 9.6-6: Changes in Mean Monthly Discharge in the Application Case relative to the Base Case

Location	Percent (%) Change Relative to the Base Case												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	1.6%	1.6%	1.3%	1.7%	1.3%	1.4%	1.5%	1.7%	1.9%	1.9%	1.8%	1.7%	1.6%
Clearwater River below Forrest Lake	1.2%	1.2%	1.1%	1.0%	1.0%	1.0%	1.0%	1.2%	1.4%	1.4%	1.4%	1.3%	1.2%
Clearwater River below Beet Lake	1.2%	1.1%	1.0%	1.0%	0.8%	1.0%	0.9%	1.2%	1.3%	1.4%	1.4%	1.3%	1.1%
Clearwater River below Naomi Lake	1.1%	1.1%	0.9%	0.9%	0.6%	0.8%	0.7%	1.1%	1.3%	1.3%	1.3%	1.2%	1.0%
Clearwater River above Mirror River confluence	0.9%	0.9%	0.7%	0.4%	0.5%	0.6%	0.5%	1.0%	1.1%	1.2%	1.0%	1.0%	0.8%

Source: Appendix 9A.

Table 9.6-7: Predicted Application Case Summarized Flow Characteristics

Location	Mean Annual Minimum Daily Flow		Mean Annual Daily Flow		Mean Annual Maximum Daily Flow	
	(m^3/s)	% Change	(m^3/s)	% Change	(m^3/s)	% Change
Clearwater River below Patterson Lake	0.88	1.6%	1.38	1.6%	1.93	1.4%
Clearwater River below Forrest Lake	1.49	1.1%	2.27	1.1%	3.22	1.0%
Clearwater River below Beet Lake	1.57	1.1%	2.44	1.1%	3.88	0.9%
Clearwater River below Naomi Lake	1.86	1.1%	3.13	1.0%	5.42	0.7%
Clearwater River above the Mirror River confluence	2.74	1.0%	5.81	0.7%	12.90	0.7%

Source: Appendix 9A.

9.6.1.3 *Stream Channel Parameters*

Increases in flows downstream of the Project may result in small changes in Clearwater River channel parameters. Predicted changes in river channel parameters using wetted area as the representative parameter are provided in Table 9.6-8. The CRDN expressed concerns about changes to water levels and flows on the Clearwater River from the Project, which could affect travel on the river (TSD V.2: CRDN). Increases in wetted area are predicted to be a maximum of 1.2% at all locations and are not expected be large enough to be detectable or to affect navigation. Therefore, changes in Clearwater River channel parameters are not expected to affect navigation for Indigenous land users, resource users and recreationists.

Table 9.6-8: Changes in Wetted Area at the Mean Annual Flow for the Application Case relative to the Base Case

Location	Mean Annual Flow (m^3/s)	Wetted Area at the Mean Annual Flow (m^2)	% Change Wetted Area
Clearwater River below Patterson Lake	1.38	5.3	1.2%
Clearwater River below Beet Lake	2.44	14.6	0.3%
Clearwater River below Naomi Lake	3.13	14.0	0.3%
Clearwater River above the Mirror River confluence	5.81	34.8	0.6%

Source: Appendix 9A; Annex IV.2.

9.6.1.4 *Fluvial Sediment Transport*

The predicted increase in flows downstream of the Project in the Application Case is small in magnitude and not expected to result in a measurable change to the fluvial sediment transport regime. In a year with an average flood, erosion from the Clearwater River below Patterson Lake Upper Reach and deposition in the Lower Reach may increase by a non-detectable amount for the Application Case relative to the Base Case, and the net balance of sediment transported to Forrest Lake is expected to remain unchanged. Geomorphology and sediment transport observations for the Clearwater River reach between Patterson and Forrest lakes is provided in Section 9.3.2.2. The Upper Reach flows from Patterson Lake about 580 m downstream before it bifurcates (i.e., where a single channel splits into two separate channels) into the two channels that constitute the Lower Reach. The North Channel is 170 m long and relatively narrow and deep. The South Channel is 300 m long and relatively wide and shallow.

Fluvial sediment transport was assessed for the Clearwater River below Patterson Lake along the reach from Patterson Lake to the north end of Forrest Lake. Changes in sediment transport assessed at one location in the Upper Reach and in both the Lower Reach North Channel and South Channel are provided in Table 9.6-9. With a slight increase in mean annual maximum daily flows, estimated sediment transport is also expected to increase slightly as measured by cumulative mass change along the reach. Small (2%) erosional losses of sediment are expected in the Upper Reach, though the changes may not be measurable relative to existing conditions. However, this erosional loss is offset by a 3% increase in sediment deposition in the lower reaches, which may also not be measurable. A net erosion of sediment from the Clearwater River below Patterson Lake and deposition in the Forrest Lake – North Basin is expected, but this loss is the same magnitude for the Application Case as the Base Case (Table 9.3-11).

Table 9.6-9: Application Case Fluvial Sediment Transport in the Clearwater River below Patterson Lake

Assessment Case	Mean Annual Maximum Daily Flow (m^3/s)	Longitudinal Cumulative Mass Change (t/yr)					
		Upper Reach	% Change	Lower Reach			Net Balance
				North Channel	South Channel	% Change	
Base Case	1.89	-86	n/a	27	36	n/a	-23
Application Case	1.92	-88	2%	28	37	3%	-23

Source: Appendix 9B.
n/a = not applicable.

9.6.2 Reasonably Foreseeable Development Case

The RFD Case includes the Base Case, Application Case, and Fission Patterson Lake South Property effects under historical climate conditions.

The Fission Patterson Lake South Property is an RFD located on the west shore of Patterson Lake where the North Arm and South Arm meet. The Fission Patterson Lake South Property activities would remove area from the Patterson Lake watershed, withdraw water from Patterson Lake, and release water to Patterson Lake. This development would withdraw fresh water from the Patterson Lake North Arm West Basin and discharge treated effluent and treated sewage to the Patterson Lake South Arm (Fission 2019). The Fission Patterson Lake South Property would have a net discharge of water to Patterson Lake during construction and operations, further increasing flows in the Clearwater River below Patterson Lake.

The RFD Case assumes a net discharge of water to Patterson Lake from Project activities and the Fission Patterson Lake South Property during the Project lifespan. The net discharge of water to the receiving environment would result in an increase to Patterson Lake water levels and flows in the Clearwater River below Patterson Lake.

In the absence of detailed information, construction of Fission Patterson Lake South Property was assumed to occur over a three-year period commencing in 2025. The operating period (production and processing) was expected to be seven years long and extend from 2027 to 2033 (Fission 2019). The year 2027 was assumed to include construction activities as well as operating activities. This is conservative as it assumes Fission Patterson Lake South Property construction and operation overlaps with the Project.

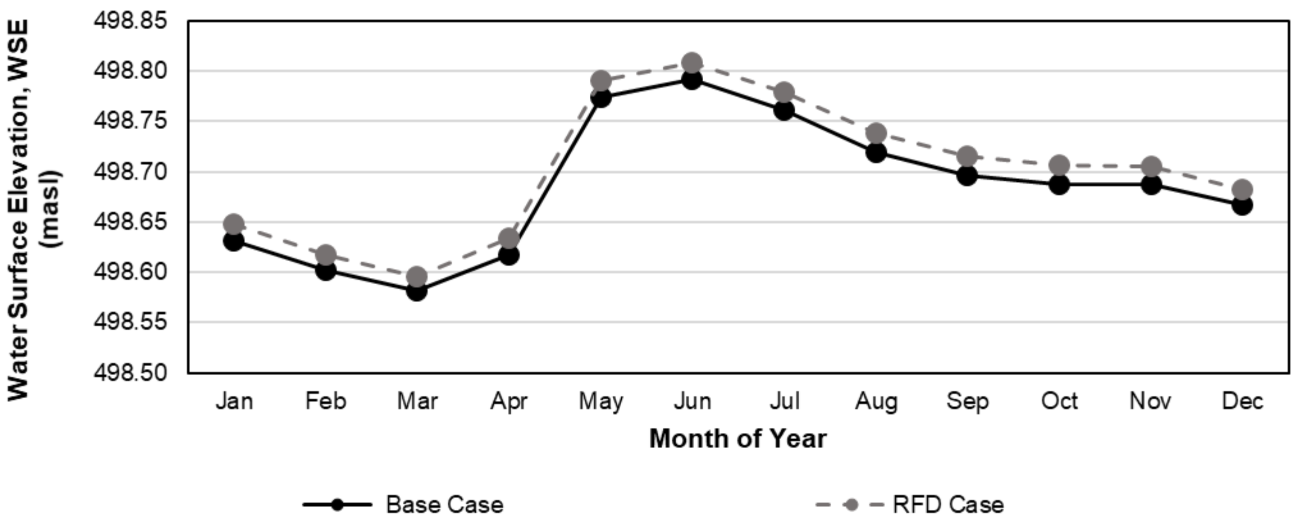
Effects are likely to occur but are uncertain given that the Fission Patterson Lake South Property has recently entered the formal regulatory application process. The duration of the change due to Fission Patterson Lake South Property is expected to be limited due to its relatively short operating period.

Results from the RFD Case are summarized in this subsection with additional detail on methods and results provided in Appendix 9A.

9.6.2.1 Waterbody Water Surface Elevation

For the RFD Case, increases in Patterson Lake WSE are predicted to be slightly higher than the Base Case in all months, as shown in Figure 9.6-8 (Table 9.6-10 and Table 9.6-11). For Patterson Lake, predicted average increases in WSE are highest during spring freshet in April (i.e., 0.035 m) and May (i.e., 0.027 m) and increases are less for the other months. Regional hydrological model results for Forrest, Beet, and Naomi lakes show nearly uniform increases in every month of the year and all are less than 0.01 m, which represents a small increase that would be difficult to differentiate from existing conditions. On an annual basis, percent changes in WSE are expected to range from 0.4% for Beet and Naomi lakes to 2.2% for Patterson Lake (Table 9.6-12).

Figure 9.6-5: Patterson Lake Monthly Water Surface Elevation for the Reasonably Foreseeable Developments Case and Base Case



masl = metres above sea level.

Table 9.6-10: Predicted Reasonably Foreseeable Developments Case Mean Monthly Lake Water Surface Elevations

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	498.643	498.614	498.595	498.652	498.801	498.806	498.774	498.734	498.714	498.706	498.705	498.679	498.702
Forrest Lake	498.322	498.294	498.277	498.313	498.455	498.476	498.450	498.417	498.401	498.397	498.391	498.357	498.379
Beet Lake	498.299	498.280	498.261	498.273	498.372	498.351	498.331	498.315	498.309	498.308	498.319	498.318	498.311
Naomi Lake	498.260	498.239	498.230	498.273	498.428	498.392	498.355	498.332	498.325	498.322	498.308	498.283	498.312

masl = metres above sea level; WSE = water surface elevation.

Table 9.6-11: Changes in Mean Monthly Lake Water Surface Elevations in the Reasonably Foreseeable Developments Case relative to the Base Case

Location	Change in Monthly WSE (m)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	0.011	0.012	0.014	0.035	0.027	0.014	0.013	0.015	0.017	0.019	0.017	0.013	0.017
Forrest Lake	0.008	0.007	0.007	0.008	0.007	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.008
Beet Lake	0.004	0.004	0.004	0.004	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Naomi Lake	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004

WSE = water surface elevation.

Table 9.6-12: Percent Changes in Lake Water Surface Elevations in the Reasonably Foreseeable Developments Case relative to the Base Case

Location	Percent Change in Monthly WSE (%)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	1.5%	1.7%	2.0%	4.7%	3.1%	1.5%	1.5%	1.8%	2.2%	2.4%	2.1%	1.6%	2.2%
Forrest Lake	1.4%	1.5%	1.5%	1.5%	1.1%	1.1%	1.1%	1.3%	1.3%	1.4%	1.4%	1.4%	1.3%
Beet Lake	0.4%	0.4%	0.4%	0.4%	0.3%	0.4%	0.4%	0.4%	0.4%	0.5%	0.4%	0.4%	0.4%
Naomi Lake	0.4%	0.4%	0.4%	0.4%	0.2%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%

WSE = water surface elevation.

The RFD Case results indicate the predicted range of Patterson Lake WSEs would be 0.859 m based on 43 years of daily mean values (Table 9.6-13), which is slightly less than the Base Case range of 0.878 m (Table 9.4-4). The range in WSEs at locations farther downstream is also expected to be slightly reduced (i.e., by less than 0.003 m); these changes would not be able to be differentiated from existing conditions.

Table 9.6-13: Reasonably Foreseeable Development Case Waterbody Water Surface Elevation Statistics

Location	Waterbody WSE			
	Mean (masl)	Maximum (masl)	Minimum (masl)	Range (m)
Patterson Lake	498.702	499.165	498.306	0.859
Forrest Lake	498.380	498.719	498.022	0.697
Beet Lake	498.312	498.501	498.117	0.384
Naomi Lake	498.313	498.575	498.054	0.521

masl = metres above sea level; WSE = water surface elevation.

9.6.2.2 Watercourse Flow Rates

For the RFD Case, predicted flows for the Clearwater River downstream of Patterson Lake are expected to increase relative to the Base Case in response to a net discharge of water to Patterson Lake from Fission Patterson Lake South Property activities during the timeline associated with construction, operations, and active closure as well as Project activities during the timeline associated with Construction, Operations, and the Active Closure Stage. Predicted increases include simulation of the largest increase during the lifespan of the Project and are variable over time. The effect on flows is predicted to cease following the Active Closure Stage.

Predictions of mean monthly discharge in the Clearwater River below Patterson Lake for the RFD Case are compared with the Base Case in Figure 9.6-6. Mean monthly flows are provided in Table 9.6-14, changes in mean monthly flows are provided in Table 9.6-15, and percent changes are provided in Table 9.6-16. Mean monthly flows for the Clearwater River below Patterson Lake are expected to increase between 2.7% and 3.6%, and the annual mean increase is expected to be 3.1%. For locations farther downstream, percent increases in annual mean flow are predicted to be less than 2.0%. These changes would not be detectable at the hydrometric stations as they are within the acceptable margin of error of individual discharge measurements and would be difficult to distinguish from existing conditions.

Figure 9.6-6: Clearwater River below Patterson Lake Monthly Flows in the Reasonably Foreseeable Development Case and Base Case

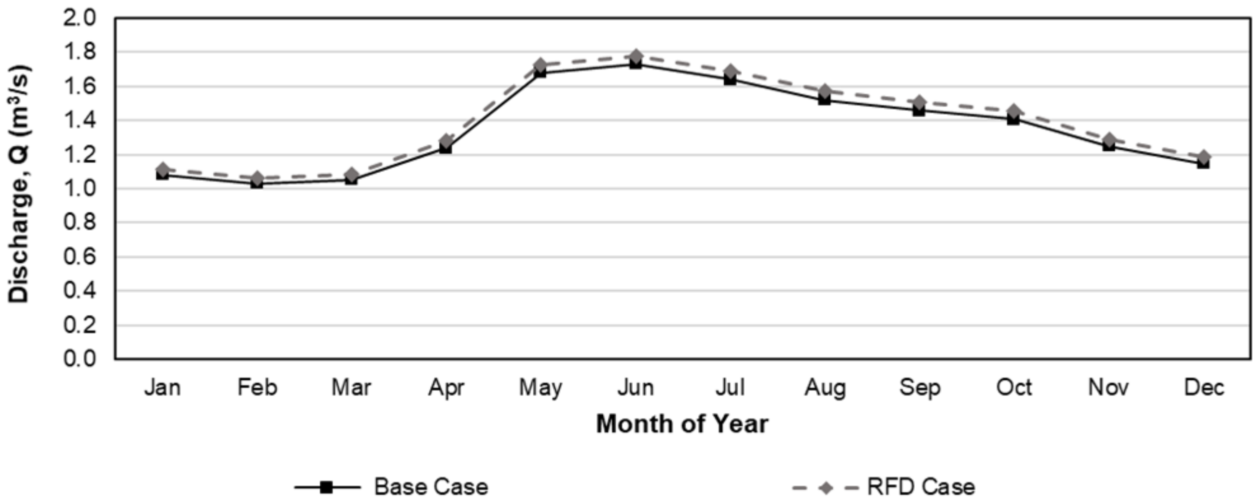


Table 9.6-14: Reasonably Foreseeable Development Case Mean Monthly Discharges

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	1.11	1.06	1.08	1.28	1.72	1.78	1.69	1.57	1.51	1.46	1.29	1.18	1.39
Clearwater River below Forrest Lake	1.92	1.77	1.69	1.88	2.72	2.85	2.68	2.47	2.39	2.38	2.34	2.13	2.27
Clearwater River below Beet Lake	2.02	1.87	1.81	2.11	3.35	3.05	2.79	2.60	2.55	2.54	2.40	2.22	2.44
Clearwater River below Naomi Lake	2.49	2.27	2.17	2.62	4.63	4.09	3.58	3.30	3.24	3.23	3.05	2.75	3.12
Clearwater River above Mirror River confluence	3.56	3.51	3.55	6.07	10.00	8.03	6.68	6.08	6.06	6.06	5.40	4.01	5.75

Table 9.6-15: Changes in Mean Monthly Discharges in the Reasonably Foreseeable Development Case from the Base Case

Location	Percent (%) Change Relative to the Base Case											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clearwater River below Patterson Lake	3.1%	3.1%	3.0%	3.1%	2.7%	2.7%	3.0%	3.4%	3.6%	3.5%	3.3%	3.1%
Clearwater River below Forrest Lake	1.9%	1.9%	1.9%	1.9%	1.7%	1.7%	1.7%	2.0%	2.1%	2.1%	2.0%	1.9%
Clearwater River below Beet Lake	1.8%	1.8%	1.7%	1.9%	1.4%	1.6%	1.6%	1.8%	1.9%	2.0%	1.9%	1.9%
Clearwater River below Naomi Lake	1.5%	1.5%	1.5%	1.5%	1.0%	1.1%	1.3%	1.4%	1.6%	1.6%	1.5%	1.5%
Clearwater River above Mirror River	1.1%	1.0%	1.0%	0.7%	0.4%	0.6%	0.6%	0.9%	1.0%	1.0%	0.8%	1.1%

Table 9.6-16: Summarized Flow Characteristics for the Reasonably Foreseeable Development Case

Location	Mean Annual Minimum Daily Flow		Mean Annual Daily Flow		Mean Annual Maximum Daily Flow	
	(m^3/s)	% Change	(m^3/s)	% Change	(m^3/s)	% Change
Clearwater River below Patterson Lake	0.89	3.4%	1.40	3.1%	1.95	2.6%
Clearwater River below Forrest Lake	1.51	1.9%	2.29	1.9%	3.24	1.6%
Clearwater River below Beet Lake	1.58	1.9%	2.46	1.7%	3.90	1.3%
Clearwater River below Naomi Lake	1.87	1.7%	3.14	1.4%	5.43	0.9%
Clearwater River above Mirror River	2.76	1.6%	5.81	0.7%	12.82	0.1%

9.6.2.3 *Stream Channel Parameters*

In the RFD Case, increased mean annual flows downstream of the Project relative to existing conditions are anticipated to result in small changes to stream channel parameters. Predicted changes in stream channel parameters using wetted area as the representative parameter are provided in Table 9.6-17. Changes are predicted to be up to 2.3% at the Clearwater River below Patterson Lake. Wetted area is expected to increase by 0.12 m^2 at this location, and the main change in channel dimensions is related to increased wetted width (i.e., 0.08 m) with only a small (i.e., 0.01 m) predicted increase in average water depth. These changes are not expected to be detectable relative to existing conditions.

Table 9.6-17: Changes in Wetted Area at the Mean Annual Flow for the Reasonably Foreseeable Development Case relative to the Base Case

Location	Mean Annual Flow (m^3/s)	Wetted Area at the Mean Annual Flow (m^2)	% Change Wetted Area
Clearwater River below Patterson Lake	1.40	5.3	2.3%
Clearwater River below Beet Lake	2.46	14.6	0.6%
Clearwater River below Naomi Lake	3.14	14.0	0.4%
Clearwater River above the Mirror River confluence	5.81	34.8	0.6%

Source: Appendix 9A; Annex IV.2.

9.6.2.4 *Fluvial Sediment Transport*

Fluvial sediment transport was assessed for the Clearwater River below Patterson Lake along the reach from Patterson Lake to the north end of Forrest Lake. Changes in sediment transport assessed for the Upper Reach (upstream of the channel bifurcation) and in both the north and south lower reaches (close to the Forrest Lake inflow) are provided in Table 9.6-18. With a slight increase in mean annual maximum daily flows, estimated sediment transport is also expected to increase slightly relative to existing conditions as measured by cumulative mass change along the reach. Erosional losses of sediment of about 5% are expected in the Upper Reach although the changes may not be measurable relative to existing conditions. However, this loss is offset by a 6% increase in sediment deposition in the lower reaches, which may also not be measurable. The net balance of sediment transport for the entire reach is expected to be a loss of sediment to Forrest Lake at the Clearwater River inflow, but loss is the same magnitude for the RFD Case as the Base Case (Table 9.3-11).

Table 9.6-18: Fluvial Sediment Load in the Clearwater River below Patterson Lake for the Reasonably Foreseeable Development Case relative to the Base Case

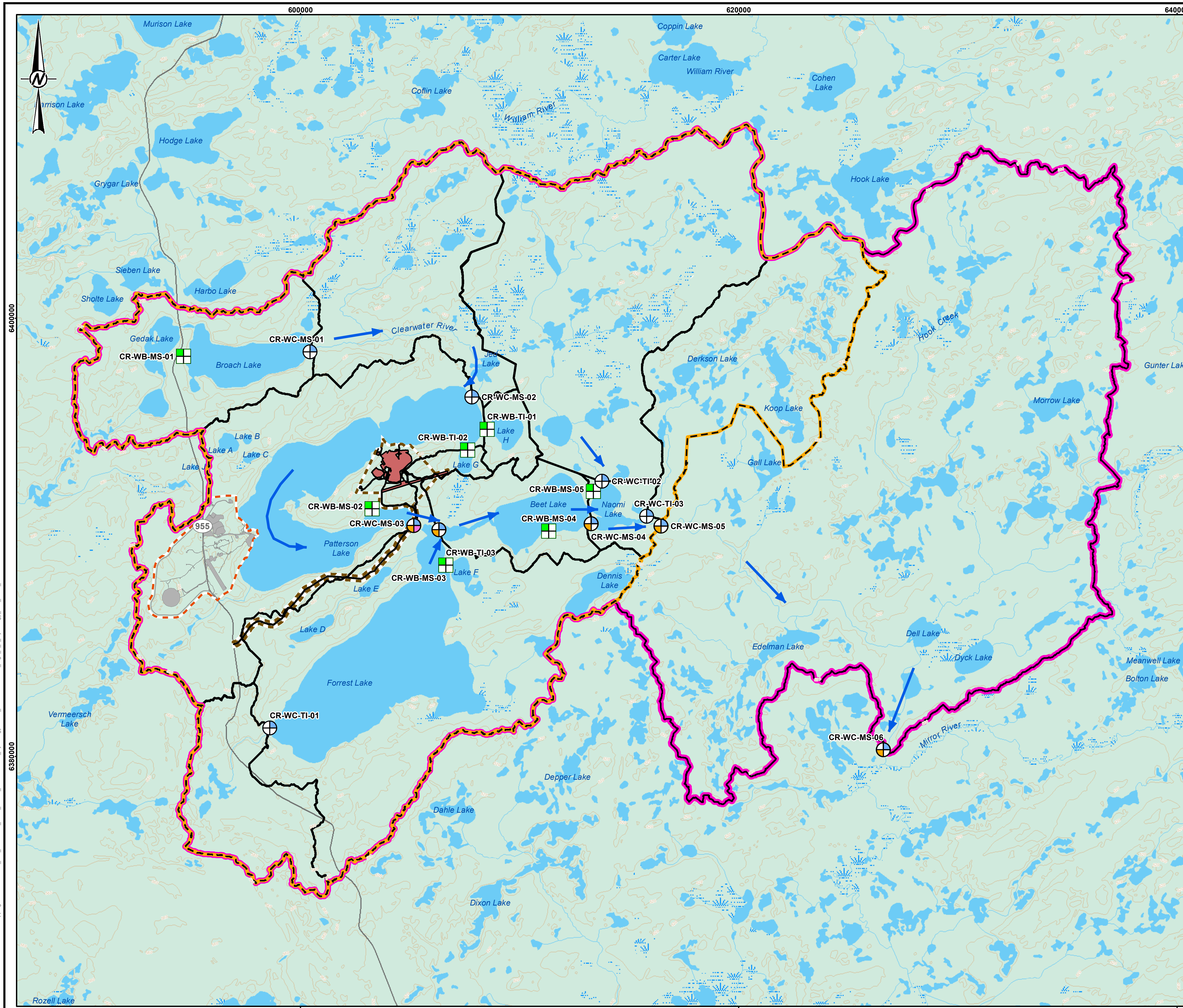
Assessment Case	Mean Annual Maximum Daily Flow (m^3/s)	Longitudinal Cumulative Mass Change (t/yr)						
		Upper Reach	% Change	Lower Reach			Net Balance
				North Channel	South Channel	% Change	
Base Case	1.89	-86	n/a	27	36	n/a	-23
RFD Case	1.95	-90	5%	29	38	6%	-23

Source: Appendix 9B.
n/a = not applicable; RFD = reasonably foreseeable development.

9.6.3 Reasonably Foreseeable Development Case (including Climate Change)

The RFD Case (including climate change) includes all developments assessed for the Base Case, Application Case, and the Fission Patterson Lake South Property as well as climate change that may interact with the Project and other developments to affect hydrology. The climate change scenario used in the RFD Case (including climate change) represents projected climate change for the 2050s and therefore provides more conservative results compared to using projections from the 2020s (Section 9.4). The projects included in the RFD Case (including climate change) are shown in Figure 9.6-7.

The water level increase in Patterson Lake in the RFD Case (including climate change) would propagate downstream and diminish in relative magnitude as the watershed area and ambient flows increase. However, the future increases in Patterson Lake water levels relative to the Base Case are mainly due to changes to hydrology related to the climate change scenario (Section 9.4).



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED

WATER BODY HYDROMETRIC STATIONS

- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- STREAM CHANNEL PARAMETERS
- FLUVIAL SEDIMENT TRANSPORT
- WATERCOURSE FLOW RATE

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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

HYDROLOGY REASONABLY FORESEEABLE DEVELOPMENT CASE

CONSULTANT

wsp

PROJECT		20144150	PHASE		3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN		REV. 0
GIS	LB/NO	2023-02-10	**FIGURE 9.6-7**		
CHECK	RWP	2023-02-10			
REVIEW	NPS	2023-02-10			

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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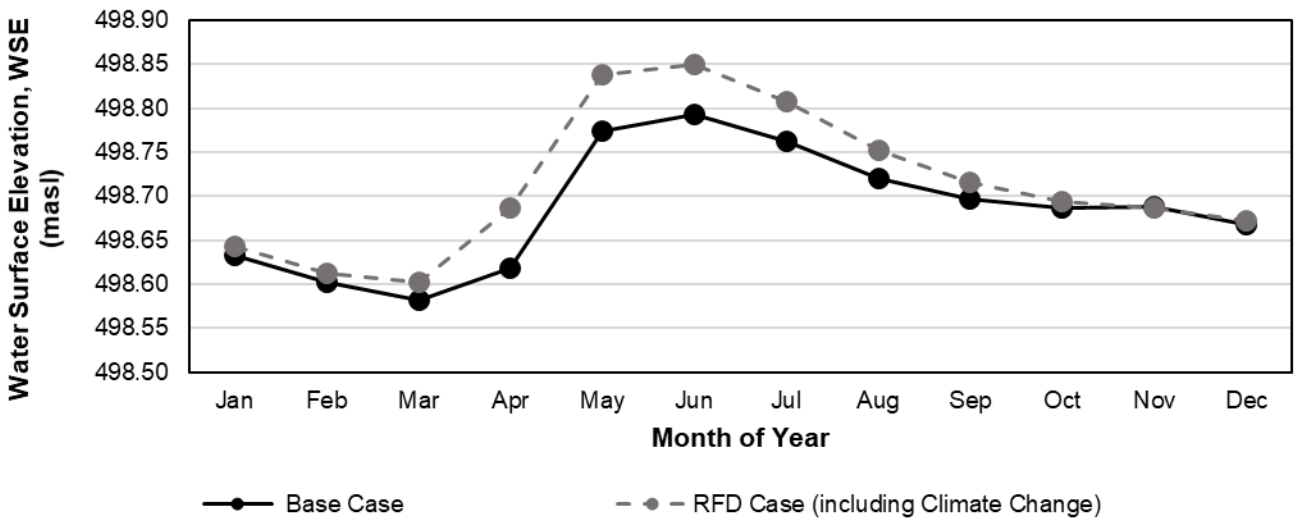
9.6.3.1 Waterbody Water Surface Elevations

Patterson Lake WSE is expected to increase in the RFD Case (including climate change) relative to the Base Case in response to climate change and a net discharge of water to Patterson Lake from the Project and Fission Patterson Lake South Property. Predictions of mean monthly Patterson Lake WSEs for the RFD Case (including climate change) are compared with the Base Case in Figure 9.6-8. Predicted mean monthly WSEs are summarized in Table 9.6-19 and changes in mean monthly values are presented in Table 9.6-20. Percent changes in waterbody WSEs are provided in Table 9.6-21. Climate change accounts for most of the predicted changes for the RFD Case (including climate change), including an earlier spring freshet and higher flows during the months of April through August (Figure 9.4-1).

Figure 9.6-8: Patterson Lake Monthly Water Surface Elevation in the Reasonably Foreseeable Development Case (including Climate Change) and Base Case



masl = metres above sea level; RFD = reasonably foreseeable development.

Table 9.6-19: Reasonably Foreseeable Development Case (including Climate Change) Mean Monthly Lake Water Surface Elevation

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	498.638	498.609	498.605	498.709	498.847	498.846	498.801	498.745	498.712	498.693	498.686	498.669	498.713
Forrest Lake	498.314	498.291	498.287	498.359	498.500	498.510	498.471	498.423	498.394	498.380	498.371	498.345	498.387
Beet Lake	498.291	498.266	498.255	498.302	498.395	498.366	498.340	498.316	498.303	498.296	498.299	498.306	498.311
Naomi Lake	498.254	498.238	498.237	498.318	498.458	498.411	498.365	498.332	498.317	498.307	498.291	498.268	498.316

Source: Appendix 9A.
masl = metres above sea level; WSE = water surface elevation.

Table 9.6-20: Reasonably Foreseeable Development Case (including Climate Change) Changes in Mean Monthly Lake Water Surface Elevation relative to the Base Case

Location	Change in Monthly WSE (m)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	0.006	0.007	0.024	0.091	0.073	0.053	0.039	0.026	0.015	0.006	-0.002	0.003	0.028
Forrest Lake	0.000	0.004	0.017	0.053	0.052	0.042	0.028	0.013	0.001	-0.008	-0.012	-0.005	0.016
Beet Lake	-0.004	-0.009	-0.001	0.033	0.026	0.019	0.013	0.005	-0.001	-0.008	-0.015	-0.008	0.004
Naomi Lake	-0.002	0.003	0.011	0.049	0.032	0.021	0.013	0.004	-0.003	-0.010	-0.013	-0.010	0.008

Source: Appendix 9A.
WSE = water surface elevation.

Table 9.6-21: Reasonably Foreseeable Development Case (including Climate Change) Percent Change in Mean Monthly Lake Water Surface Elevation Relative to the Base Case

Location	Percent Change in Monthly WSE (%)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	0.8%	1.0%	3.5%	12.5%	8.3%	5.9%	4.5%	3.1%	1.9%	0.7%	-0.3%	0.4%	3.5%
Forrest Lake	0.0%	0.9%	3.5%	10.3%	7.9%	6.1%	4.2%	2.2%	0.2%	-1.3%	-2.0%	-0.8%	2.6%
Beet Lake	-0.4%	-1.0%	-0.2%	3.6%	2.5%	1.9%	1.3%	0.5%	-0.1%	-0.8%	-1.6%	-0.8%	0.4%
Naomi Lake	-0.2%	0.3%	1.1%	4.7%	2.7%	1.8%	1.2%	0.4%	-0.3%	-0.9%	-1.2%	-1.0%	0.7%

WSE = water surface elevation.

In the RFD Case (including climate change), the predicted range of Patterson Lake WSEs is 0.99 m based on 43 years of daily mean values (Table 9.6-22), which is 0.11 m higher than the Base Case range of 0.88 m (Table 9.4-4). At all the waterbodies, maximum values are expected to increase and minimum values are expected to decrease from the values shown in Table 9.3-4. For the other receiving environment waterbodies, the range of WSEs (i.e., the variability) is also predicted to increase relative to the Base Case, mainly because of the climate change scenario. It is noted that the range is lower for the RFD Case (including climate change) than for the climate change scenario.

Table 9.6-22: Reasonably Foreseeable Development Case (including Climate Change) Waterbody Water Surface Elevation Statistics

Location	Waterbody WSE			
	Mean (masl)	Maximum (masl)	Minimum (masl)	Range (m)
Patterson Lake	498.714	499.237	498.248	0.989
Forrest Lake	498.388	498.770	497.962	0.808
Beet Lake	498.312	498.515	498.083	0.432
Naomi Lake	498.317	498.590	498.016	0.574

masl = metres above sea level; WSE = water surface elevation.

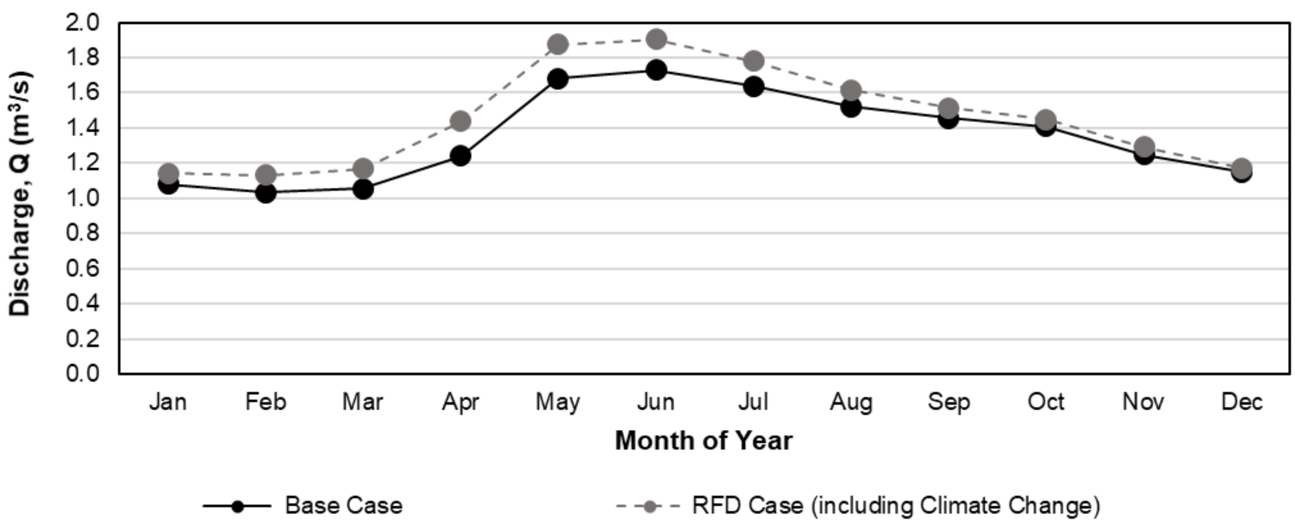
9.6.3.2 Watercourse Flow Rates

Flows in the Clearwater River below Patterson Lake are expected to increase in the RFD Case (including climate change) in response to climate change and, to a lesser degree, developments. The changes that can be attributed to climate change are discussed in detail in Section 9.4.2. Predictions of mean monthly flows in the Clearwater River below Patterson Lake for the RFD Case (including climate change) are compared with the

Base Case in Figure 9.6-9. Mean monthly flows are provided in Table 9.6-23, changes in mean monthly values are provided in Table 9.6-24, and percent changes are provided in Table 9.6-25. Increases in mean monthly flows above the Base Case are predicted for every month of the year and the increases are highest for the months of February through July. Increases are mainly due to the influence of the climate change scenario and, to a lesser extent, to the cumulative developments (Section 9.6.3).

Percent increases in mean annual flows above existing conditions are highest for the Clearwater River below Patterson Lake (i.e., 7.6%) and the increase was slightly lower upstream (i.e., between 4.9% and 7.0% depending on the location). Mean annual minimum daily flows are predicted to increase for the Clearwater River below Patterson and Forrest lakes but decrease for the other locations farther downstream. Mean annual maximum daily flows are predicted to increase for all locations (i.e., between 3.9% and 9.7% depending on the location).

Figure 9.6-9: Clearwater River below Patterson Lake Monthly Flows for the Reasonably Foreseeable Development Case (including Climate Change) and Base Case



RFD = reasonably foreseeable development.

Table 9.6-23: Reasonably Foreseeable Development Case (including Climate Change) Mean Monthly Discharges

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	1.14	1.13	1.17	1.44	1.88	1.90	1.78	1.61	1.51	1.45	1.29	1.17	1.46
Clearwater River below Forrest Lake	1.91	1.79	1.76	2.17	3.05	3.11	2.84	2.52	2.36	2.31	2.26	2.10	2.35
Clearwater River below Beet Lake	2.03	1.89	1.89	2.50	3.71	3.30	2.94	2.64	2.51	2.45	2.30	2.15	2.53
Clearwater River below Naomi Lake	2.47	2.29	2.27	3.20	5.15	4.40	3.75	3.34	3.18	3.11	2.91	2.65	3.23
Clearwater River above Mirror River confluence	3.47	3.61	4.09	7.51	10.85	8.75	7.11	6.27	6.13	6.05	5.44	4.13	6.12

Source: Appendix 9A.

Table 9.6-24: Changes in Mean Monthly Discharges for the Reasonably Foreseeable Development Case (including Climate Change) relative to the Base Case

Location	Percent (%) Change Relative to the Base Case												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	5.6%	9.5%	10.9%	16.0%	11.6%	10.2%	8.6%	6.2%	3.9%	3.0%	3.6%	2.1%	7.6%
Clearwater River below Forrest Lake	1.4%	2.6%	6.4%	17.4%	14.1%	11.1%	7.9%	4.2%	1.1%	-1.0%	-1.5%	0.5%	5.3%
Clearwater River below Beet Lake	2.4%	3.2%	6.2%	20.5%	12.3%	9.6%	6.9%	3.2%	0.2%	-1.7%	-2.1%	-1.1%	5.0%
Clearwater River below Naomi Lake	0.9%	2.4%	6.4%	23.9%	12.4%	8.9%	6.3%	2.6%	-0.2%	-2.2%	-3.0%	-2.0%	4.7%
Clearwater River above Mirror River confluence	-1.4%	3.6%	16.3%	24.5%	8.9%	9.5%	7.1%	4.1%	2.2%	0.8%	1.6%	4.1%	6.8%

Source: Appendix 9A.

Table 9.6-25: Summarized Flow Characteristics for Reasonably Foreseeable Development Case (including Climate Change)

Location	Mean Annual Minimum Daily Flow		Mean Annual Daily Flow		Mean Annual Maximum Daily Flow	
	(m^3/s)	% Change	(m^3/s)	% Change	(m^3/s)	% Change
Clearwater River below Patterson Lake	0.89	3.0%	1.46	7.5%	2.07	9.0%
Clearwater River below Forrest Lake	1.49	1.0%	2.36	5.4%	3.50	9.7%
Clearwater River below Beet Lake	1.55	-0.3%	2.54	5.1%	4.17	8.3%
Clearwater River below Naomi Lake	1.84	-0.3%	3.25	4.9%	5.81	8.1%
Clearwater River above the Mirror River confluence	2.66	-2.0%	6.17	7.0%	13.3	3.9%

Source: Appendix 9A.

9.6.3.3 Stream Channel Parameters

In the RFD Case (including climate change), increased mean annual flows downstream of the Project are anticipated to result in small changes to stream channel parameters that are mainly due to increases in flows resulting from climate change. Predicted changes in stream channel parameters using wetted area as the representative parameter are provided in Table 9.6-26. Changes are predicted to be up to 5.7% at the Clearwater River below Patterson Lake. Wetted area is expected to increase by 0.31 m^2 at this location in the RFD Case (including climate change). The main changes in channel dimensions are related to increased wetted width (i.e., 0.21 m), with only a small (i.e., 0.02 m) increase in average water depth. Therefore, these changes are not expected to be large enough in magnitude to change how the watercourses are used by humans for navigation, may in fact slightly improve navigation, and are well within the range of natural variation.

Table 9.6-26: Changes in Wetted Area at the Mean Annual Flow for the Reasonably Foreseeable Development Case (including Climate Change) relative to the Base Case

Location	Mean Annual Flow (m^3/s)	Wetted Area at the Mean Annual Flow (m^2)	% Change Wetted Area
Clearwater River below Patterson Lake	1.46	5.5	5.7%
Clearwater River below Beet Lake	2.54	14.8	1.8%
Clearwater River below Naomi Lake	3.25	14.2	1.5%
Clearwater River above the Mirror River confluence	6.17	36.7	5.6%

Source: Appendix 9A; Annex IV.2.

9.6.3.4 Fluvial Sediment Transport

Fluvial sediment transport was assessed for the Clearwater River below Patterson Lake along the reach from Patterson Lake to the north end of Forrest Lake. Changes in sediment load assessed at one location in the Upper Reach (upstream of the channel bifurcation) and in both the north and south lower reaches (close to Forrest Lake inflow) are provided in Table 9.6-27. Flood flows are predicted to increase in the RFD Case (including climate change) due to increased net discharge from developments, as well as with wetter and warmer conditions from climate change; estimated sediment transport is also predicted to increase as measured by cumulative mass change along the reach. Erosional losses are expected in the Upper Reach with increased flows; however, this loss is offset by sediment deposition in the lower reaches. The net balance for the entire reach was negative, which represents a net loss of sediment from the reach to downstream areas, but this loss is predicted to be of a similar magnitude as the Base Case. The bulk of the changes in fluvial sediment transport are due to changes in flows from climate change (Table 9.4-8).

Table 9.6-27: Fluvial Sediment Load in the Clearwater River below Patterson Lake for the Reasonably Foreseeable Development Case (including Climate Change) relative to the Base Case

<table>
<tr><th rowspan="3">Assessment Case</th><th rowspan="3">Median Annual Maximum Daily Flow (m^3/s)</th><th colspan="6">Longitudinal Cumulative Mass Change (t/yr)</th></tr>
<tr><th rowspan="2">Upper Reach</th><th rowspan="2">% Change</th><th colspan="3">Lower Reach</th><th rowspan="2">Net Balance</th></tr>
<tr><th>North Channel</th><th>South Channel</th><th>% Change</th></tr>
<tr><td>Base Case</td><td>1.89</td><td>-86</td><td>n/a</td><td>27</td><td>36</td><td>n/a</td><td>-23</td></tr>
<tr><td>RFD Case</td><td>2.05</td><td>-97</td><td>13%</td><td>33</td><td>41</td><td>17%</td><td>-23</td></tr>
</table>

Source: Appendix 9B.
RFD = reasonably foreseeable development.

9.7 Residual Effects Classification

Residual effects after the implementation of mitigation are described for the Application Case and RFD Case scenarios and summarized in Table 9.7-1 according to direction, magnitude, geographic extent, duration/reversibility, frequency, and probability of occurrence, following the methods described in Section 9.2.9. Residual effects for the RFD Case scenarios are presented in terms of the total (i.e., RFD Case [including climate change]) as well as the sub-components of the RFD Case and climate change scenario.

The classification is structured to clearly communicate the residual effects for each of the assessment cases, the Application Case and the RFD Case scenarios. The Application Case for hydrology represents predictions of the combined effects of the previous and existing projects/activities and natural factors in the Base Case plus the effects from the Project. The Application Case represents the incremental, Project-specific changes that are predicted to occur to hydrology. The assessment of the RFD Case scenarios was classified based on the RFD Case, climate change scenario, and RFD Case (including climate change), which includes both cumulative developments and climate change. The RFD Case includes the Base Case, Application Case, and Fission Patterson Lake South Property effects under historical climate conditions. The climate change scenario includes the effect of projected climate change without the Application Case and Fission Patterson Lake South Property effects. The RFD Case (including climate change) includes the combined effects of the RFD Case and climate change scenarios.

The residual effects classification for waterbody water levels is structured using a summary table organized to present each waterbody expected to be affected by the Project. The receiving environment waterbodies carried forward for the residual effects analysis included Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake.

The residual effects classification for watercourse stream flows is structured using a summary table organized to present each watercourse expected to be affected by the Project. The receiving environment watercourses carried forward for the residual effects analysis included the Clearwater River below Patterson Lake, the Clearwater River below Forrest Lake, the Clearwater River below Beet Lake, the Clearwater River below Naomi Lake, and the Clearwater River above the Mirror River confluence.

Changes in stream channel parameters are based on predicted changes in mean annual flows in the hydrology RSA and results are therefore in the same direction as predicted changes to mean annual flows. For simplicity, the stream channel parameters listed in the residual effects classification table references predicted percent changes to channel wetted area that are based on changes in mean annual flow conditions.

Percent changes during the Application Case and the RFD Case are the percent changes relative to corresponding measurement indicator values for the Base Case. Effects during the Application Case are classified as reversible because the magnitude and direction of effects to a measurement indicator is predicted to cease after Active Closure. Effective implementation of mitigation outlined in Section 9.5 is expected to reduce the magnitude and duration of residual effects on hydrology.

Table 9.7-1: Classification of Residual Effects for the Clearwater River Hydrology Nodes

Measurement Indicator	Criterion	Rating / Effect Size			
		Application Case	RFD Case Scenarios		
			RFD Case	Climate Change	Total (i.e., RFD Case [including Climate Change])
Waterbody WSE	Direction	Increase	Increase	Decrease and Increase	Increase
	Magnitude	Ranges from 0.2% (0.002 m) annual increase at Beet and Naomi lakes to 1.0% (0.008 m) at Patterson Lake (low magnitude)	Ranges from 0.4% (0.004 m) at Beet and Naomi lakes to 2.2% (0.017 m) at Patterson Lake (low magnitude)	Ranges from -0.01% (0.000 m) annual decrease for Beet Lake, and 0.33% (0.004 m) annual increase for Naomi Lake to 1.6% (0.013 m) at Patterson Lake (low magnitude)	Ranges from 0.4% (0.004 m) annual increase for Beet Lake to 3.5% (0.028 m) at Patterson Lake (low magnitude)
	Geographic extent	Regional	Regional	Beyond regional	Regional[b]
	Duration[a]	Long-term: 43 years (2025 to 2068)	Medium-term: Maximum of 15 years (nominally modelled as 2025 to 2039) of temporal overlap between the Project and the Fission Patterson Lake South Property. Effect on water quantity primarily during construction and operations period of nine years (nominally modelled as 2025 to 2033)	Permanent	Permanent
	Reversibility	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Irreversible	Irreversible
	Frequency	Continuous	Continuous	Continuous/periodic	Continuous/periodic
	Probability of occurrence	Certain	Probable	Probable	Probable

Table 9.7-1: Classification of Residual Effects for the Clearwater River Hydrology Nodes

Measurement Indicator	Criterion	Rating / Effect Size			
		Application Case	RFD Case Scenarios		
			RFD Case	Climate Change	Total (i.e., RFD Case [including Climate Change])
Watercourse mean annual maximum daily flow	Direction	Increase	Increase	Increase	Increase
	Magnitude	Ranges from 0.7% at Clearwater River above Mirror River confluence to 1.4% at Clearwater River below Patterson Lake (low magnitude)	Ranges from 0.1% at Clearwater River above Mirror River to 2.6% at Clearwater River below Patterson Lake (low magnitude)	Ranges from 3.2% at Clearwater River above Mirror River confluence to 8.0% at Clearwater River below Patterson Lake (low magnitude)	Ranges from 3.9% at Clearwater River above Mirror River confluence to 9.7% at Clearwater River below Forrest Lake (low magnitude)
	Geographic extent	Regional	Regional	Beyond regional	Regional[b]
	Duration[a]	Long-term: 43 years (2025 to 2068)	Medium-term: Maximum of 15 years (nominally modelled as 2025 to 2039) of temporal overlap between the Project and the Fission Patterson Lake South Property. Effect on water quantity primarily during construction and operations period of nine years (nominally modelled as 2025 to 2033)	Permanent	Permanent
	Reversibility	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Irreversible	Irreversible
	Frequency	Continuous	Continuous	Continuous/periodic	Continuous/periodic
	Probability of occurrence	Certain	Probable	Probable	Probable

Table 9.7-1: Classification of Residual Effects for the Clearwater River Hydrology Nodes

Measurement Indicator	Criterion	Rating / Effect Size			
		Application Case	RFD Case Scenarios		
			RFD Case	Climate Change	Total (i.e., RFD Case [including Climate Change])
Watercourse mean annual flow	Direction	Increase	Increase	Increase	Increase
	Magnitude	Ranges from 0.7% at Clearwater River above Mirror River confluence to 1.6% at Clearwater River below Patterson Lake (low magnitude)	Ranges from 0.7% at Clearwater River above Mirror River confluence to 3.1% at Clearwater River below Patterson Lake (low magnitude)	Ranges from 3.4% at Clearwater River below Beet Lake to 6.2% at Clearwater River above Mirror River confluence (low magnitude)	Ranges from 4.9% Clearwater River below Naomi Lake to 7.5% Clearwater River below Patterson Lake (low magnitude)
	Geographic extent	Regional	Regional	Beyond regional	Regional[b]
	Duration[a]	Long-term: 43 years (2025 to 2068)	Medium-term: Maximum of 15 years (nominally modelled as 2025 to 2039) of temporal overlap between the Project and the Fission Patterson Lake South Property. Effect on water quantity primarily during construction and operations period of nine years (nominally modelled as 2025 to 2033)	Permanent	Permanent
	Reversibility	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Irreversible	Irreversible
	Frequency	Continuous	Continuous	Continuous/periodic	Continuous/periodic
	Probability of occurrence	Certain	Probable	Probable	Probable

Table 9.7-1: Classification of Residual Effects for the Clearwater River Hydrology Nodes

Measurement Indicator	Criterion	Rating / Effect Size			
		Application Case	RFD Case Scenarios		
			RFD Case	Climate Change	Total (i.e., RFD Case [including Climate Change])
Watercourse mean annual minimum daily flow	Direction	Increase	Increase	Decrease	Increase (Patterson Lake) and decrease (downstream in the RSA)
	Magnitude	Ranges from 1.0% at Clearwater River above Mirror River confluence to 1.6% at Clearwater River below Patterson Lake (low magnitude)	Ranges from 1.6% at Clearwater River above Mirror River confluence to 3.4% at Clearwater River below Patterson Lake (low magnitude)	Ranges from -3.1% at Clearwater River above Mirror River confluence to -0.3% at Clearwater River below Patterson Lake (low magnitude)	Ranges from -2.0% at Clearwater River above Mirror River confluence to 3.0% at Clearwater River below Patterson Lake (low magnitude)
	Geographic extent	Regional	Regional	Beyond regional	Regional[b]
	Duration[a]	Long-term: 43 years (2025 to 2068)	Medium-term: Maximum of 15 years (nominally modelled as 2025 to 2039) of temporal overlap between the Project and the Fission Patterson Lake South Property. Effect on water quantity primarily during construction and operations period of nine years (nominally modelled as 2025 to 2033)	Permanent	Permanent
	Reversibility	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Irreversible	Irreversible
	Frequency	Continuous	Continuous	Continuous/periodic	Continuous/periodic
	Probability of occurrence	Certain	Probable	Probable	Probable

Table 9.7-1: Classification of Residual Effects for the Clearwater River Hydrology Nodes

Measurement Indicator	Criterion	Rating / Effect Size			
		Application Case	RFD Case Scenarios		
			RFD Case	Climate Change	Total (i.e., RFD Case [including Climate Change])
Stream channel parameters (wetted area)	Direction	Increase	Increase	Increase	Increase
	Magnitude	Ranges from 0.3% at the Clearwater River below Beet and Naomi lakes to 1.2% at the Clearwater River below Patterson Lake (low magnitude)	Ranges from 0.4% at the Clearwater River below Naomi Lake to 2.3% at the Clearwater River below Patterson Lake (low magnitude)	Ranges from 1.1% at the Clearwater River below Naomi Lake to 3.5% at the Clearwater River below Patterson Lake (low magnitude)	Ranges from 1.5% at the Clearwater River below Naomi Lake to 5.7% at the Clearwater River below Patterson Lake (low magnitude)
	Geographic extent	Regional	Regional	Beyond regional	Regional[b]
	Duration[a]	Long-term: 43 years (2025 to 2068)	Medium-term: Maximum of 15 years (nominally modelled as 2025 to 2039) of temporal overlap between the Project and the Fission Patterson Lake South Property. Effect on water quantity primarily during construction and operations period of nine years (nominally modelled as 2025 to 2033)	Permanent	Permanent
	Reversibility	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Irreversible	Irreversible
	Frequency	Continuous	Continuous	Continuous/periodic	Continuous/periodic
	Probability of occurrence	Certain	Probable	Probable	Probable

Table 9.7-1: Classification of Residual Effects for the Clearwater River Hydrology Nodes

Measurement Indicator	Criterion	Rating / Effect Size			
		Application Case	RFD Case Scenarios		
			RFD Case	Climate Change	Total (i.e., RFD Case [including Climate Change])
Fluvial sediment transport at mean annual flood	Direction	Neutral	Neutral	Neutral	Neutral
	Magnitude	Negligible	Negligible	Negligible	Negligible
	Geographic extent	Local	Local	Beyond regional	Regional[(b)]
	Duration[(a)]	Long-term: 43 years (2025 to 2068)	Medium-term: Maximum of 15 years (nominally modelled as 2025 to 2039) of temporal overlap between the Project and the Fission Patterson Lake South Property. Effect on water quantity primarily during construction and operations period of nine years (nominally modelled as 2025 to 2033)	Permanent	Permanent
	Reversibility	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Reversible at the end of the Active Closure Stage as pumping to/from Patterson Lake ceases	Irreversible	Irreversible
	Frequency	Continuous	Continuous	Continuous/periodic	Continuous/periodic
	Probability of occurrence	Certain	Probable	Probable	Probable

a) For the purpose of ease of reference in modelling, construction of the Project and Fission Patterson Lake South Property were assumed to start in 2025. This assumption is conservative as it assumes effects from construction of Project and Fission Patterson Lake South Property occur at the same time.
b) The geographic extent for total change under RFD Case (including climate change) is regional to represent the cumulative effect of developments rather than global climate change effects, which would have a beyond regional geographic extent.
RFD = reasonably foreseeable development; RSA = regional study area; WSE = water surface elevation.

9.8 Prediction Confidence and Uncertainty

The purpose of the assessment is to predict future conditions for regional hydrology, based on the assessment cases. The methods adopted for this assessment included extensive baseline studies as well as quantitative modelling and resulted in an understanding of the hydrological system, provided context for natural variability and responses to climate, and allowed for the quantitative assessment of Project effects. Therefore, predictions based on the methods adopted carry a high degree of confidence.

As with any predictions of future conditions, the predictions made in this assessment embody some degree of uncertainty. The assessment applied a precautionary approach to address uncertainty by identifying the greatest magnitude, duration, and geographic extent of potential adverse effects when a range of possible outcomes was possible. Consequently, uncertainty was addressed in a manner that increased the level of confidence that residual effects were conservatively estimated.

In general, the sources of uncertainty in predictions are associated with baseline data collection and modelling. Each of these main sources of uncertainty is discussed in the subsections that follow.

9.8.1 Baseline Hydrology Data

The baseline hydrology data were used to characterize short-term conditions in the RSA and to calibrate the hydrological model. Uncertainties in the hydrometric data collected during the baseline period and how these uncertainties were reduced to increase the level of confidence in the data are described here. The confidence in hydrology results is related to the following factors:

- natural variability in meteorological and hydrological conditions over time;
- period of baseline data collection and timing of field visits in relation to natural variability; and
- accuracy of baseline data collected, methods used, and quality assurance and control measures taken.

Natural variability in meteorological and hydrological conditions cannot be controlled. The conditions observed during the baseline data collection program, which represented a period of two years from August 2018 to August 2020, are unlikely to be as variable as those over the long term (i.e., decades). Over time, as additional data are collected over a wider range of conditions, uncertainty is reduced. For this assessment, the initial baseline period is represented by more than two years of hydrology data. The assessment also adopted a hybrid approach incorporating numerical models, as discussed in Section 9.8.2, to expand the view of conditions beyond the baseline period. The baseline data collection period between 2018 and 2020 spanned a range of hydrological conditions; for example, measured flows at the Clearwater River below Patterson Lake ranged from a low of 0.984 m^3/s on 26 March 2019 to 2.35 m^3/s on 10 July 2020, with the 2019 open water season being relatively dry and the 2020 open water season being relatively wet.

The timing of baseline data collection was planned such that seasonal variations were observed at the baseline hydrometric stations; data were collected in each of spring, summer, fall, and winter. The highest seasonal flows tend to occur in spring in response to snowmelt; however, wet periods in summer are also possible due to high amounts of rainfall. Meteorological data were also collected year-round.

Quality assurance measures in meteorological and hydrometric data collection included the following:

- appropriate site selection for the meteorological station and for watercourses to avoid placing hydrometric stations where backwater would be more frequent or likely, where possible;
- use of industry standard methods to collect data;
- use of detailed specific work instructions prior to field visits to clarify work tasks, methods, and equipment to be used;
- use of redundancy in taking important measurements such as completing two complete level circuits and/or measuring the WSE at each station using more than one method (e.g., level survey and staff gauge reading and/or document height of water above logger with a tape measure);
- documentation of site conditions through use of standardized field forms for consistency at the hydrometric sites, and taking photos at sites during each field visit;
- storage and management of data in a consistent and organized manner known to the entire technical team to avoid data loss and facilitate the data review process; and
- use of data storage methods that were backed up regularly to avoid data loss.

Quality control measures applied during meteorological and hydrometric data collection included the following:

- use of industry standard methods to collect data;
- use of calibrated equipment with calibrations documented;
- data checking while in the field to confirm that results obtained seemed reasonable;
- data review by a second experienced person once data were compiled;
- completion of regular field trip reports that were reviewed by senior technical staff as well as NexGen;
- comparison of unit runoff and water level results for all the hydrometric stations together to identify outliers or potential errors; and
- comparison of meteorological, snow survey, and hydrometric data to regional datasets to identify potential bias or errors.

9.8.2 Model Predictions

A fit-for-purpose regional hydrology model was developed to characterize the existing hydrological regime in the RSA over a range of climatic conditions. The regional hydrology model was structured to reflect the spatial distribution and hydrological processes of the receiving environment in the RSA and was calibrated using two years of baseline hydrometric data collected within the RSA. The calibration showed good agreement with baseline data. The regional hydrology model was validated against long-term regional data and produced results that were consistent with regional records of water yield at the appropriate spatial scale. The model was used to support quantitative assessment of Project effects in a realistic way.

The following are specific sources of uncertainty in modelling:

- **Unknown initial conditions:** The water levels for the lakes in the RSA at the start of the model simulation were required to characterize initial conditions. Water levels coinciding with the historical climate data and start of future model simulations are not known. Water levels observed in August 2018 were assumed to be representative of initial conditions in August 2025, which was arbitrarily selected as a nominal model start point for ease of reference and is considered appropriate from a modelling perspective.
- **Current climate data:** Meteorological variables, particularly rainfall, wind speed, and humidity, may vary in magnitude over different terrain (i.e., lakes and terrestrial coverage) and this may influence lake evaporation estimates. The approach adopted for this assessment assumed that the spatial variability of meteorological conditions was negligible within the model domain (1,076 km^2). Global reanalysis data were used to develop a long-term climate record for the specific location of the Project based on the nearest grid cell. This approach was checked and confirmed based on long-term climate data collected by Environment and Climate Change Canada in northern Saskatchewan in the Regional Meteorological and Hydrological Characterization Report (Annex IV.1). The climate data used for this assessment were based on a combination of local measurements and spatially gridded data for the exact location of the Project.
- **Geographic variability of climate change projections:** The nature, rate, and magnitude of climate change is spatially variable. Site-specific future climate projections were developed for the Project based on spatially gridded data for the exact location of the Project. The site-specific climate change projections and the methods used to develop them are described as part of Section 22.

- **Variability of modelled climate change projections:** The nature, rate, and magnitude of climate change is variable among different sources of modelled projections. Site-specific future climate projections were developed for the Project through analysis of available projections from a multi-model ensemble. The multi-model ensemble consists of available regional scale projections from several climate models representing different future climate scenarios (e.g., level of greenhouse gas emissions). To address the inherent uncertainty in future climate projections, the projections were summarized using exceedance percentiles across the ensemble, allowing the level of assumed risk to vary according to how the climate projections are being used (Section 22, Assessment of Effects of the Environment on the Project and Appendix 22A, Climate Change Dataset Summary Report).

A detailed summary of sources of uncertainty and mitigation measures are presented in TSD XVIII, Site-Wide Water Balance and Water Quality Modelling Report.

9.9 Monitoring, Follow-Up, and Adaptive Management

Monitoring follow-up programs for hydrology would be used to:

- confirm effects predictions and address uncertainty identified in Section 9.8;
- evaluate the effectiveness of mitigation actions and reclamation, and modify or enhance them as necessary through monitoring and developing updated mitigation measures, if needed;
- identify unanticipated negative effects, including possible accidents and malfunctions; and
- contribute to the overall continual improvement of the Project and assure the local communities the potential Project effects have been minimized.

In 2021, hydrometric monitoring was conducted at the baseline hydrology stations included in Annex IV.2. This continued data collection would extend the baseline monitoring period and data available. Selected hydrometric stations would also be monitored during the Project phases using remotely operated telemetry stations, which could be used to verify the receiving environment predictions of minimal changes in flows and water levels during the proposed Project duration in the future. Proposed remotely operated stations being considered include the following:

- Clearwater River below Patterson Lake;
- Clearwater River below Beet Lake;
- Clearwater River below Naomi Lake;
- Clearwater River above the confluence with the Mirror River; and
- Clearwater River below Broach Lake.

The details of future hydrology monitoring are discussed in detail in the Section 23.

In addition, Environmental Committees (i.e., one per primary Indigenous Group) composed of two NexGen and two Indigenous Group representatives would be established to act in an oversight manner to monitor the environmental performance of the Project and verify the parties are implementing the regulatory and environmental commitments made under the Benefit Agreements negotiated with each Indigenous Group.

Indigenous Groups have made recommendations related to mitigating the effects of the Project on the environment, including community-led long-term environmental testing and monitoring during construction and operation of the Project (TSD IV: MN-S; TSD V.2: CRDN; YNLRO 2019). NexGen has committed to provide funding for the lifespan of the Project for a full-time independent Indigenous Monitor chosen by each primary Indigenous Group; this Indigenous Monitor would have access to conduct environmental sampling for the Project, subject to the Indigenous Monitor complying with appropriate health and safety and other reasonable site-specific policies. The Indigenous Monitor would be able to report openly and without restriction to the Environmental Committee and Indigenous Group's community members on the performance of the Project. The Indigenous Monitor would also provide regular reports to the Environmental Committee who, in turn, would report to the Implementation Committee and provide them with an annual report of activities undertaken and monitoring results.

9.10 Key Findings

Predicted changes to regional hydrology from the Project were assessed in the Application Case. The Project would result in a net discharge of water to Patterson Lake from Construction to the Active Closure Stage, which is predicted to result in small but undetectable increases in WSEs and watercourse flow rates in the receiving environment, with the largest of these minimal increases expected in Patterson Lake and the Clearwater River below Patterson Lake. The increase in flows would propagate downstream but diminish in magnitude as the watershed area and ambient flows increase. The magnitude of changes to WSEs and flows along the Clearwater River are not expected to affect navigation, as they are predicted to be well within the range of natural seasonal and annual variability.

Climate change is expected to affect the hydrological regime in the RSA during the lifespan of the Project. Project and cumulative developments effects were assessed both with (i.e., the RFD Case [including climate change]) and without (i.e., the Application Case and RFD Case) the climate change scenario. The climate change scenario represents the mean of climate change projections for 2041 to 2070 applied to the historical climate record used in the regional hydrological model (i.e., the historical climate for the years 1979 to 2021). Climate change is expected to result in wetter and warmer conditions in the RSA, with shorter winters and generally earlier spring snowmelt. Regional hydrological model results show increased mean WSEs and watercourse flows in the RSA. Variability of WSEs and flows would increase, which is indicated through increases in the range of daily mean WSE over a 43-year period, including an increase in mean annual maximum daily flows and a decrease in mean annual minimum daily flows. The increase in mean monthly WSEs and flows is expected to be highest in the spring months of March through May, partly due to earlier snow melt.

Cumulative effects to receiving environment hydrology from combined developments, Project activities, Fission Patterson Lake South Property activities, and climate change were assessed in the RFD Case scenarios. Both the Project and Fission Patterson Lake South Property would have a net discharge of water to Patterson Lake, slightly increasing flows in the Clearwater River below Patterson Lake; these changes were assessed with both historical climate conditions and with climate change. Increases are expected in WSEs in waterbodies downstream of Patterson Lake along the Clearwater River, and in stream flows at the Clearwater River evaluation nodes downstream of Patterson Lake. However, most of the predicted future increases in flows relative to the Base Case are due to predicted climate changes affecting hydrology, rather than developments.

Increase in mean annual daily flow downstream of the Project would result in small changes in stream channel parameters. Predicted changes in stream channel parameters, using wetted area as the representative parameter, were evaluated within the RSA, which was assessed at locations from the Clearwater River below Patterson Lake downstream to the Clearwater River above the Mirror River confluence. Changes to stream channel parameters were assessed using coincident measurement of flows and channel wetted area over a wide range of flow conditions measured between 2018 and 2020. Predicted increases would result in negligible (i.e., likely undetectable) changes for the Application Case and RFD Case. In the climate change scenario, the increase in wetted area is expected to be as high as 5.1% for the Clearwater River above the Mirror River confluence with generally smaller effects at other locations in the RSA. In the RFD Case (including climate change), there is predicted to be a 5.6% increase for the Clearwater River below Patterson Lake (i.e., an increase of 0.3 m^2), which is mainly expressed in the channel as an increase in channel wetted width of about 0.2 m and a 0.02 m increase in average water depth; this may slightly improve navigation and is within the range of natural variability.

Changes in median annual maximum daily flows for the Clearwater River reach between Patterson Lake and Forrest Lake were used to predict potential changes to the fluvial sediment regime using a 1-D hydraulic and sediment transport model. Predicted increases to the median annual maximum daily flow values resulted in corresponding increases in erosion at the upstream reach in the Application Case and RFD Case, but also increased sedimentation at downstream reaches. All assessment cases resulted in negligible changes in net transport of sediment for the Clearwater River reach between Patterson Lake and Forrest Lake compared to the Base Case, which would not be detectable.

The effect of the Project on hydrology in the RSA is expected to be small and likely not possible to detect. The effects of the predicted hydrological changes on water quality are addressed in Section 10, and on fish and fish habitat in Section 11.

9.11 References

Acts and Regulations

Canadian Environmental Assessment Act, 2012. SC 2012, c 19, s 52. Repealed, 2019, c 28, s 9. Available at https://laws-lois.justice.gc.ca/eng/acts/C-15.21/20170622/P1TT3xt3.html.

Literature Cited

ACFN (Athabasca Chipewyan First Nation). 2019. NexGen Energy Ltd. Rook 1 Project. July 2019.

BBOP (Business and Biodiversity Offset Programme). 2021. Key Concepts: The Mitigation Hierarchy. Washington, D.C. Accessed September 2021. Available at https://www.forest-trends.org/bbop/bbop-key-concepts/mitigation-hierarchy/.

Beanlands G, Duinker P. 1983. An ecological framework for environmental impact assessment in Canada. Halifax Nova Scotia: Institute for Resources and Environmental Studies, Dalhousie University. 132 p.

BNDN-JWG (Birch Narrows Dene Nation-Joint Working Group). 2019. Meeting Notes. Meeting #2. 4 December 2019.

BNDN-JWG. 2021. Meeting Notes. Meeting #10. 22 April 2021.

BRDN-JWG (Buffalo River Dene Nation-Joint Working Group). 2019. Meeting Notes. Meeting #1. 1 November 2019.

BRDN-JWG. 2020. Meeting Notes. Meeting #4. 21 February 2020.

CEA Agency (Canadian Environmental Assessment Agency). 2018. Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Interim Technical Guidance. March 2018 Version 2. Available at http://publications.gc.ca/collections/collection_2018/acee-ceaa/En106-204-2018-eng.pdf.

CHRS (Canadian Heritage Rivers System). 2021. Accessed 15 July 2021. Available at https://chrs.ca/en/rivers/clearwater-river.

CNSC (Canadian Nuclear Safety Commission). 2019. Disposition Table of Public and Indigenous Groups' Comments on Project Description – Rook I Project. E-Doc: 6001783. Submitted 12 December 2019. Available at https://iaac-aeic.gc.ca/050/evaluations/proj/80171/contributions/id/35239.

CNSC. 2020. REGDOC-2.9.1, Environmental Protection: Environmental Principles, Assessments and Protection Measures, Version 1.2. September 2020. Available at https://www.cnsc-ccsn.gc.ca/eng/acts-and-regulations/regulatory-documents/published/html/regdoc2-9-1-vol1-2/.

CNSC. 2021. Generic Guidelines for the Preparation of an Environmental Impact Statement - Pursuant to the *Canadian Environmental Assessment Act, 2012*. Available at https://www.cnsc.gc.ca/eng/resources/environmental-protection/ceaa-2012-generic-eis-guidelines/.

CRDN (Clearwater River Dene Nation). 2019a. Clearwater River Dene Nation Comments on Project Description NexGen Energy Ltd.'s Rook I Project. 31 May 2019.

CRDN. 2019b. Comments in Respect License Renewal for Orano Canada Inc. Cluff Lake Project. Canadian Nuclear Safety Commission. CMD 19-H3.12. File 6.01.07.

CRDN-JWG (Clearwater River Dene Nation-Joint Working Group). 2021. Meeting Notes. Meeting #4. 24 March 2021.

DFO (Fisheries and Oceans Canada). 2013. Framework for Assessing the Ecological Flow Requirements to support Fisheries in Canada. 16 p. Available at https://waves-vagues.dfo-mpo.gc.ca/Library/348881.pdf.

Dingman SL. 2002. Physical Hydrology (New York: Macmillan Publishing Co).

ENV (Saskatchewan Ministry of the Environment). 2021. Guidelines for the Terms of Reference and Environmental Impact Statement. 43 p.

ESRI (Environmental Systems Research Institute). 2018. ArcGIS Desktop 10.6.1, User Guide. Redlands, California.

Fission (Fission Uranium Corp.). 2019. Technical Report on the Pre-Feasibility Study of the Patterson Lake South Property using Underground Mining Methods, Northern Saskatchewan, Canada. NI 43-101 Report. Prepared by Roscoe Postle Associates Inc. for Fission Uranium Corp. November 2019.

Fission. 2021. Fission Project Description. Prepared by Clifton Engineering Group Inc. and Canada North Environmental Services Limited Partnership for Fission Energy Corp. 22 November 2021.

Forest Lake Outfitters. 2021. Forest Lake Outfitters Limited Website. Accessed 15 June 2021. Available at http://www.forestlakeoutfitters.ca.

GoldSim. 2018. Probabilistic Simulation Environment, User's Guide. GoldSim Technology Group. Issaquah, Washington.

Gordon ND, McMahon TA, Finlayson BL, Gippel CJ, Nathan RJ. 2004. Stream Hydrology: An Introduction for Ecologists, Second Edition. John Wiley & Sons, Ltd., Chichester, England.

Hegmann G, Cocklin C, Creasey R, Dupuis S, Kennedy A, Kinglsey L, Ross W, Spaling H, Stalker D. 1999. Cumulative effects assessment practitioners guide. Prepared by AXYS Environmental Consulting Ltd. and the CEA Working Group for the Canadian Environmental Assessment Agency. Hull, QC.

Maidment DR. 1993. The Handbook of Hydrology. McGraw-Hill, New York.

MN-S (Métis Nation – Saskatchewan). 2019. Submission to the Canadian Nuclear Safety Commission and Saskatchewan Ministry of the Environment re: NexGen Rook 1 Project Submitted by: NexGen Energy Ltd. Reference Document: Rook 1 Project, Project Description. Submitted by Metis Nation of Saskatchewan. April 2019.

MN-S-JWG (Métis Nation – Saskatchewan-Joint Working Group). 2020. Meeting Notes. Meeting #4. 27 February 2020.

NexGen (NexGen Energy Ltd.). 2016. Bathymetry data for Patterson Lake provided in Digital Format.

NexGen. 2019. Community Information Session. Round One – June 2019. Submitted to Saskatchewan Ministry of Environment - Environmental Assessment Branch. Canadian Nuclear Safety Commission (CNSC). July 2019.

The Mathworks Inc. 2021. MATLAB® version R2021a Software.

USACE (United States Army Corps of Engineers). 2019. HEC-RAS River Analysis System. Developed by the Hydrologic Engineering Centre, Davis, CA.

WSA (Water Security Agency). 2021. Digital Data for Licensed Allocations in the Clearwater River Watershed. Data provided on 6 July 2021 by A. Thornton.

YNLRO (Ya'thi Néné Lands and Resources Office). 2019. Comments concerning the NexGen Energy Ltd. Rook I Project Description. Written Submission from the Ya'thi Néné Lands and Resources Office In the Matter of; NexGen Energy Ltd. Rook I Project Description. May 2019.

Appendix 9A Hydrological Modelling Summary Report

Abbreviations and Units of Measure

Abbreviation	Definition
EA	Environmental Assessment
EIS	Environmental Impact Statement
ERA5	European Reanalysis 5
ERAI	European Reanalysis Interim
LSA	local study area
NRMSE	Normalized Root Mean Square Error
NSE	Nash-Sutcliffe efficiency
Project	Rook I Project
R	correlation coefficient
RFD	reasonably foreseeable development
RSA	regional study area
SWWBM	site-wide water balance and water quality model
WSE	water surface elevation

Unit	Definition
%	percent
°C	degrees Celsius
km	kilometre
km^2	square kilometre
m	metre
m^3/d	cubic metres per day
m^3/s	cubic metres per second
masl	metres above sea level
mm	millimetre
mm/d	millimetres per day
mm/°C/d	millimetres per degrees Celsius per day
yr	year

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Attachment 9A-1 Bathymetry Maps

9A1 INTRODUCTION

9A1.1 Context

The regional hydrological model for the Rook I Project (Project) was developed to characterize existing conditions and predict Project effects on the hydrological regime as part of the hydrology effects assessment in Section 9, Hydrology, of the Environmental Impact Statement (EIS). In addition, the model provided the basis for aspects of the surface water quality modelling (EIS Appendix 10A, Surface Water Quality Modelling Report). This appendix summarizes the hydrology modelling completed in support of the Environmental Assessment (EA) for the Project, including the regional hydrological modelling. The model scenarios, structure, setup, and results are discussed in detail.

Water is important to culture, as a conduit for transportation, and is the basis for healthy, functioning, and resilient aquatic and terrestrial ecosystems. The quantity of water and the way it moves through and is stored in the natural environment shapes the way it is used. For these reasons, hydrology was identified as an intermediate component for the EA, and water levels in waterbodies and flows in watercourses were identified as associated measurement indicators.

9A1.2 Purpose and Approach to Modelling

Quantitative assessment of Project effects on hydrology is fundamental to understanding the total effects of the Project on the biophysical, cultural, and socio-economic environments. Quantitative modelling of existing conditions over an extended period provides understanding of the hydrological system and context for natural variability and responses to climate, and forms the basis for quantitative effects assessment. Quantitative modelling of expected conditions once primary Project activities are applied to the existing hydrological system allows for the quantitative assessment of Project effects on hydrology.

The model summary report is organized as follows:

- Section 9A2, Study Areas, communicates the study areas related to the hydrology effects assessment and supporting hydrological modelling.
- Section 9A3, Methods, details the methods adopted to clearly communicate steps, data, and constraints.
- Section 9A4, Results, presents results associated with the modelling study objectives.
- Section 9A5, Uncertainty and Limitations, discusses study limitations and approaches to mitigating uncertainty.
- Section 9A6, Key Findings, summarizes key findings that should be taken away from this study.

9A1.3 Modelling Study Objectives

The objective of this appendix is to document the technical aspects of hydrological modelling completed in support of the EA. The key objectives of the hydrological modelling work are as follows:

- Characterize the existing hydrological regime across a range of climatic conditions.
- Support quantitative assessment of Project effects at key evaluation nodes in the drainage network.
- Support quantitative assessment of cumulative effects at key evaluation nodes.

- Quantify change to the existing hydrological regime that may occur because of climate change.
- Characterize uncertainty in the projected climate change hydrological regime associated with uncertainty in climate change projections.
- Provide information to support the effects assessment for Project activities on related intermediate components, such as hydrogeology and surface water quality and associated valued components (i.e., fish and fish habitat).

The modelling study objectives are expected to meet requirements of the Project Terms of Reference (EIS Appendix 1A, Concordance Tables) and the generic guidelines for preparation of an EIS developed by the Canadian Nuclear Safety Commission (CNSC 2021).

9A2 STUDY AREAS

The study area for the model matches the regional study area (RSA) adopted for the hydrology effects assessment (Section 9A2.1, Hydrology Assessment Study Area). A site-wide water balance and water quality model (SWWBM) was developed to estimate how water and loads move through the Project site over time and at various phases of the Project. The study area for the site model that encompasses the Project footprint is summarized in Section 9A2.2, Site Model Study Area, with additional details in Technical Support Document (TSD) XVIII, Site-Wide Water Balance and Water Quality Modelling Report. The SWWBM study area is located within the geographic extent of the RSA.

9A2.1 Hydrology Assessment Study Area

The study areas for the hydrological assessment and the model include the following:

- **Local study area (LSA):** the Clearwater River watershed to Naomi Lake outlet (located within the RSA); and
- **Regional study area:** the Clearwater River watershed above the Mirror River confluence.

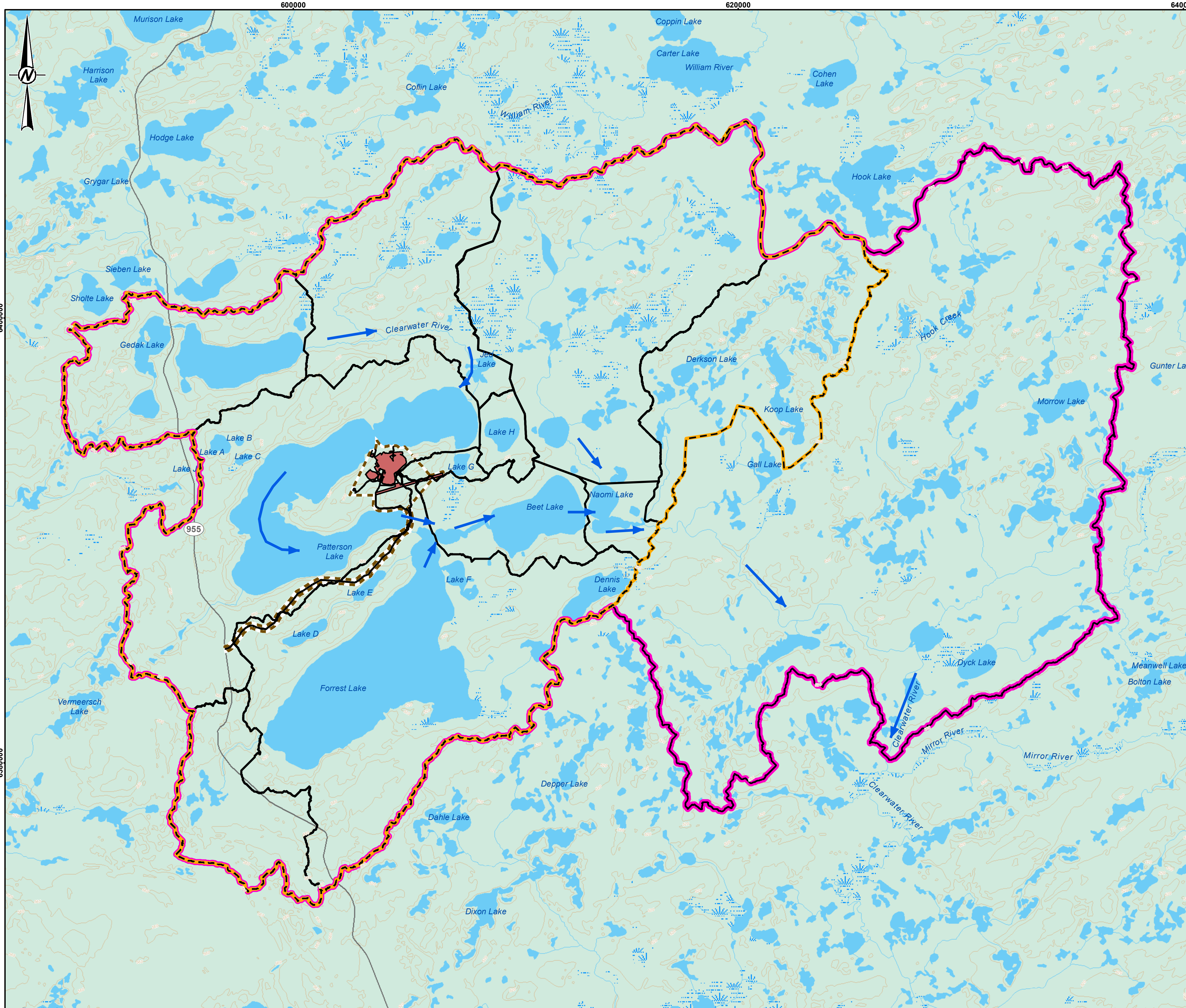
The Project would be located adjacent to Patterson Lake near the headwaters of the Clearwater River system at Broach Lake. The Upper Clearwater River flows from Broach Lake through a series of lakes including Patterson, Forrest, Beet, and Naomi lakes from upstream to downstream. From Naomi Lake, the Clearwater River flows another 20 km southeast before reaching the Mirror River confluence. The Clearwater River between Naomi Lake and Dell Lake transitions to intermittent braiding of multiple channels interrupted by occasional riffles and rapids. Between Dell Lake and the Mirror River confluence, the Clearwater River is broad and shallow, with a sand substrate and emergent macrophyte (i.e., aquatic plants that have roots on streambeds or lake beds) vegetation. Below the Mirror River confluence, the Clearwater River deepens with higher flow volumes from the Mirror River, and the channel form changes to meandering within a well-defined river valley. Farther downstream, the Clearwater River flows through Lloyd Lake, which is just upstream of the Clearwater River Provincial Park; the downstream end of the park is at the Saskatchewan-Alberta border.

Based on hydrological characteristics of the region and a high-level framing of the potential direct effects of the Project, the LSA is defined as the Clearwater River watershed to the Naomi Lake outlet (Figure 9A-1). The Clearwater River watershed above the Naomi Lake outlet drains an area of 685 km^2. Direct effects on hydrology may include changes to flows or water levels. The RSA for hydrology includes waterbodies and watercourses within the Clearwater River watershed above the Mirror River confluence, which includes the LSA (Figure 9A-1).

The Clearwater River watershed above the Mirror River confluence drains an area of 1,076 km^2. The spatial extent of the Clearwater River watershed above the Mirror River confluence is expected to provide an ecologically relevant RSA for the EA. The RSA spans an area that provides habitat requirements for a discernible population unit for large-bodied fish species where cumulative effects may occur.

9A2.2 Site Model Study Area

A fully integrated internal (i.e., within the spatial and temporal boundaries of the Project) SWWBM was developed for the Project. The details of the SWWBM are documented in Technical Support Document XVIII. The SWWBM was developed using GoldSim (2018) and integrates information of various forms and sources to estimate how water and loads move through the system over time and at various stages of the Project life. All site water management infrastructure and water management activities associated with the Project are accounted for in the SWWBM. The battery limit between the SWWBM and the model is defined by the spatial domain of the SWWBM. At the boundary, outputs from the SWWBM (e.g., fresh water intake flow rates and treated effluent discharge flow rates) are used as inputs to the hydrological model.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 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

HYDROLOGY ASSESSMENT STUDY AREA

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	LB/NO	2023-02-07	**FIGURE 9A-1**	
CHECK	RWP	2023-02-07		
REVIEW	NPS	2023-02-07		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

9A3 METHODS

This subsection discusses the overall approach to model development, testing, and application for characterizing existing conditions in the Base Case, as well as the information that forms the foundation for the assessment of effects against the Base Case. The methods presented communicate the model battery limits, model metadata, and input data, as well as approaches for model parameterization, calibration, and validation, and the scenarios that ultimately guide its application to fulfill the study objectives (Section 9A1.3, Modelling Study Objectives).

9A3.1 Spatial Domain

The spatial domain of the model is the RSA, which is spatially distributed (i.e., divided) into sub-watersheds and waterbodies as required to describe the hydrology of the RSA. The model is spatially distributed to account for predominant watershed-scale hydrological processes in waterbodies and terrestrial watersheds. The spatial domain is shown in Figure 9A-2.

Results are generated for evaluation nodes representing waterbodies (i.e., lakes) and watercourses (i.e., rivers and lake outflow channels) in the RSA. Evaluation nodes in the model that represent waterbodies include (in order from upstream to downstream) Broach Lake, Lake H, Lake G, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake. Evaluation nodes in the model to represent watercourses are typically located at lake outlets and include (in order from upstream to downstream): Clearwater River below Broach Lake, Clearwater River above Patterson Lake, Lake H Outlet, Lake G Outlet, Clearwater River below Patterson Lake, Clearwater River below Forrest Lake, Clearwater River below Beet Lake, Clearwater River below Naomi Lake, and Clearwater River above the Mirror River Confluence, which is located at the RSA boundary. The locations of the evaluation nodes are shown in Figure 9A-2.

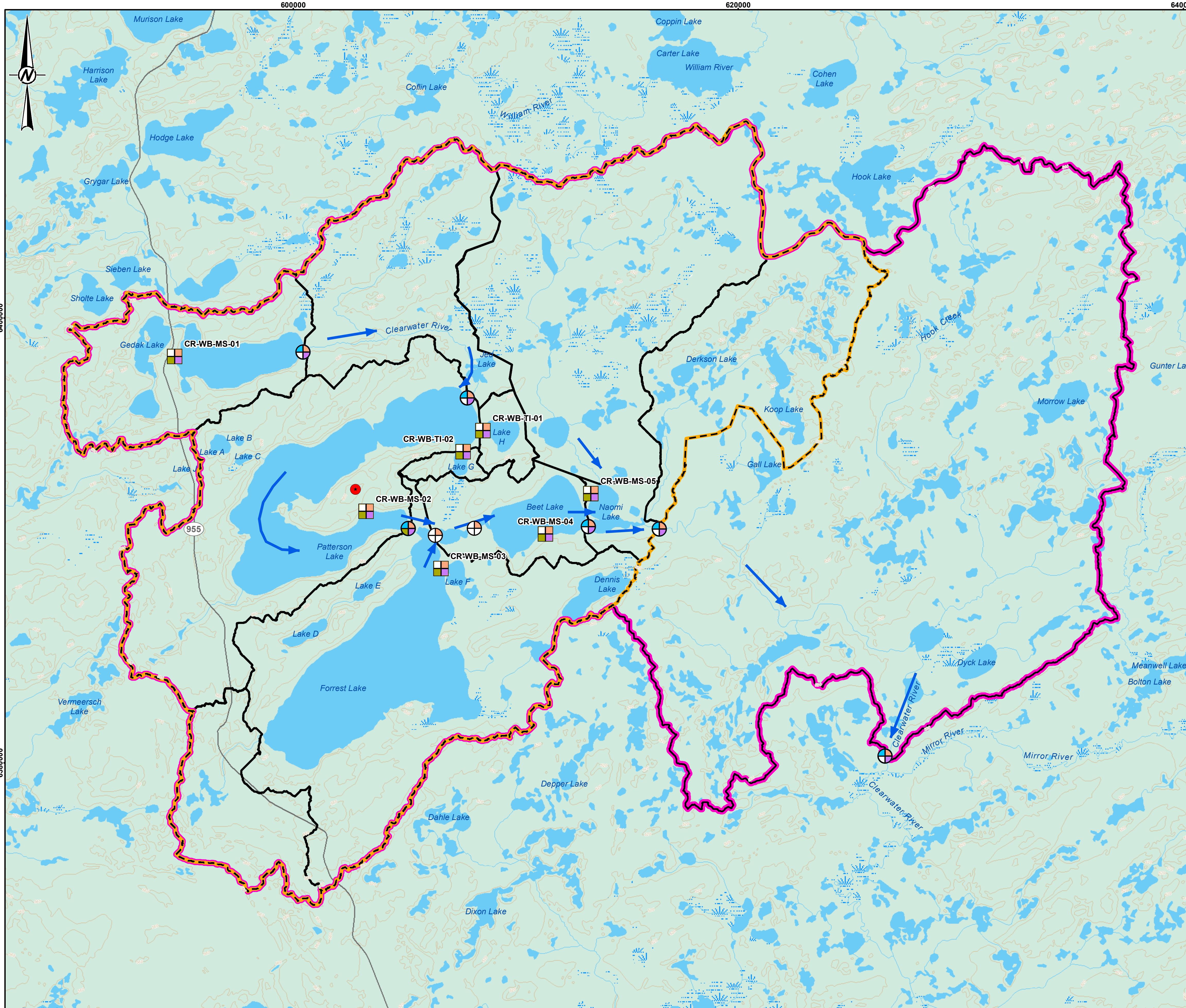
9A3.2 Temporal Domain

The model was developed to support continuous simulations on a daily time step. The temporal domain adopted for the model differed according to the phase of model development and included different temporal domains for model calibration, model validation, and predictive model simulations that were influenced by data availability and the purpose of the model application. The temporal domains adopted for different stages in the model development and modelling simulations are summarized in Table 9A-1.

Table 9A-1: Summary of Temporal Domains Adopted for Different Stages of Model Development

Stage of Model Development	Temporal Domain	Rationale
Calibration	August 2018 to August 2020	▪ The monitoring period for measured hydrometric monitoring data.
Validation	August 1979 to August 2020	▪ The overlapping period of the historical climate record (1979-2020) and the historical discharge record for the Douglas River near Cluff Lake (1975-2020), which were used to simulate and check the model performance.
Predictive model simulations	August 2025 to December 2068[(a)]	▪ Representative of the Project phases and stage. ▪ Aligned with the simulations completed for the SWWBM.
Predictive model simulations for far-future scenario	August 2025 to beyond December 2107	▪ To allow for transition of the model to the far-future scenario (simulation >80 years) for the purposes of effects assessment for other disciplines.

a) The Base Case model simulations from August 2025 to December 2068 represent historical conditions based on historical climate data and without application of predicted Project effects. The historical dataset was applied to a future model run time to align the input climate data time series with the Project lifespan.
> = greater than; SWWBM = site-wide water balance and water quality model.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED
- METEOROLOGICAL STATION

HYDROLOGICAL MODEL NODES - WATERBODY

- BASELINE HYDROMETRIC MONITORING
- DETAILED BATHYMETRIC SURVEY
- CALIBRATION POINT
- EVALUATION POINT

HYDROLOGICAL MODEL NODES - WATERCOURSE

- BASELINE HYDROMETRIC MONITORING
- DETAILED BATHYMETRIC SURVEY
- CALIBRATION POINT
- EVALUATION POINT

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

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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

EXISTING CONDITIONS HYDROLOGICAL MODEL SPATIAL DOMAIN

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	LB/NO	2023-02-07		
CHECK	RWP	2023-02-07	**FIGURE 9A-2**	
REVIEW	NPS	2023-02-07		

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The model is based on a series of equations that have several different input variables including parameters that define characteristics of the spatial domain or parts of the spatial domain. Once the model is built, it is calibrated and tested prior to being used for prediction. Model calibration is the adjustment of certain parameter values to improve the match between model predictions relative to measured data and is discussed in detail in Section 9A3.8, Model Calibration. The temporal domain used for model calibration is constrained to the period when measured data are available, and as such, is a historical timeframe. Model validation (Section 9A3.9) is used to evaluate performance of the calibrated model against the observations for a historical timeframe other than the model calibration period but also when measured data are available.

The temporal domain for the predictive model simulations is a projection to a future timeframe associated with different Project phases and stages. Construction is arbitrarily assumed to begin in the year 2025 for the purposes of modelling. Offsetting this start date by a few years to account for Project timelines would not materially affect the model's predictions. Construction is a four-year period, inclusive of pre-development activities (RPA 2020) and 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. Operations is a 24-year period that includes all activities associated with the mining and processing of ore, tailings and waste rock management, management of domestic waste and hazardous materials, water management and treated effluent discharge, surface storage of clean material, site maintenance, progressive reclamation, and transportation of the people and materials to and from the Project. Decommissioning and Reclamation (i.e., Closure) includes two stages: the Active Closure Stage and Transitional Monitoring Stage. The Active Closure Stage is expected to be a five-year period and concludes the active decommissioning and reclamation activities post-Operations. The Transitional Monitoring Stage is assumed to be a 10-year monitoring period extending from the end of the Active Closure Stage to the handover of Institutional Control.

The far-future scenario represents a steady state equilibrium when seepages from the Project are predicted to report to Patterson Lake. The time horizon associated with the far-future scenario extends from the end of Closure to a point in the far-future that represents a steady-state equilibrium when seepages and runoff from the Project are predicted to report to Patterson Lake in perpetuity.

9A3.3 Model Scenarios and Assessment Cases

Model scenarios were developed to support the modelling objectives in Section 9A1.3, Modelling Study Objectives. The EA assessment cases included a Base Case, Application Case, and Reasonably Foreseeable Development (RFD) Case. The assessment cases and effects assessment are discussed in detail in the hydrology assessment in EIS Section 9, but are presented here for context and interpretation of scenarios:

- **Base Case** is generally represented by existing conditions. The Base Case describes the existing environment in the LSA and RSA before application of the Project to provide an understanding of the current conditions that may be influenced by the Project. The temporal boundary of the Base Case includes the combined effects from previous and existing human disturbances and natural factors (e.g., fire, floods, and drought) on the environment and hydrology. As such, existing conditions represent the cumulative effects of historical and current environmental pressures that have influenced the observed condition/patterns of hydrology (CEA Agency 2018).
- **Application Case** represents predictions of the combined effects of the previous and existing projects/activities and natural factors in the Base Case plus the effects from the Project. This case was also used to identify and assess incremental, Project-specific changes that are predicted to occur to hydrology.

- **Reasonably Foreseeable Development Case** for hydrology represents predictions of the combined effects of the Base Case, Application Case, and RFDs that have not yet been approved, as well as considerations for climate change. The assessment of the RFD Case was analyzed and classified based on the following scenarios:
  - **Reasonably Foreseeable Development Case:** includes the Application Case plus the Fission Patterson Lake South Property (Section 9.6.2). The RFD Case includes the Base Case, Application Case, and Fission Patterson Lake South Property effects under historical climate conditions.
  - **Climate change scenario:** includes the effect of climate change as discussed in Section 9.4 without the inclusion of Project or Fission Patterson Lake South Property effects. The climate change scenario used in the RFD Case (including climate change) represents projected climate change for the 2050s.
  - **Reasonably Foreseeable Development Case (including climate change):** includes the combined effects of the RFD Case and climate change scenarios (Section 9.6.3).

The scenarios summarized in Table 9A-2 are expected to provide the information required to satisfy the anticipated expectations of Indigenous and local communities, provincial regulators (ENV 2021), and the federal Canadian Nuclear Safety Commission. The hydrological model was calibrated based on historical monitoring data and then used for effects assessment in the following scenarios, intended to meet the modelling study objectives discussed in Section 9A1.3:

- **Scenario 1: Base Case (i.e., existing conditions):** The conditions that exist in the receiving environment prior to initiating the Project. This model consists of ambient hydrological processes with no Project interactions.
- **Scenario 2: Sensitivity of effects assessment to climate cycles:** This scenario simulates the highest projected effect of the Project under all historical climate conditions. This scenario applies a snapshot of Project effects when the adverse effects from Project activities are predicted to be the greatest, which is anticipated to be year +23 of Operations, to 43 different years in the Base Case. This approach provides insight into sensitivity of model results to timing of Project activities relative to natural climate cycles.
- **Scenario 3: Application Case:** The Application Case represents predictions of the combined effects of the previous and existing projects or activities and natural factors in the Base Case plus the effects from the Project. The Application Case includes the Base Case plus Project activities during Construction, Operations, and Closure (i.e., Year -4 to +39). The Project activities included in the Application Case are quantitative outputs from the SWWBM.
- **Scenario 4: Far-future scenario:** The far-future scenario represents a steady state equilibrium when seepages from the Project are predicted to report to Patterson Lake. The time horizon associated with the far-future scenario extends from the end of Closure to a point in the far-future that represents a steady-state equilibrium when seepages and runoff from the Project are predicted to report to Patterson Lake in perpetuity.
- **Scenario 5: RFD Case (including climate change):** The RFD Case includes RFDs that have not yet been approved, namely the Fission Patterson Lake South Property, which is planned by Fission Uranium Corp. (Fission 2019, 2021). The RFD Case also considers how natural factors and climate change may interact with the Project and other developments to affect hydrology. The mean projected climate change

for the 2050s (i.e., 2041 to 2070) relative to the period from 1981 to 2010 was applied to the historical climate record as discussed in Section 9A3.6.5, Climate Change.

- **Scenarios 6 to 10: Climate change scenarios:** Climate change scenarios were incorporated to inform the potential effects of climate change on the Project. Expected climate change conditions contemporary with the Project period were represented by the mean projected climate change for the 2050s (i.e., 2041 to 2070) Section 9A3.6.5. Additional sensitivity scenarios were included to understand uncertainty in climate change projections and quantify sensitivity to the range of potential climate change outcomes.
- **Scenario 14: RFD Case:** The cumulative effect of developments on hydrology without climate change was assessed by incorporating Project activities, Fission Patterson Lake South Property activities, and historical climate.

Scenario numbers 11, 12, and 13 were not used in hydrological modelling to avoid confusion with water quality modelling scenarios, which are described in Appendix 10A.

Table 9A-2: Summary of Scenarios for Receiving Environment Hydrology Modelling

ID	Description	Primary Use	Project Phase	Fission Patterson Lake South Property Phase	Time	Climate	Information Objective
1	Base Case	Base Case assessment case	None	None	TS-D (D)	H	Existing conditions
2	Sensitivity case – steady state project effects	Sensitivity	Year	None	TS-D (D)	H[(a)]	Sensitivity of assessment
3	Application Case – variable state project effects	Application Case assessment case	All phases	None	TS-D (D)	H	Effects assessment
4	Far-future scenario	Sensitivity	Far-Future	None	TS-M (D)	H	Effects assessment
5	RFD Case (including climate change) – Rook I + Fission Patterson Lake South Property + Climate change	RFD Case assessment case	All phases	Life of mine	TS-D (D)	CC-M	Cumulative effects
6	Climate change, mean	Sensitivity	All phases	None	TS-D (D)	CC-M	Climate change
7	Climate change, warm dry	Sensitivity	All phases	None	TS-D (D)	CC-WD	Climate change
8	Climate change, warm wet	Sensitivity	All phases	None	TS-D (D)	CC-WW	Climate change
9	Climate change, cool dry	Sensitivity	All phases	None	TS-D (D)	CC-CD	Climate change
10	Climate change, cool wet	Sensitivity	All phases	None	TS-D (D)	CC-CW	Climate change
11	Not used – water quality model only						
12							
13							
14	RFD Case	Sensitivity	All phases	None	TS-D (D)	H	Cumulative effects

a) Scenario 2 adopts the historical climate year 2006, which is associated with the modelled year 23 of operations assumed to occur in nev2052 in the Application Case Assessment Case on an annual loop.

TS-D (D) = daily time series run in deterministic mode; TS-M (D) monthly time series run in a deterministic mode; H = historical climate time series; CC = climate change; RFD = reasonably foreseeable development; M = mean; WD = warm and dry; WW = warm and wet; CD = cool and dry; CW = cool and wet.

9A3.4 Software

The software selected for regional hydrological modelling was a generalized systems dynamic modelling platform called GoldSim. Systems dynamics concepts and platforms are often used to develop water balance models; while they do not have the benefit of pre-packaged hydrological process algorithms available from hydrology-specific software, they are highly flexible and can be configured to be fit for purpose with all equations, parameters, and hydrological processes required. A visual interface is available to transparently view these underlying formulas and inputs (i.e., the model is not a "black box"). The processes related to atmospheric losses (i.e., sublimation, lake evaporation, and evapotranspiration) were modelled by a separate software program called MATLAB due to time efficiency as well as computational and model complexity constraints. The MATLAB outputs were then directly input into the GoldSim modelling platform.

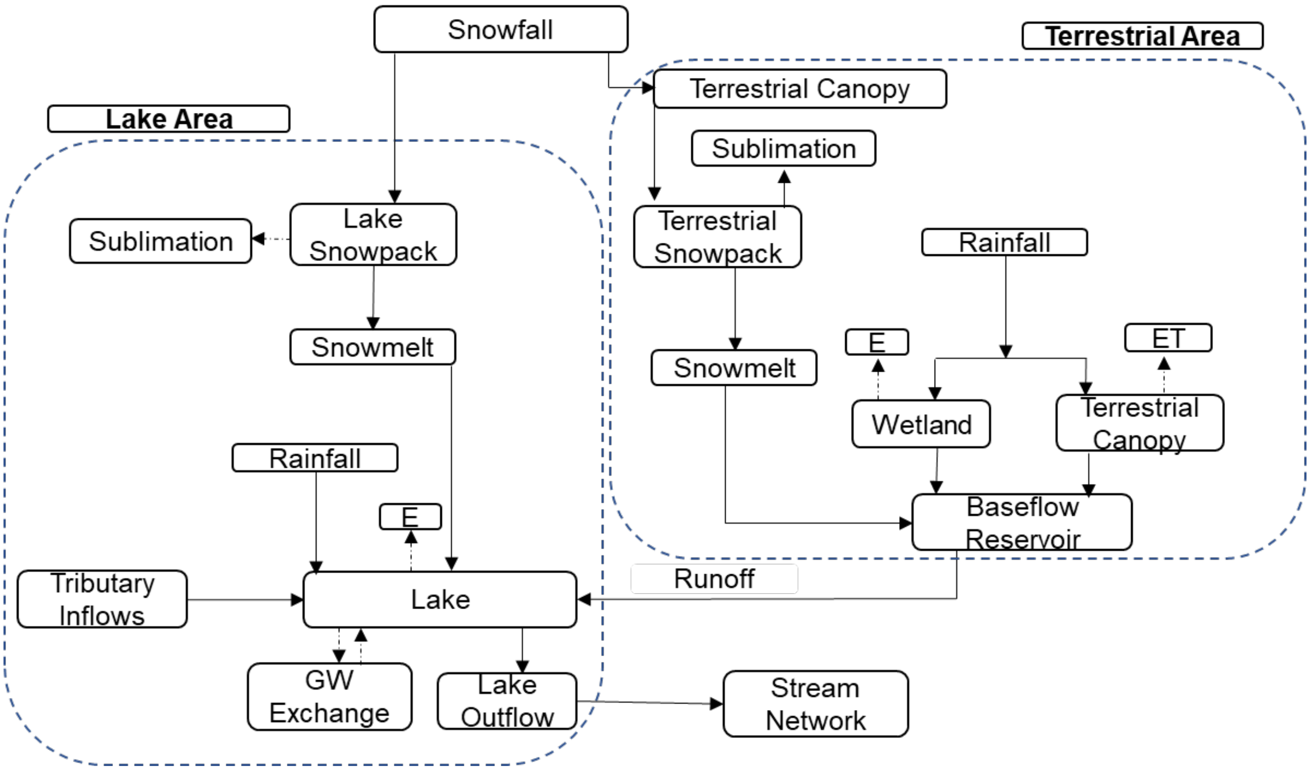
9A3.5 Model Structure and Configuration

The model integrates several hydrological processes used to calculate water levels and stream flows on a daily timescale. The model structure and configuration are designed to simulate the physical characteristics of the watershed and numerically represent how water interacts with it through runoff generation, loss, storage, and routing. Surface watersheds were delineated based on topography to determine the direction of flow accumulation and contributing area. In general, the landscape for each watershed was divided into waterbodies and terrestrial contributing areas. The configuration of the model, as shown on the simplified process schematic in Figure 9A-3, is designed to capture physical hydrological processes.

Accounting for storage of water in different layers of the physical environment in the model is important for simulating the timing of water movement. The storage in the terrestrial landscape was modelled as a three-layer system (i.e., snowpack, forest canopy, and soil/subsurface) with different modelling assumptions for these layers. The model simulated snow accumulation and storage as snowpack, accounting for incremental sublimation losses to the atmosphere through the winter until being incrementally released as snowmelt. In forested terrestrial areas, the model simulated a portion of rainfall being stored in the forest canopy and incrementally lost to the atmosphere as evapotranspiration, with the excess falling to the forest floor. In terrestrial (i.e., non-lake) areas classified as wetland, the simulated atmospheric loss was by evaporation. The model simulated excess water at the terrestrial area ground surface (i.e., the sum of rain and snowmelt less the losses by lake evaporation, evapotranspiration, and canopy storage) was routed to a subsurface baseflow storage reservoir. The simulated outflow from the baseflow reservoir was proportional to its storage volume, and baseflow (i.e., outflow from the baseflow reservoir) was routed directly into the waterbodies within the watershed, the Clearwater River mainstem, or tributary streams to the Clearwater River mainstem. The initial conditions for baseflow reservoir storage in the model were treated as a calibration parameter to match simulated and observed discharge at the outset of the model runs. Model routines were also incorporated to reduce base flow rates during the winter months.

Storage in waterbodies was modelled as a two-layer system (i.e., snowpack and lake storage). The lake water balance was calculated by accounting for daily storage based on the summed inflows to the waterbody, less evaporative losses and daily lake outflow. Groundwater exchange was accounted for at lakes based on results from the regional groundwater model (Annex III, Hydrogeology Baseline Report). Daily lake outflow was calculated based on the standard open-water rating curve for the lake outlet based on the water surface elevation (WSE). The main waterbodies along the Clearwater River mainstem included Broach Lake, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake. As described in Section 9A3.2, Temporal Domain, some simulations start in historic periods (e.g., 1979) when monitoring is not available in the RSA and some simulations start in the future. The initial condition for the calibration period was based on observations in August 2018. The initial conditions for lake water storage that were unknown were assumed to be similar as of August 2018, which is assumed to represent a normal condition for August in other years.

Figure 9A-3: General Schematic of Hydrological Processes in the Regional Hydrological Model for Existing Conditions



GW = groundwater; E = evaporation; ET = evapotranspiration.

9A3.6 Input Data

The primary input data required to develop the model include physical characteristics of the watershed and hydrography generated from publicly available geospatial data, baseline hydrometric monitoring and lake morphometry data, historical climate data, projected future climate data considering climate change, and information on existing and future water management infrastructure within the spatial domain. The data described in the following subsections were used to derive inputs to the hydrologic model.

9A3.6.1 Surface Watersheds and Landcover

Physical watershed characteristics were derived based on publicly available geospatial data and geographic information system software. The watershed characteristics include mapping of the waterbodies and watercourses that make up the drainage network, sub-watershed area, wetland area, terrestrial area, and lake area. Surface watersheds are used to define the amount of area that flows to a specific point in the drainage network and are important as they serve as common spatial boundaries.

Watershed boundaries and stream network were delineated for the RSA using a digital elevation model and mapped stream network data. Canadian Digital Elevation Model data (NRCan 2019) for the surrounding region were used as the digital elevation model base data. The mapped stream network was represented by the National Hydrologic Network flow path dataset for the region. These data were imported to Green Kenue software (NRC-CHC 2012), which was used to delineate watershed boundaries for hydrometric station locations. National Hydrographic Network watercourse alignments were used to establish predefined channels to guide the search algorithm used by Green Kenue software in areas of low relief such as flood plains and wetlands. The spatial resolution of the digital elevation model is 20 m by 20 m. The interpreted network was compared with visible streams, wetlands, and upland features shown on recent satellite imagery for the region. The watershed boundaries were also reviewed against satellite imagery as well as contours generated from the digital elevation model and hydrography features and corrected as required. The sub-watersheds within the RSA are summarized in Table 9A-3.

Landcover is an important factor in many hydrological processes including storage, runoff generation, and atmospheric loss calculations. The distribution of landcover type was defined for each sub-watershed based on a geographic information system summary of ecosites within the watershed RSA. Further differentiation of landcover for the purposes of hydrological modelling was not deemed necessary based on hydrometric monitoring data, experience in the region, and preliminary modelling results.

Table 9A-3: Existing Conditions Sub-watershed Areas within the Regional Study Area

Sub-watershed	Description / Hydrometric Stations[a]	Land Surface Area (%)	Lake Surface Area (%)	Wetland Surface Area (%)	Total Area (km^2)
Broach Lake	Clearwater River below Broach Lake (CR-WC-MS-01) and (CR-WB-MS-01)	76	17	8	56.4
Above Patterson Lake	Watershed downstream of Broach Lake and upstream of Patterson Lake (CR-WC-MS-02)	91	0	9	64.6
Lake H	Lake H (CR-WB-TI-01)	77	23	0	7.36
Lake G	Lake G (CR-WB-TI-02)	84	16	0	3.75
Patterson Lake	Clearwater River below Patterson Lake (CR-WC-MS-03) and (CR-WB-MS-02)	72	28	0	132
Forrest Lake	Forrest Lake (CR-WB-MS-03)	72	24	4	181
Beet Lake	Clearwater River below Beet Lake (CR-WC-MS-04) and (CR-WB-MS-04)	66	31	3	29.0
Tributary to Naomi Lake	Tributary inflow to Naomi Lake (CR-WC-TI-02)	73	0	27	134
Tributary downstream of Naomi Lake	Tributary inflow downstream of Naomi Lake (CR-WC-TI-03)	87	0	13	67.5
Naomi Lake	Clearwater River below Naomi Lake (CR-WC-MS-05) and (CR-WB-MS-05)	77	23	0	10.5
Above Mirror River confluence	Watershed below Naomi Lake above Mirror River confluence (CR-WC-MS-06)	89	0	11	390
Total	Cumulative watershed area at CR-WC-MS-06	81	10	9	1,076

a) Hydrometric stations are described in detail Annex IV.2: Hydrometric Monitoring Characterization Report and monitoring activities related to modelling existing conditions are described in Table 9A-4.

9A3.6.2 Lake Morphometry

Physical characteristics of lakes, or lake morphometry, influence how water is stored and routed through the drainage network. Bathymetric mapping of lakes was available for Patterson Lake (NexGen 2016), Broach Lake, Lake G, Lake H, Forrest Lake, Beet Lake (Annex V.1, Aquatic Environment Baseline Report), and Naomi Lake (Annex V.3, Naomi Lake Bathymetry Report). Baseline digital bathymetry data were used to generate bathymetric maps and establish stage-storage relationships for Broach Lake, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake as well as Lake G and Lake H. The bathymetric maps of major lakes in the assessment, including tabular summaries of stage, storage, and area, are presented in Attachment 9A-1, Bathymetry Maps.

Based on their size and shape, all lakes were simulated as a single basin except for Patterson Lake, which was divided into three basins, and Forrest Lake, which was divided into two basins. The separate basins of Patterson Lake and Forrest Lake are used in water quality modelling.

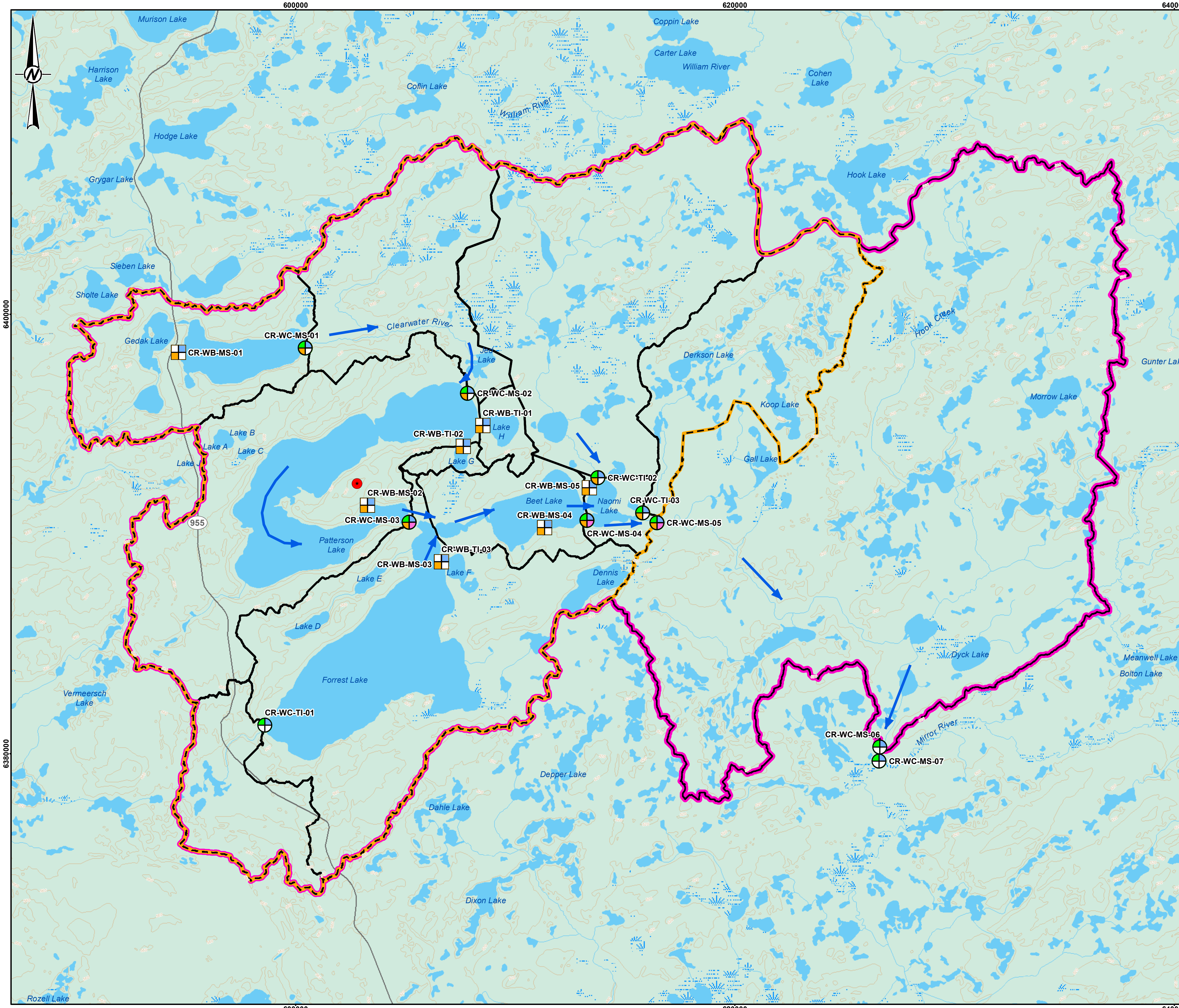
9A3.6.3 Hydrometric Monitoring Data

Continuous records of WSE and discharge were used to inform model calibration and test the model's performance in simulating real-world conditions. A hydrometric monitoring baseline program undertaken for the Project was initiated in August 2018 and data were collected to October 2020.

Baseline monitoring relevant to the model included the following surveys:

- late winter snow surveys within Patterson Lake watershed in 2018 and 2019;
- water level monitoring at 8 stations on lakes and ponds in the Clearwater River watershed; and
- streamflow monitoring at 12 stations on streams and rivers in the Clearwater River watershed.

Figure 9A-4 provides a visual summary of the key locations and monitoring activities. Details of the hydrometric monitoring methods and observations are provided in Annex IV.2. The baseline hydrometric monitoring activities related to modelling existing conditions are also summarized in Table 9A-4.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED
- METEOROLOGICAL STATION

WATERBODY HYDROMETRIC STATIONS

- DISCHARGE
- SURVEYED BENCHMARK (GEODETIC DATUM)
- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- DISCHARGE
- SURVEYED BENCHMARK (GEODETIC DATUM)
- TOTAL SUSPENDED SOLIDS AND BEDLOAD
- WATER SURFACE ELEVATION

0 5 10
1:175,000 KILOMETRES

REFERENCE(S)
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 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
BASELINE HYDROMETRIC MONITORING WITHIN THE REGIONAL STUDY AREA

CONSULTANT
wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	LB/NO	2023-02-07		
CHECK	RWP	2023-02-07	**FIGURE 9A-4**	
REVIEW	NPS	2023-02-07		

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Table 9A-4: Baseline Hydrometric Monitoring Activities Related to Modelling Existing Conditions

Type	Locations	Station ID	Cumulative Area (km²)	Baseline Hydrometric Monitoring			
				Period of Record	Discharge	WSE	Bathymetry
Watercourses	Clearwater River below Broach Lake	CR-WC-MS-01	56.4	2018-2020	✓	✓	×
	Clearwater River above Patterson Lake	CR-WC-MS-02	121	2018-2020	✓	✓	✓
	Clearwater River below Patterson Lake	CR-WC-MS-03	264	2018-2020	✓	✓	×
	Clearwater River below Beet Lake	CR-WC-MS-04	473	2018-2020	✓	✓	×
	Clearwater River below Naomi Lake	CR-WC-MS-05	685	2018-2020	✓	✓	×
	Clearwater River above the Mirror River confluence	CR-WC-MS-06	1,070	2018-2020	✓	✓	×
Waterbodies	Broach Lake	CR-WB-MS-01	56.4	2018-2020	×	✓	✓
	Patterson Lake	CR-WB-MS-02	264	2018-2020	×	✓	✓
	Forrest Lake	CR-WB-MS-03	445	2018-2020	×	✓	✓
	Beet Lake	CR-WB-MS-04	473	2018-2020	×	✓	✓
	Naomi Lake	CR-WB-MS-05	685	2018-2020	×	✓	✓
	Lake H	CR-WB-TI-01	7.36	2018-2020	×	✓	✓
	Lake G	CR-WB-TI-02	3.75	2018-2020	×	✓	✓

× = data are not available; ✓ = data are available; WSE = water surface elevation.

In general, water level was monitored continuously using automated instrumentation. Discharge was calculated based on continuous water level measurements and site-specific open-water rating curves developed based on paired measurements of water level and discharge. Direct observation of water level was not possible at all stations throughout the monitoring period because of the ice conditions encountered during winter. However, hydrometric monitoring was continued during winter for some watercourse stations where conditions permitted.

For hydrometric stations where direct observation of water level was not possible over winter, missing data were gap-filled using prorated field observations from nearby stations in the RSA, in combination with regional observations at the Water Survey of Canada Station 07MA003: Douglas River near Cluff Lake. By default, the nearest neighbouring hydrometric station with winter discharge data was prorated based on cumulative watershed area to develop a flow per unit area that was then applied to cumulative watershed area draining to the station being gap-filled.

Snow water equivalent of the snowpack in place in the Patterson Lake watershed from snow surveys conducted on 17 April 2018 (78.5 mm) and 23 March 2019 (75.5 mm) were also incorporated as calibration data, along with remotely sensed snowpack data such as GlobSnow (ESA 2020) when snow surveys were not possible.

9A3.6.4 Current Climate

Climate is the summary or long-term average of weather over a long period of time, usually 30 years or more. Climate is represented numerically by long-term meteorological datasets. Variations in meteorological parameters over time drive variations in hydrology. The meteorological data used in the model to represent current climate include precipitation (rain and snow), ambient air temperature, dew point temperature, wind speed, and net all-wave radiation on a daily timescale.

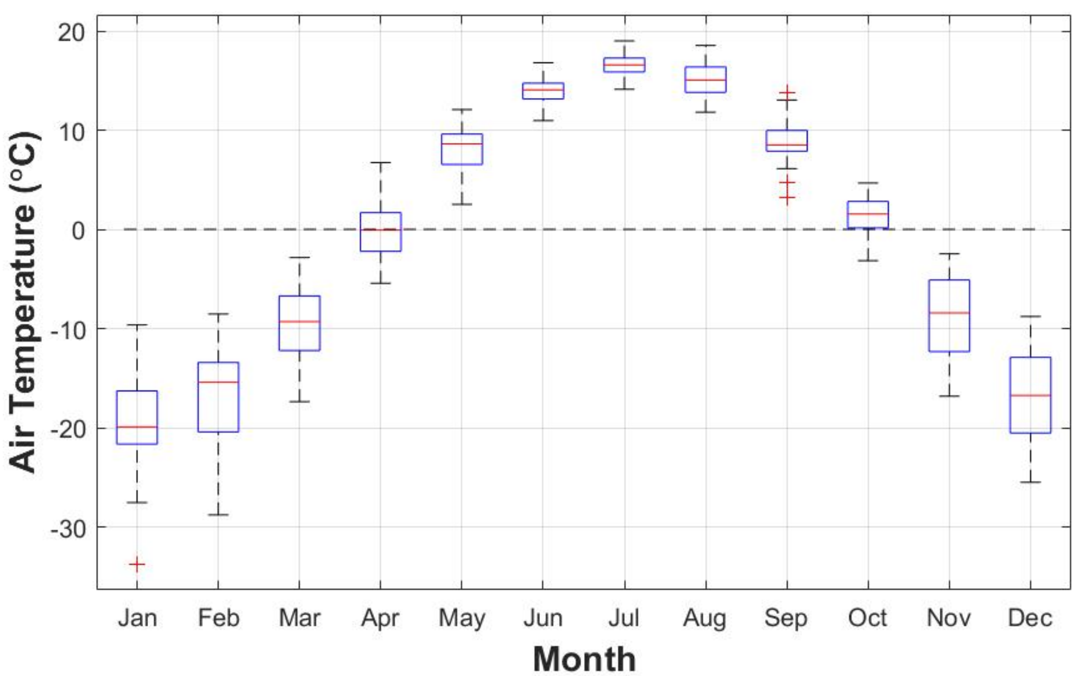
The current climate record was developed based on a combination of global reanalysis data and local observations. European Reanalysis Interim (ERAI) and European Reanalysis 5 (ERA5) are both global climate reanalysis datasets produced by the European Centre for Medium-Range Weather Forecasts. More details about the dataset and its suitability for the Project based on its comparison with regional observations at Environment and Climate Change Canada stations in the region has been reported in Annex IV.1, Regional Meteorological and Hydrological Characterization Report.

Annex IV.1 established that ERAI air temperature and precipitation data were valid for northern Saskatchewan by comparing data observed at long-term meteorological stations operated by Environment and Climate Change Canada with ERAI data compiled for the same location. The correlation was found to be acceptable at a monthly time step and was in general agreement with long-term averages. The use of reanalysis products permitted the extension of the climate record beyond the measurement period for site data (i.e., three to six years depending on parameter) to account for a broader range of natural variability over a 41-year period. Total precipitation, rainfall, and snowfall were based on ERAI data for the Project location from 1 January 1979 to 31 July 2018, and observations from the Rook I meteorological station were adopted for 1 August 2018 to 31 October 2020. Ambient air temperature, dew point temperature, wind speed, and net all-wave radiation were derived from the ERAI database from 1 January 1979 to 31 August 2019 (i.e., when ERAI was replaced by ERA5 data) and then from 1 November 2019 to 31 October 2020 based on the ERA5 database.

9A3.6.4.1 Air Temperature

The daily average air temperature record for the LSA was derived from the European Centre for Medium-Range Weather Forecasts ERAI database from 1 January 1979 to 31 August 2019 and ERA5 database from 1 November 2019 to 31 October 2020 (ECMWF 2021). The daily average air temperature record was compiled from 1 January 1979 to 31 October 2020. The mean monthly average air temperature is presented in Figure 9A-5. The monthly average air temperature ranged from a low of -20°C in January to a high of 17°C in July, with an annual average of -1°C.

Figure 9A-5: Inter-annual Variability of Mean Monthly Air Temperature for the Local Study Area

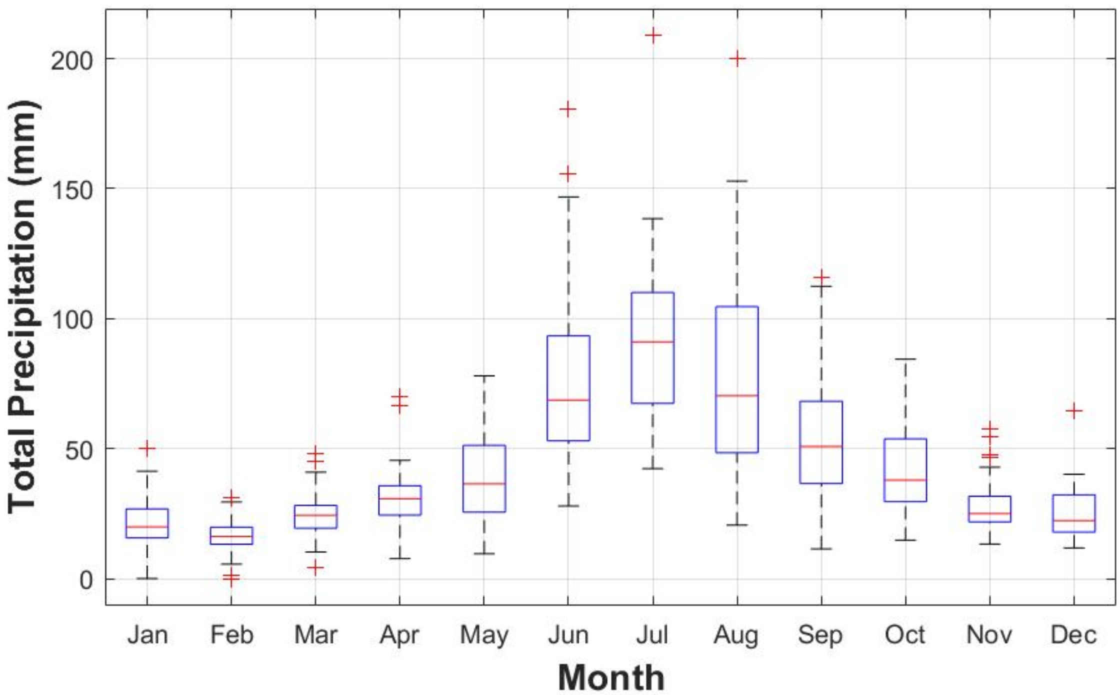


Note: The length of the box in the plots represents the inter-quartile range (25th and 75th inter-quartiles) with the median denoted by the horizontal line within the box. The whiskers represent the minimum and maximum values of the dataset, and any outliers are shown by a "+" symbol, when present.

9A3.6.4.2 Total Precipitation

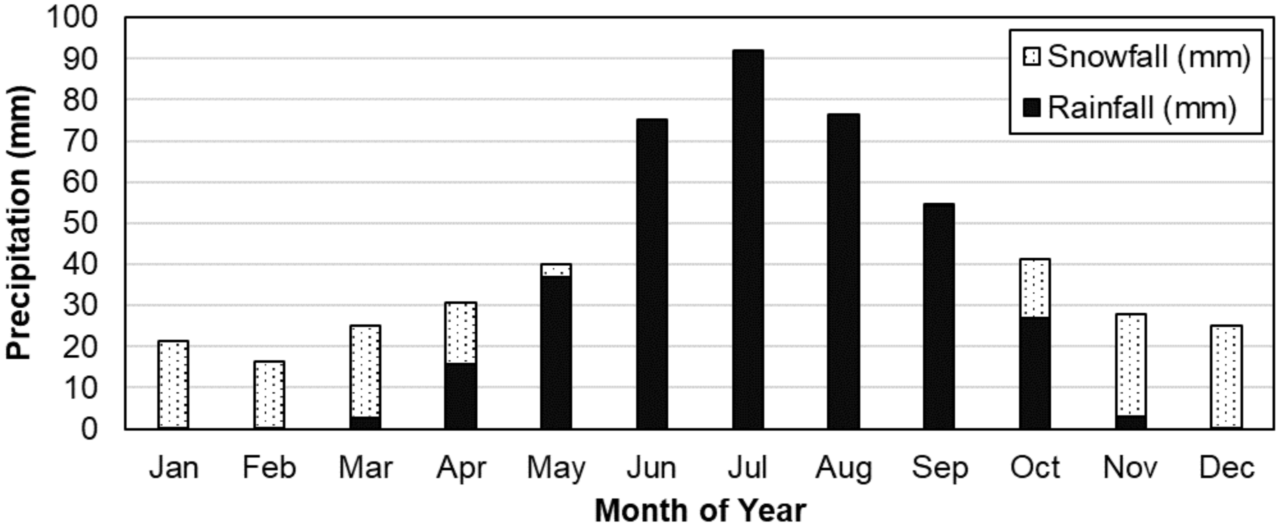
A continuous daily record of total precipitation was developed for the Project location based on a combination of ERAI data (ECMWF 2021) between 1 January 1979 and 31 July 2018 and site observations from 1 August 2018 to 31 October 2020. The mean annual total precipitation at the Project location was 526 mm of water equivalent, with the summer months experiencing the highest precipitation, as shown in Figure 9A-6. The distribution of precipitation into rain and snow was 73% (384 mm) rain and 27% (142 mm) snow. Annual snowfall was observed to range from 79 mm to 208 mm in the historical record, while the annual rainfall was observed to range from 259 mm to 530 mm. The average monthly apportioning of total precipitation as rain or snow is presented in Figure 9A-7.

Figure 9A-6: Average Monthly Total Precipitation at the Rook I Project Location



Note: The length of the box in the plots represents the inter-quartile range (25th and 75th inter-quartiles) with the median denoted by the horizontal line within the box. The whiskers represent the minimum and maximum values of the dataset, and any outliers are shown by a "+" symbol, when present.

Figure 9A-7: Derived Historical Monthly Total Precipitation as Rainfall and Snowfall at the Rook I Project Location



9A3.6.4.3 Atmospheric Loss

Water is lost to the atmosphere by evaporation from free water surfaces, evapotranspiration by plants, and sublimation (i.e., snow evaporation), whereby solid snow is transformed directly to water vapour.

Evaporation

Lake evaporation was estimated on a daily time step using the Penman Combined method (Dingman 2002) modified for lake evaporation estimation by considering change in heat storage in the waterbody (McJannet et al. 2013). The heat storage term was a function of Julian day, net shortwave radiation, and net longwave radiation following Jensen (2010). Required meteorological observations, including ambient air temperature, dew point temperature, wind speed, shortwave radiation, and longwave radiation were compiled for January 1979 to August 2021 based on ERAI and ERA5 data. The mean annual lake evaporation was estimated to be 538 mm, and mean monthly estimates are summarized in Table 9A-5. The maximum mean monthly lake evaporation was 122 mm in July.

Evapotranspiration

Actual evapotranspiration from terrestrial land surfaces was estimated on a daily time step using the Granger and Gray (1989) model, which accounts for moisture availability in non-saturated surfaces. The relative drying power parameter was estimated as a function of 2 m wind speed, based on a linear approximation as suggested by Penman (1948). Required meteorological observations, including ambient air temperature, dew point temperature, wind speed, and net radiation were compiled from January 1979 to October 2020 based on ERAI and ERA5 data. The mean annual evapotranspiration was estimated to be 274 mm and mean monthly estimates are summarized in Table 9A-5. The maximum mean monthly evapotranspiration was 76 mm in June.

Sublimation

Sublimation loss was estimated on a daily time step using the Kuchment and Gelfan (1996) model. The model is based on vapour pressure deficit, which is estimated by air and snow temperatures. The required snow surface temperature was back-calculated from outgoing longwave radiation using the Stefan-Boltzmann relationship, assuming an emissivity of 1 (Vionnet et al. 2012). A daily averaged record of required meteorological observations, including ambient air temperature, wind speed, and outgoing longwave radiation was developed from January 1979 to October 2021 based on ERAI and ERA5 data. The mean annual sublimation losses were estimated as 41 mm; mean monthly sublimation losses are summarized in Table 9A-5.

Table 9A-5: Summary of Mean Monthly Climate and Potential Atmospheric Losses in Base Case

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Air temperature (°C)	-20	-17	-10	0	8	14	17	15	9	1	-9	-17	-1
Rainfall (mm)	0	0	3	16	37	75	92	77	54	27	3	0	384
Snowfall (mm)	21	16	22	15	3	0	0	0	1	14	25	25	142
Lake evaporation (mm)	0	0	5	35	85	98	122	101	62	26	2	0	538
Evapotranspiration (mm)	0	0	0	0	38	76	73	54	25	7	0	0	274
Sublimation (mm)	4	5	9	8	1	0	0	0	0	4	6	5	41

9A3.6.4.4 Trends in Current Climate

Trend analyses in historical climate inform how climate has changed in the recent past and may be useful in understanding climate in the near future. The climate for the Prairie provinces has experienced increasing temperature and precipitation trends over the past 60 years. The latest Environment and Climate Change Canada Report, *Canada's Changing Climate Report* (Bush and Lemmen 2019), reported increases in temperature (+1.9°C) and increases in annual and seasonal precipitation (+7%) between 1948 to 2016 for the Prairie provinces. A trend analysis for current climate was completed as part of the EIS Appendix 22A, Climate Change Dataset Summary Report, based on climate from 1980 to 2010; the decadal trend analysis found statistically significant increasing trends in total annual precipitation, with monthly trends in precipitation only significant for the winter months from November through March. The current climate extreme indices are consistent with the current climate trends, showing warming minimum temperature trends and likely wetter conditions.

9A3.6.4.5 Incorporation of Climate in the Regional Hydrological Model

The historical climate record, consisting of several meteorological parameters on a daily time step, served as the basis for the calibration, validation, and predictive modes of the model simulations. In the calibration and validation stages, the historical climate date was matched with the same model date (1 June 2019 matched to 1 June 2019). In the predictive mode model simulations, the historical time of the climate time series was shifted to align with the anticipated future Project phases: 1 January 1979 was matched with 1 January 2025 and the time series ran sequentially to its end on 31 October 2066. The time series was re-cycled by matching 1 November 1979 to 1 November 2066, and the climate time series was run sequentially through to 31 December 2068. For simulations extending beyond 2068 into the far future, the time series was re-initiated on 1 January 2069 and run through to 31 December 2107 and beyond 2107, the climate time series from 1 January 2069 to 31 December 2107 was allowed to loop when the end of the time climate record was reached, allowing for a long time horizon (more than 100-year simulation runs). Separation of the time series from 2069 to 2107 from the earlier time series was necessary to allow for time looping of continuous runs over longer time horizons.

9A3.6.5 Climate Change

The potential effects of climate change were assessed by incorporating monthly changes to temperature and precipitation developed in the climate change assessment completed as part of EIS Appendix 22A. Site-specific future climate projections were developed for the Project through analysis of available projections from a multi-model ensemble. The multi-model ensemble consists of available regional scale projections from several climate models representing different future climate scenarios (e.g., level of greenhouse gas emissions). The mean changes of projections for 2041 to 2070 relative to the period from 1981 to 2010 were applied to the historical climate record compiled for the Project using the monthly adjustment factors detailed in Table 9A-6 and shown in Figure 9A-8. The period from 2041 to 2070 presents an upper bound in terms of climate change during the Project timeline. Adjusting the historical climate record based on this approach accounts for changes due to climate change, incorporates seasonality, and maintains the integrity of climate cycles that may continue as the climate changes. Monthly average atmospheric temperatures, rainfall, snowfall, and atmospheric losses under mean climate change conditions are summarized as change in temperature and change in precipitation. A summary of climate data based on mean projected climate for the 2050s is provided in Table 9A-7.

Table 9A-6: Monthly Factors used to Adjust Historical Climate Record for Climate Change Sensitivity Scenarios

Period	Scenarios									
	Mean		Cold Wet		Cold Dry		Warm Wet		Warm Dry	
	ΔT (°C)	ΔP (%)	ΔT (°C)	ΔP (%)	ΔT (°C)	ΔP (%)	ΔT (°C)	ΔP (%)	ΔT (°C)	ΔP (%)
	Mean	Mean	5%	95%	5%	5%	95%	95%	95%	5%
January	3.6	12.0	0.4	30.3	0.4	-4.6	6.6	30.3	6.6	-4.6
February	2.7	8.1	0.2	29.0	0.2	-11.6	5.7	29.0	5.7	-11.6
March	2.4	10.2	0.3	29.6	0.3	-8.7	5.1	29.6	5.1	-8.7
April	2.1	9.0	0.6	29.2	0.6	-10.7	4.5	29.2	4.5	-10.7
May	1.9	11.9	0.5	39.2	0.5	-12.3	3.8	39.2	3.8	-12.3
June	1.9	4.8	0.3	27.8	0.3	-12.5	3.8	27.8	3.8	-12.5
July	2.2	2.9	0.6	22.1	0.6	-15.5	4.3	22.1	4.3	-15.5
August	2.2	4.8	0.7	26.5	0.7	-19.4	4.1	26.5	4.1	-19.4
September	2.1	6.5	0.6	23.0	0.6	-9.9	4.0	23.0	4.0	-9.9
October	2.3	9.1	0.9	31.1	0.9	-6.2	3.9	31.1	3.9	-6.2
November	3.1	9.9	0.9	28.0	0.9	-3.6	5.5	28.0	5.5	-3.6
December	3.5	11.5	1.1	29.1	1.1	-4.8	6.5	29.1	6.5	-4.8
Annual	2.5	6.9	0.9	14.5	0.9	-1.0	4.6	14.5	4.6	-1.0

ΔT = change in temperature; ΔP = change in precipitation.

Figure 9A-8: Monthly Adjustment Factors used to Develop Climate Change Sensitivity Scenarios

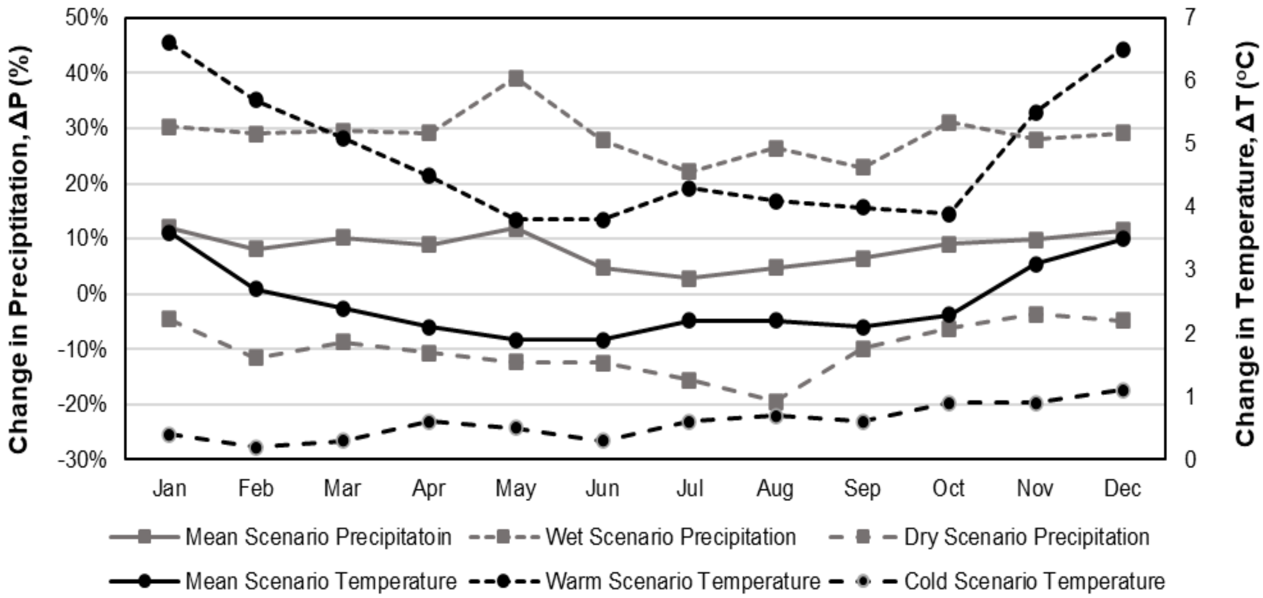


Table 9A-7: Summary of Climate Data based on Mean Projected Climate for the 2050s

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average temperature (°C)	-16	-14	-7	2	10	16	19	17	11	4	-6	-13	2
Rainfall (mm)	0	0	3	17	41	78	94	80	58	29	3	0	404
Snowfall (mm)	24	17	25	16	3	0	0	0	1	15	27	28	156
Lake evaporation (mm)	1	2	10	44	92	111	142	122	83	45	10	2	662
Evapotranspiration (mm)	0	0	0	0	37	80	77	58	28	10	0	0	289
Sublimation (mm)	3	5	7	5	1	0	0	0	0	3	6	5	34

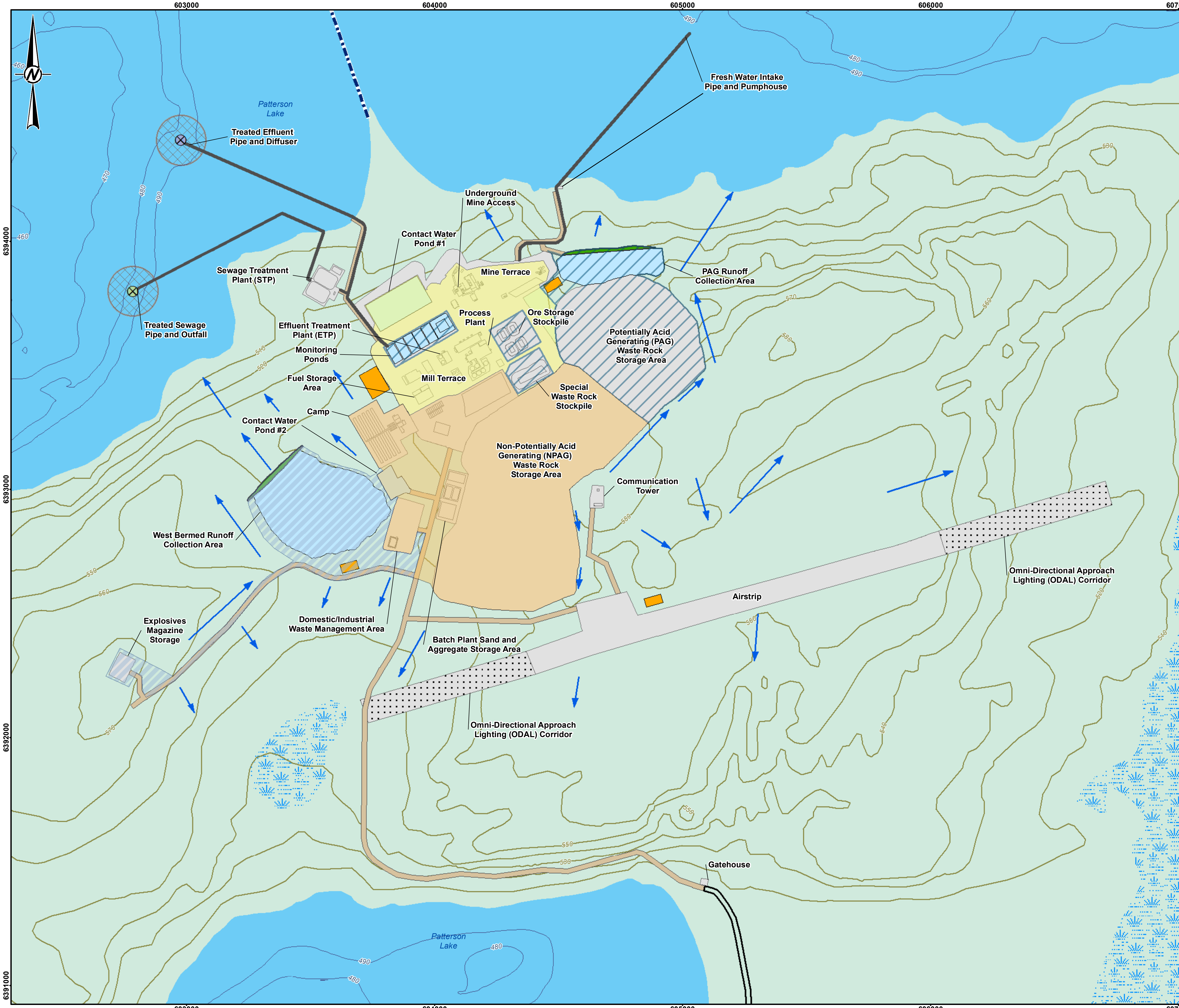
9A3.6.6 Existing Water Management Infrastructure

No permanent surface water management infrastructure (e.g., dams, dikes, water intakes, or waste water outfalls) is currently present within the model domain. There are no existing surface water works registered with the Province of Saskatchewan, although Fission Uranium Corp. has three registered groundwater withdrawal projects in the vicinity of the west shore of Patterson Lake (WSA 2021).

9A3.6.7 Project Water Management

A fully integrated internal (i.e., within the spatial and temporal boundaries of the Project) SWWBM was developed for the Project (TSD XVIII). The SWWBM was developed using GoldSim and integrates information of various forms and sources to estimate how water and loads move through the system over time and at various stages of the Project life. All site water management infrastructure and water management activities associated with the Project are accounted for in the SWWBM. The proposed project infrastructure and site water management activities during operations are shown in Figure 9A-9. The results generated for specific intake and discharge elements of the SWWBM exchange water between the SWWBM and receiving environment model domains are summarized in Table 9A-8 and can be described as follows:

- Fresh water supply for the Project would be withdrawn from Patterson Lake via an intake in the Patterson Lake North Arm – East Basin. Fresh water demand for the Project consists of water for domestic consumption, for use in the fire water loop, a portion of process plant water, and surface industrial uses. The simulated fresh water demand is variable based on demands according to Project activities, camp population, and ore production over time.
- Treated effluent would be discharged via the mine effluent diffuser to the Patterson Lake North Arm – West Basin. The feed to the effluent treatment plant would include components of recovered groundwater from the underground workings, process plant water, collected and captured runoff from mineralized or potentially mineralized surfaces on site, and runoff from non-mineralized surfaces that do not meet water-quality-based environmental release targets. The treated effluent would be held in four treated effluent monitoring ponds, tested relative to water quality environmental release targets, and released as a batch release if targets are met. The daily rate of treated effluent release would vary throughout the Mine Life based on a variety of Project activities. Treated effluent discharged to Patterson Lake was accounted for by discharge calculated from the SWWBM: Q02 – Treated Effluent Discharge.
- Treated sewage would be released via the treated sewage outfall to the Patterson Lake North Arm – West Basin. Sewage would be generated from domestic use and would be discharged in a continuous release via the treated sewage outfall into the Patterson Lake North Arm – West Basin. Treated sewage discharged to Patterson Lake was accounted for by discharge calculated from the SWWBM: Q03 – Sewage Discharge.
- Surface runoff from the West Surface Runoff would discharge to the Patterson Lake North Arm – West Basin. During operations, the West Surface Runoff Discharge would include non-contact water from downstream of the mine-controlled area as well as non-mineralized contact water that has been tested and confirmed to be acceptable for release. Water generated from West Surface Runoff was accounted for by discharge calculated from the SWWBM: Q01 – West Surface Runoff.
- Surface runoff from the East Surface Runoff would discharge to the Patterson Lake North Arm – East Basin. During operations, surface runoff would consist of non-contact water from outside the mine-controlled area. Following closure, runoff from reclaimed, covered, and revegetated surfaces within the former mine-controlled area would be routed to the East Perimeter Diversion and discharged to the Patterson Lake North Arm – East Basin. Water generated from East Surface Runoff was accounted for by discharge calculated from the SWWBM: Q05 – East Surface Runoff.
- The mine-controlled area, as well as the area associated with the West Surface Runoff and East Surface Runoff pathways, were input as a daily time series that was subtracted from the terrestrial watershed area reporting to Patterson Lake North Arm – East Basin and Patterson Lake North Arm – West Basin.



LEGEND
- BATHYMETRY CONTOUR ELEVATION (5 m INTERVAL)
- ELEVATION CONTOUR (10 m INTERVAL)
- GENERAL FLOW DIRECTION
- LAKE BASIN DIVISION
- 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
- EFFLUENT TREATED PIPE DIFFUSER
- SEWAGE TREATED PIPE OUTFALL
- PROPOSED REGULATED MIXING ZONE
- DRAINAGE TO SITE RUNOFF POND #1
- DRAINAGE TO SITE RUNOFF POND #2
- SELF CONTAINED
- TO WEST BERMED RUNOFF COLLECTION AREA

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.
3. BATHYMETRY CONTOURS DERIVED FROM DATA COLLECTED BY NEXGEN, 2016.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
ROOK I PROJECT SURFACE WATER MANAGEMENT INFRASTRUCTURE DURING OPERATIONS

CONSULTANT
wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-07		
CHECK	RWP	2023-02-07	FIGURE 9A-9	
REVIEW	NPS	2023-02-07		

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PATH: I:\CLIENTS\NexGen\20144150\Mapping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\09_Hydrology\17x11\20144150_Fig9A_9_Project_Surface_Water_Management_Infrastructure_Rev0.mxd PRINTED ON: 2023-02-07 AT: 1:50:24 PM

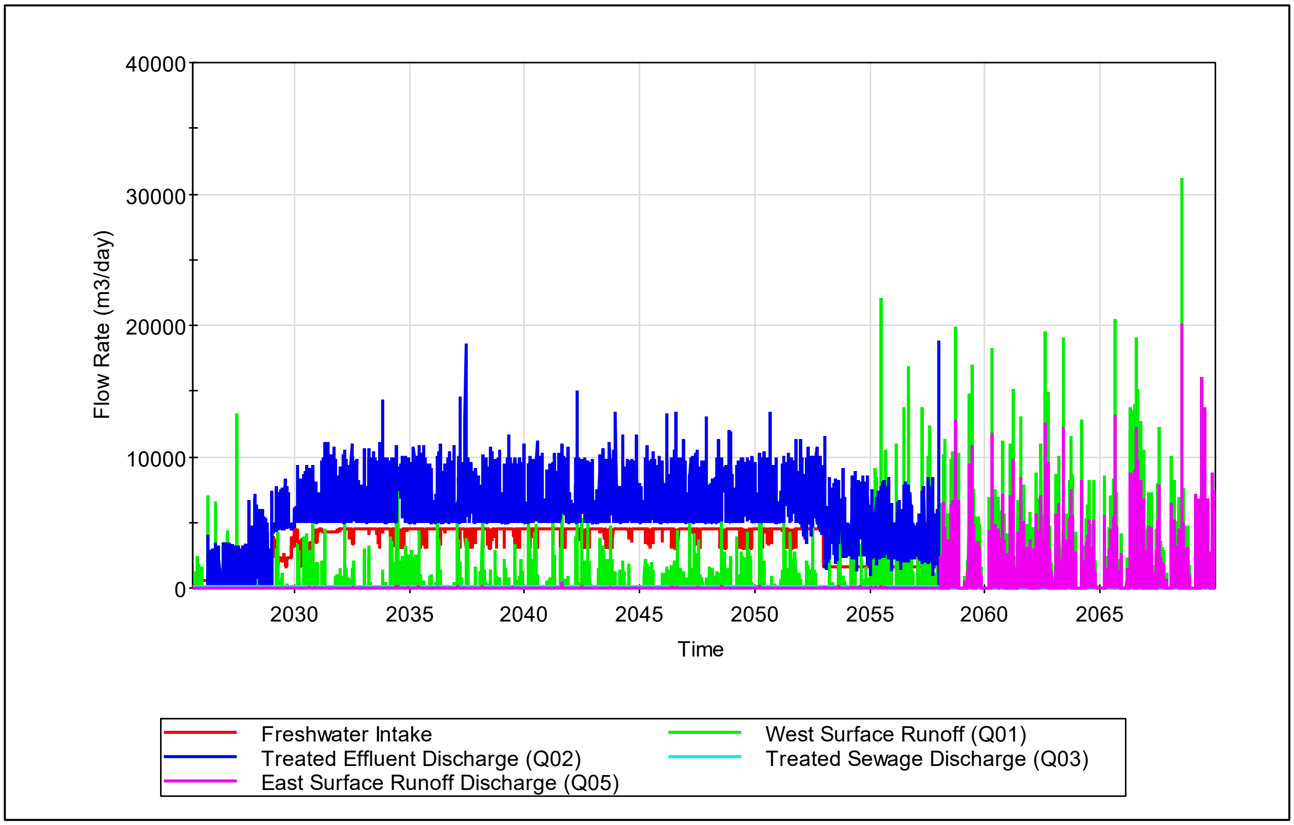
Table 9A-8: Rook I Project Interactions Incorporated in the Regional Hydrological Model

Interaction	Frequency	Incorporation in Regional Hydrological Model	Routing
Fresh water supply – north intake	Daily time series of intake	Daily time series for the extraction rate from Patterson Lake in the Application Case SWWBM.	From Patterson Lake North Arm – East Basin
Treated effluent discharge	Daily time series of discharge	Daily time series for the nominal discharge rate to Patterson Lake in the Application Case SWWBM.	To Patterson Lake North Arm – West Basin
Treated sewage discharge	Daily time series of discharge	Daily time series for the nominal discharge rate to Patterson Lake in the Application Case SWWBM.	To Patterson Lake North Arm – West Basin
East surface runoff	Daily time series of discharge	Daily runoff time series in the Application Case SWWBM.	To Patterson Lake North Arm – East Basin
West surface runoff	Daily time series of discharge	Daily runoff time series in Application Case SWWBM.	To Patterson Lake North Arm– West Basin
Closed-Circuit area	Daily time series of area	Closed-circuit area removed from the watershed area draining to Patterson Lake. The closed-circuit area will be diverted first to the effluent treatment plant before being discharged as release water to Patterson Lake.	Removed from Patterson Lake North Arm – East Basin Receiving Environment Watershed
			Removed from Patterson Lake North Arm – West Basin Receiving Environment Watershed

SWWBM = site-wide water balance and water quality model.

The rates of withdrawal and discharge from Patterson Lake vary over the life of the mine as shown in Figure 9A-10. In Figure 9A-10, the timescale is long relative to the individual records in the time series; as a result, the separation between days is not always visible.

Figure 9A-10: Flow Rates between the Rook I Project and Receiving Environments under Historical Climate Conditions

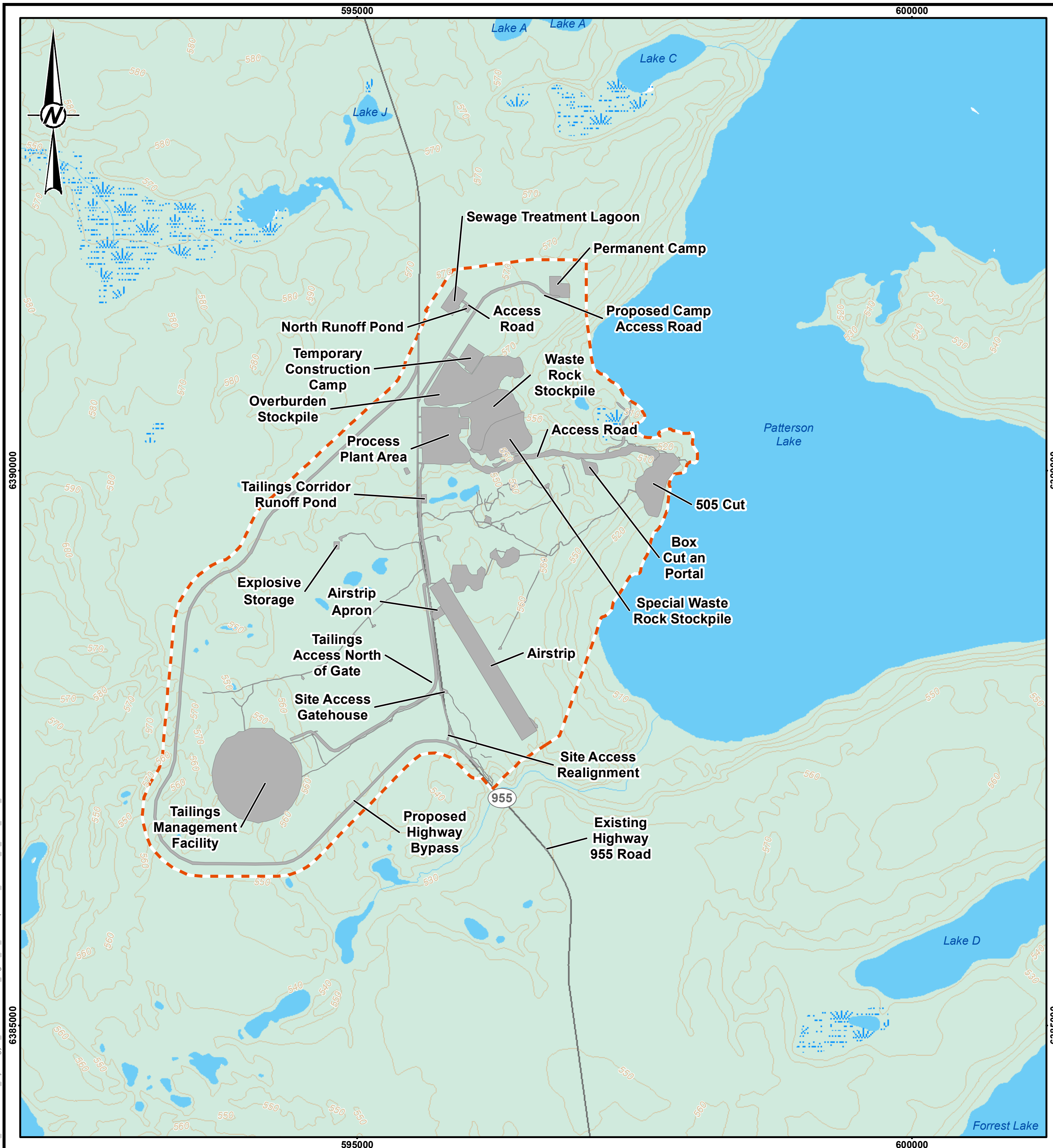


9A3.6.8 Reasonably Foreseeable Development Water Management

Reasonably foreseeable developments that have not yet been approved, namely the Fission Patterson Lake South Property, are included in Scenario 5. The RFD Case also considered how natural factors and climate change (i.e., precipitation) may interact with the Project and other developments to affect hydrology. Cumulative effects on hydrology were assessed by supplementing the GoldSim hydrological model with the anticipated activities of the Fission Patterson Lake South Property, which are all expected to take place within the watershed draining to Patterson Lake and influence the water balance of Patterson Lake. The Fission Patterson Lake South Property activities during operations were accounted for in the GoldSim model to represent the various hydrological interactions (i.e., fresh water withdrawals, treated effluent discharge, and treated sewage discharge) from the Fission Patterson Lake South Property.

The Fission Patterson Lake South Property is planned to be located on the west shore of Patterson Lake at the most westerly point where the North Arm and South Arm meet (Figure 9A-11). Based on the pre-feasibility report (Fission 2019), the Fission Patterson Lake South Property is expected to withdraw fresh water from the Patterson Lake North Arm – West Basin and discharge treated effluent and treated sewage to the Patterson Lake South Arm. Construction of the Fission Patterson Lake South Property is expected to occur over a three-year period that was assumed to commence in 2025, and the operating period is expected to be seven years long and extend from 2028 to 2033 including part of 2027.

During Fission Patterson Lake South Property operation, the area that falls within the anticipated mine footprint for the Fission Patterson Lake South Property was removed from the terrestrial watershed reporting to the Patterson Lake South Arm or Patterson Lake North Arm – West Basin according to local topography so that area would not be double counted in the model. The hypothetical Fission Patterson Lake South Property footprint is 1.54 km^2, of which 1.34 km^2 is expected to have controlled runoff during Fission Patterson Lake South Property operations. Surface infrastructure footprint areas were sorted into controlled and uncontrolled areas for site water management based on relevant regulatory requirements for site water management at uranium mining and process plant buildings. The area removed from the Patterson Lake South Arm watershed during construction and operation of the Fission Patterson Lake South Property was 0.77 km^2, which decreases to 0.54 km^2 following closure. The area removed from the Patterson Lake North Arm – West Basin watershed during construction and operation of the Fission Patterson Lake South Property was 0.57 km^2, which decreases to 0.15 km^2 following closure. During operations, the area removed represents the land surface for which runoff is anticipated to be collected, captured, contained, and treated prior to release to the environment, and is reflected in estimates of treated effluent discharge. Following closure, the area removed is associated with the area of the Fission Patterson Lake South Property waste rock storage area, which is expected to report to the North Arm West Basin, and the Fission Patterson Lake South Property above-ground tailings management facility, which is expected to report to the South Arm. Note that the area is removed from the receiving environment watershed because it is accounted for elsewhere in the model to mitigate double counting of the area and runoff generated. The areas associated with access roads, airstrip, and trails were not included in the controlled area and assumed to run off to adjacent natural surfaces.



LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA

0 1 2

1:50,000 KILOMETRES

REFERENCE(S)

1. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
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

DEVELOPMENTS INCLUDED IN THE REASONABLY FORESEEABLE DEVELOPMENT CASE

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2023-02-07	SCALE AS SHOWN	REV. 0
GIS	LB/NO	2023-02-07	FIGURE 9A-11	
CHECK	RWP	2023-02-07		
REVIEW	NPS	2023-02-07		

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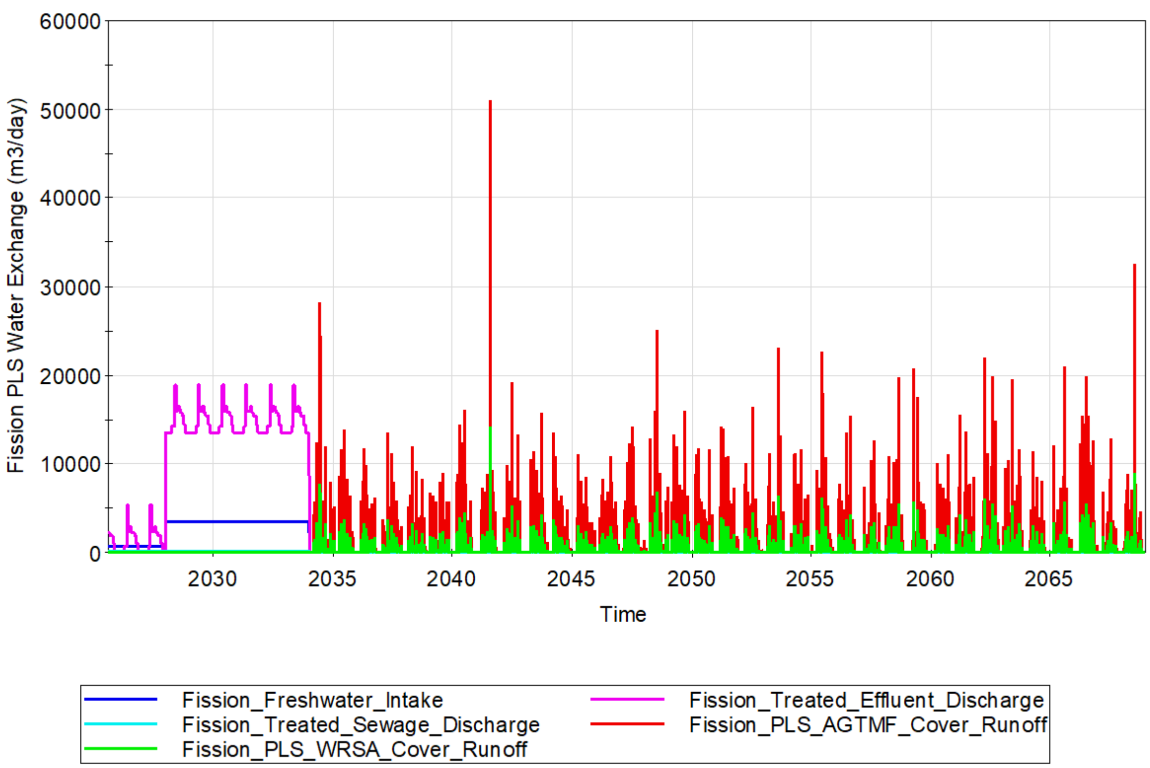
A monthly water balance was estimated for the Fission Patterson Lake South Property during construction and operations based on the Fission Patterson Lake South Property pre-feasibility report (Fission 2019), supplemented by data from the Project to fill gaps where information was unavailable from the pre-feasibility report. The Project provides a reasonable surrogate as it shares similar climate and geography and would have similar regulatory expectations as the Fission Patterson Lake South Property. In the estimated water balance, treated effluent is expected to consist of captured runoff from a mine-controlled area, water used for industrial uses, process plant water, and groundwater recovered from the underground workings. Runoff from the mine-controlled area was estimated based on a monthly water balance, assuming runoff coefficients for different surface catchments. The climate data used to estimate runoff was historical (Section 9A3.6.4, Current Climate) or climate change (Section 9A3.6.5) data depending on the scenario. Process water was assumed to consist of fresh water from Patterson Lake. The estimated rate of process water generation was prorated from Rook I rates based on annual ore production rates. The Fission Patterson Lake South Property is anticipated to extend under Patterson Lake and the inflow to the mine underground is expected to be up to 10,360 m^3/d (Fission 2019). Following closure of the Fission Patterson Lake South Property, surface runoff was calculated for the waste rock storage area and above-ground tailings management facility using a runoff coefficient of 0.95 and assumed to drain freely to Patterson Lake (Figure 9A-12).

Figure 9A-12: Fission Patterson Lake South Property Estimated Flow Rates based on Historical Climate Conditions



PLS = Patterson Lake South; WRSA = waste rock storage area; AGTMF = above-ground tailings management facility.

9A3.7 Model Parameterization

This subsection discusses the development of select parameters required to describe the hydrological processes accounted for in the hydrological model. The details about atmospheric losses are described in Section 9A3.6.4.3.

Snowmelt

Daily snowmelt was estimated using a temperature index (i.e., degree day) model (Dingman 2002). In this method, a base or threshold temperature, taken in this case to be 0°C, was subtracted from the daily mean air temperature. This difference was then multiplied by a melt coefficient to determine snowmelt water equivalent depth. The melt coefficient for the area of the Project was empirically derived by model calibration and was found to be 3.0 mm/°C/d.

Canopy Storage

Storage in the forest canopy is important as it abstracts rainfall from runoff generation and makes it available for loss to the atmosphere. Canopy storage was accounted for in the model as a storage reservoir. The hydrological function of the plant canopy is to intercept precipitation before it reaches the ground surface. The intercepted water then evaporates and is abstracted from runoff generation processes. The simple canopy method used in the model uses a water depth equivalent storage to represent the amount of precipitation that is intercepted and allowed to evaporate during and following storm events. Ten percent of daily rainfall was abstracted to canopy storage, and once the storage in the plant canopy was satisfied, excess rainfall was permitted to fall to the ground surface. A maximum effective combined canopy storage (i.e., crown, stem, branches, and forest floor) of 10 mm was used. Once water stored in the canopy was evaporated, the canopy storage returned to zero.

Surface/Subsurface Storage and Flow

The soils in the area of the Project are predominantly sandy in texture; therefore, it was assumed that all the water reaching the ground surface would infiltrate and be routed to a subsurface baseflow storage reservoir. The subsurface runoff calculations were conducted using a linear baseflow reservoir method. The model simulations of baseflow from the terrestrial portions of the landscape were based on an instantaneous volume of the baseflow (i.e., subsurface storage) reservoir and a watershed-specific baseflow recession constant in percent per day. The recession constant was used to describe the rate at which baseflow recedes following a storm event. A degree day model was used to account for the ice effects on flows in shallow channels that triggered the winter decay function once the air temperature fell below 0°C until a positive air temperature threshold in spring was reached. The winter baseflow was not allowed to recede below a minimum threshold of 0.15 mm/d, the value of which was established based on a review of long-term historical observations between November 1 and April 15 in the Douglas River near Cluff Lake (WSC Station 05MA003) (WSC 2021).

Groundwater Exchange

Groundwater exchange was accounted for by integrating results from the Regional Groundwater Model (Annex III, Hydrogeology Baseline Report) that overlapped the spatial domain of the hydrological model. The groundwater exchange with the surface water environment was calculated as the difference between the groundwater recharge and the groundwater discharging through the surface water features (i.e., waterbodies and watercourses) within that watershed. The rate of groundwater exchange was applied to the storage reservoir controlling outflow in each of the watersheds of the hydrological model. The groundwater contribution was prorated by the area for incomplete basins. A summary of groundwater fluxes within the RSA is provided in Table 9A-9.

Table 9A-9: Groundwater Fluxes as Estimated by Groundwater Modelling

Basin	Groundwater Recharge (m^3/d)	Groundwater Outflow (m^3/d)	Net Loss / Gain (m^3/d)
Patterson Lake	56,295	58,580	2,285
Broach Lake	11,193	7,917	-3,276
Clearwater River above Patterson Lake	25,388	18,532	-6,856
Tributary inflow to Naomi Lake	33,175	28,312	-4,863
Tributary inflow downstream of Naomi Lake[a]	14,355	12,250	-2,104
Lake H	2,500	2,430	-70
Lake G	1,540	1,030	-510
Forrest Lake	45,815	41,335	-4,480
Beet Lake	8,487	9,151	664
Naomi Lake[b]	1,585	1,709	124

a) Prorated from values for the tributary inflow to Naomi Lake based on area assuming that groundwater exchange for the tributary inflow downstream of Naomi Lake is limited to the surface watershed.
b) Prorated from values for Beet Lake based on area.

Lake Outflow Rating Curve

The rating curve in its standardized form was incorporated in the model to estimate outflow from the waterbodies (i.e., Broach Lake, Lake G, Lake H, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake) based on their WSEs. The standard rating curve equation takes the following form:

$$Q = a * (WSE - WL_{Datum})^c + d$$

where Q is outflow in m^3/s, WSE is the WSE of the lake (m), WL_{Datum} is the water level stage datum (m), which was determined based on 2018 to 2020 hydrometric monitoring, and $a, c,$ and d are the empirical coefficients. Winter conditions and ice effects were not considered when flows were estimated by the rating curve in its original form. Regional flow observations suggested that backwater from ice effects may cause flows to be overestimated by up to 20%. Ice effects were accounted for by applying a linear reduction in discharge with accumulated cold content calculated based on ambient air temperatures following a degree day threshold.

9A3.8 Model Calibration

Continuous hydrological models are developed with the objectives of correctly predicting magnitude and timing of hydrograph peaks, predicting low-flow magnitude, and providing a good representation of the recession curve to properly establish the initial conditions prior to the next runoff event (Beven 2012). Unknown model parameters with larger uncertainty are often calibrated to achieve the desired modelling goals. In general, model calibration targeted the annual water yield averaged over the simulation period, the magnitude of annual peaks, and the magnitude of the annual low flows. The overall goodness of fit of the hydrograph shape, shape of the hydrograph recession, and response to effective precipitation (snowmelt or rainfall) were also targets. Different model parameters were calibrated to improve the simulation of processes active for different seasons. For example, snowmelt parameters were modified to improve the fit of the hydrograph response to spring snowmelt, and base flow recession parameters were modified to improve the fit of hydrographs to low flows during late winter.

Hydrological model calibration used daily values of water level and discharge collected in the RSA between August 2018 and August 2020. The primary watercourse calibration nodes were located along the Clearwater River mainstem below Broach Lake, above Patterson Lake, below Patterson Lake, below Beet Lake, below Naomi Lake, and above the Mirror River confluence. The primary waterbody calibration nodes in the model were Broach Lake, Patterson Lake, Lake G, Lake H, Forrest Lake, Beet Lake, and Naomi Lake.

The model parameters including snowmelt coefficient, initial storage in baseflow reservoir, baseflow recession constant, baseflow recession constant, coefficients for rating curve for lake outflow, and ice effects (i.e., percentage drop in flow based on cold content/degree day) were calibrated to better simulate flows against the observations from August 2018 to August 2020. Missing values were estimated using nearby measured data to fill gaps by prorating daily discharge by area. The calibration period covered a range of conditions including dry (e.g., 2018) and wet (e.g., 2020) years. The supporting data are presented in Annex IV.2. The model calibration and evaluation nodes within the RSA are listed in Table 9A-10 and shown in Figure 9A-4. The parameters and processes inferred from model calibration were adopted for longer period simulations, both at the calibration points as well as at other analogous locations where no hydrometric gauge monitoring information is available.

Table 9A-10: Model Calibration and Evaluation Nodes within the Regional Study Area of the Model Domain

Type	Locations	Hydrometric Station ID	Cumulative Area (km^2)	Calibration Node	Evaluation Node
Watercourses	Clearwater River below Broach Lake	CR-WC-MS-01	56.4	✓	✓
	Clearwater River above Patterson Lake	CR-WC-MS-02	121	✓	✓
	Clearwater River below Patterson Lake	CR-WC-MS-03	264.4	✓	✓
	Clearwater River below Beet Lake	CR-WC-MS-04	473.4	✓	✓
	Tributary inflow to Naomi Lake	CR-WC-TI-02	607.4	✓	×
	Tributary inflow downstream of Naomi Lake	CR-WC-TI-03	685.4	✓	×
	Clearwater River above the Mirror River confluence	CR-WC-MS-06	1,076	✓	×
Waterbodies	Broach Lake	CR-WB-MS-01	56.4	✓	×
	Patterson Lake	CR-WB-MS-02	264.4	✓	×
	Forrest Lake	CR-WB-MS-03	445	✓	×
	Beet Lake	CR-WB-MS-04	473.4	✓	×
	Naomi Lake	CR-WB-MS-05	685.4	✓	×
	Lake H	CR-WB-TI-01	7.36	✓	×
	Lake G	CR-WB-TI-02	3.75	✓	×

× = data are not available; ✓ = data are available.

Model calibration was evaluated using graphical techniques and quantitative statistics. The quantitative performance of the model was evaluated statistically through the calculation of residuals, the residual mean, the normalized root mean square error (NRMSE), correlation coefficient (R), and Nash-Sutcliffe efficiency (NSE). A brief definition of the statistical measures is provided below:

- **Residual:** The residual is the difference between observed and simulated daily discharge at a specific location. A difference of 0 m^3/s would indicate a perfect match of simulations and observations.
- **Residual mean:** The residual mean is the sum of all absolute value residuals divided by the total number of residuals. A difference of 0 m^3/s would indicate a perfect match of simulations and observations.

- **Normalized root mean square error**: The NRMSE is the square root of the averaged squared residual divided by the difference between the maximum and minimum observed daily mean discharge. It relates root mean square error with the observed range of the variable and thus can be interpreted as a fraction of the overall range resolved by the model. It is also known as a scatter index, where a smaller value represents better agreement between the model simulations and observations.
- **Correlation coefficient (R):** The R is a statistical measure to compare the linear association between simulated and observed daily discharge. An R of 1 would indicate a perfect match of simulated and observed daily discharge at a specific location and an R of 0 would indicate no linear association.
- **Nash-Sutcliffe efficiency:** The Nash-Sutcliffe model efficiency coefficient is a widely used goodness-of-fit measure that assesses the predictive power of hydrological models. The NSE is a normalized statistic that determines the relative magnitude of the residual variance relative to the measured data variance (Moriasi et al. 2007). The performance ratings adapted for evaluating calibration were as follows: an NSE less than 0.50 is considered unsatisfactory, an NSE between 0.5 and 0.65 is considered satisfactory, an NSE between 0.65 and 0.75 is considered good, and an NSE greater than 0.75 is considered very good (Moriasi et al. 2007). An NSE of 1 would correspond to a perfect match of modelled discharge and observed data.

The statistical performance evaluation of the hydrological model is summarized in Table 9A-11. The calibration results are quantified for the model evaluation nodes listed in Table 9A-11. The model nodes used for evaluation were those with sufficient observed data to support quantitative performance evaluation and those stations that were the most important to supporting quantitative assessment of Project effects and cumulative effects. The values of objective function matrices suggest that variability in flows in terms of timing and magnitude are well captured by the model. A comparison between simulated and observed daily discharge at the model evaluation nodes is presented in Figure 9A-13 to Figure 9A-16. Overall, the seasonal variations in discharge were well captured at all points. The mean residual and NRMSE indicate that simulated values are similar in magnitude to measured data. The R value indicates that there is a linear association between observed and simulated discharge and the NSE indicates that the calibration performance was satisfactory, good, or very good depending on the station. Model calibration performance was best at the Clearwater River below Patterson Lake, Station CR-WC-MS-03.

Table 9A-11: Quantitative Summary of Calibration Results at the Model Evaluation Nodes

Station	Δ_{mean} (m^3/s)	NRMSE	R	NSE	Performance Rating
CR-WC-MS-01	0.04	0.26	0.92	0.70	Good
CR-WC-MS-02	0.16	0.46	0.78	0.72	Good
CR-WC-MS-03	0.10	0.13	0.92	0.76	Very good
CR-WC-MS-04	0.46	0.21	0.85	0.63	Satisfactory

Δ_{mean} = mean residual; NRMSE = normalized root mean square error; R = correlation coefficient; NSE = Nash-Sutcliffe efficiency.

The simulated water yield was compared to observed or estimated water yield from the hydrometric monitoring program. The percent error ranged from -10% to +16% for all stations but was on average +6% for the calibration period. This means that, overall, the meteorological data used for the calibration period and the model simulations themselves are acceptable for describing the hydrological conditions in the spatial domain of the model.

Figure 9A-13: Observed, Estimated (from Regional Discharge prorated by the Area), and Simulated Daily Discharge at the Clearwater River below Broach Lake (CR-WC-MS-01), August 2018 to August 2020

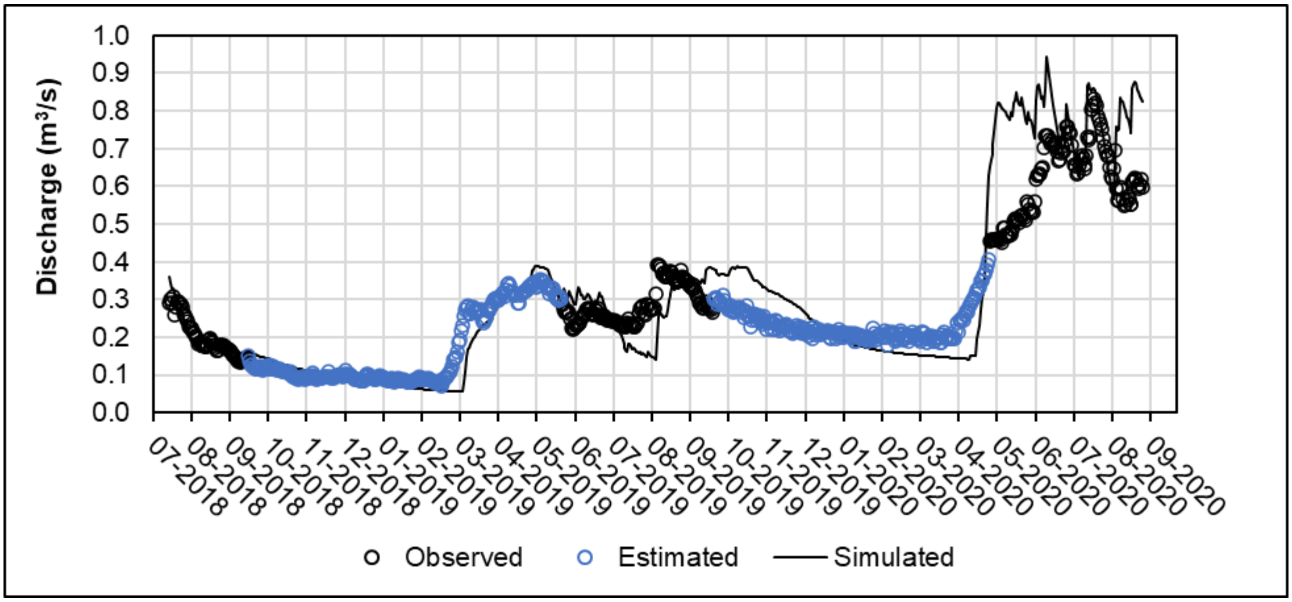


Figure 9A-14: Observed, Estimated, and Simulated Daily Discharge at the Clearwater River above Patterson Lake (CR-WC-MS-02), August 2018 to August 2020

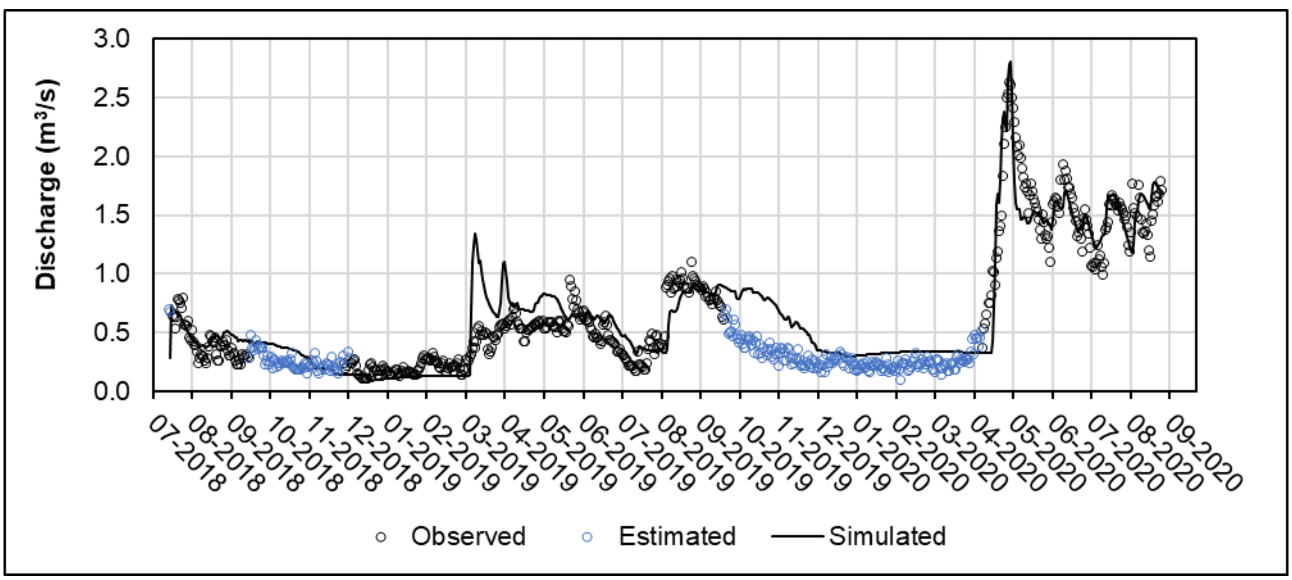


Figure 9A-15: Observed, Estimated, and Simulated Daily Discharge at the Clearwater River below Patterson Lake (CR-WC-MS-03), August 2018 to August 2020

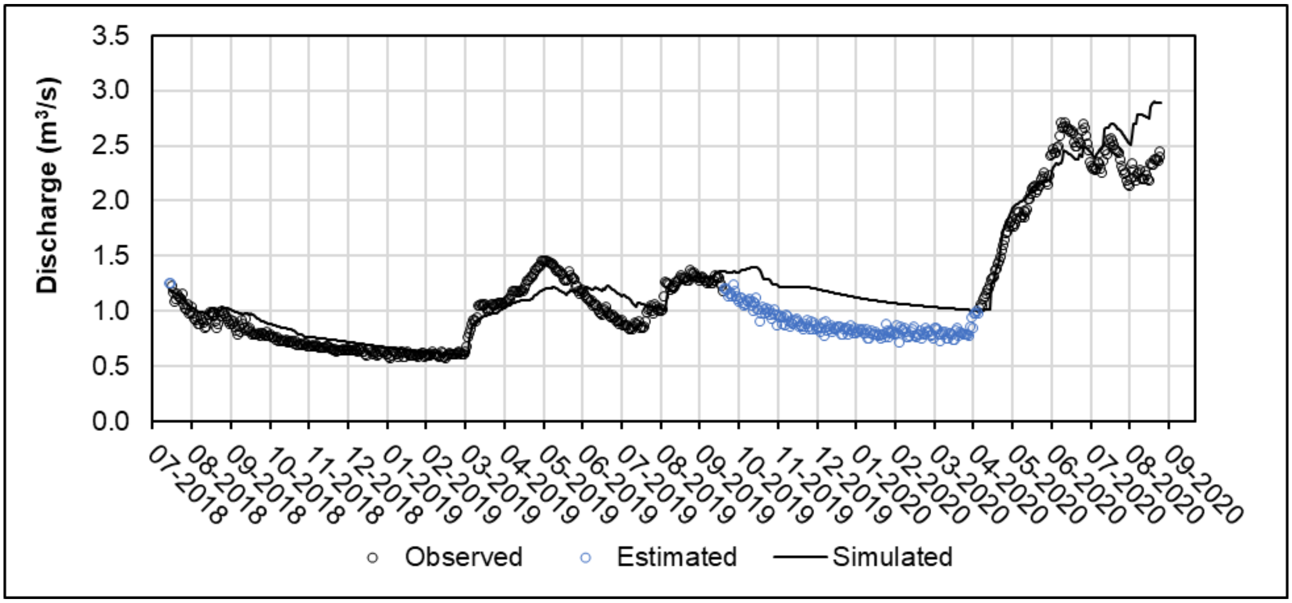
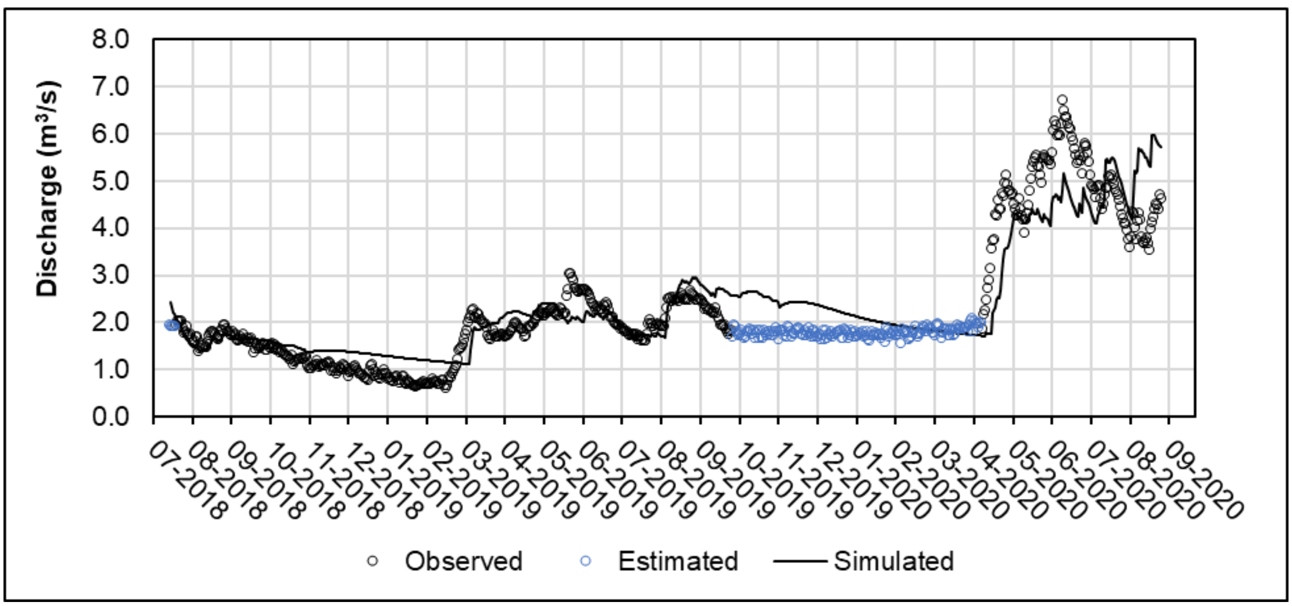


Figure 9A-16: Observed, Estimated, and Simulated Daily Discharge at the Clearwater River below Beet Lake (CR-WC-MS-04), August 2018 to September 2020

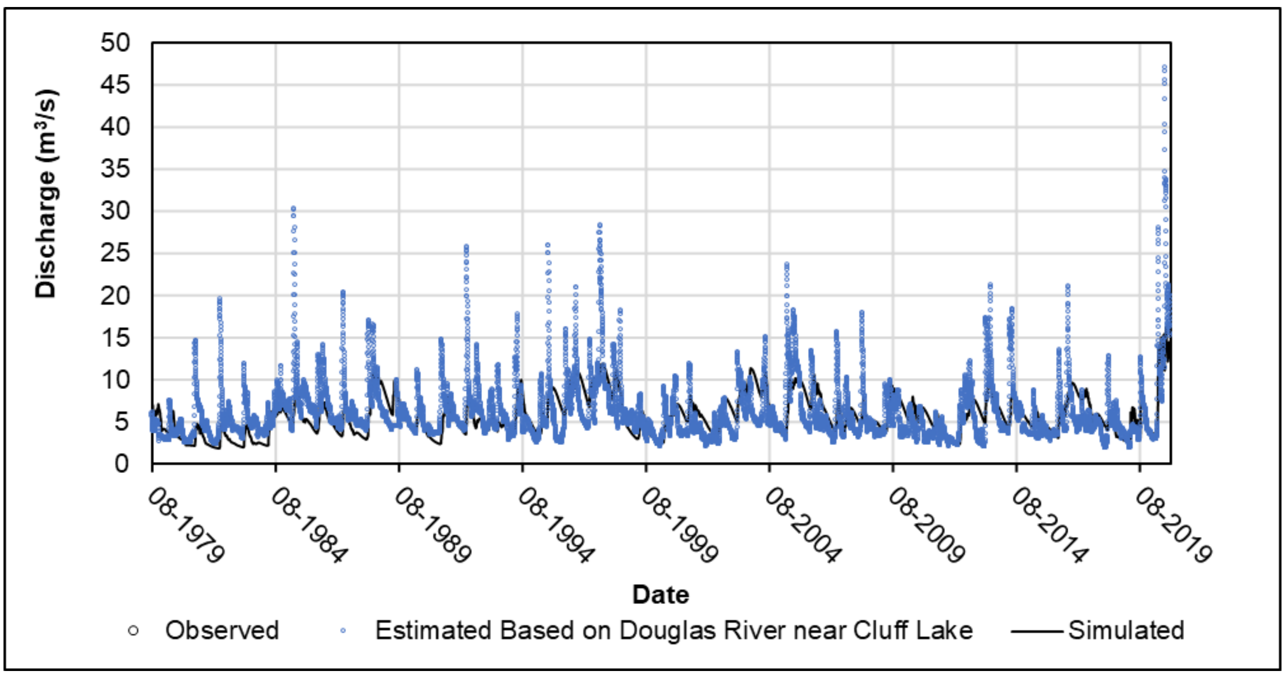


9A3.9 Model Validation

In general, model validation involves evaluating model performance against the observations for a time period other than the model calibration period. All available hydrometric monitoring data were used for model calibration to calibrate the model based on as much data as possible and over the largest possible range of conditions. Therefore, direct validation at the same nodes as used in calibration was not possible. Instead, independent validation was completed using regional data to compare the model results for similarity in terms of inter-annual and seasonal variability in discharge. Regional observations (WSC Station 07MA003: Douglas River near Cluff Lake) were prorated by the watershed area.

A comparison of model-simulated and estimated discharge based on regional flow observations at the outlet of the RSA is presented in Figure 9A-17. Overall, the inter-annual and seasonal variability in stream flows were well captured by the model. The magnitude of the flows may differ because of potential varying storage capacities and hydrological characteristics of different watersheds. A statistical measure (R) was used to quantify the correlation between model simulated and estimated flows. The R was 0.582 for the Clearwater River above the Mirror River confluence (CR-WC-MS-06) station. The model validation is not a direct comparison of simulated versus measured values and as a result other metrics listed in Section 9A3.9, Model Validation, were not evaluated.

Figure 9A-17: Comparison of Model Simulated, Observed, and Estimated Discharge at the Clearwater River above Mirror River Confluence (CR-WC-MS-06), August 1979 to August 2019



Note: Estimated discharge is based on regional unit discharge at Douglas River adjusted for the Clearwater River above Mirror River Confluence.

9A3.10 Model Outputs and Analysis

The raw outputs of the predictive model simulations are time series values of WSE or discharge at spatially distributed evaluation nodes on a daily time step over the period from August 2025 to December 2068. Model result outputs are generated for evaluation nodes representing waterbodies (i.e., lakes) and watercourses (i.e., rivers and lake outflow channels) in the RSA. The evaluation nodes were introduced in Section 9A2.1, Hydrology Assessment Study Area, and are shown in Figure 9A-4. The 43-year daily time series for the different model scenarios and assessment cases are analyzed outside of the model domain to summarize the hydrological characteristics of the RSA over longer time periods (e.g., monthly or annual) representing average or extreme conditions. Waterbody WSE values are presented to the nearest millimetre rather than three significant figures because it is possible to measure waterbody WSE to the millimetre assuming calm conditions. Watercourse flowrate values are presented to three significant figures because of changes in precision with changes in scale. Annual water yield values are presented to three significant figures.

Table 9A-12 presents a summary of the values discussed further in Section 9A3.6, Input Data, including a definition of the value and its source.

Table 9A-12: Raw Model Outputs and Values Derived from Model Outputs

Value	Units	Definition	Source
Daily discharge	m^3/s	The simulated average discharge for a specific day.	Model output
Daily WSE	masl	The simulated average WSE for a specific day.	Model output
Monthly mean discharge	m^3/d	The average discharge for a given month based on all days in the simulation record.	Derived from daily discharge model output
Monthly mean WSE	masl	The average WSE for a given month based on the simulation record.	Derived from daily WSE model output
Mean annual minimum daily flow	m^3/s	The average minimum daily flow during an annual period based on the simulation record.	Derived from daily discharge model output
Mean annual minimum 7-day flow, (7QN)	m^3/s	The 7 consecutive days of low flow during an annual period, with a return period of N (i.e., number) years.	Derived from daily discharge model output
Mean annual flow	m^3/s	The average daily flow during an annual period based on the simulation record.	Derived from daily discharge model output
Mean annual maximum daily flow	m^3/s	The average maximum daily flow during an annual period based on the simulation record.	Derived from daily discharge model output
Annual water yield	mm	The total annual volume that runs off an area expressed in a depth of water distributed over the cumulative watershed area.	Derived from daily discharge model output
Return period	yr	The time interval for which an event will occur once on the average.	Inverse of exceedance probability
Frequency distribution	n/a	Probability distribution used in flood frequency analysis to define a relationship between extreme event magnitude and probability of exceedance at a particular location. Frequency distributions used in analysis included Weibull and extreme value distributions.	Used in frequency analysis

n/a = not applicable; masl = metres above sea level; WSE = water surface elevation.

9A3.11 Model Assumptions

Several assumptions are referenced in the Section 9A2 as input data and parameters. Key assumptions of the model are as follows:

- Spatial variability of meteorological conditions within the model domain was assumed to be negligible.
- All the water reaching the ground surface is assumed to infiltrate and be routed to a subsurface baseflow storage reservoir rather than flow over land. Infiltration and routing to the subsurface baseflow storage reservoir occurs in a single time step.
- Water body water surface elevations observed in August 2018 were assumed to be representative of initial conditions in August 2025 to provide a realistic starting point for model simulations.
- Construction for the Fission Patterson Lake South Property was assumed to start at the same time as the Project.

9A4 RESULTS

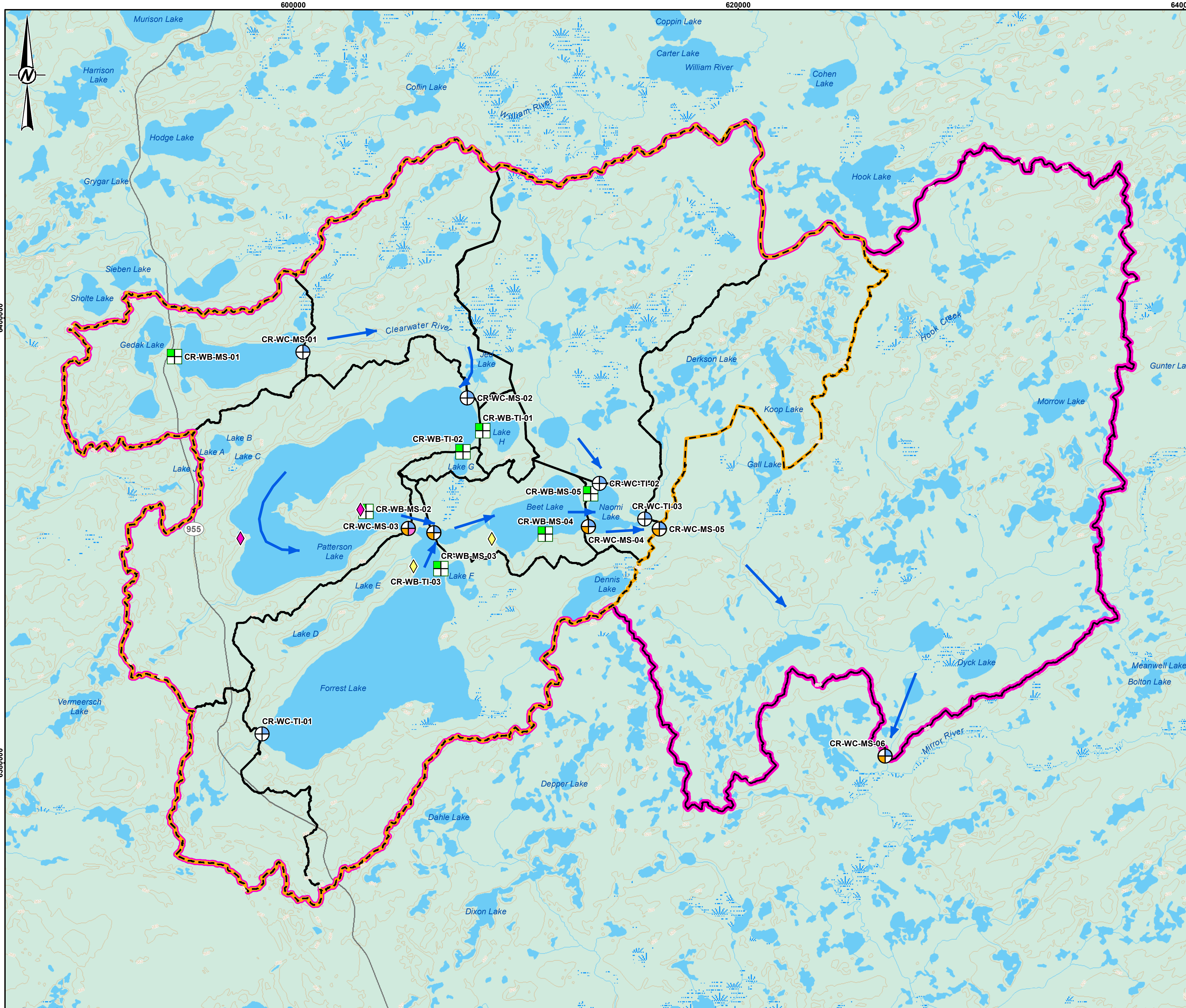
This subsection discusses the model results as they relate to the objectives noted in Section 9A1.3, Modelling Study Objectives. The results presented summarize simulation of the hydrological conditions in the Base Case, Application Case, RFD Case, and the climate change and RFD (including climate change) scenarios.

9A4.1 Base Case

Existing hydrological conditions were summarized by the Base Case model. The Base Case simulation (Scenario 1) characterized long-term seasonal and inter-annual variation under the current climate conditions in the RSA. For the purposes of standardizing comparison to the predictive cases, the Base Case model was run over the same hypothetical simulation period as the Application Case and RFD Case scenarios. The Base Case simulations reflect the seasonal and inter-annual variations that are typical of the Project location.

Existing hydrological conditions are typically characterized by snow accumulation and receding discharge rates through the winter months between October and March, snow and ice melt and rising hydrograph between April and June, and gradual hydrograph recession between July and September when outputs (e.g., atmospheric losses and discharge) exceed inputs (e.g., rainfall). The seasonal variations are superimposed on longer term oscillations in climate resulting in a range of conditions from dry to wet. The hydrographs of the Clearwater River in the LSA are attenuated by the storage available in the lakes as well as subsurface storage.

The relatively large lakes in the upper reaches of the RSA, including Broach, Patterson, Forrest, Beet, and Naomi lakes, mean that evaporative losses are high relative to the sub-watersheds in the eastern portion of the RSA, and these catchments yield less outflow. The existing hydrological conditions in the RSA that are reflected in the Base Case simulation are shown in Figure 9A-18.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED

WATER BODY HYDROMETRIC STATIONS

- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- STREAM CHANNEL PARAMETERS
- FLUVIAL SEDIMENT TRANSPORT
- WATERCOURSE FLOW RATE

LOCAL WATER USERS

- EXPLORATION CAMP
- OUTFITTERS CAMP

0 5 10
1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 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

HYDROLOGY UNDER EXISTING CONDITIONS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	LB/NO	2023-02-07		
CHECK	RWP	2023-02-07	**FIGURE 9A-18**	
REVIEW	NPS	2023-02-07		

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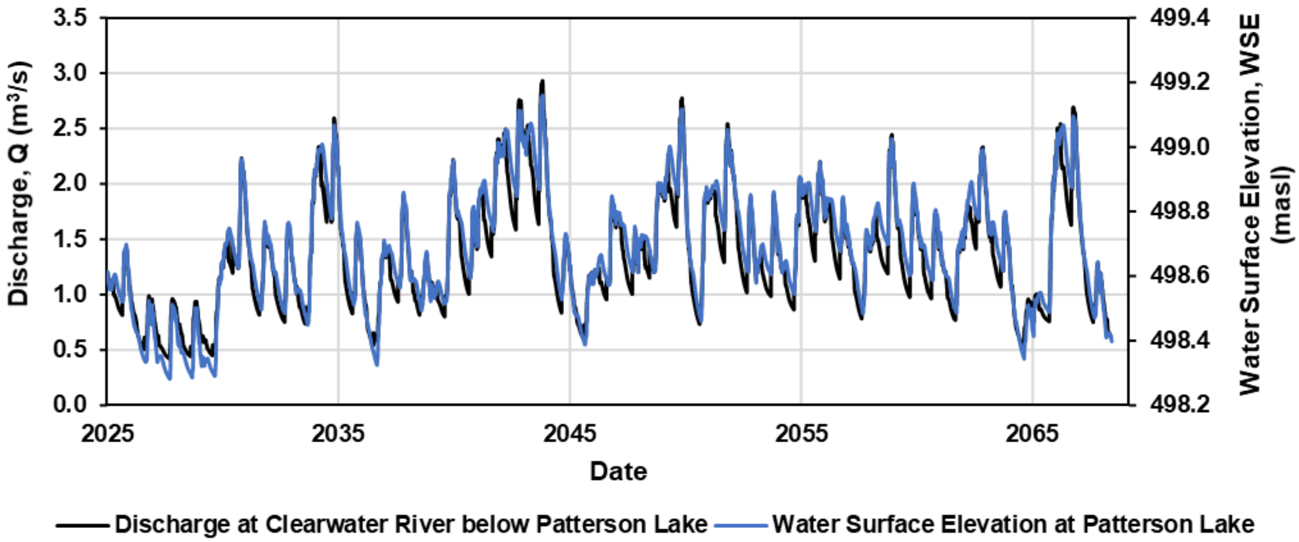
The full simulated time series of Patterson Lake WSE and outflow at Clearwater River below Patterson Lake discharge is shown in Figure 9A-19. The daily discharge simulated for the Clearwater River below Patterson Lake ranges from a minimum of 0.42 m^3/s to a maximum of 2.93 m^3/s. The daily water levels simulated for Patterson Lake range from a minimum of 498.282 metres above sea level (masl) to a maximum of 499.160 masl. Climate oscillations (i.e., cyclical wave like patterns) with multi-year to multi-decadal periods are reflected in the simulations.

Figure 9A-19: Base Case Simulation for Patterson Lake and the Clearwater River below Patterson Lake



masl = metres above sea level.

A numerical summary of the existing hydrological conditions in the RSA is provided in the following:

- Normal seasonal fluctuations of WSEs in waterbodies are summarized in Table 9A-13 and normal seasonal fluctuations of discharge in watercourses are summarized in Table 9A-14.
- Annual extremes for discharge in the RSA, including minimum daily, minimum weekly, average daily, and maximum daily discharges are presented in Table 9A-15.
- The Base Case annual water yield frequency analysis is presented in Table 9A-16.
- The range of annual maximum daily flows in the RSA is presented in Table 9A-17.
- The range of annual minimum daily flows is presented in Table 9A-18 and annual minimum weekly flows, which are commonly of interest for assessment of the aquatic ecosystem, are presented in Table 9A-19.
- Characteristic discharge hydrographs for each of the watercourse evaluation nodes are presented in Figure 9A-20 through Figure 9A-26.
- Discharge values are presented to three significant digits while waterbody WSEs are presented to the 1 mm.

Table 9A-13: Base Case Simulated Mean Monthly Waterbody Water Surface Elevations

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Broach Lake	526.656	526.644	526.650	526.737	526.825	526.781	526.733	526.701	526.691	526.694	526.695	526.671	526.706
Lake H	499.441	499.426	499.421	499.465	499.581	499.554	499.516	499.489	499.481	499.485	499.490	499.469	499.485
Lake G	499.874	499.856	499.845	499.878	500.003	500.004	499.965	499.929	499.912	499.909	499.913	499.897	499.915
Patterson Lake	498.632	498.602	498.581	498.618	498.774	498.792	498.762	498.720	498.696	498.687	498.688	498.666	498.685
Forrest Lake	498.314	498.286	498.270	498.306	498.448	498.469	498.443	498.409	498.393	498.389	498.382	498.350	498.372
Beet Lake	498.295	498.276	498.257	498.269	498.369	498.347	498.327	498.311	498.305	498.304	498.315	498.314	498.307
Naomi Lake	498.256	498.235	498.226	498.269	498.425	498.389	498.351	498.328	498.320	498.317	498.303	498.278	498.308

masl = metres above sea level; WSE = water surface elevation.

Table 9A-14: Base Case Simulated Mean Monthly Flows

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Broach Lake	0.134	0.119	0.132	0.286	0.540	0.430	0.315	0.246	0.230	0.230	0.211	0.171	0.254
Clearwater River above Patterson Lake	0.209	0.240	0.292	0.813	1.162	0.863	0.671	0.572	0.559	0.560	0.474	0.265	0.557
Lake H	0.027	0.024	0.025	0.034	0.061	0.058	0.049	0.041	0.040	0.039	0.034	0.029	0.038
Lake G	0.007	0.006	0.006	0.015	0.037	0.025	0.018	0.015	0.015	0.016	0.013	0.009	0.015
Clearwater River below Patterson Lake	1.08	1.03	1.05	1.24	1.68	1.73	1.64	1.52	1.46	1.41	1.25	1.15	1.35
Clearwater River below Forrest Lake	1.89	1.74	1.66	1.85	2.68	2.80	2.64	2.42	2.34	2.33	2.30	2.09	2.23
Clearwater River below Beet Lake	1.99	1.83	1.78	2.08	3.30	3.01	2.75	2.56	2.51	2.49	2.35	2.18	2.40
Clearwater River below Naomi Lake	2.45	2.23	2.13	2.58	4.58	4.04	3.53	3.25	3.19	3.18	3.00	2.71	3.07
Clearwater River above Mirror River Confluence	3.52	3.48	3.52	6.03	9.97	7.99	6.64	6.03	6.00	6.01	5.35	3.96	5.71

Table 9A-15: Summarized Flow Characteristics for the Base Case

Evaluation Node within the Model Spatial Domain	Mean Annual Minimum Daily Flow (m^3/s)	Mean Annual Minimum 7-Day Flow (m^3/s)	Mean Annual Flow (m^3/s)	Mean Annual Maximum Daily Flow (m^3/s)
Clearwater River below Broach Lake	0.082	0.083	0.257	0.633
Clearwater River above Patterson Lake	0.120	0.124	0.564	1.759
Lake H outlet	0.019	0.019	0.039	0.074
Lake G outlet	0.004	0.004	0.016	0.052
Clearwater River below Patterson Lake	0.864	0.870	1.36	1.90
Clearwater River below Forrest Lake	1.48	1.49	2.24	3.19
Clearwater River below Beet Lake	1.55	1.57	2.42	3.85
Clearwater River below Naomi Lake	1.84	1.86	3.10	5.38
Clearwater River above the Mirror River confluence	2.71	2.74	5.77	12.8

Table 9A-16: Base Case Annual Water Yield Frequency Analysis

Hydrological Condition	Return Period (Years)	Estimated Annual Water Yield (mm)						
		Clearwater River below Broach Lake	Clearwater River above Patterson Lake	Clearwater River below Patterson Lake	Clearwater River below Forrest Lake	Clearwater River below Beet Lake	Clearwater River below Naomi Lake	Clearwater River above Mirror River Confluence
Wet	100	267	263	262	256	257	255	277
	75	261	257	258	252	253	251	272
	50	253	249	251	246	247	244	265
	35	245	242	245	240	241	238	258
	20	231	229	235	230	231	228	246
	10	211	211	220	215	216	213	229
	5	187	189	201	196	198	195	208
Average (mean)	n/a	144	147	162	159	161	158	169
Median	2	142	146	163	159	162	158	168
Dry	5	99	104	124	121	124	122	129
	10	78	84	104	102	105	103	111
	20	63	69	89	87	90	89	97
	35	54	59	78	76	80	79	88
	50	49	54	72	71	74	74	83
	75	44	49	67	65	69	69	78
	100	41	46	63	61	65	66	75

Note: Weibull distribution was used for frequency analysis of all evaluation nodes.
n/a = not applicable.

Table 9A-17: Base Case Annual Daily Maximum Discharge Frequency Analysis

Hydrological Condition	Return Period (Years)	Estimated Annual Peak Flow (m^3/s)						
		Clearwater River below Broach Lake	Clearwater River above Patterson Lake	Clearwater River below Patterson Lake	Clearwater River below Forrest Lake	Clearwater River below Beet Lake	Clearwater River below Naomi Lake	Clearwater River above Mirror River Confluence
Wet	100	1.12	4.10	3.19	5.28	6.12	8.19	20.5
	75	1.10	3.93	3.14	5.20	6.04	8.10	20.2
	50	1.07	3.70	3.05	5.08	5.91	7.96	19.7
	35	1.04	3.50	2.98	4.96	5.79	7.82	19.2
	20	0.99	3.17	2.84	4.75	5.56	7.55	18.4
	10	0.91	2.75	2.63	4.43	5.21	7.14	17.2
	5	0.81	2.31	2.38	4.01	4.76	6.58	15.6
Average (mean)	n/a	0.63	1.76	1.90	3.19	3.85	5.38	12.8
Median	2	0.63	1.64	1.89	3.19	3.85	5.42	12.7
Dry	5	0.45	1.13	1.43	2.38	2.95	4.21	9.97
	10	0.37	0.92	1.20	1.97	2.49	3.58	8.63
	20	0.30	0.76	1.02	1.64	2.12	3.07	7.56
	35	0.25	0.65	0.90	1.41	1.86	2.71	6.83
	50	0.22	0.59	0.83	1.28	1.71	2.50	6.41
	75	0.20	0.53	0.75	1.14	1.55	2.28	5.97
	100	0.18	0.49	0.70	1.05	1.45	2.13	5.67

Note: Extreme value distribution was used for frequency analysis of all evaluation nodes.
n/a = not applicable.

Table 9A-18: Base Case Frequency Analysis of Annual Daily Minimum Discharge

Hydrological Condition	Average Return Period (Years)	Estimated Annual Low Flow (m^3/s)						
		Clearwater River below Broach Lake	Clearwater River above Patterson Lake	Clearwater River below Patterson Lake	Clearwater River below Forrest Lake	Clearwater River below Beet Lake	Clearwater River below Naomi Lake	Clearwater River above Mirror River Confluence
Wet	100	0.229	0.447	1.53	2.53	2.62	3.20	5.31
	75	0.220	0.427	1.50	2.48	2.57	3.13	5.15
	50	0.207	0.399	1.45	2.40	2.49	3.03	4.93
	35	0.196	0.373	1.40	2.33	2.42	2.93	4.72
	20	0.177	0.330	1.32	2.21	2.30	2.77	4.39
	10	0.151	0.273	1.22	2.04	2.12	2.54	3.93
	5	0.122	0.210	1.09	1.83	1.92	2.27	3.41
Average (mean)	n/a	0.082	0.120	0.864	1.48	1.55	1.84	2.71
Median	2	0.074	0.109	0.846	1.45	1.53	1.79	2.56
Dry	5	0.038	0.038	0.631	1.11	1.17	1.38	1.93
	10	0.025	0.013	0.536	0.951	1.01	1.21	1.69
	20	0.016	0.000	0.469	0.840	0.897	1.09	1.55
	35	0.012	0.000	0.428	0.772	0.827	1.01	1.47
	50	0.010	0.000	0.407	0.737	0.790	0.978	1.43
	75	0.008	0.000	0.386	0.703	0.754	0.944	1.40
	100	0.007	0.000	0.374	0.682	0.732	0.924	1.38

Note: Weibull distribution was used for frequency analysis of all evaluation nodes.
n/a = not applicable.

Table 9A-19: Base Case Frequency Analysis of Annual Minimum 7-Day Mean Discharge

Hydrological Condition	Average Return Period (Years)	Estimated Annual Low Flow (m^3/s)						
		Clearwater River below Broach Lake	Clearwater River above Patterson Lake	Clearwater River below Patterson Lake	Clearwater River below Forrest Lake	Clearwater River below Beet Lake	Clearwater River below Naomi Lake	Clearwater River above Mirror River Confluence
Wet	100	0.230	0.454	1.54	2.55	2.64	3.23	5.37
	75	0.222	0.434	1.50	2.49	2.59	3.16	5.22
	50	0.209	0.406	1.46	2.42	2.51	3.06	4.99
	35	0.198	0.380	1.41	2.35	2.44	2.96	4.79
	20	0.179	0.337	1.33	2.22	2.31	2.80	4.45
	10	0.153	0.281	1.22	2.05	2.14	2.57	3.98
	5	0.124	0.218	1.09	1.84	1.93	2.30	3.46
Average (mean)	n/a	0.083	0.124	0.870	1.49	1.57	1.86	2.74
Median	2	0.075	0.114	0.851	1.46	1.54	1.81	2.60
Dry	5	0.039	0.041	0.635	1.11	1.18	1.39	1.94
	10	0.025	0.016	0.539	0.954	1.02	1.21	1.70
	20	0.016	0.001	0.470	0.841	0.901	1.09	1.55
	35	0.012	0.000	0.429	0.772	0.829	1.01	1.47
	50	0.009	0.000	0.407	0.736	0.790	0.976	1.43
	75	0.007	0.000	0.386	0.701	0.753	0.941	1.39
	100	0.006	0.000	0.374	0.679	0.730	0.920	1.37

Note: Weibull distribution was used for frequency analysis of all evaluation nodes.
n/a = not applicable.

Figure 9A-20: Base Case Characteristic Conditions based on Simulated Flows at Clearwater River below Broach Lake (CR-WC-MS-01)

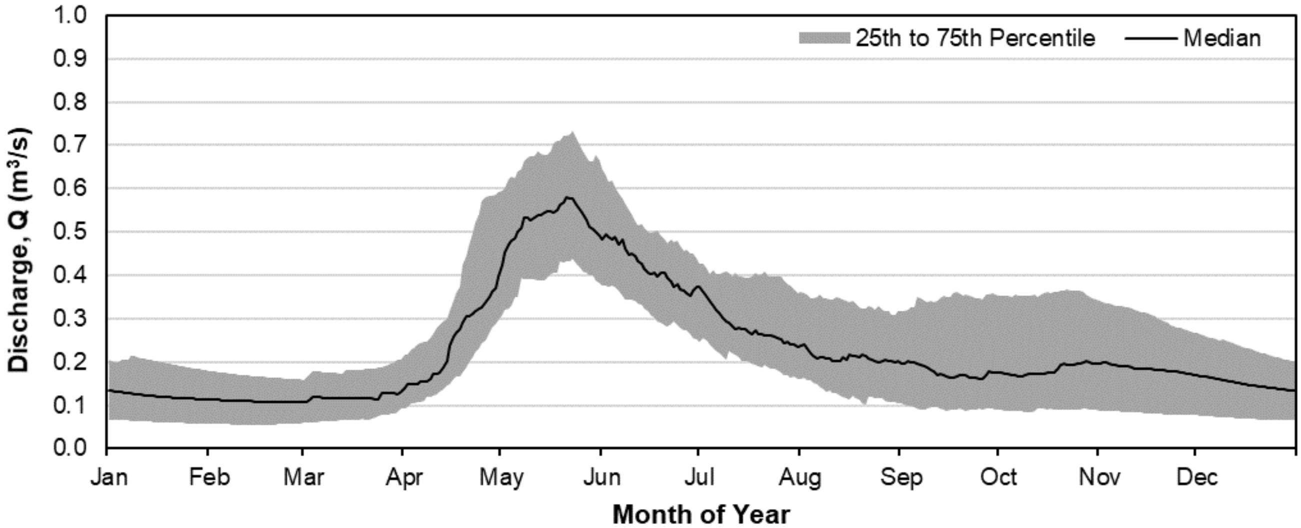


Figure 9A-21: Base Case Characteristic Conditions based on Simulated Flows at Clearwater River above Patterson Lake (CR-WC-MS-02)

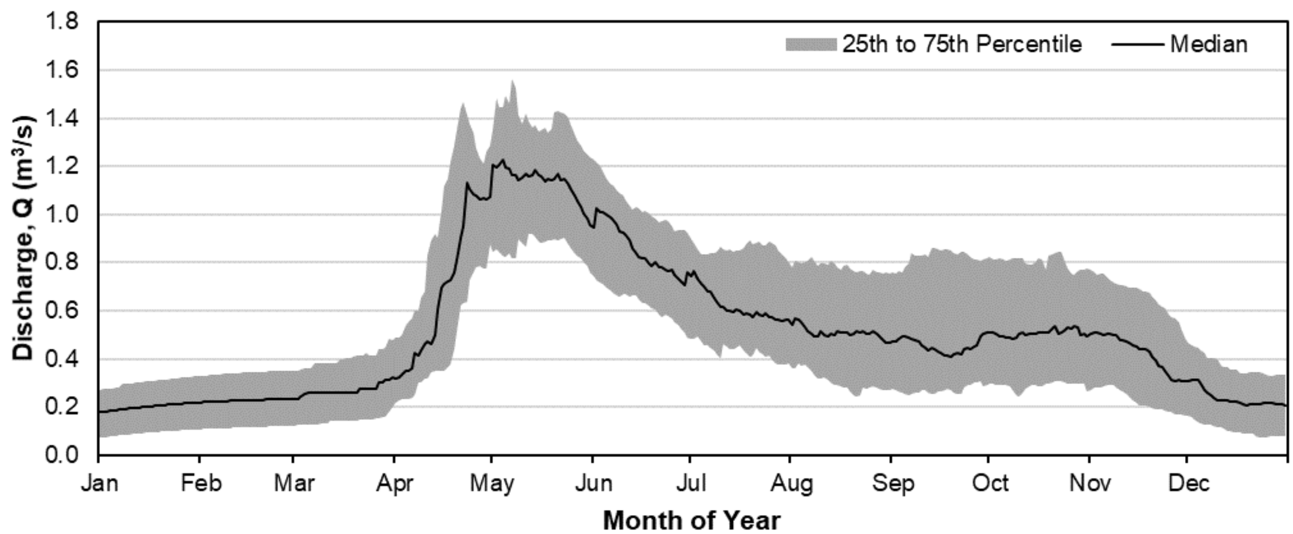


Figure 9A-22: Base Case Characteristic Conditions based on Simulated Flows at Clearwater River below Patterson Lake (CR-WC-MS-03)

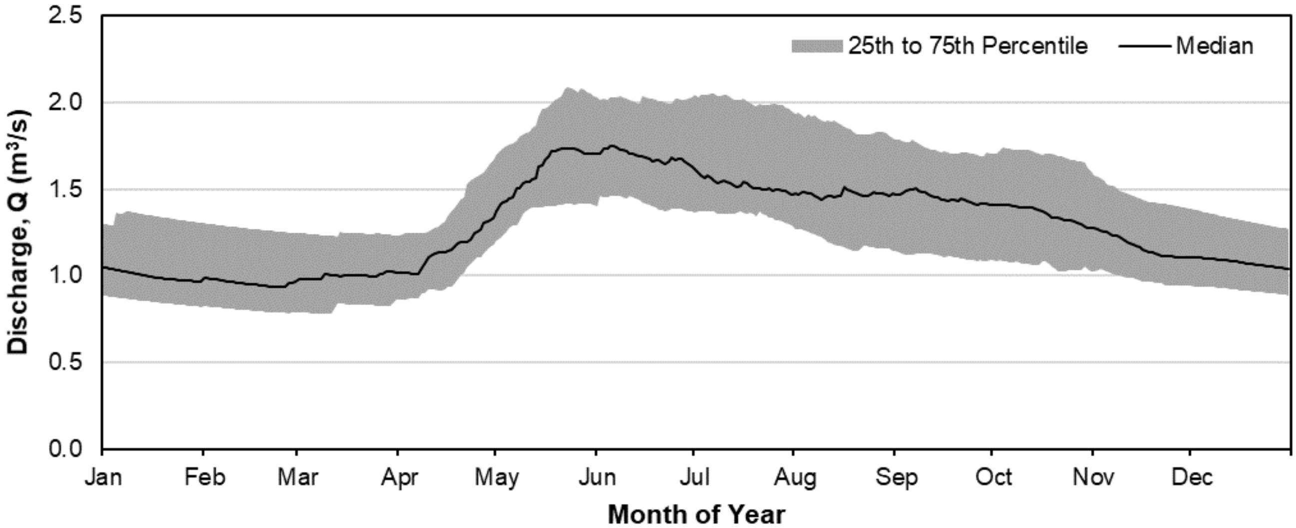


Figure 9A-23: Base Case Characteristic Conditions based on Simulated Flows at Clearwater River below Forrest Lake

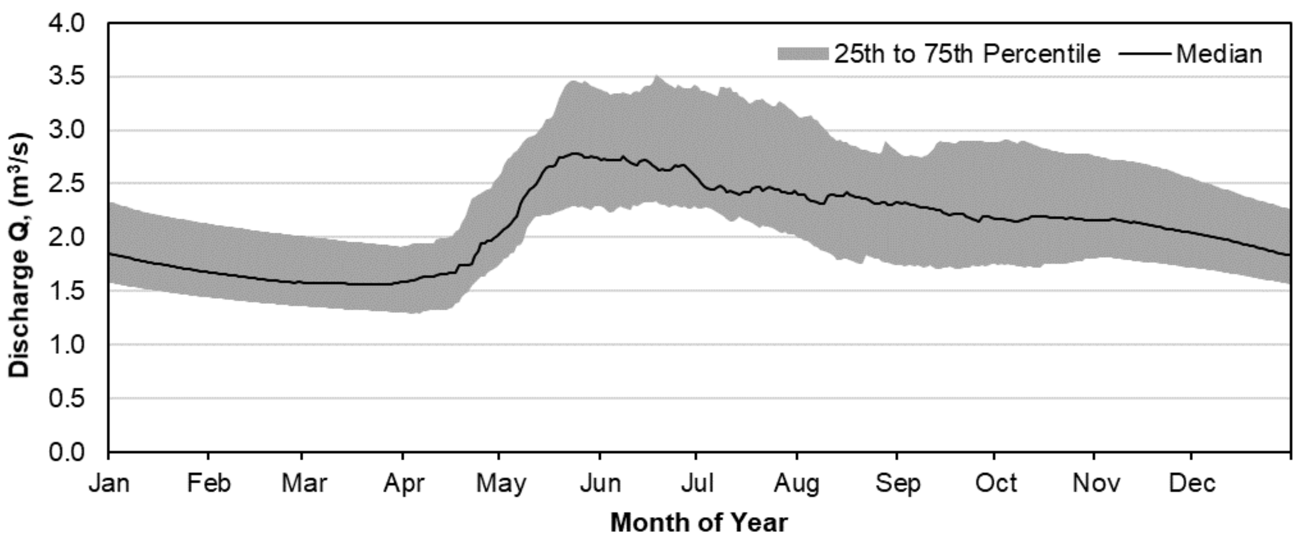


Figure 9A-24: Base Case Characteristic Conditions based on Simulated Flows at Clearwater River below Beet Lake (CR-WC-MS-04)

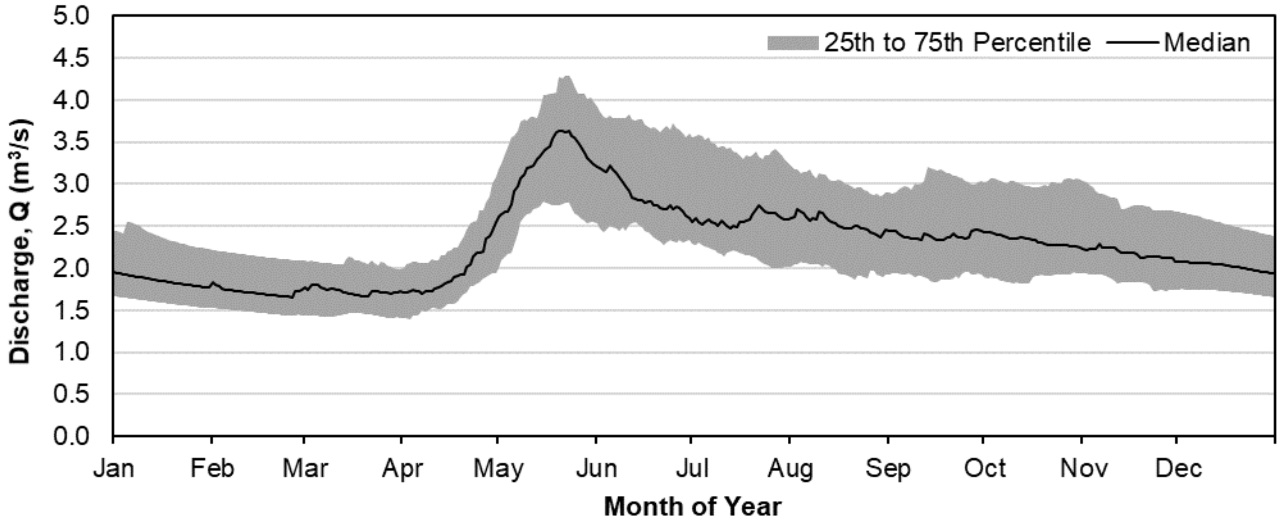


Figure 9A-25: Base Case Characteristic Conditions based on Simulated Flows at Clearwater River below Naomi Lake (CR-WC-MS-05)

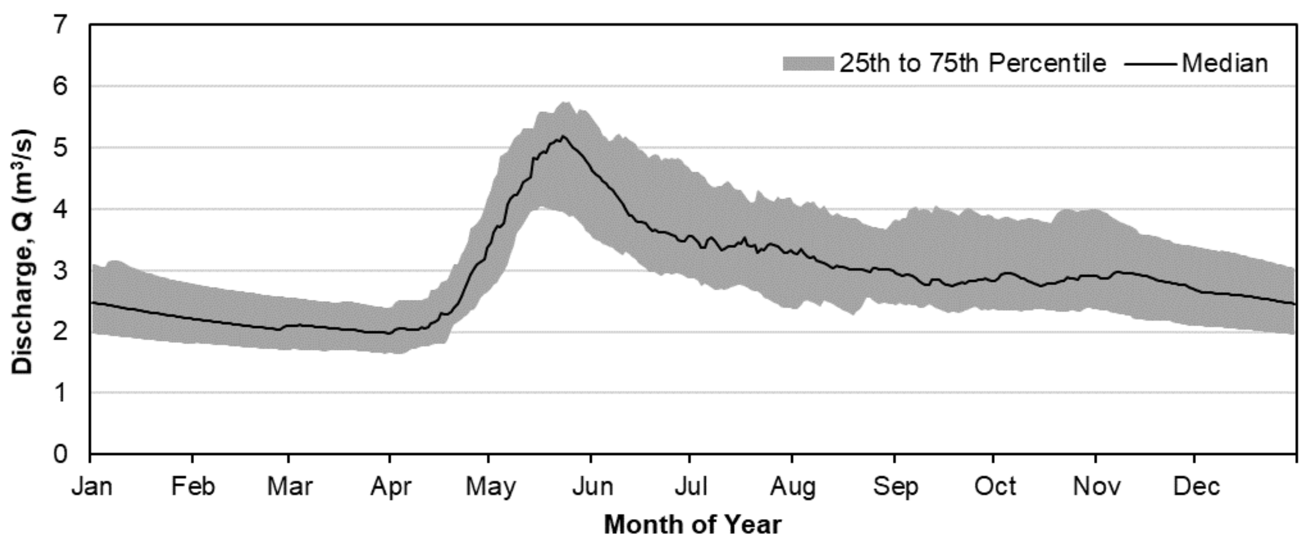
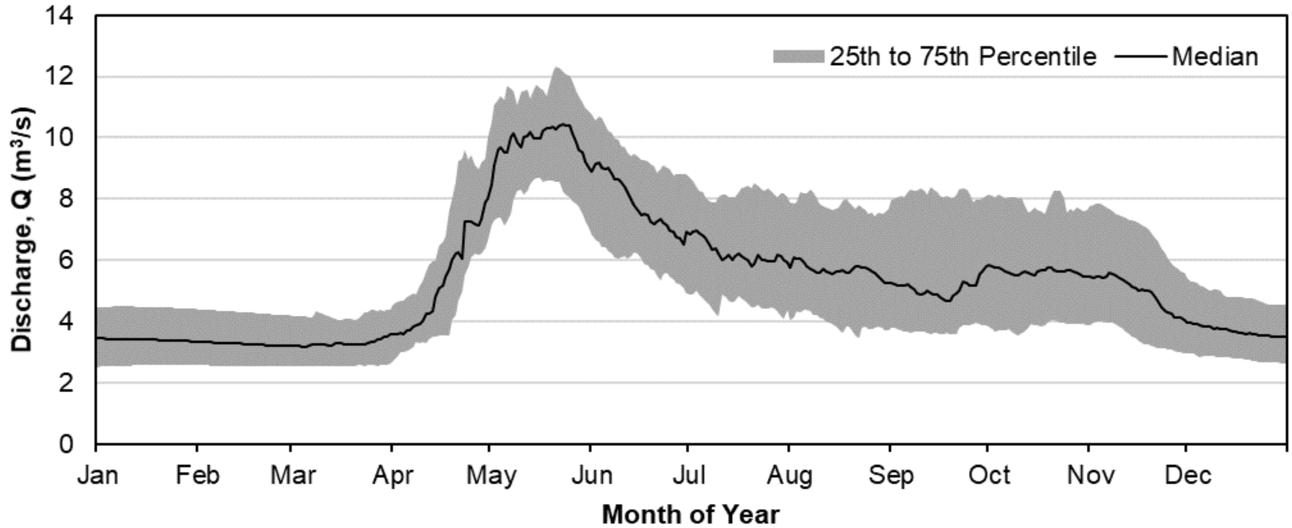


Figure 9A-26: Base Case Characteristic Conditions based on Simulated Flows at Clearwater River above Mirror River Confluence (CR-WC-MS-06)



9A4.2 Climate Change Scenarios

The potential effects of climate change were assessed by adjusting the current climate to reflect the mean projected climate change for the 2050s, based on the climate change assessment in EIS Appendix 22A-1, Detailed Climate Change Methodology. The sensitivity of hydrological projections to uncertainty in climate projections over this period is evaluated to provide context for interpretation of projection results. No Project activities were considered when evaluating the effects of climate change on the Base Case hydrology.

9A4.2.1 Mean Climate Change Scenario

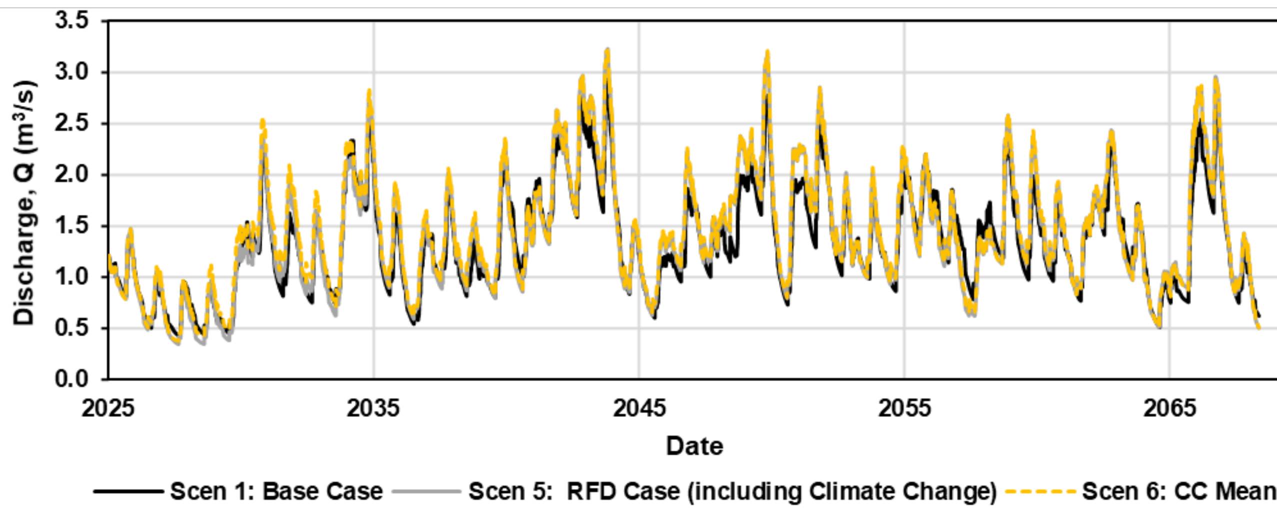
Climate change in the region of the Project and across the globe is probable during the Project lifespan. The nature of the change to historical climate varies geographically and would be dynamic over time. Climate change projections were incorporated by considering the projected monthly changes to temperature and precipitation. The mean scenario (Table 9A-6) focuses on the mean projected values from the multi-model ensemble and is incorporated into the RFD Case. Under the mean climate change case, temperature, and precipitation, as well as potential atmospheric losses to lake evaporation and evapotranspiration, are expected to increase. Sublimation is expected to decrease due to shorter snow-covered periods. The hydrological change in response to climate change is complex and varies throughout the RSA because of differences in land cover and position within the drainage network.

A numerical summary of climate change scenario conditions and changes is provided in the following tables and figures:

- A comparison of daily WSE in Patterson Lake in the Base Case and climate change showing inter-annual variation and distribution of effects is shown in Figure 9A-27.
- A comparison of monthly WSE in Patterson Lake in the Base Case and climate change showing seasonal distribution of effects is shown in Figure 9A-28.

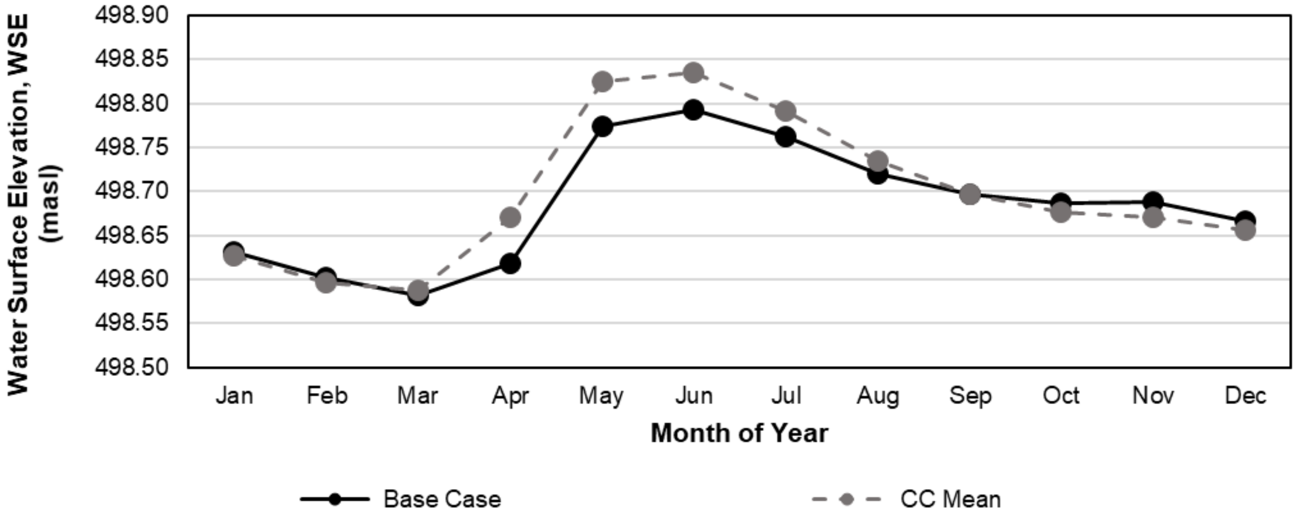
- Climate change average monthly WSE of waterbodies is summarized in Table 9A-20 with the change relative to the Base Case summarized in Table 9A-21 as a depth in metres and in Table 9A-22 as a percent of the Base Case annual range.
- A comparison of average monthly discharge in the Clearwater River below Patterson Lake under climate change and Base Case conditions is shown in Figure 9A-29.
- Climate change discharge in watercourses is summarized in Table 9A-23 with the change relative to the Base Case summarized in Table 9A-24 as a percent of the Base Case mean monthly discharge.
- Climate change annual extremes for discharge in the RSA, including minimum daily, minimum weekly, average daily, and maximum daily discharges along with the change relative to the Base Case, are presented in Table 9A-25.

Figure 9A-27: Clearwater River below Patterson Lake Discharge in the Base Case, Reasonably Foreseeable Development Case, and Climate Change Scenarios



RFD = reasonably foreseeable development; CC = climate change.

Figure 9A-28: Patterson Lake Mean Monthly Water Surface Elevation in the Climate Change Scenario and Base Case



masl = metres above sea level; CC = climate change.

Table 9A-20: Climate Change Scenario Mean Monthly Lake Water Surface Elevation

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Broach Lake	526.655	526.647	526.675	526.785	526.836	526.783	526.725	526.684	526.668	526.668	526.674	526.666	526.706
Lake H	499.862	499.846	499.844	499.911	500.034	500.023	499.971	499.922	499.897	499.888	499.889	499.881	499.914
Lake G	499.437	499.422	499.427	499.505	499.598	499.561	499.516	499.482	499.469	499.470	499.475	499.463	499.485
Patterson Lake	498.627	498.594	498.590	498.694	498.833	498.831	498.785	498.728	498.694	498.675	498.669	498.654	498.698
Forrest Lake	498.306	498.283	498.278	498.351	498.493	498.503	498.464	498.415	498.386	498.372	498.362	498.337	498.379
Beet Lake	498.287	498.263	498.252	498.299	498.391	498.363	498.335	498.311	498.299	498.292	498.295	498.301	498.307
Naomi Lake	498.250	498.233	498.233	498.314	498.455	498.408	498.361	498.328	498.313	498.303	498.286	498.263	498.312

masl = metres above sea level; WSE = water surface elevation.

Table 9A-21: Expected Change in Mean Monthly Lake Water Surface Elevation due to Climate Change

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Broach Lake	-0.002	0.003	0.025	0.049	0.011	0.003	-0.008	-0.017	-0.023	-0.025	-0.021	-0.006	-0.001
Lake H	-0.011	-0.010	-0.001	0.033	0.031	0.019	0.006	-0.006	-0.015	-0.021	-0.024	-0.016	-0.001
Lake G	-0.004	-0.004	0.006	0.040	0.017	0.007	-0.001	-0.007	-0.012	-0.015	-0.016	-0.006	0.000
Patterson Lake	-0.005	-0.008	0.009	0.076	0.059	0.039	0.023	0.008	-0.003	-0.012	-0.019	-0.012	0.013
Forrest Lake	-0.008	-0.004	0.009	0.045	0.045	0.034	0.020	0.005	-0.007	-0.016	-0.020	-0.013	0.008
Beet Lake	-0.008	-0.013	-0.005	0.029	0.023	0.015	0.009	0.001	-0.006	-0.012	-0.020	-0.012	0.000
Naomi Lake	-0.006	-0.002	0.007	0.045	0.030	0.018	0.009	-0.001	-0.008	-0.014	-0.018	-0.015	0.004

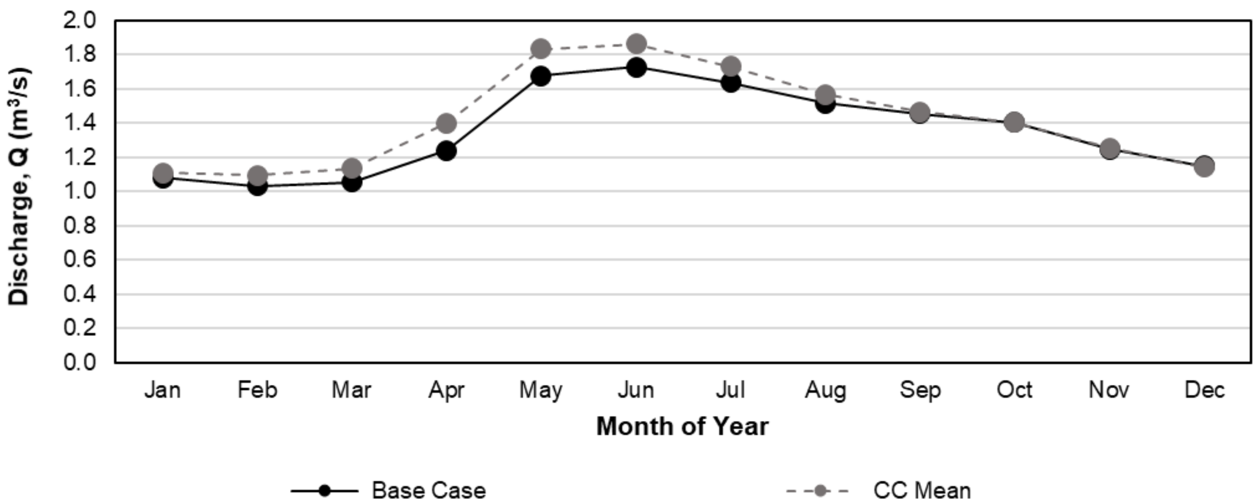
masl = metres above sea level; WSE = water surface elevation.

Table 9A-22: Expected% Change in Mean Monthly Lake Water Surface Elevation due to Climate Change

Location	Change in Mean Monthly WSE (%)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Broach Lake	-0.7	1.2	9.2	13.4	2.5	0.7	-2.3	-5.2	-7.2	-8.0	-6.6	-1.9	-0.4
Lake H	-0.8	-1.0	1.5	8.6	2.9	1.2	-0.1	-1.5	-2.6	-3.0	-3.2	-1.3	0.1
Lake G	-1.3	-1.2	-0.1	3.8	3.1	1.9	0.6	-0.7	-1.6	-2.3	-2.7	-1.8	-0.2
Patterson Lake	-0.6	-1.1	1.4	10.4	6.7	4.3	2.7	1.0	-0.3	-1.5	-2.3	-1.6	1.58
Forrest Lake	-1.6	-0.8	1.8	8.7	6.8	5.1	3.1	0.9	-1.2	-2.7	-3.4	-2.3	1.21
Beet Lake	-0.8	-1.4	-0.6	3.2	2.2	1.5	0.9	0.1	-0.6	-1.3	-2.0	-1.3	-0.01
Naomi Lake	-0.6	-0.2	0.7	4.4	2.5	1.6	0.8	-0.1	-0.7	-1.3	-1.6	-1.4	0.33

WSE = water surface elevation.

Figure 9A-29: Clearwater River below Patterson Lake Mean Monthly Flows in the Climate Change Scenario and Base Case



CC = climate change.

Table 9A-23: Climate Change Scenario Mean Monthly Flows

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Broach Lake	0.146	0.138	0.181	0.412	0.587	0.444	0.306	0.224	0.201	0.203	0.194	0.174	0.268
Clearwater River above Patterson Lake	0.210	0.274	0.426	1.042	1.215	0.933	0.704	0.580	0.558	0.560	0.495	0.311	0.609
Lake H outlet	0.027	0.025	0.027	0.043	0.070	0.064	0.050	0.040	0.037	0.036	0.032	0.029	0.040
Lake G outlet	0.007	0.007	0.008	0.022	0.043	0.029	0.019	0.014	0.014	0.015	0.014	0.011	0.017
Clearwater River below Patterson Lake	1.109	1.095	1.137	1.401	1.835	1.863	1.734	1.567	1.467	1.405	1.256	1.141	1.42
Clearwater River below Forrest Lake	1.878	1.753	1.731	2.131	3.006	3.067	2.796	2.478	2.321	2.266	2.221	2.066	2.31
Clearwater River below Beet Lake	1.998	1.856	1.862	2.461	3.663	3.246	2.890	2.594	2.468	2.404	2.264	2.115	2.48
Clearwater River below Naomi Lake	2.436	2.253	2.240	3.161	5.109	4.348	3.702	3.285	3.139	3.070	2.873	2.616	3.19
Clearwater River above Mirror River confluence	3.436	3.569	4.063	7.464	10.817	8.697	7.047	6.205	6.077	6.005	5.392	4.086	6.07

Table 9A-24: Change in Discharge from Base Case to Mean Projected Climate Change for the 2050s

Location	Percent (%) Change Relative to the Base Case												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Broach Lake	9.1	15.7	37.6	44.1	8.6	3.2	-2.7	-9.0	-12.7	-11.4	-8.3	1.9	6.4
Clearwater River above Patterson Lake	0.7	14.3	46.0	28.1	4.5	8.1	4.8	1.4	-0.1	-0.1	4.5	17.7	10.8
Lake H outlet	-0.1	3.4	8.7	24.4	14.6	9.3	3.1	-2.5	-6.0	-5.7	-5.0	-2.6	3.5
Lake G outlet	0.1	0.1	0.2	0.6	0.6	0.4	0.2	0.0	-0.1	-0.1	0.1	0.2	0.2
Clearwater River below Patterson Lake	2.7	6.1	7.9	13.0	9.3	7.8	5.8	3.1	0.7	-0.1	0.6	-0.7	4.7
Clearwater River below Forrest Lake	-0.4	0.8	4.4	15.3	12.4	9.4	6.1	2.3	-0.8	-2.8	-3.3	-1.3	3.5
Clearwater River below Beet Lake	0.6	1.3	4.5	18.6	10.9	7.9	5.1	1.4	-1.5	-3.4	-3.8	-2.8	3.2
Clearwater River below Naomi Lake	-0.5	0.9	5.0	22.4	11.5	7.6	4.8	1.0	-1.6	-3.5	-4.4	-3.4	3.3
Clearwater River above Mirror River confluence	-2.5	2.6	15.5	23.8	8.5	8.9	6.2	3.0	1.3	0.0	0.7	3.1	5.9

Table 9A-25: Climate Change Scenario Summarized Flow Characteristics and Change from the Base Case

Location	Mean Annual Minimum Daily Flow		Mean Annual Daily Flow		Mean Annual Maximum Daily Flow	
	(m^3/s)	% Change	(m^3/s)	% Change	(m^3/s)	% Change
Clearwater River below Broach Lake	0.077	-6.7%	0.270	5.1%	0.676	6.8%
Clearwater River above Patterson Lake	0.109	-9.1%	0.616	9.1%	1.78	1.0%
Clearwater River below Patterson Lake	0.862	-0.3%	1.42	4.7%	2.03	6.6%
Clearwater River below Forrest Lake	1.46	-1.0%	2.32	3.6%	3.45	8.0%
Clearwater River below Beet Lake	1.52	-2.3%	2.50	3.4%	4.11	6.8%
Clearwater River below Naomi Lake	1.81	-2.0%	3.21	3.5%	5.76	7.0%
Clearwater River above the Mirror River confluence	2.63	-3.1%	6.13	6.2%	13.2	3.2%

9A4.2.2 Sensitivity to Climate Change Projections

The projections of future climate change vary, and the magnitude and timing of changes to climate are uncertain. The uncertainty in any one projection of future climate is mitigated partly through analysis of available projections from a multi-model ensemble. To address the inherent uncertainty in future climate projections, the projections are summarized using exceedance percentiles across the ensemble, allowing the level of risk assumed to vary according to how the climate projections are being used.

Four additional scenarios were simulated to characterize the sensitivity of future hydrological conditions to uncertainty in the climate change projections. The sensitivity to climate change scenarios, Scenario 7 to Scenario 10, capture combinations of extreme future conditions by selecting either the 5th or 95th percentile projected values for temperature and precipitation. Scenario 7 is the warm dry climate change extreme. Scenario 8 is the warm wet climate change extreme. Scenario 9 is the cool dry climate change extreme. Scenario 10 is the cool wet climate change extreme.

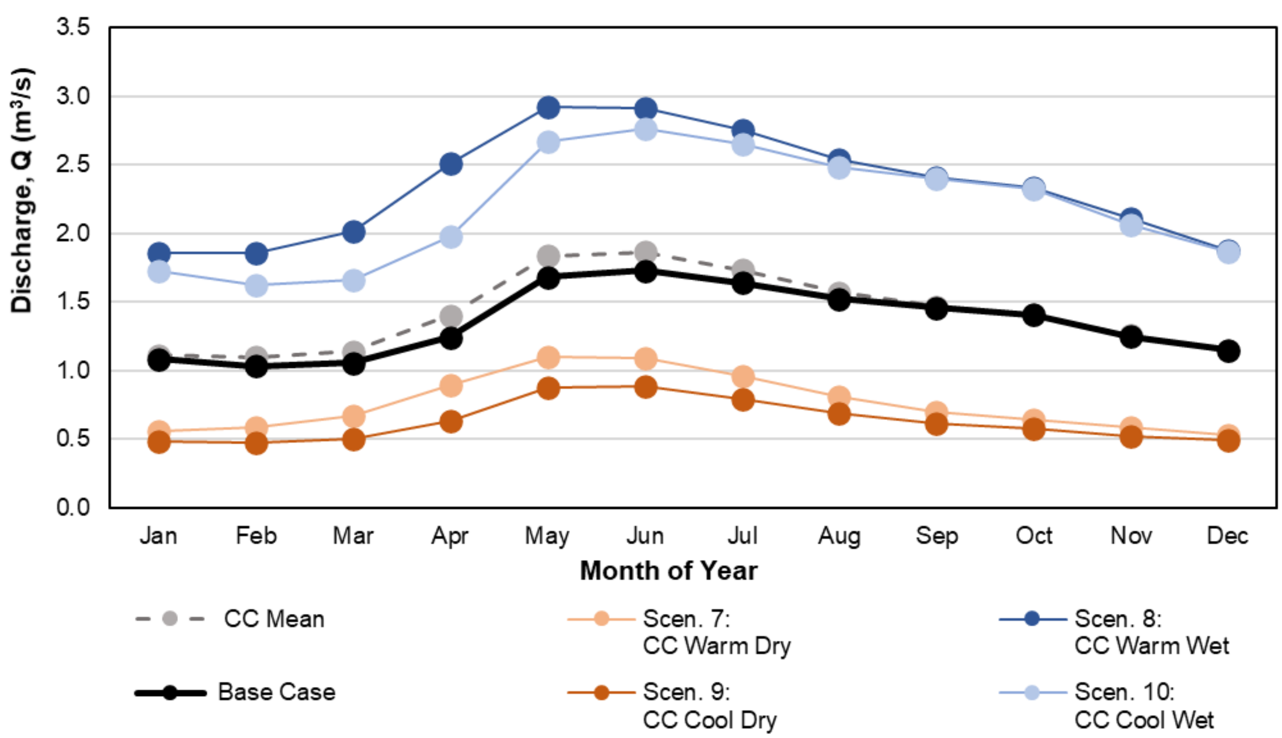
A comparison of monthly discharge in the Clearwater River below Patterson Lake under projected mean climate change conditions (Scenario 6) to the extreme sensitivity cases (Scenario 7 to Scenario 10) is shown in Figure 9A-30. The high degree of variability in the climate projections is manifested in the hydrology model simulations. The extreme wet scenarios result in large increases to flows relative to the Base Case of 73% (Scenario 8) and 62% (Scenario 10). Under the warm scenario, end-of-winter flows increase earlier in the year than under the Cool and Base Case projections, in response to warmer temperatures in February and March.

The extreme dry scenarios result in large decreases to flows relative to the Base Case of -44% (Scenario 7) and -52% (Scenario 9). Under the warm scenario, end-of-winter flows increase earlier in the year than under the Cool and Base Case projections, in response to warmer temperatures in February and March.

A numerical summary of the sensitivity of future hydrological conditions to uncertainty in the climate change projections is provided in the following tables and figures:

- A comparison of average monthly discharge under expected and extreme climate change scenarios for Clearwater River below Patterson Lake is summarized in Figure 9A-30.
- A comparison of average monthly discharge under expected and extreme climate change scenarios for the Clearwater River below Patterson Lake is summarized in Table 9A-26 and the percent change from the Base Case is summarized in Table 9A-27.

Figure 9A-30: Clearwater River below Patterson Lake Discharge under Mean and Extreme Climate Projections



CC = climate change.

Table 9A-26: Clearwater River below Patterson Lake Discharge under Mean and Extreme Climate Change Projections

Scenario	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Scenario 6: CC Mean	1.11	1.09	1.14	1.40	1.84	1.86	1.73	1.57	1.47	1.40	1.26	1.14	1.42
Scenario 7: CC warm dry	0.556	0.588	0.668	0.893	1.10	1.09	0.961	0.809	0.698	0.644	0.583	0.532	0.760
Scenario 8: CC warm wet	1.86	1.86	2.02	2.51	2.93	2.92	2.76	2.54	2.41	2.33	2.11	1.88	2.34
Scenario 9: CC cool dry	0.481	0.473	0.500	0.632	0.873	0.885	0.792	0.687	0.612	0.579	0.523	0.493	0.628
Scenario 10: CC cool wet	1.73	1.63	1.66	1.98	2.67	2.77	2.65	2.48	2.40	2.32	2.06	1.87	2.18

CC = climate change.

Table 9A-27: Climate-Change-Related Variation in Clearwater River below Patterson Lake Discharge

Scenario	Percent (%) Change Relative to the Base Case												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Scenario 6: CC mean	2.7	6.1	7.9	13.0	9.3	7.8	5.8	3.1	0.7	-0.1	0.6	-0.7	4.8
Scenario 7: CC warm dry	-48.5	-43.0	-36.6	-28.0	-34.5	-36.9	-41.3	-46.8	-52.1	-54.2	-53.3	-53.7	-43.8
Scenario 8: CC warm wet	71.7	80.2	91.3	102.8	74.2	68.7	68.2	66.9	65.5	65.6	69.2	63.4	73.2
Scenario 9: CC cool dry	-55.4	-54.1	-52.6	-49.0	-48.0	-48.8	-51.7	-54.8	-58.0	-58.8	-58.1	-57.1	-53.6
Scenario 10: CC cool wet	59.7	57.6	57.2	59.8	58.8	60.0	61.9	63.3	64.5	65.2	65.0	62.6	61.4

CC = climate change.

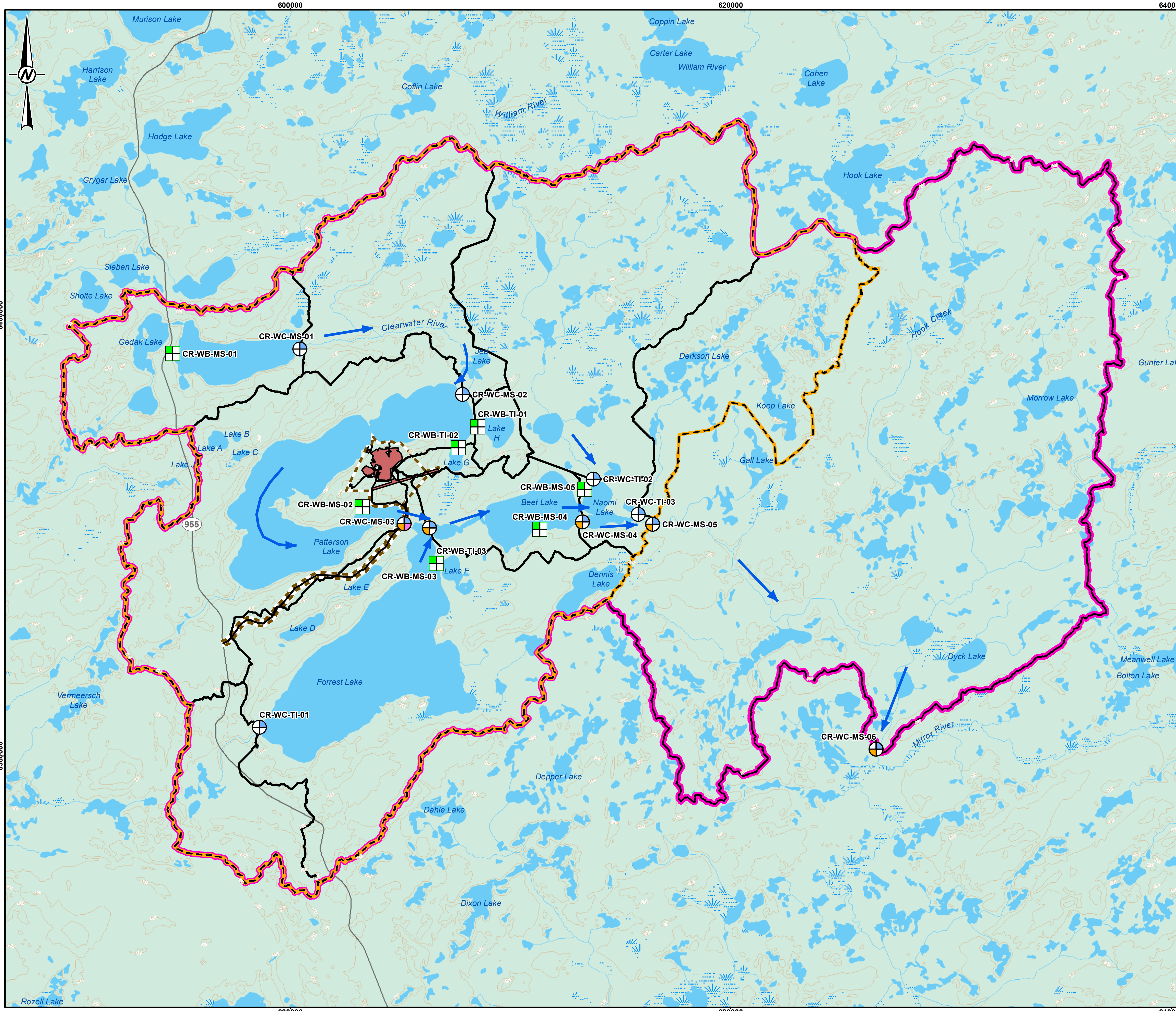
9A4.3 Application Case

9A4.3.1 Environmental Assessment Application Case

The Application Case (Scenario 3) simulated the expected conditions during the different Project phases under current climate conditions. Scenario 2 was treated as a sensitivity case rather than an assessment case and is discussed in detail in Section 9A4.2.2, Sensitivity to Climate Change Projections. The Project is expected to result in a net discharge of water to the receiving environment, due primarily to dewatering of the underground mine workings during Operations. The hydrological conditions in the RSA that are reflected in the Application Case simulation, showing the maximum build out of Project-related infrastructure, are shown in Figure 9A-31.

A numerical summary of Application Case conditions and changes is provided in the following tables and figures:

- A comparison of daily WSEs in Patterson Lake in the Base Case and Application Case, showing inter-annual variation and distribution of effects, is shown in Figure 9A-32.
- A comparison of monthly WSEs in Patterson Lake in the Base Case and Application Case, showing seasonal distribution of effects, is shown in Figure 9A-33.
- Application Case average monthly WSE of waterbodies is summarized in Table 9A-28 with the change relative to the Base Case summarized in Table 9A-29 as a depth in metres and in Table 9A-30 as a percent of the Base Case annual range.
- A comparison of average monthly discharge in the Clearwater River below Patterson Lake under Base Case and Application Case conditions is shown in Figure 9A-34.
- Application Case discharge in watercourses is summarized in Table 9A-31 with the change relative to the Base Case summarized in Table 9A-32 as a percent of the Base Case mean monthly discharge.
- Annual extremes for discharge in the RSA, including minimum daily, minimum weekly, average daily, and maximum daily discharges along with the change relative to the Base Case are presented in Table 9A-33.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED

WATER BODY HYDROMETRIC STATIONS

- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- STREAM CHANNEL PARAMETERS
- FLUVIAL SEDIMENT TRANSPORT
- WATERCOURSE FLOW RATE

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 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

HYDROLOGY APPLICATION CASE

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	LB/NO	2023-02-07		
CHECK	RWP	2023-02-07	**FIGURE 9A-31**	
REVIEW	NPS	2023-02-07		

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Figure 9A-32: Clearwater River below Patterson Lake Discharge for Application Case and Base Case

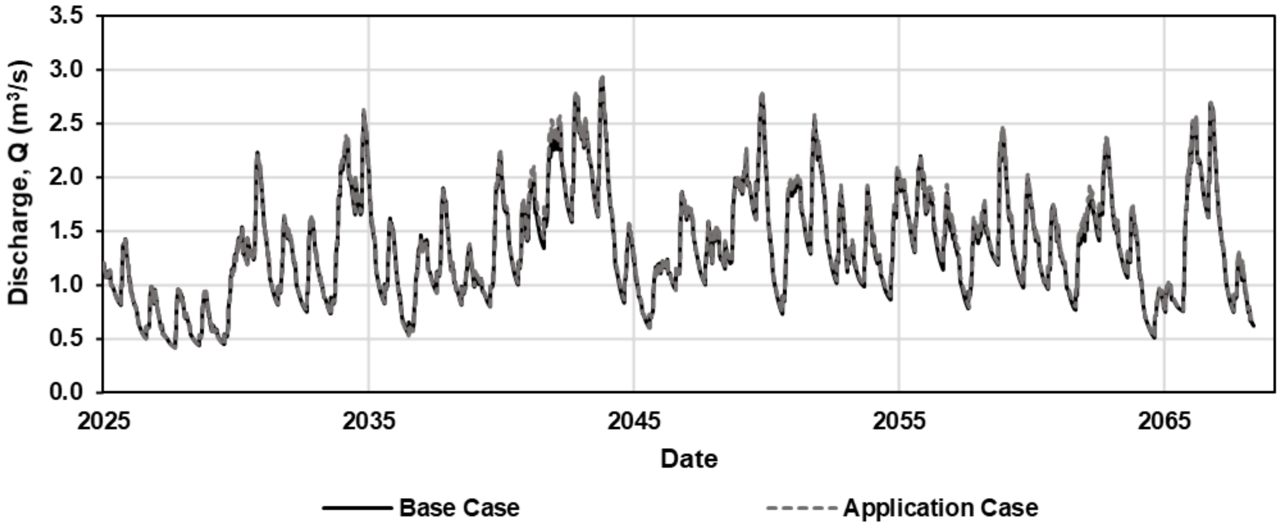
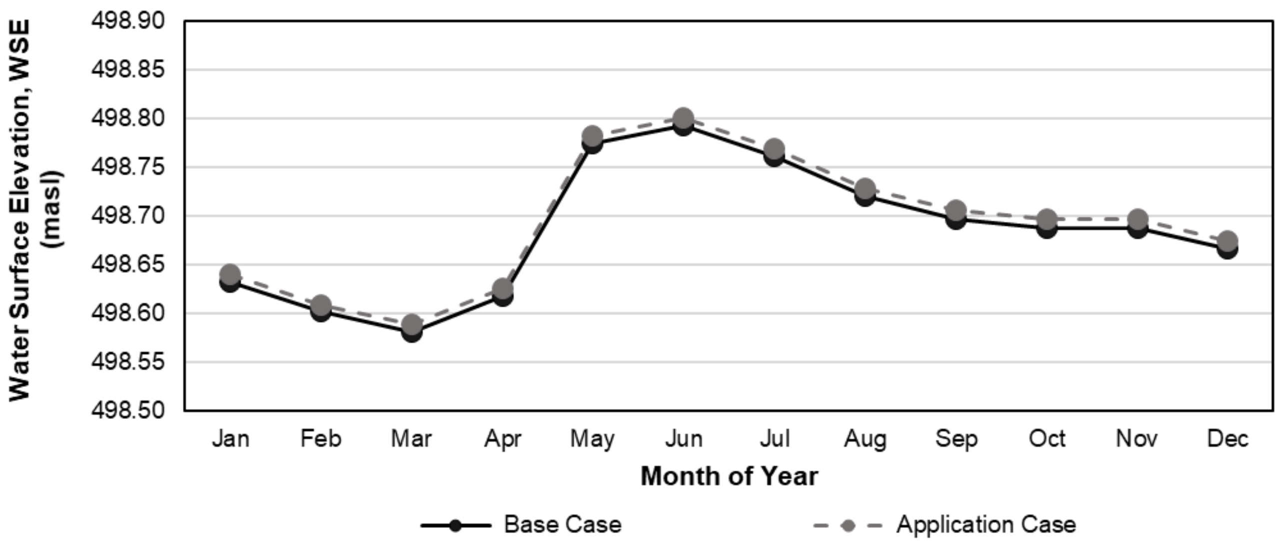


Figure 9A-33: Patterson Lake Mean Monthly Water Surface Elevation for Application Case and Base Case



masl = metres above sea level.

Table 9A-28: Predicted Application Case Mean Monthly Lake Water Surface Elevations

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	498.640	498.609	498.588	498.625	498.782	498.800	498.770	498.729	498.706	498.696	498.697	498.674	498.693
Forrest Lake	498.318	498.290	498.273	498.309	498.452	498.472	498.447	498.414	498.398	498.393	498.387	498.354	498.375
Beet Lake	498.297	498.278	498.259	498.271	498.370	498.349	498.329	498.313	498.307	498.306	498.317	498.316	498.309
Naomi Lake	498.259	498.237	498.227	498.271	498.427	498.391	498.353	498.331	498.323	498.320	498.306	498.281	498.311

WSE = water surface elevation; masl = metres above sea level.

Table 9A-29: Changes in Mean Monthly Lake Water Surface Elevations in Application Case Relative to the Base Case

Location	Change in Monthly WSE (m)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	0.008	0.007	0.007	0.007	0.007	0.008	0.008	0.009	0.009	0.010	0.009	0.008	0.008
Forrest Lake	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004	0.004
Beet Lake	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Naomi Lake	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.002

WSE = water surface elevation.

Table 9A-30: Percent Changes in Lake Water Surface Elevations in Application Case Relative to the Base Case

Location	Percent Change in Monthly WSE (%)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	1.0%	1.0%	1.0%	1.0%	0.8%	0.8%	0.9%	1.1%	1.2%	1.2%	1.1%	1.1%	1.0%
Forrest Lake	0.7%	0.7%	0.7%	0.6%	0.5%	0.6%	0.5%	0.7%	0.7%	0.8%	0.7%	0.7%	0.7%
Beet Lake	0.2%	0.2%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.2%	0.2%
Naomi Lake	0.2%	0.2%	0.2%	0.2%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%

WSE = water surface elevation.

Figure 9A-34: Clearwater River below Patterson Lake Monthly Flows in the Application Case and Base Case

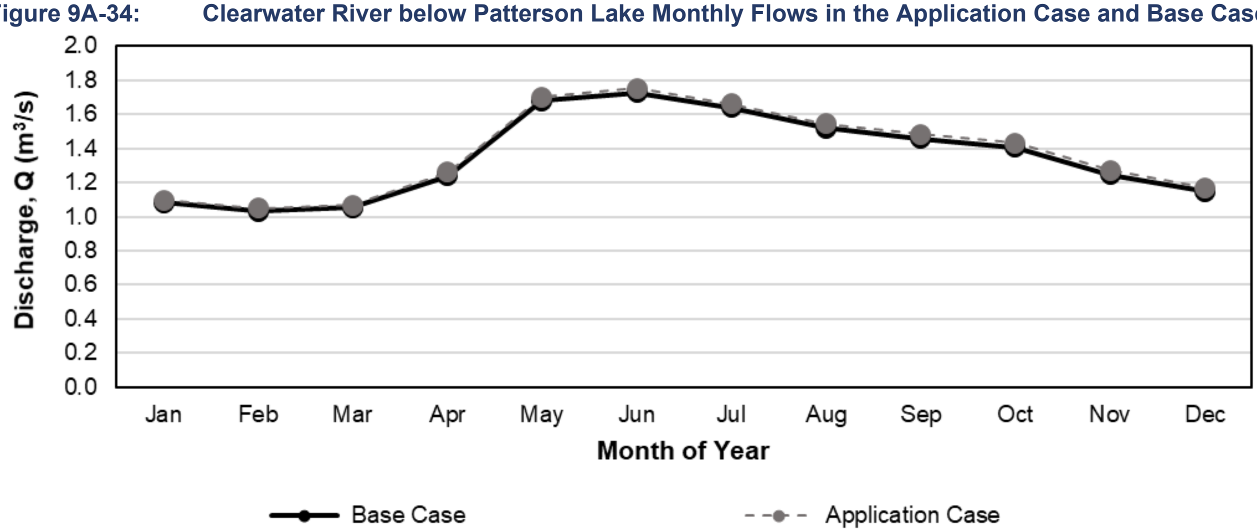


Table 9A-31: Predicted Application Case Mean Monthly Discharge

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	1.10	1.05	1.07	1.26	1.70	1.75	1.66	1.55	1.48	1.43	1.27	1.17	1.37
Clearwater River below Forrest Lake	1.91	1.76	1.68	1.87	2.70	2.83	2.66	2.45	2.37	2.36	2.33	2.12	2.25
Clearwater River below Beet Lake	2.01	1.85	1.80	2.10	3.33	3.04	2.77	2.59	2.54	2.52	2.39	2.20	2.43
Clearwater River below Naomi Lake	2.48	2.26	2.15	2.61	4.61	4.07	3.56	3.29	3.23	3.22	3.04	2.74	3.11
Clearwater River above Mirror River	3.56	3.51	3.54	6.05	10.0	8.04	6.67	6.09	6.07	6.08	5.41	4.00	5.75

Table 9A-32: Changes in Mean Monthly Discharge in Application Case Relative to the Base Case

Location	Percent (%) Change Relative to the Base Case												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	1.6	1.6	1.3	1.7	1.3	1.4	1.5	1.7	1.9	1.9	1.8	1.7	1.6
Clearwater River below Forrest Lake	1.2	1.2	1.1	1.0	1.0	1.0	1.0	1.2	1.4	1.4	1.4	1.3	1.2
Clearwater River below Beet Lake	1.2	1.1	1.0	1.0	0.8	1.0	0.9	1.2	1.3	1.4	1.4	1.3	1.1
Clearwater River below Naomi Lake	1.1	1.1	0.9	0.9	0.6	0.8	0.7	1.1	1.3	1.3	1.3	1.2	1.0
Clearwater River above Mirror River	0.9	0.9	0.7	0.4	0.5	0.6	0.5	1.0	1.1	1.2	1.0	1.0	0.8

Table 9A-33: Predicted Application Case Summarized Flow Characteristics

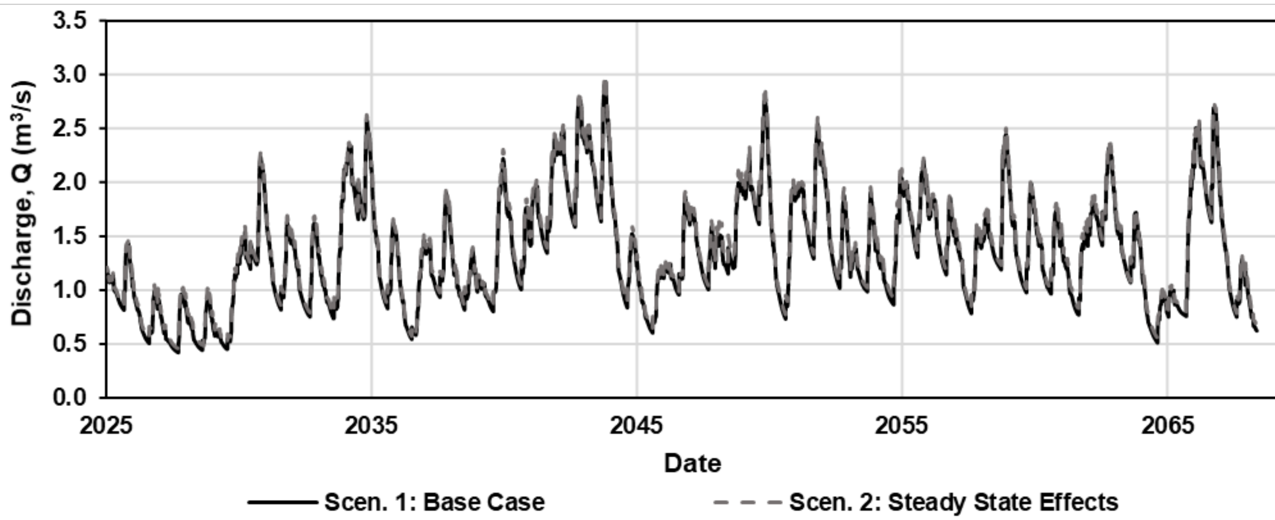
Location	Mean Annual Minimum Daily Flow		Mean Annual Daily Flow		Mean Annual Maximum Daily Flow	
	(m^3/s)	% Change	(m^3/s)	% Change	(m^3/s)	% Change
Clearwater River below Patterson Lake	0.88	1.6%	1.38	1.6%	1.93	1.4%
Clearwater River below Forrest Lake	1.49	1.1%	2.27	1.1%	3.22	1.0%
Clearwater River below Beet Lake	1.57	1.1%	2.44	1.1%	3.88	0.9%
Clearwater River below Naomi Lake	1.86	1.1%	3.13	1.0%	5.42	0.7%
Clearwater River above the Mirror River	2.74	1.0%	5.81	0.7%	12.90	0.7%

9A4.3.2 Sensitivity of Effects Assessment to Climate Cycles

The Application Case (Scenario 3) applied the anticipated Project effects as a time series. Climate is naturally variable, and it is uncertain if the Project timeline would synchronize with the climate cycles as has been assumed in the modelling exercise. An additional scenario characterized sensitivity of model predictions to climate cycles (i.e., if the Project effects aligned with a dry or wet year). Scenario 2 applies a snapshot of Project effects when adverse effects from Project activities (i.e., during Construction, Operations, and Closure) are predicted to be the greatest. A single Project year is repeated in a loop, while the climate time series progresses year to year like the Base Case and Application Case (Scenario 3). In theory, this tests the highest projected effect of the Project on all historical climate years.

A comparison between Scenario 2 and Scenario 3 is shown in Figure 9A-35. The net discharge from the Project to the receiving environment is small and the results do not appear to be sensitive to the timing of effects relative to climate cycles.

Figure 9A-35: Comparison of Clearwater River below Patterson Lake Discharge in the Application Case with Variable Effects and the Sensitivity to Steady State Effects

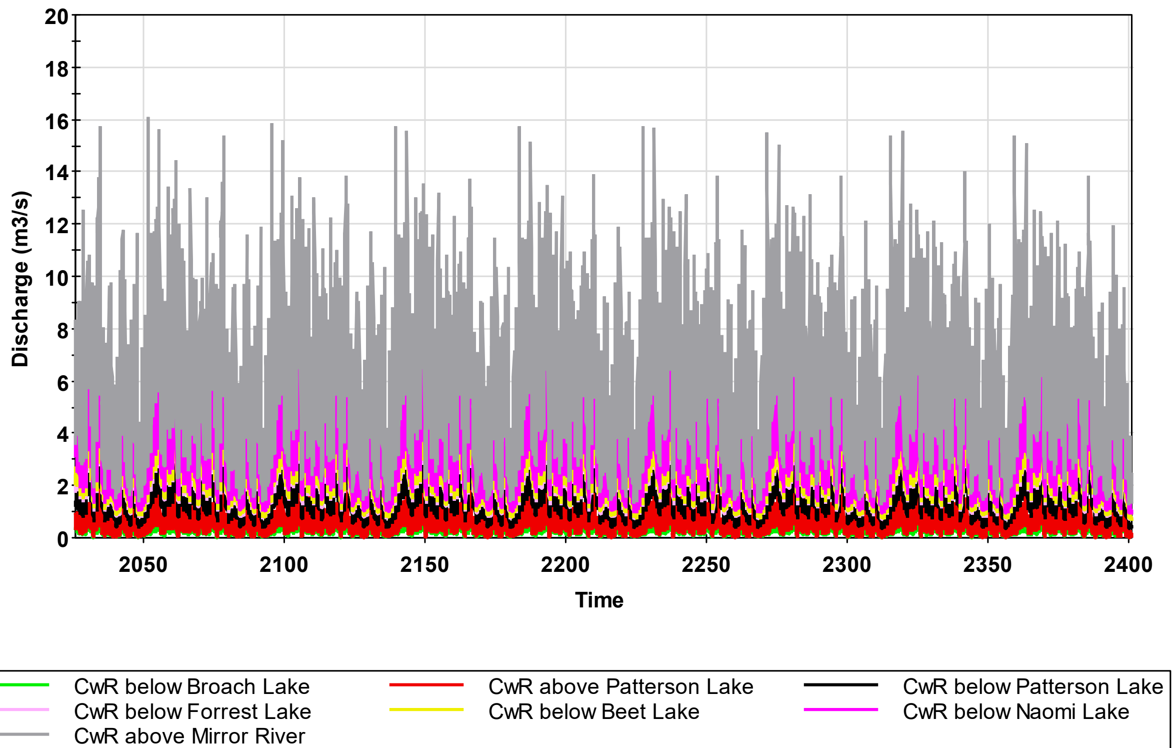


9A4.3.3 Far-Future Scenario

A sample of the far-future scenario results is presented in Figure 9A-36. The far-future scenario simulations consisted of the Application Case that transitions to a long-term simulation representative of conditions following Institutional Control. The current climate was adopted into the far-future scenario to mitigate uncertainty in climate projections. The far-future scenario is intended to simulate conditions far beyond the time horizons applied to the climate change study (Section 22), which end in 2100. Climate would continue to change beyond the year 2100 but projections are not available beyond that point. The current climate is a known climate condition for the RSA and in the absence of projections for climate hundreds and thousands of days beyond present day, it is the most reliable basis for simulation of the far-future scenario.

The far-future scenario is not a Project phase and no change to regional hydrology associated with the Project is expected in the far-future beyond Institutional Control. However, the model results for the far-future scenario have been carried forward in analysis by other disciplines, such as water quality, and are presented here for information.

Figure 9A-36: Far-Future Scenario Simulation of Hydrological Conditions in the Regional Study Area



CwR = Clearwater River.

9A4.4 Reasonably Foreseeable Development Case Conditions

9A4.4.1 Reasonably Foreseeable Development Case

The sensitivity of the RFD Case to climate change was evaluated to provide context for interpretation of projection results. In the RFD Case, historical climate was considered when evaluating the effects of cumulative developments (the Project and Fission Patterson Lake South Property) on the Base Case hydrology.

A numerical summary of cumulative developments scenario conditions and change is provided in the following tables and figures:

- A comparison of daily WSE in Patterson Lake in the Base Case and RFD Case showing inter-annual variation and distribution of effects is shown in Figure 9A-37.
- A comparison of monthly WSE in Patterson Lake in the Base Case and RFD Case showing seasonal distribution of effects is shown in Figure 9A-38.
- RFD case average monthly WSE of waterbodies is summarized in Table 9A-40 with the change relative to the Base Case summarized in Table 9A-35 and Table 9A-36 as a depth in metres or percent of Base Case annual range, respectively.
- A comparison of average monthly discharge in the Clearwater River below Patterson Lake under Base Case and RFD case conditions is shown in Figure 9A-39.

- RFD case discharge in watercourses is summarized in Table 9A-37 with the change relative to the Base Case summarized in Table 9A-38 as a percent of the Base Case mean monthly discharge.
- Annual extremes for discharge in the RSA, including minimum daily, minimum weekly, average daily, and maximum daily discharges along with the change relative to the Base Case, are presented in Table 9A-39.

Figure 9A-37: Clearwater River below Patterson Lake Discharge for the Reasonably Foreseeable Development Case and Base Case

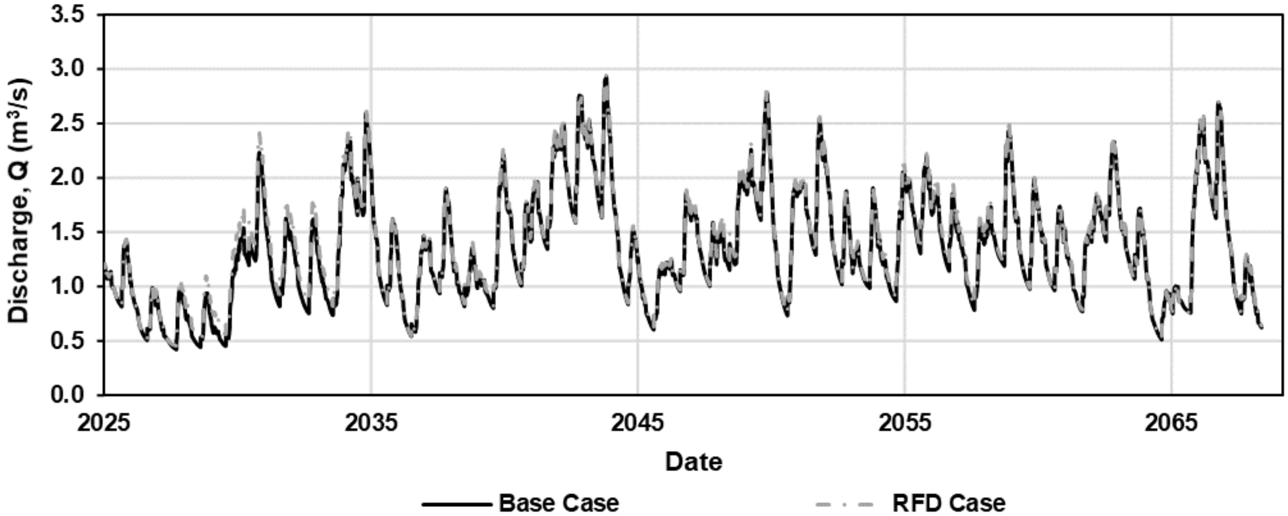
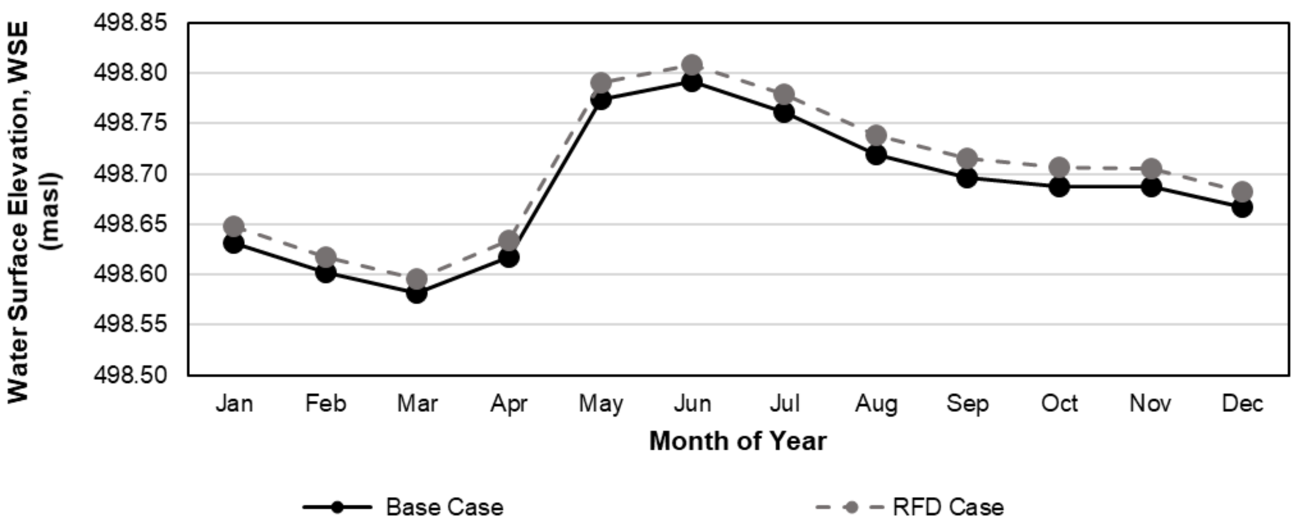


Figure 9A-38: Patterson Lake Monthly Water Surface Elevation for the Reasonably Foreseeable Development Case and Base Case



masl = metres above sea level.

Table 9A-34: Predicted Reasonably Foreseeable Development Case Mean Monthly Lake Water Surface Elevations

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	498.643	498.614	498.595	498.652	498.801	498.806	498.774	498.734	498.714	498.706	498.705	498.679	498.702
Forrest Lake	498.322	498.294	498.277	498.313	498.455	498.476	498.450	498.417	498.401	498.397	498.391	498.357	498.379
Beet Lake	498.299	498.280	498.261	498.273	498.372	498.351	498.331	498.315	498.309	498.308	498.319	498.318	498.311
Naomi Lake	498.260	498.239	498.230	498.273	498.428	498.392	498.355	498.332	498.325	498.322	498.308	498.283	498.312

WSE = water surface elevation; masl = metres above sea level.

Table 9A-35: Changes in Mean Monthly Lake Water Surface Elevations in the Reasonably Foreseeable Development Case Relative to the Base Case

Location	Change in Monthly WSE (m)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	0.011	0.012	0.014	0.035	0.027	0.014	0.013	0.015	0.017	0.019	0.017	0.013	0.017
Forrest Lake	0.008	0.007	0.007	0.008	0.007	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.008
Beet Lake	0.004	0.004	0.004	0.004	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Naomi Lake	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004

WSE = water surface elevation.

Table 9A-36: Percent Changes in Lake Water Surface Elevations in the Reasonably Foreseeable Development Case Relative to the Base Case

Location	Percent Change in Monthly WSE (%)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	1.5	1.7	2.0	4.7	3.1	1.5	1.5	1.8	2.2	2.4	2.1	1.6	2.2
Forrest Lake	1.4	1.5	1.5	1.5	1.1	1.1	1.1	1.3	1.3	1.4	1.4	1.4	1.3
Beet Lake	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4
Naomi Lake	0.4	0.4	0.4	0.4	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4

WSE = water surface elevation.

Figure 9A-39: Clearwater River below Patterson Lake Monthly Flows in the Reasonably Foreseeable Development Case and Base Case

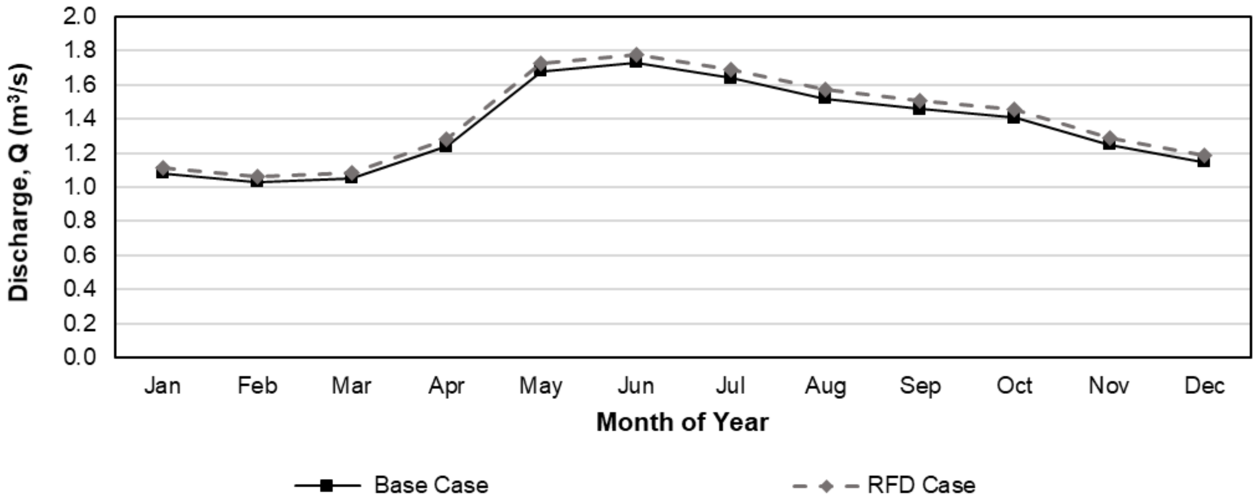


Table 9A-37: Reasonably Foreseeable Development Case Scenario Mean Monthly Discharges

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	1.11	1.06	1.08	1.28	1.72	1.78	1.69	1.57	1.51	1.46	1.29	1.18	1.39
Clearwater River below Forrest Lake	1.92	1.77	1.69	1.88	2.72	2.85	2.68	2.47	2.39	2.38	2.34	2.13	2.27
Clearwater River below Beet Lake	2.02	1.87	1.81	2.11	3.35	3.05	2.79	2.60	2.55	2.54	2.40	2.22	2.44
Clearwater River below Naomi Lake	2.49	2.27	2.17	2.62	4.63	4.09	3.58	3.30	3.24	3.23	3.05	2.75	3.12
Clearwater River above Mirror River confluence	3.56	3.51	3.55	6.07	10.00	8.03	6.68	6.08	6.06	6.06	5.40	4.01	5.75

Table 9A-38: Changes in Mean Monthly Discharges in Reasonably Foreseeable Development Case from Base Case

Location	Percent (%) Change Relative to the Base Case											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clearwater River below Patterson Lake	3.1	3.1	3.0	3.1	2.7	2.7	3.0	3.4	3.6	3.5	3.3	3.1
Clearwater River below Forrest Lake	1.9	1.9	1.9	1.9	1.7	1.7	1.7	2.0	2.1	2.1	2.0	1.9
Clearwater River below Beet Lake	1.8	1.8	1.7	1.9	1.4	1.6	1.6	1.8	1.9	2.0	1.9	1.9
Clearwater River below Naomi Lake	1.5	1.5	1.5	1.5	1.0	1.1	1.3	1.4	1.6	1.6	1.5	1.5
Clearwater River above Mirror River	1.1	1.0	1.0	0.7	0.4	0.6	0.6	0.9	1.0	1.0	0.8	1.1

Table 9A-39: Summarized Flow Characteristics for Reasonably Foreseeable Development Case

Location	Mean Annual Minimum Daily Flow		Mean Annual Daily Flow		Mean Annual Maximum Daily Flow	
	(m^3/s)	% Change	(m^3/s)	% Change	(m^3/s)	% Change
Clearwater River below Patterson Lake	0.89	3.4%	1.40	3.1%	1.95	2.6%
Clearwater River below Forrest Lake	1.51	1.9%	2.29	1.9%	3.24	1.6%
Clearwater River below Beet Lake	1.58	1.9%	2.46	1.7%	3.90	1.3%
Clearwater River below Naomi Lake	1.87	1.7%	3.14	1.4%	5.43	0.9%
Clearwater River above Mirror River	2.76	1.6%	5.81	0.7%	12.82	0.1%

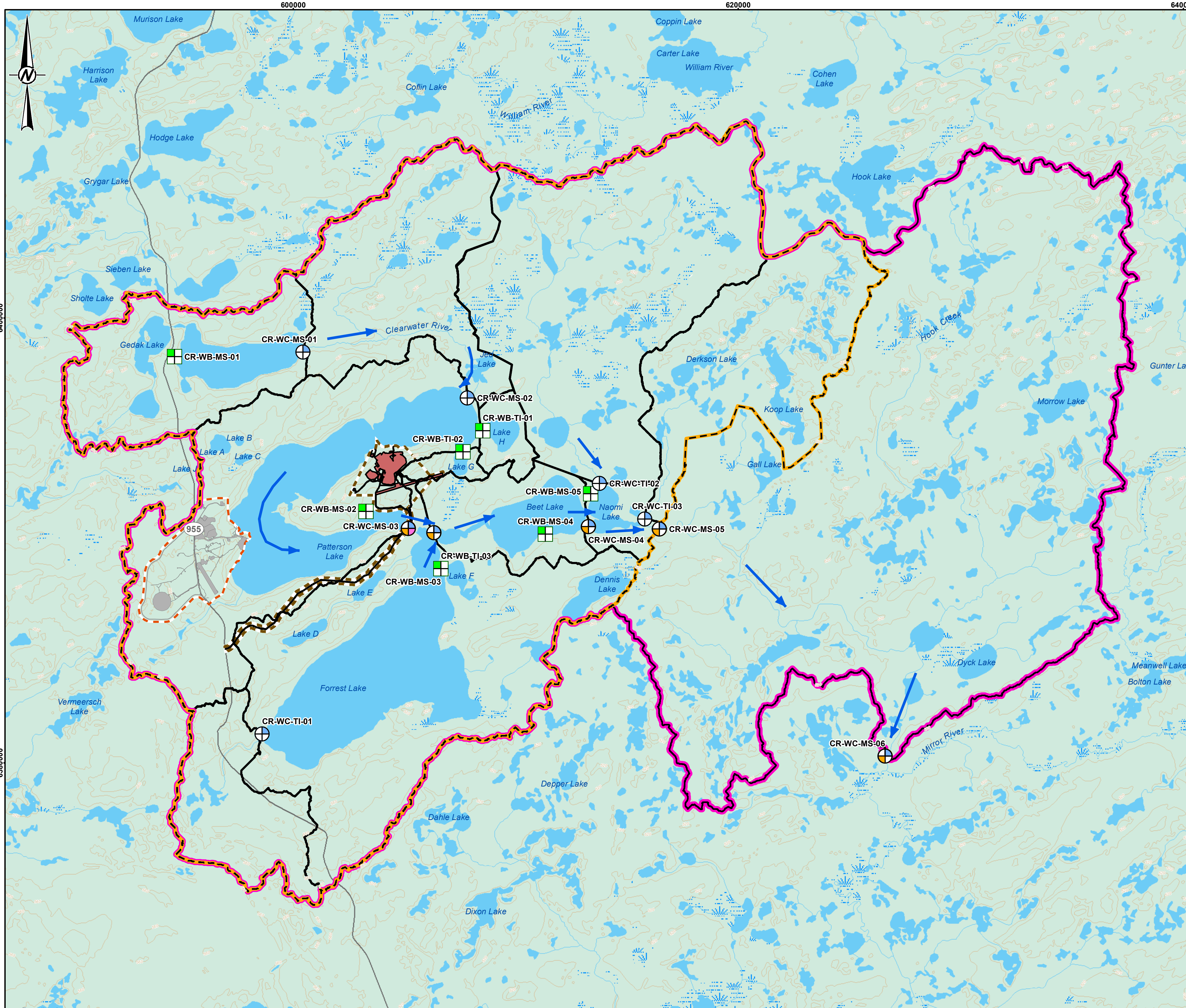
9A4.4.2 Reasonably Foreseeable Development Case (Including Climate Change)

The RFD Case (including climate change) (Scenario 5) simulates hydrological conditions considering other developments that have not yet been approved, namely the Fission Patterson Lake South Property as well as natural factors and climate change, which may interact with the Project and other developments to affect hydrology. Hydrological conditions in the RSA during the RFD Case, showing the maximum build out of Project-related infrastructure, is shown in Figure 9A-40.

Climate change, the effects of which are discussed in detail in Section 9A4.2, Climate Change Scenarios, is projected to result in wetter and warmer conditions in the RSA with a shorter winter period and earlier timing of spring. Average annual temperature is projected to increase by approximately 3°C. The changes to hydrology resulting from changes to climate would be complex and vary throughout the season. The hydrological change in response to climate change is complex and is also spatially variable because of differences in land cover and position within the drainage network. The potential future climate used to support the RFD Case was summarized in Table 9A-10.

A numerical summary of RFD Case (including climate change) conditions and change is provided in the following tables and figures:

- A comparison of daily WSE in Patterson Lake in the Base Case and RFD Case (including climate change) showing inter-annual variation and distribution of effects is shown in Figure 9A-41.
- A comparison of monthly WSE in Patterson Lake in the Base Case and RFD Case (including climate change) showing seasonal distribution of effects is shown in Figure 9A-42.
- RFD Case (including climate change) average monthly WSE of waterbodies is summarized in Table 9A-40 with the change relative to the Base Case summarized in Table 9A-41 and Table 9A-42 as a depth in metres or percent of the Base Case annual range, respectively.
- A comparison of average monthly discharge in the Clearwater River below Patterson Lake under Base Case and RFD Case (including climate change) conditions is shown in Figure 9A-43.
- RFD Case (including climate change) discharge in watercourses is summarized in Table 9A-43 with the change relative to the Base Case summarized in Table 9A-44 as a percent of the Base Case mean monthly discharge.
- Annual extremes for discharge in the RSA, including minimum daily, minimum weekly, average daily, and maximum daily discharges along with the change relative to the Base Case, are presented in Table 9A-45.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- PROPOSED PROJECT FOOTPRINT
- MAXIMUM DISTURBANCE AREA
- FISSION PATTERSON LAKE SOUTH PROPERTY FOOTPRINT
- PATTERSON LAKE SOUTH PROPERTY HYPOTHETICAL MAXIMUM DISTURBANCE AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED

WATER BODY HYDROMETRIC STATIONS

- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- STREAM CHANNEL PARAMETERS
- FLUVIAL SEDIMENT TRANSPORT
- WATERCOURSE FLOW RATE

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. FISSION (FISSION URANIUM CORP.) OBTAINED FROM 2019 TECHNICAL REPORT ON THE PRE-FEASIBILITY STUDY OF THE PATTERSON LAKE SOUTH PROPERTY USING UNDERGROUND MINING METHODS.
3. 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

HYDROLOGY REASONABLY FORESEEABLE DEVELOPMENT CASE

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	LB/NO	2023-02-07		
CHECK	RWP	2023-02-07	**FIGURE 9A-40**	
REVIEW	NPS	2023-02-07		

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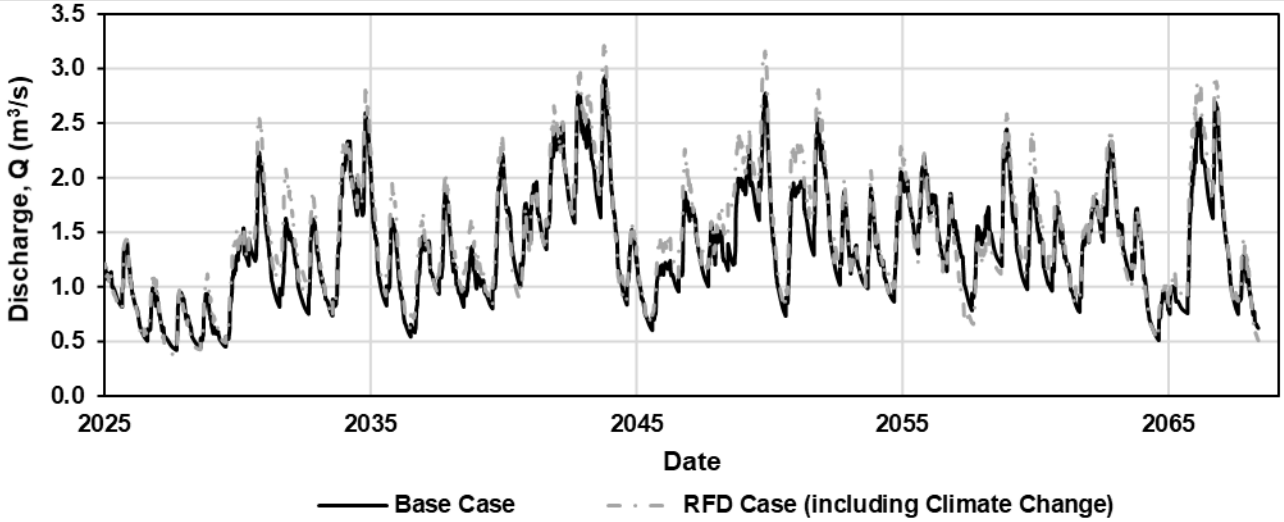
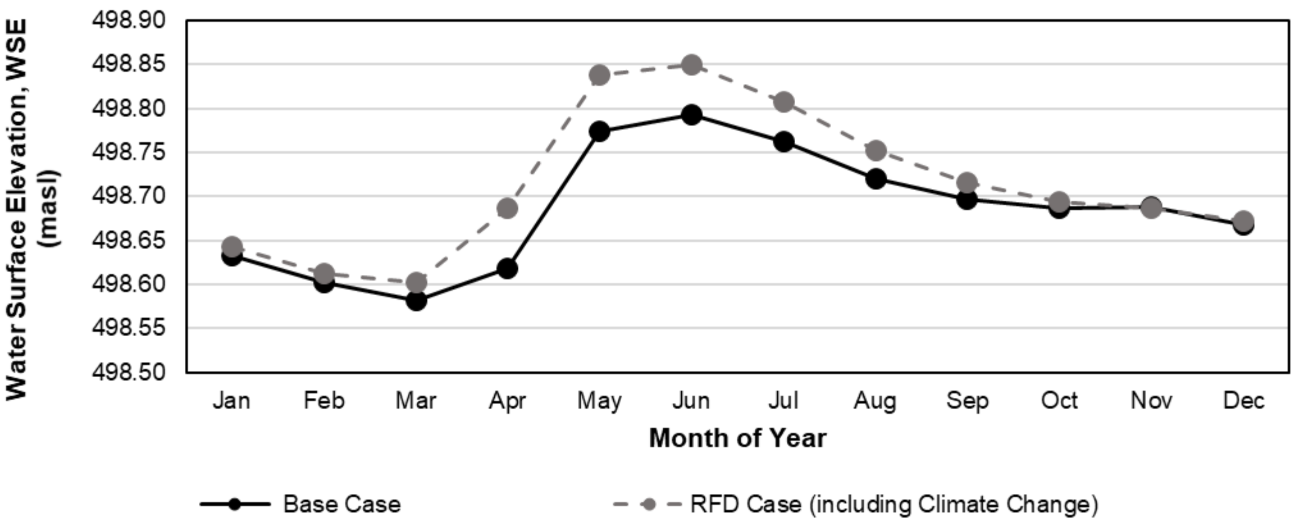
Figure 9A-41: Clearwater River below Patterson Lake Discharge in the Reasonably Foreseeable Development Case (Including Climate Change) and Base Case



RFD = reasonably foreseeable development.

Figure 9A-42: Patterson Lake Monthly Water Surface Elevation in the Reasonably Foreseeable Development Case (Including Climate Change) and Base Case



masl = metres above sea level; RFD = reasonably foreseeable development.

Table 9A-40: Reasonably Foreseeable Development Case (Including Climate Change) Mean Monthly Lake Water Surface Elevation

Location	Mean Monthly WSE (masl)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	498.638	498.609	498.605	498.709	498.847	498.846	498.801	498.745	498.712	498.693	498.686	498.669	498.713
Forrest Lake	498.314	498.291	498.287	498.359	498.500	498.510	498.471	498.423	498.394	498.380	498.371	498.345	498.387
Beet Lake	498.291	498.266	498.255	498.302	498.395	498.366	498.340	498.316	498.303	498.296	498.299	498.306	498.311
Naomi Lake	498.254	498.238	498.237	498.318	498.458	498.411	498.365	498.332	498.317	498.307	498.291	498.268	498.316

WSE = water surface elevation; masl = metres above sea level.

Table 9A-41: Reasonably Foreseeable Development Case (Including Climate Change) Changes in Mean Monthly Lake Water Surface Elevation Relative to the Base Case

Location	Change in Monthly WSE (m)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	0.006	0.007	0.024	0.091	0.073	0.053	0.039	0.026	0.015	0.006	-0.002	0.003	0.028
Forrest Lake	0.000	0.004	0.017	0.053	0.052	0.042	0.028	0.013	0.001	-0.008	-0.012	-0.005	0.016
Beet Lake	-0.004	-0.009	-0.001	0.033	0.026	0.019	0.013	0.005	-0.001	-0.008	-0.015	-0.008	0.004
Naomi Lake	-0.002	0.003	0.011	0.049	0.032	0.021	0.013	0.004	-0.003	-0.010	-0.013	-0.010	0.008

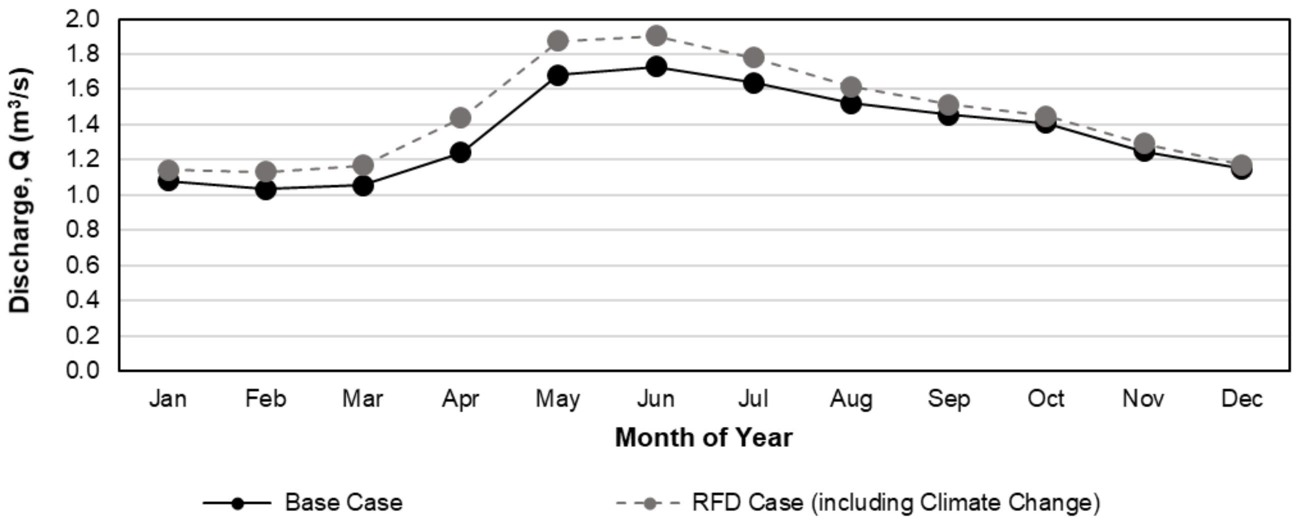
WSE = water surface elevation.

Table 9A-42: Reasonably Foreseeable Development Case (Including Climate Change) Percent Change in Mean Monthly Lake Water Surface Elevation Relative to the Base Case

Location	Percent Change in Monthly WSE (%)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Patterson Lake	0.8	1.0	3.5	12.5	8.3	5.9	4.5	3.1	1.9	0.7	-0.3	0.4	3.5
Forrest Lake	0.0	0.9	3.5	10.3	7.9	6.1	4.2	2.2	0.2	-1.3	-2.0	-0.8	2.6
Beet Lake	-0.4	-1.0	-0.2	3.6	2.5	1.9	1.3	0.5	-0.1	-0.8	-1.6	-0.8	0.4
Naomi Lake	-0.2	0.3	1.1	4.7	2.7	1.8	1.2	0.4	-0.3	-0.9	-1.2	-1.0	0.7

WSE = water surface elevation.

Figure 9A-43: Clearwater River below Patterson Lake Monthly Flows in the Reasonably Foreseeable Development Case (Including Climate Change) and Base Case



RFD = reasonably foreseeable development.

Table 9A-43: Reasonably Foreseeable Development Case (Including Climate Change) Mean Monthly Discharges

Location	Mean Monthly Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	1.14	1.13	1.17	1.44	1.88	1.90	1.78	1.61	1.51	1.45	1.29	1.17	1.46
Clearwater River below Forrest Lake	1.91	1.79	1.76	2.17	3.05	3.11	2.84	2.52	2.36	2.31	2.26	2.10	2.35
Clearwater River below Beet Lake	2.03	1.89	1.89	2.50	3.71	3.30	2.94	2.64	2.51	2.45	2.30	2.15	2.53
Clearwater River below Naomi Lake	2.47	2.29	2.27	3.20	5.15	4.40	3.75	3.34	3.18	3.11	2.91	2.65	3.23
Clearwater River above Mirror River confluence	3.47	3.61	4.09	7.51	10.9	8.75	7.11	6.27	6.13	6.05	5.44	4.13	6.12

Table 9A-44: Changes in Mean Monthly Discharges in the Reasonably Foreseeable Development Case (Including Climate Change) Relative to the Base Case

Location	Percent (%) Change Relative to the Base Case												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Clearwater River below Patterson Lake	5.6	9.5	10.9	16.0	11.6	10.2	8.6	6.2	3.9	3.0	3.6	2.1	7.6
Clearwater River below Forrest Lake	1.4	2.6	6.4	17.4	14.1	11.1	7.9	4.2	1.1	-1.0	-1.5	0.5	5.3
Clearwater River below Beet Lake	2.4	3.2	6.2	20.5	12.3	9.6	6.9	3.2	0.2	-1.7	-2.1	-1.1	5.0
Clearwater River below Naomi Lake	0.9	2.4	6.4	23.9	12.4	8.9	6.3	2.6	-0.2	-2.2	-3.0	-2.0	4.7
Clearwater River above Mirror River confluence	-1.4	3.6	16.3	24.5	8.9	9.5	7.1	4.1	2.2	0.8	1.6	4.1	6.8

Table 9A-45: Summarized Flow Characteristics for the Reasonably Foreseeable Development Case (Including Climate Change)

Location	Mean Annual Minimum Daily Flow		Mean Annual Daily Flow		Mean Annual Maximum Daily Flow	
	(m^3/s)	% Change	(m^3/s)	% Change	(m^3/s)	% Change
Clearwater River below Patterson Lake	0.890	3.0%	1.46	7.5%	2.07	9.0%
Clearwater River below Forrest Lake	1.49	1.0%	2.36	5.4%	3.50	9.7%
Clearwater River below Beet Lake	1.55	-0.3%	2.54	5.1%	4.17	8.3%
Clearwater River below Naomi Lake	1.84	-0.3%	3.25	4.9%	5.81	8.1%
Clearwater River above Mirror River	2.66	-2.0%	6.17	7.0%	13.3	3.9%

9A5 UNCERTAINTY AND LIMITATIONS

The purpose of the hydrological modelling study is to characterize existing conditions and predict the future conditions for the hydrology effects assessment. The predictions made in this hydrological modelling study embody some degree of uncertainty. There is uncertainty inherent in any modelling, particularly in the prediction of future conditions. The modelling effort applied a precautionary approach to address uncertainty by evaluating hydrology over a range of meteorological conditions to understand the range of possible outcomes. The model was calibrated (i.e., trained) using three years of site-specific hydrometric measurements collected within the RSA. The calibration showed good agreement with site-specific hydrometric measurements. The model was validated against long-term regional data and produced results that are consistent with regional records of water yield at appropriate spatial scale for comparison. Consequently, uncertainty was addressed in a manner that increased the level of confidence that residual effects would not be worse than predicted.

The following are specific sources of uncertainty for the hydrological modelling and methods used to address the uncertainty:

- **Unknown initial conditions:** The water levels for all the lakes in the RSA at the start of the model simulation were required to characterize initial conditions. Water levels coinciding with the historical climate data and start of future model simulations are not known. Water levels observed in August 2018 were assumed to be representative of initial conditions in August 2025 and provide a realistic starting point. Notwithstanding the difference in year from assumed to actual water level, the model is likely to have converged to within calibrated ranges within approximately one to two months.
- **Current climate data:** Meteorological variables, particularly rainfall, wind speed and humidity, may vary in magnitude over different terrain (i.e., lakes and terrestrial coverage) and this may influence lake evaporation estimates. The approach adopted for this assessment assumed that the spatial variability of meteorological conditions was negligible within the model domain (1,076 km^2). Global reanalysis data were used to develop a long-term climate record for the specific Project location, based on the nearest grid cell (i.e., ERAI meteorological data were grid-averaged based on ERAI data that have an 80 km by 80 km spatial resolution). This approach was checked and confirmed based on long-term climate data collected by Environment and Climate Change Canada in northern Saskatchewan in Annex IV.1. The best available climate data, based on a combination of local measurements and spatially gridded data for the exact location of the Project, were used for the purposes of this assessment.

- **Geographic variability of climate change projections:** The nature, rate, and magnitude of climate change is spatially variable. Site-specific future climate projections were developed for the Project based on spatially gridded data for the exact location of the Project.
- **Variability of modelled climate change projections:** The nature, rate, and magnitude of climate change outcomes are variable between different sources of modelled projections. Site-specific future climate projections were developed for the Project through analysis of available projections from a multi-model ensemble. The multi-model ensemble consists of available regional scale projections from several climate models representing different future climate scenarios (e.g., level of greenhouse gas emissions). To address the inherent uncertainty in future climate projections, the projections are summarized using exceedance percentiles across the ensemble, allowing the level of risk assumed to vary according to how the climate projections are being used. The site-specific climate change projections and the methods used are described as part of EIS Section 22.

9A6 KEY FINDINGS

The key findings from the hydrological modelling study are as follows:

- A fit-for-purpose model was developed to characterize the existing hydrological regime in the RSA over a range of climatic conditions. The model is structured to reflect the spatial distribution and hydrological processes of the receiving environment and was calibrated (i.e., trained) using two years of site-specific hydrometric measurements collected within the RSA. The calibration showed good agreement with site-specific hydrometric measurements. The model was validated against long-term regional data and produced results that are consistent with regional records of water yield at appropriate spatial scale for comparison.
- The Base Case simulation characterizes existing hydrological conditions in the RSA and provides a long-term representation of seasonal and inter-annual variation over a range of meteorological conditions that have occurred over an extended period.
- The Application Case was simulated to estimate the expected conditions during the different Project phases under the current climate conditions. Project activities are accounted for in the model by integrating results from the SWWBM over the same simulation period. The Application Case simulations support quantitative assessment of Project effects on water levels and flows at key evaluation nodes in the drainage network.
- The Application Case was found to not be sensitive to the coincident timing of maximum Project effects and different meteorological conditions. As result, the findings of this study are not expected to be influenced by variations in the timing of climate cycles relative to the timing of Project phases.
- Far-future scenario conditions were simulated, but far-future hydrology in the receiving environment is expected to be unchanged by Project activities beyond the date of Institutional Control.
- The RFD Case (including climate change) was simulated to estimate cumulative effects on receiving environment hydrology resulting from Project activities and Fission Patterson Lake South Property activities, as well as the projected climate for the 2050s. The RFD Case (including climate change) simulations supports quantitative assessment of cumulative effects on water levels and flows at key evaluation nodes in the drainage network.

- The RFD Case was simulated to estimate cumulative effects of Project activities and Fission Patterson Lake South Property activities with historical climate. The RFD Case simulation supports quantitative assessment of cumulative effects on water levels and flows at key evaluation nodes in the drainage network and leads to better understanding of the sensitivity of the assessment to climate change.
- The hydrological regime under projected climate change conditions contemporary with the Project was characterized. Climate change is expected to result in wetter and warmer conditions in the RSA with shorter winter periods and earlier timing of spring. The hydrological change in response to climate change is complex and varies throughout the RSA because of differences in land cover and position within the drainage network.
- The results reported above were assessed in the EIS Section 9, which further supports the assessment of potential effects to other intermediate components such as Surface Water Quality as well as valued components such as Fish and Fish Habitat.

CLOSING

WSP is pleased to submit this report to NexGen in support of the environmental assessment for the Rook I Project. For details on the limitations and use of information presented in this report, please refer to the Study Limitations subsection following this page. If you have any questions or require additional details related to this study, please contact the undersigned.

WSP Canada Inc.

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Number **C0868**
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Water Resources	22672	

STUDY LIMITATIONS

This report has been prepared by WSP Canada Inc. (WSP) for NexGen Energy Ltd. (Client) and for the express purpose of supporting the Environmental Assessment (EA) of the proposed Rook I Project. This report is provided for the exclusive use by the Client. WSP authorizes use of this report by other parties involved in, and for the specific and identified purpose of, the EA review process. Any other use of this report by others is prohibited and is without responsibility to WSP.

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The scope and the period of WSP's services are as described in WSP's proposal, and are subject to restrictions and limitations. WSP did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the report. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by WSP in regard to it. Any assessments, designs and advice made in this report are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this report. Where data supplied by the Client or other external sources (including without limitation, other consultants, laboratories, public databases), including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by WSP for incomplete or inaccurate data supplied by others.

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The report is of a summary nature and is not intended to stand alone without reference to the instructions given to WSP by the Client, communications between WSP and the Client, and to any other reports prepared by WSP for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be to the foregoing and to the entirety of the report. WSP cannot be responsible for use of portions of the report without reference to the entire report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client and were prepared for the specific purpose set out herein. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. WSP accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

REFERENCES

Literature Cited

Beven K. 2012. Rainfall-Runoff Modelling: The Primer (Second Edition). Wiley Blackwell. Hoboken, NJ. 457 p.

Bush E, Lemmen DS, editors. 2019. Canada's Changing Climate Report; Government of Canada, Ottawa, On. 444 p.

CNSC (Canadian Nuclear Safety Commission). 2021. Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the *Canadian Environmental Assessment Act, 2012*. Available at https://nuclearsafety.gc.ca/eng/resources/environmental-protection/ceaa-2012-generic-eis-guidelines.cfm.

CEA Agency (Canadian Environmental Assessment Agency). 2018. Assessing Cumulative Environmental Effects under the *Canadian Environmental Assessment Act, 2012*. Interim Technical Guidelines. March 2018 Version 2. Available at http://publications.gc.ca/collections/collection_2018/acee-ceaa/En106-204-2018-eng.pdf.

Dingman SL. 2002. Physical Hydrology (New York: Macmillan Publishing Co).

ECMWF (European Centre for Medium-Range Weather Forecasts). 2021. ERA interim and ERA 5 data. Accessed May 2021. Available at http://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/.

ENV (Saskatchewan Ministry of the Environment). 2021. Guidelines for the Terms of Reference and Environmental Impact Statement. 43 p.

ESA (European Space Agency). 2020. GlobSnow Project - Finnish Meteorological Institute: GlobSnow SWE Data. Accessed April 2020. Available at http://www.globsnow.info/swe/.

GoldSim. 2018. Probabilistic Simulation Environment, User's Guide. GoldSim Technology Group. Issaquah, Washington.

Granger RJ, Gray DM. 1989. Evaporation from natural non-saturated surfaces. Journal of Hydrology 111; 21-29.

Jensen EM. 2010. Estimating evaporation form water surfaces. CSU/ARS Evapotranspiration Workshop. Fort Collins, CO. Parts of several sections were extracted from Chapter 6, ASCE Manual 70, second edition, Jul 08 draft.

Kuchment LS, Gelfan AN. 1996. The determination of snowmelt rate and the meltwater outflow from a snowpack for modelling river runoff generation. Journal of Hydrology 179: 23-36.

McJannet DL, Cook FJ, Burn S. 2013. Comparison of techniques for estimating evaporation from an irrigation water storage. Water Resources Research 49; 1415-1428.

Moriasi DN, Arnold JG, Van Liew MW, Bingner RL, Harmel RD, Veith TL. 2007. Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations. Transactions of the American Society of Agricultural and Biological Engineers. Vol. 50(3): 885-900.

NexGen (NexGen Energy Ltd.). 2016. Bathymetry data for Patterson Lake provided in Digital Format.

NRCan (Natural Resources Canada). 2019. Canadian Digital Elevation Model (CDEM) data. Accessed June 2019. Available at https://open.canada.ca/data/en/dataset/957782bf-847c-4644-a757-e383c0057995.

NRC-CHC (National Research Council Canadian Hydraulics Centre). 2012. Green-Kenue Visualization and Analysis for Hydrological Applications Version 3.3.10.

Penman HL. 1948. Natural evaporation from open water, bare soil, and grass. Proc. R. Soc. London 193:120-145.

Fission (Fission Uranium Corp.). 2019. Technical Report on the Pre-Feasibility Study of the Patterson Lake South Property using Underground Mining Methods, Northern Saskatchewan, Canada. NI 43-101 Report. Prepared by Roscoe Postle Associates Inc. for Fission Uranium Corp. November 2019.

Fission. 2021. Fission Project Description. Prepared by Clifton Engineering Group Inc. and Canada North Environmental Services Limited Partnership for Fission Energy Corp. 22 November 2021.

RPA (Roscoe Postle Associates Inc.) 2020. RPA Arrow Deposit Updated EA Plan. Dated November 2020.

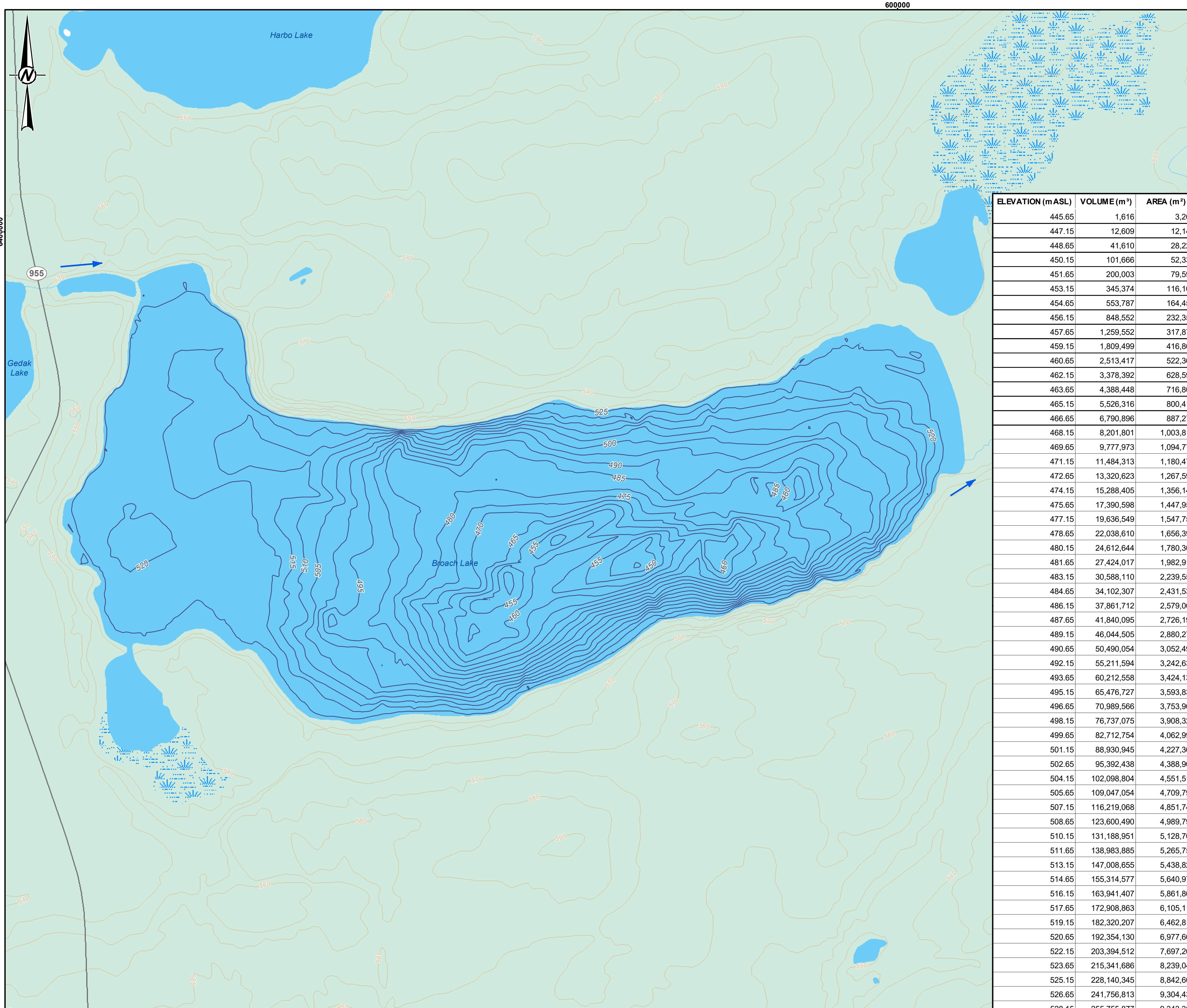
Stephens, M.A. 1974. EDF Statistics for Goodness-of-Fit Statistics with Unknown Parameters, Annals of Statistics: 4, pp 357-369.

Vionnet V, Brun E, Morin S, Boone A, Faroux S, Moigne PL. 2012. The detailed snowpack scheme crocus and its implementation in SURFEX v7.2. Geosci. Model Dev. 5:773-791.

WSA (Water Security Agency). 2021. Re: Licensed Water Allocations. Email from Andrew Thornton dated 9 July 2021.

WSC (Water Survey of Canada). 2021. Archived and Real-time Hydrometric Data. Accessed February 2021. Available at https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/monitoring/survey.html.

Attachment 9A-1 Bathymetry Maps



ELEVATION (m ASL)	VOLUME (m³)	AREA (m²)
445.65	1,616	3,268
447.15	12,609	12,143
448.65	41,610	28,227
450.15	101,666	52,338
451.65	200,003	79,597
453.15	345,374	116,107
454.65	553,787	164,456
456.15	848,552	232,358
457.65	1,259,552	317,877
459.15	1,809,499	416,864
460.65	2,513,417	522,361
462.15	3,378,392	628,597
463.65	4,388,448	716,806
465.15	5,526,316	800,416
466.65	6,790,896	887,276
468.15	8,201,801	1,003,812
469.65	9,777,973	1,094,773
471.15	11,484,313	1,180,477
472.65	13,320,623	1,267,598
474.15	15,288,405	1,356,146
475.65	17,390,598	1,447,959
477.15	19,636,549	1,547,755
478.65	22,038,610	1,656,390
480.15	24,612,644	1,780,309
481.65	27,424,017	1,982,912
483.15	30,588,110	2,239,553
484.65	34,102,307	2,431,531
486.15	37,861,712	2,579,008
487.65	41,840,095	2,726,190
489.15	46,044,505	2,880,270
490.65	50,490,054	3,052,494
492.15	55,211,594	3,242,638
493.65	60,212,558	3,424,130
495.15	65,476,727	3,593,834
496.65	70,989,566	3,753,969
498.15	76,737,075	3,908,327
499.65	82,712,754	4,062,996
501.15	88,930,945	4,227,361
502.65	95,392,438	4,388,901
504.15	102,098,804	4,551,511
505.65	109,047,054	4,709,791
507.15	116,219,068	4,851,743
508.65	123,600,490	4,989,794
510.15	131,188,951	5,128,704
511.65	138,983,885	5,265,750
513.15	147,008,655	5,438,820
514.65	155,314,577	5,640,972
516.15	163,941,407	5,861,861
517.65	172,908,863	6,105,113
519.15	182,320,207	6,462,810
520.65	192,354,130	6,977,668
522.15	203,394,512	7,697,200
523.65	215,341,686	8,239,046
525.15	228,140,345	8,842,605
526.65	241,756,813	9,304,436
528.15	255,755,877	9,343,368

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (5 m INTERVAL)
- WATERCOURSE
- FLOW DIRECTION
- WATERBODY
- WETLAND
- WOODED

0 500 1,000
1:25,000 METRES

NOTE(S)

1. WATER SURFACE ELEVATION DAILY AVERAGE ESTIMATED BASED ON MONITORING BY GOLDER TO BE 526.650 mASL ON OCTOBER 9-10, 2018.
2. LAKE VOLUME ON OCTOBER 9-10, 2018 = 241,756,813 m^3.

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
3. BATHYMETRY WAS COLLECTED BY CANNORTH CONSULTING USING A HUMMINGBIRD 999CI HD SI DEPTH SOUNDER MOUNTED ON A ZODIAC PORTABLE BOAT.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

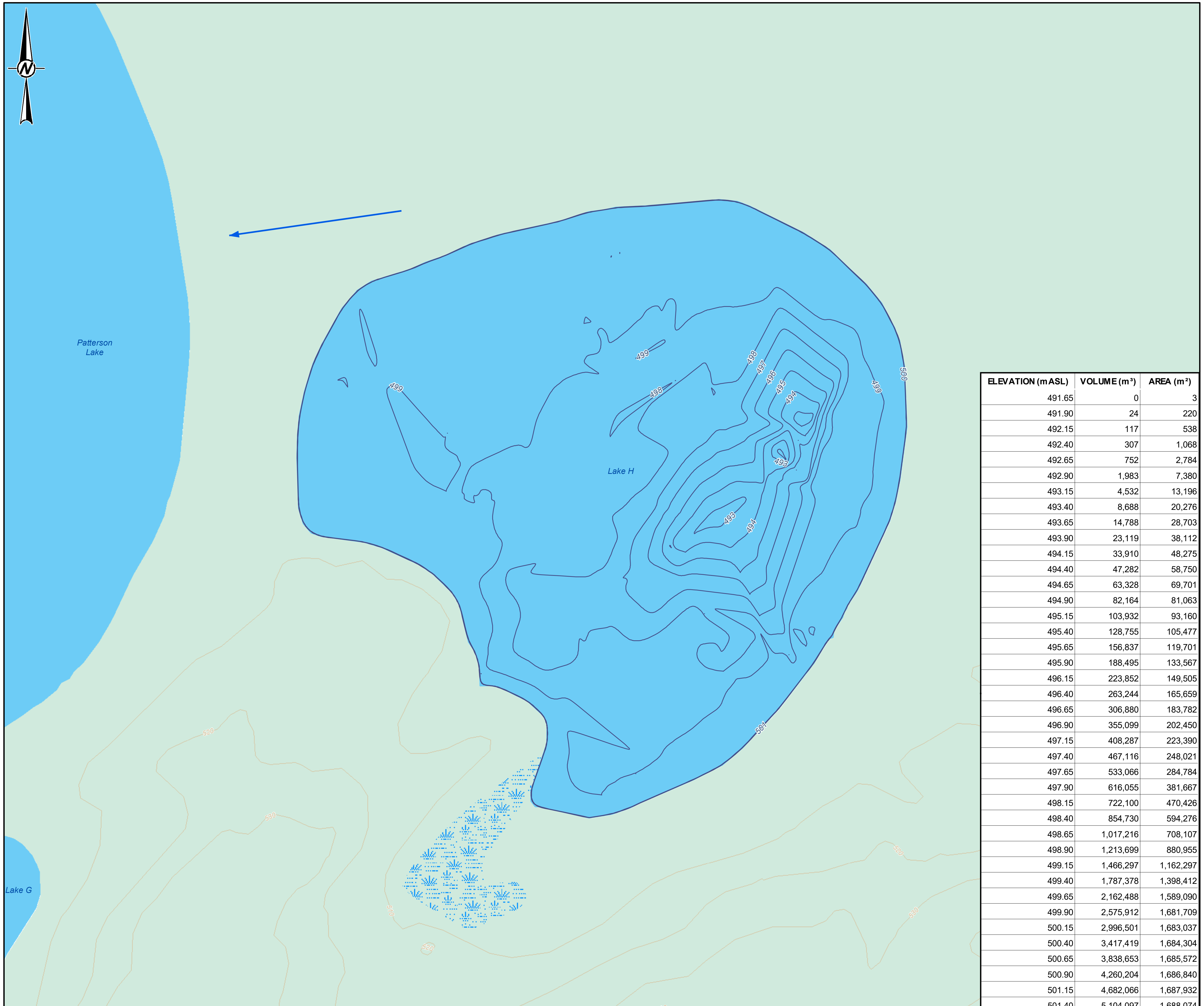
PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
BROACH LAKE BATHYMETRY

CONSULTANT
wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-07		
CHECK	RWP	2023-02-07	**FIGURE 9A.1-1**	
REVIEW	NPS	2023-02-07		

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



ELEVATION (mASL)	VOLUME (m³)	AREA (m²)
491.65	0	3
491.90	24	220
492.15	117	538
492.40	307	1,068
492.65	752	2,784
492.90	1,983	7,380
493.15	4,532	13,196
493.40	8,688	20,276
493.65	14,788	28,703
493.90	23,119	38,112
494.15	33,910	48,275
494.40	47,282	58,750
494.65	63,328	69,701
494.90	82,164	81,063
495.15	103,932	93,160
495.40	128,755	105,477
495.65	156,837	119,701
495.90	188,495	133,567
496.15	223,852	149,505
496.40	263,244	165,659
496.65	306,880	183,782
496.90	355,099	202,450
497.15	408,287	223,390
497.40	467,116	248,021
497.65	533,066	284,784
497.90	616,055	381,667
498.15	722,100	470,426
498.40	854,730	594,276
498.65	1,017,216	708,107
498.90	1,213,699	880,955
499.15	1,466,297	1,162,297
499.40	1,787,378	1,398,412
499.65	2,162,488	1,589,090
499.90	2,575,912	1,681,709
500.15	2,996,501	1,683,037
500.40	3,417,419	1,684,304
500.65	3,838,653	1,685,572
500.90	4,260,204	1,686,840
501.15	4,682,066	1,687,932
501.40	5,104,097	1,688,074

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (1 m INTERVAL)
- WATERBODY
- FLOW DIRECTION
- WETLAND
- WOODED

0 200 400
1:10,000 METRES

NOTE(S)

1. WATER SURFACE ELEVATION DAILY AVERAGE COLLECTED BY GOLDER WAS 499.900 mASL ON AUGUST 5, 2018.
2. LAKE VOLUME ON AUGUST 5, 2018 = 2,575,912 m^3.

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
3. BATHYMETRY WAS COLLECTED BY CANNORTH CONSULTING USING A HUMMINGBIRD 999CI HD SI DEPTH SOUNDER MOUNTED ON A ZODIAC PORTABLE BOAT.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

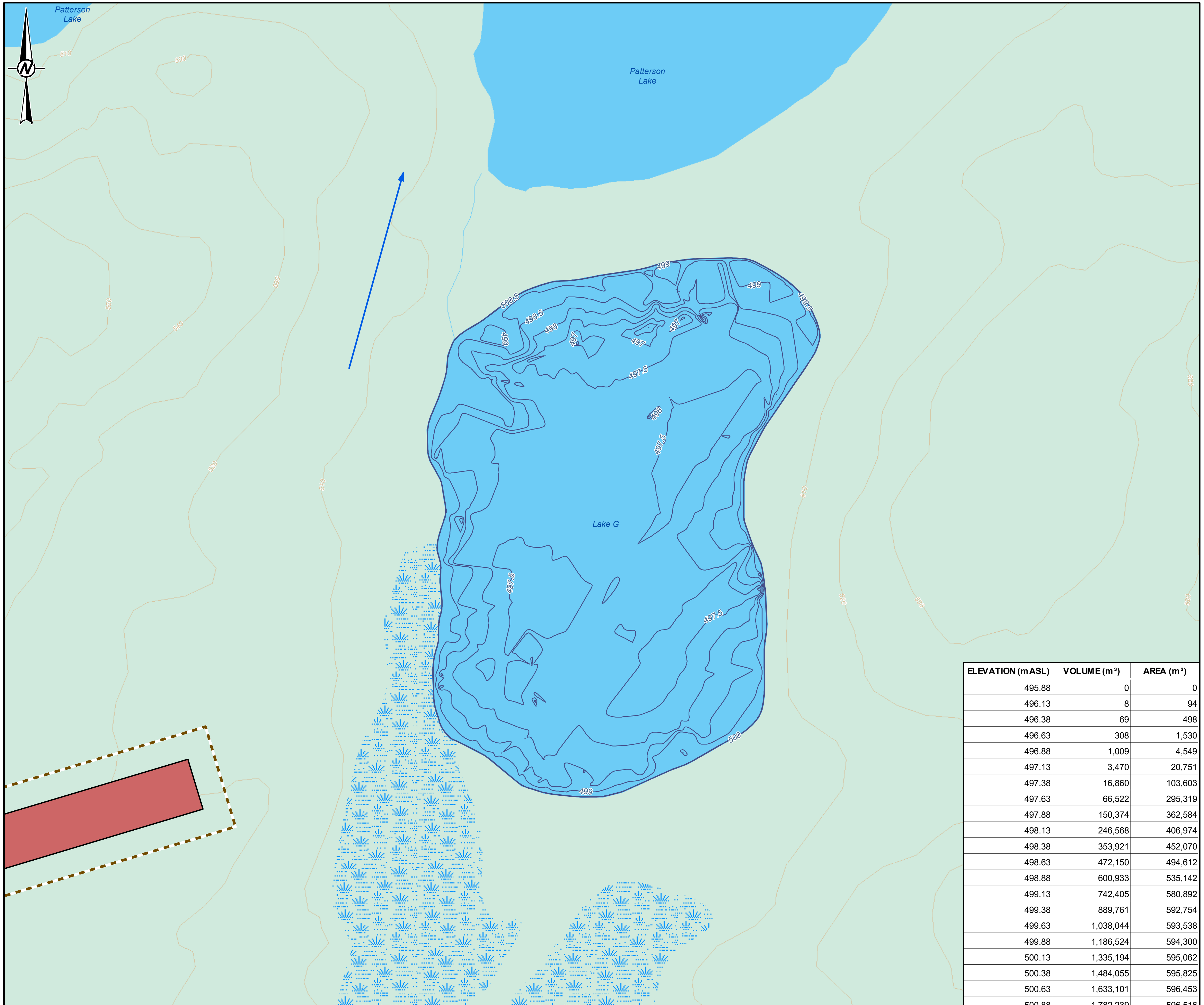
TITLE

LAKE H BATHYMETRY

CONSULTANT

wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-07		
CHECK	RWP	2023-02-07	**FIGURE 9A.1-2**	
REVIEW	NPS	2023-02-07		



LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED
- MAXIMUM DISTURBANCE AREA
- PROPOSED PROJECT FOOTPRINT
- BATHYMETRY CONTOUR ELEVATION (0.5 m INTERVAL)
- FLOW DIRECTION

ELEVATION (m ASL)	VOLUME (m³)	AREA (m²)
495.88	0	0
496.13	8	94
496.38	69	498
496.63	308	1,530
496.88	1,009	4,549
497.13	3,470	20,751
497.38	16,860	103,603
497.63	66,522	295,319
497.88	150,374	362,584
498.13	246,568	406,974
498.38	353,921	452,070
498.63	472,150	494,612
498.88	600,933	535,142
499.13	742,405	580,892
499.38	889,761	592,754
499.63	1,038,044	593,538
499.88	1,186,524	594,300
500.13	1,335,194	595,062
500.38	1,484,055	595,825
500.63	1,633,101	596,453
500.88	1,782,239	596,516

0 150 300

1:7,500 METRES

NOTE(S)

1. WATER SURFACE ELEVATION DAILY AVERAGE COLLECTED BY GOLDER WAS 499.380 mASL ON AUGUST 7, 2018.
2. LAKE VOLUME ON AUGUST 7, 2018 = 889,761 m³.

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
3. BATHYMETRY WAS COLLECTED BY CANNORTH CONSULTING USING A HUMMINGBIRD 999CI HD SI DEPTH SOUNDER MOUNTED ON A ZODIAC PORTABLE BOAT.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

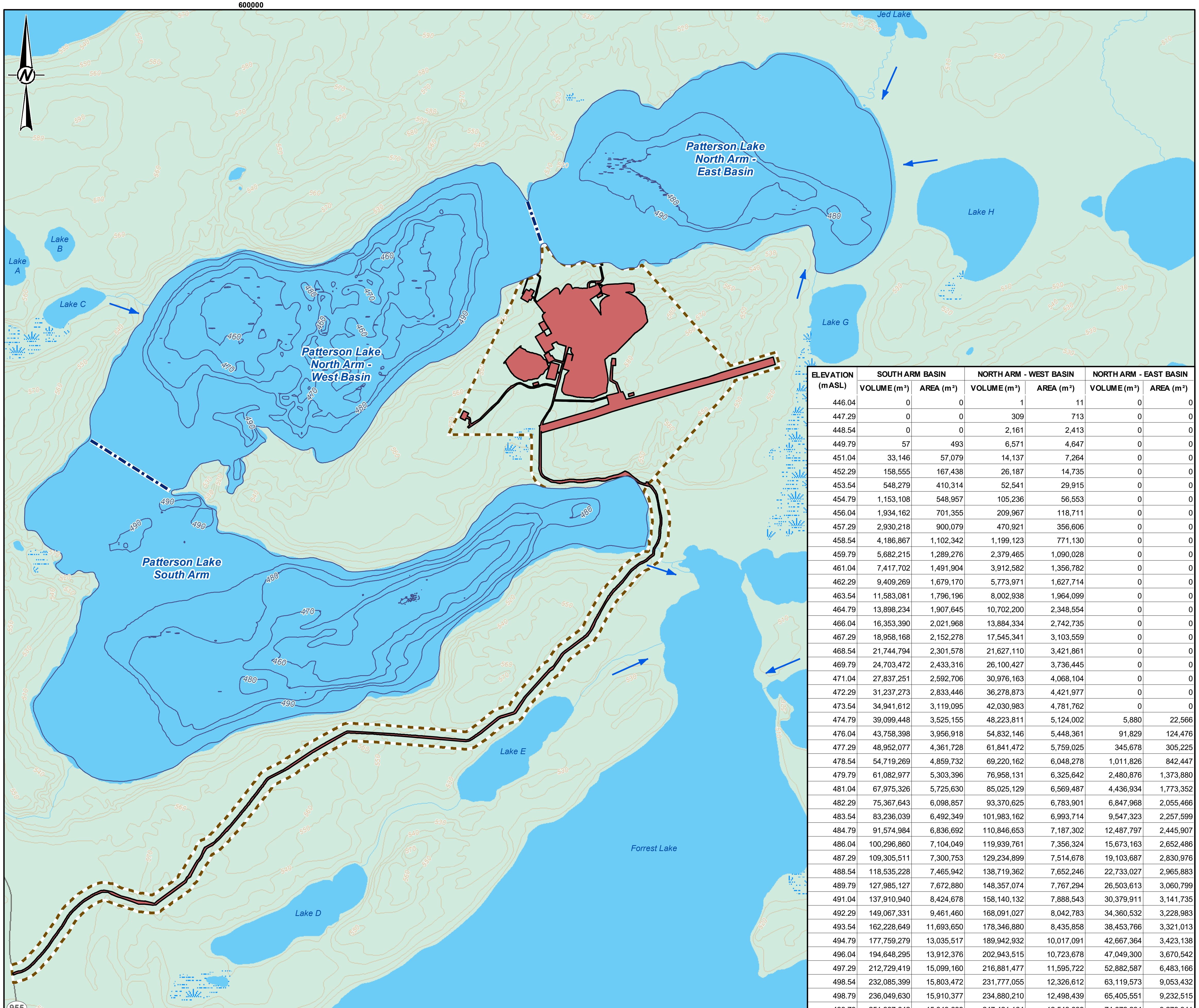
LAKE G BATHYMETRY

CONSULTANT

wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-07		
CHECK	RWP	2023-02-07		
REVIEW	NPS	2023-02-07		

FIGURE 9A.1-3



ELEVATION (mASL)	SOUTH ARM BASIN		NORTH ARM - WEST BASIN		NORTH ARM - EAST BASIN	
	VOLUME (m^3)	AREA (m^2)	VOLUME (m^3)	AREA (m^2)	VOLUME (m^3)	AREA (m^2)
446.04	0	0	1	11	0	0
447.29	0	0	309	713	0	0
448.54	0	0	2,161	2,413	0	0
449.79	57	493	6,571	4,647	0	0
451.04	33,146	57,079	14,137	7,264	0	0
452.29	158,555	167,438	26,187	14,735	0	0
453.54	548,279	410,314	52,541	29,915	0	0
454.79	1,153,108	548,957	105,236	56,553	0	0
456.04	1,934,162	701,355	209,967	118,711	0	0
457.29	2,930,218	900,079	470,921	356,606	0	0
458.54	4,186,867	1,102,342	1,199,123	771,130	0	0
459.79	5,682,215	1,289,276	2,379,465	1,090,028	0	0
461.04	7,417,702	1,491,904	3,912,582	1,356,782	0	0
462.29	9,409,269	1,679,170	5,773,971	1,627,714	0	0
463.54	11,583,081	1,796,196	8,002,938	1,964,099	0	0
464.79	13,898,234	1,907,645	10,702,200	2,348,554	0	0
466.04	16,353,390	2,021,968	13,884,334	2,742,735	0	0
467.29	18,958,168	2,152,278	17,545,341	3,103,559	0	0
468.54	21,744,794	2,301,578	21,627,110	3,421,861	0	0
469.79	24,703,472	2,433,316	26,100,427	3,736,445	0	0
471.04	27,837,251	2,592,706	30,976,163	4,068,104	0	0
472.29	31,237,273	2,833,446	36,278,873	4,421,977	0	0
473.54	34,941,612	3,119,095	42,030,983	4,781,762	0	0
474.79	39,099,448	3,525,155	48,223,811	5,124,002	5,880	22,566
476.04	43,758,398	3,956,918	54,832,146	5,448,361	91,829	124,476
477.29	48,952,077	4,361,728	61,841,472	5,759,025	345,678	305,225
478.54	54,719,269	4,859,732	69,220,162	6,048,278	1,011,826	842,447
479.79	61,082,977	5,303,396	76,958,131	6,325,642	2,480,876	1,373,880
481.04	67,975,326	5,725,630	85,025,129	6,569,487	4,436,934	1,773,352
482.29	75,367,643	6,098,857	93,370,625	6,783,901	6,847,968	2,055,466
483.54	83,236,039	6,492,349	101,983,162	6,993,714	9,547,323	2,257,599
484.79	91,574,984	6,836,692	110,846,653	7,187,302	12,487,797	2,445,907
486.04	100,296,860	7,104,049	119,939,761	7,356,324	15,673,163	2,652,486
487.29	109,305,511	7,300,753	129,234,899	7,514,678	19,103,687	2,830,976
488.54	118,535,228	7,465,942	138,719,362	7,652,246	22,733,027	2,965,883
489.79	127,985,127	7,672,880	148,357,074	7,767,294	26,503,613	3,060,799
491.04	137,910,940	8,424,678	158,140,132	7,888,543	30,379,911	3,141,735
492.29	149,067,331	9,461,460	168,091,027	8,042,783	34,360,532	3,228,983
493.54	162,228,649	11,693,650	178,346,880	8,435,858	38,453,766	3,321,013
494.79	177,759,279	13,035,517	189,942,932	10,017,091	42,667,364	3,423,138
496.04	194,648,295	13,912,376	202,943,515	10,723,678	47,049,300	3,670,542
497.29	212,729,419	15,099,160	216,881,477	11,595,722	52,882,587	6,483,166
498.54	232,085,399	15,803,472	231,777,055	12,326,612	63,119,573	9,053,432
498.79	236,049,630	15,910,377	234,880,210	12,498,439	65,405,551	9,232,515
499.79	251,987,642	15,949,639	247,421,164	12,549,839	74,672,234	9,273,941

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (10 m INTERVAL)
- LAKE BASIN DIVISION
- FLOW DIRECTION
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED
- MAXIMUM DISTURBANCE AREA
- PROPOSED PROJECT FOOTPRINT

0 1.5 3
1:50,000 KILOMETRES

NOTE(S)

1. WATER SURFACE ELEVATION ESTIMATED TO BE 498.79 mASL ASSOCIATED WITH MEAN ANNUAL FLOOD.
2. LAKE VOLUME ON JUNE 6-8, 1981:
- SOUTH ARM BASIN = 236,049,630 m^3
- NORTH ARM - WEST BASIN = 234,880,210 m^3
- NORTH ARM - EAST BASIN = 65,405,551 m^3

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
3. BATHYMETRY CONTOURS DERIVED FROM DATA COLLECTED BY NEXGEN, 2016.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

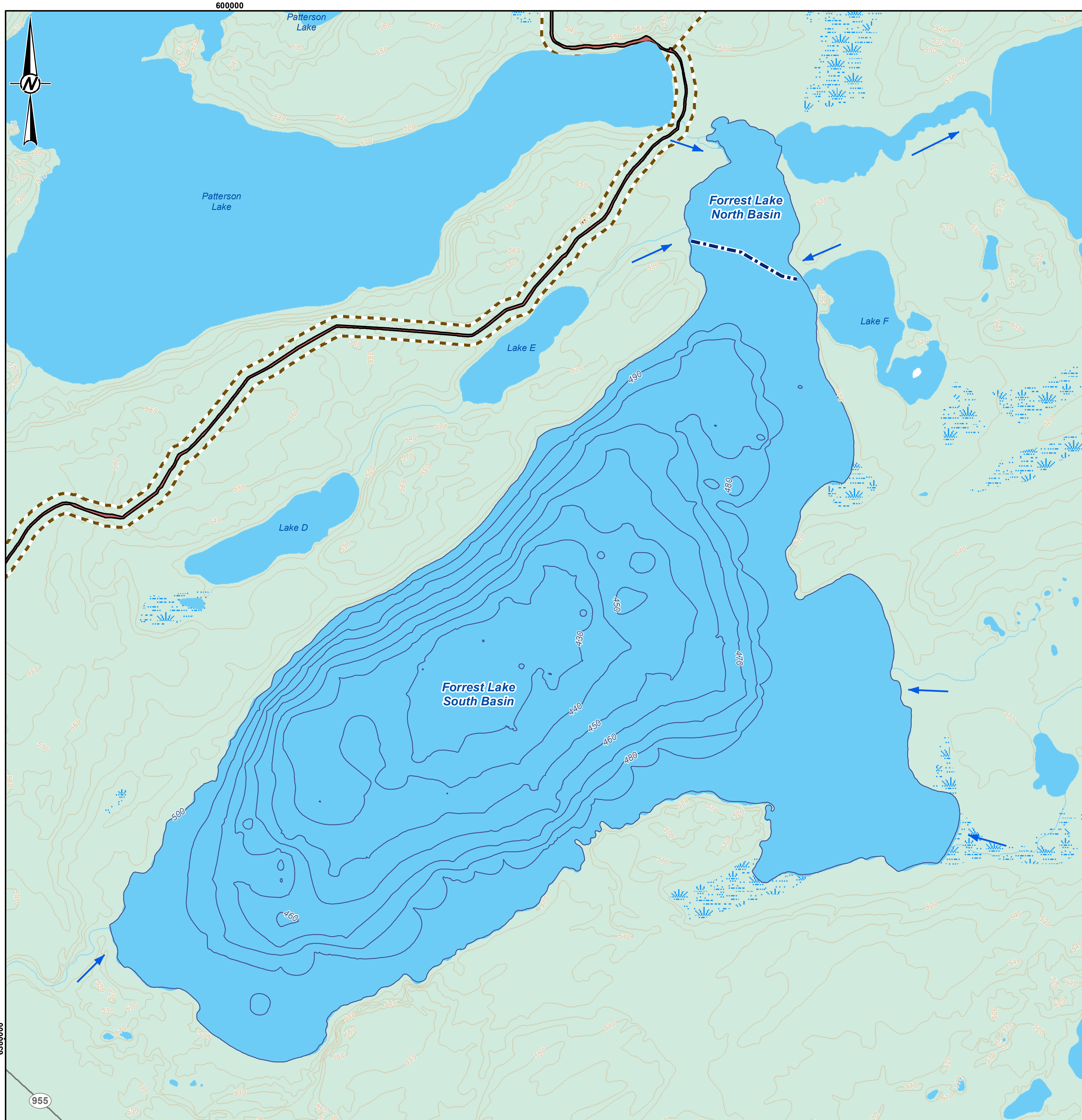
TITLE

PATTERSON LAKE BATHYMETRY

CONSULTANT

wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-07		
CHECK	RWP	2023-02-07	FIGURE 9A.1-4	
REVIEW	NPS	2023-02-07		



ELEVATION (mASL)	SOUTH BASIN		NORTH BASIN	
	VOLUME (m³)	AREA (m²)	VOLUME (m³)	AREA (m²)
413.30	0	0	0	0
414.30	15	79	0	0
415.30	320	543	0	0
416.30	1,116	1,059	0	0
417.30	2,476	1,694	0	0
418.30	4,564	2,644	0	0
419.30	8,592	5,304	0	0
420.30	16,499	20,856	0	0
421.30	117,539	165,630	0	0
422.30	330,139	258,947	0	0
423.30	648,041	391,273	0	0
424.30	1,133,092	584,223	0	0
425.30	1,848,090	852,526	0	0
426.30	2,892,644	1,249,687	0	0
427.30	4,358,816	1,650,777	0	0
428.30	6,162,471	1,951,071	0	0
429.30	8,265,099	2,252,288	0	0
430.30	10,680,034	2,561,348	0	0
431.30	13,406,194	2,902,055	0	0
432.30	16,471,968	3,229,346	0	0
433.30	19,867,036	3,558,122	0	0
434.30	23,587,901	3,886,663	0	0
435.30	27,655,688	4,245,003	0	0
436.30	32,073,738	4,594,404	0	0
437.30	36,855,532	4,972,595	0	0
438.30	42,027,801	5,389,947	0	0
439.30	47,631,099	5,805,980	0	0
440.30	53,643,971	6,226,290	0	0
441.30	60,084,870	6,659,292	0	0
442.30	66,957,044	7,079,577	0	0
443.30	74,238,438	7,496,977	0	0
444.30	81,966,091	7,951,762	0	0
445.30	90,130,107	8,373,164	0	0
446.30	98,717,082	8,801,331	0	0
447.30	107,726,263	9,218,422	0	0
448.30	117,162,800	9,648,959	0	0
449.30	127,022,209	10,074,148	0	0
450.30	137,304,096	10,483,424	0	0
451.30	147,979,897	10,866,744	0	0
452.30	159,036,738	11,253,695	0	0
453.30	170,493,352	11,664,873	0	0
454.30	182,352,805	12,042,530	0	0
455.30	194,574,794	12,405,659	0	0
456.30	207,164,162	12,768,682	0	0
457.30	220,102,328	13,107,492	0	0
458.30	233,389,432	13,479,684	0	0
459.30	247,058,847	13,857,507	0	0
460.30	261,103,918	14,236,876	0	0
461.30	275,537,360	14,633,332	0	0
462.30	290,375,241	15,034,553	0	0
463.30	305,601,312	15,414,121	0	0
464.30	321,199,387	15,780,166	0	0
465.30	337,158,158	16,135,743	0	0
466.30	353,462,991	16,472,157	0	0
467.30	370,103,813	16,813,125	0	0
468.30	387,087,910	17,154,119	0	0
469.30	404,412,200	17,496,618	0	0
470.30	422,088,856	17,858,766	0	0
471.30	440,133,307	18,237,787	0	0
472.30	458,590,416	18,688,518	0	0
473.30	477,547,075	19,240,488	0	0
474.30	497,057,113	19,755,228	0	0
475.30	517,044,332	20,215,322	0	0
476.30	537,475,556	20,640,910	0	0
477.30	558,316,751	21,039,680	0	0
478.30	579,547,613	21,419,971	0	0
479.30	601,151,148	21,781,105	0	0
480.30	623,104,467	22,125,782	0	0
481.30	645,413,184	22,497,318	0	0
482.30	668,090,606	22,855,766	0	0
483.30	691,117,173	23,191,844	0	0
484.30	714,469,945	23,513,536	0	0
485.30	738,145,978	23,839,874	0	0
486.30	762,154,878	24,182,238	0	0
487.30	786,525,009	24,569,595	0	0
488.30	811,313,119	25,016,138	0	0
489.30	836,585,155	25,548,305	0	0
490.30	862,461,510	26,263,573	0	0
491.30	889,360,645	27,566,232	0	0
492.30	917,528,999	28,755,189	0	0
493.30	946,896,509	29,989,552	0	0
494.30	977,801,939	32,380,092	1	11
495.30	1,011,709,501	35,195,020	93	254
496.30	1,047,954,730	37,335,483	992	2,291
497.30	1,086,475,086	40,073,828	220,432	1,038,126
498.30	1,127,365,188	41,264,206	1,621,246	1,493,829
499.30	1,168,666,084	41,321,148	3,118,923	1,500,292
499.80	1,189,330,999	41,338,468	3,869,651	1,502,603

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- LAKE BASIN DIVISION
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED
- MAXIMUM DISTURBANCE AREA
- PROPOSED PROJECT FOOTPRINT
- BATHYMETRY CONTOUR ELEVATION (10 m INTERVAL)
- FLOW DIRECTION

0 1.5 3
1:50,000 KILOMETRES

NOTE(S)

1. WATER SURFACE ELEVATION ESTIMATED TO BE 498.303 mASL ON JUNE 11, 2019.
2. LAKE VOLUME ON JUNE 11, 2019:
- SOUTH BASIN = 1,127,365,188 m^3
- NORTH BASIN = 1,621,246 m^3

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
3. BATHYMETRY CONTOURS DERIVED FROM JUNE 2019 BATHYMETRY SURVEY DATA.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
FORREST LAKE BATHYMETRY

CONSULTANT
wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-07		
CHECK	RWP	2023-02-07	FIGURE 9A.1-5	
REVIEW	NPS	2023-02-07		

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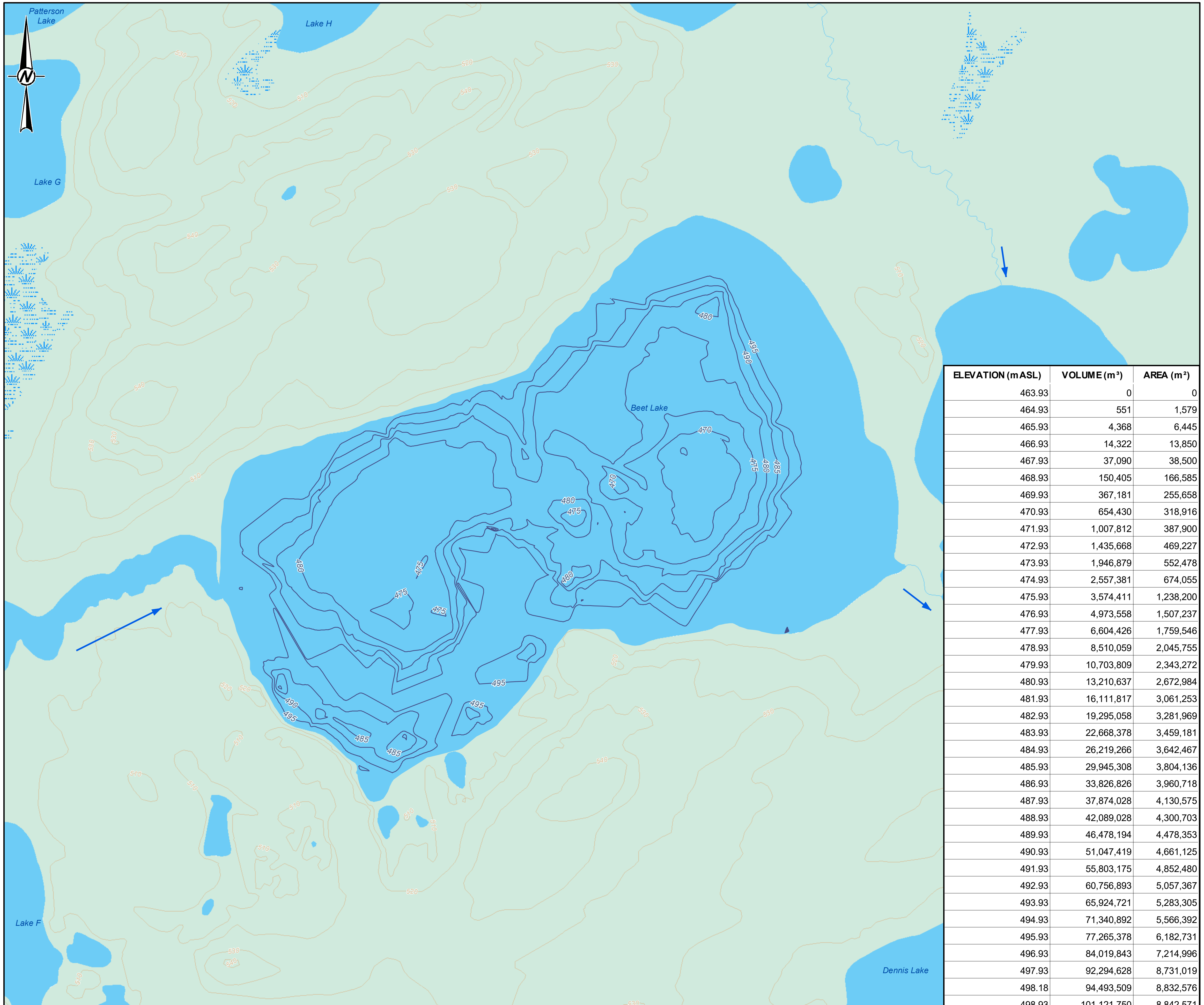
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B 25mm 0



ELEVATION (m ASL)	VOLUME (m³)	AREA (m²)
463.93	0	0
464.93	551	1,579
465.93	4,368	6,445
466.93	14,322	13,850
467.93	37,090	38,500
468.93	150,405	166,585
469.93	367,181	255,658
470.93	654,430	318,916
471.93	1,007,812	387,900
472.93	1,435,668	469,227
473.93	1,946,879	552,478
474.93	2,557,381	674,055
475.93	3,574,411	1,238,200
476.93	4,973,558	1,507,237
477.93	6,604,426	1,759,546
478.93	8,510,059	2,045,755
479.93	10,703,809	2,343,272
480.93	13,210,637	2,672,984
481.93	16,111,817	3,061,253
482.93	19,295,058	3,281,969
483.93	22,668,378	3,459,181
484.93	26,219,266	3,642,467
485.93	29,945,308	3,804,136
486.93	33,826,826	3,960,718
487.93	37,874,028	4,130,575
488.93	42,089,028	4,300,703
489.93	46,478,194	4,478,353
490.93	51,047,419	4,661,125
491.93	55,803,175	4,852,480
492.93	60,756,893	5,057,367
493.93	65,924,721	5,283,305
494.93	71,340,892	5,566,392
495.93	77,265,378	6,182,731
496.93	84,019,843	7,214,996
497.93	92,294,628	8,731,019
498.18	94,493,509	8,832,576
498.93	101,121,750	8,842,571

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- BATHYMETRY CONTOUR ELEVATION (5 m INTERVAL)
- WATERCOURSE
- FLOW DIRECTION
- WATERBODY
- WETLAND
- WOODED

0 0.5 1
1:25,000 KILOMETRES

NOTE(S)
1. WATER SURFACE ELEVATION DAILY AVERAGE COLLECTED BY GOLDER WAS 498.180 mASL ON OCTOBER 5-7, 2018.
2. LAKE VOLUME ON OCTOBER 5-7, 2018 = 94,493,509 m^3.

REFERENCE(S)
1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
3. BATHYMETRY WAS COLLECTED BY CANNORTH CONSULTING USING A HUMMINGBIRD 999CI HD SI DEPTH SOUND MOUNTED ON A ZODIAC PORTABLE BOAT.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

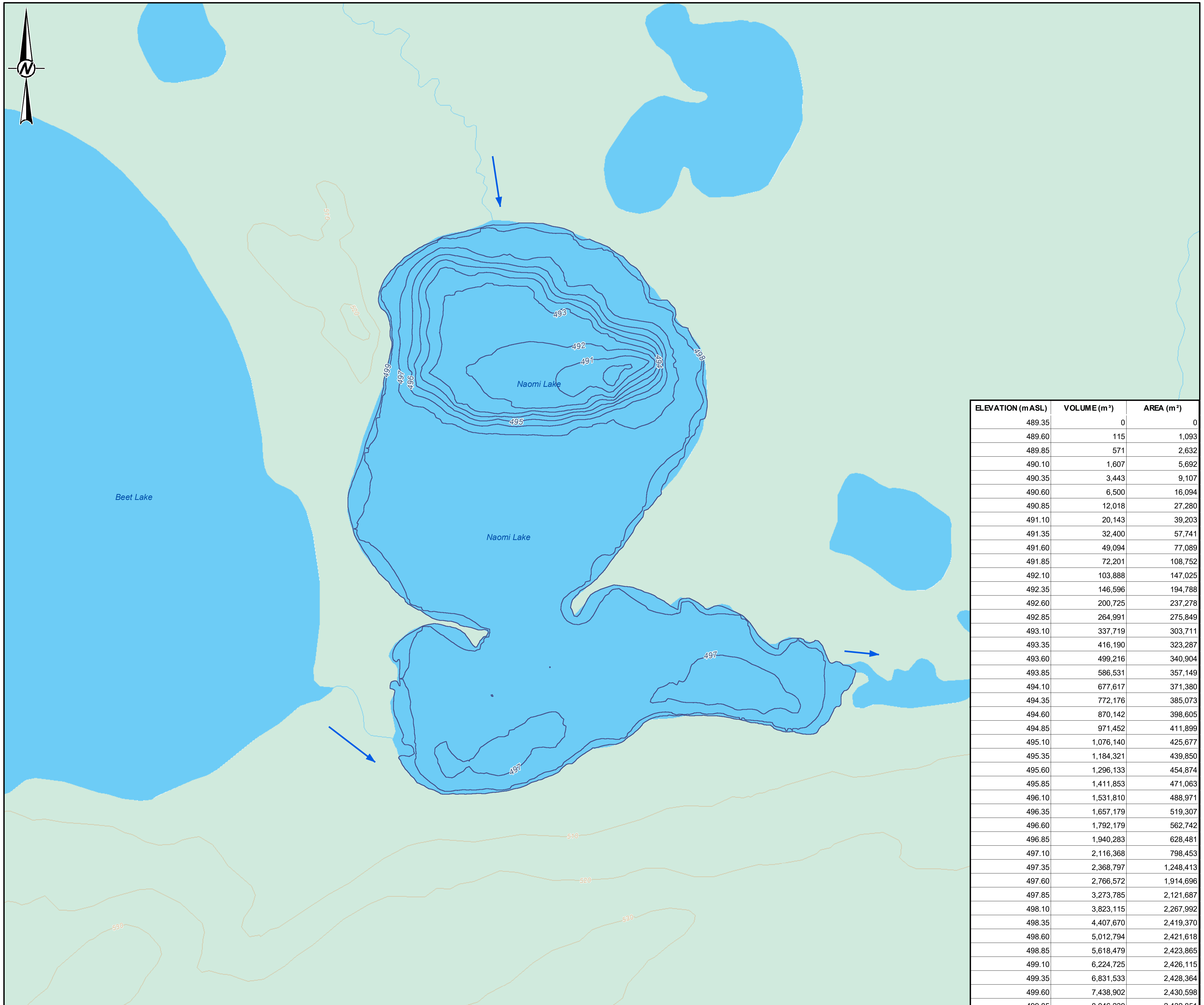
PROJECT
NexGen Energy Ltd.
ROOK I PROJECT

TITLE
BEET LAKE BATHYMETRY

CONSULTANT
wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-07		
CHECK	RWP	2023-02-07		
REVIEW	NPS	2023-02-07		

FIGURE 9A.1-6



ELEVATION (mASL)	VOLUME (m³)	AREA (m²)
489.35	0	0
489.60	115	1,093
489.85	571	2,632
490.10	1,607	5,692
490.35	3,443	9,107
490.60	6,500	16,094
490.85	12,018	27,280
491.10	20,143	39,203
491.35	32,400	57,741
491.60	49,094	77,089
491.85	72,201	108,752
492.10	103,888	147,025
492.35	146,596	194,788
492.60	200,725	237,278
492.85	264,991	275,849
493.10	337,719	303,711
493.35	416,190	323,287
493.60	499,216	340,904
493.85	586,531	357,149
494.10	677,617	371,380
494.35	772,176	385,073
494.60	870,142	398,605
494.85	971,452	411,899
495.10	1,076,140	425,677
495.35	1,184,321	439,850
495.60	1,296,133	454,874
495.85	1,411,853	471,063
496.10	1,531,810	488,971
496.35	1,657,179	519,307
496.60	1,792,179	562,742
496.85	1,940,283	628,481
497.10	2,116,368	798,453
497.35	2,368,797	1,248,413
497.60	2,766,572	1,914,696
497.85	3,273,785	2,121,687
498.10	3,823,115	2,267,992
498.35	4,407,670	2,419,370
498.60	5,012,794	2,421,618
498.85	5,618,479	2,423,865
499.10	6,224,725	2,426,115
499.35	6,831,533	2,428,364
499.60	7,438,902	2,430,598
499.85	8,046,239	2,432,851

LEGEND

- ELEVATION CONTOUR (10 m INTERVAL)
- WATERCOURSE
- WATERBODY
- WOODED
- BATHYMETRY CONTOUR ELEVATION (1 m INTERVAL)
- FLOW DIRECTION

0 0.5 1
1:15,000 KILOMETRES

NOTE(S)

1. WATER SURFACE ELEVATION ESTIMATED TO BE 498.35 mASL ON MARCH 23, 2019.
2. LAKE VOLUME ON MARCH 23, 2019 = 4,407,670 m^3.

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 2021.
2. BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
3. BATHYMETRY CONTOURS CREATED FROM GROUND PENETRATING RADAR DATA COLLECTED IN 2019.

PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

NAOMI LAKE BATHYMETRY

CONSULTANT

wsp

PROJECT	20144150		PHASE	3105 - 3
DESIGN	RP	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	AL/NO	2023-02-07		
CHECK	RWP	2023-02-07		
REVIEW	NPS	2023-02-07		

FIGURE 9A.1-7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

Appendix 9B Hydraulic and Sediment Transport Modelling Summary Report

Abbreviations and Units of Measure

Abbreviation	Definition
7QN	seven-day low flow with an average return period of "N" years
EA	Environmental Assessment
EIS	Environmental Impact Statement
HEC-RAS	Hydrologic Engineering Center River Analysis System
Project	Rook I Project
RFD	reasonably foreseeable development
RSA	regional study area
TSS	total suspended solids
WSE	water surface elevation

Unit	Definition
%	percent
°C	degrees Celsius
cm/s	centimetres per second
kg	kilogram
km	kilometre
km^2	square kilometre
L	litre
masl	metres above sea level
m	metre
m^3	cubic metre
m^3/s	cubic metres per second
m/m	metres per metre
m/s	metres per second
mg	milligram
mg/L	milligrams per litre
mm	millimetre
s	second

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9B1 INTRODUCTION

9B1.1 Context

The hydrological modelling completed for the Rook I Project (Project) was focused on the analysis of water quantity including flow rates and water surface elevations (WSEs) over time. Hydraulics is the science of how liquids, such as water, are conveyed through channels and pipes. Fluvial sediment transport is the science of the interaction between channelized flow of water and natural sediment. Fluvial sediment transport was identified as a measurement indicator for assessment of hydrology as an intermediate component.

As part of the hydrology effects assessment in Section 9 of the Environmental Impact Statement (EIS), an open channel hydraulics and sediment transport model was developed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) modelling platform to characterize existing conditions and predict Project effects on the fluvial sediment transport regime. The sediment transport module is built on top of the open channel hydraulic model. This appendix summarizes the hydraulic and sediment transport modelling completed in support of the Environmental Assessment (EA) for EIS Section 9, Hydrology.

9B1.2 Purpose and Approach to Modelling

Water is important to culture, as a conduit for transportation, and is the basis for healthy, functioning, and resilient aquatic and terrestrial ecosystems. The quantity of water and the way it moves through and is stored in the natural environment shapes the way it is used. For these reasons, hydrology was identified as an intermediate component for the EA, and fluvial sediment transport was identified as an associated measurement indicator.

As water is conveyed downstream by a watercourse, a portion of its energy is expended moving and rearranging material from the bed and banks. Fluvial sediment transport, the movement of particles by water, can be broadly divided into two classes: suspended load, where particles are suspended in the water column, and bed load, where moving particles sustain intermittent contact with the streambed (i.e., sediment rolls, slides, and bounces along the bottom of a waterway). In general, sediment transport is directly proportional to a stream's discharge rate, and sediment transport is highest during flood periods.

Quantitative modelling over a range of existing climatic conditions provides context for the natural variability of the fluvial system over a broader range of hydrologic conditions than those observed and forms the basis for the quantitative effects assessment. Quantitative modelling of expected conditions once the primary Project activities are applied to the existing hydrological system allows for the quantitative assessment of Project effects on hydrology. Quantitative assessment of Project effects on hydrology is fundamental to understanding the total effects of the Project on the biophysical, cultural, and socio-economic environments. The field data collection described herein was intended to support quantitative modelling associated with Project activities.

The fluvial sediment transport model builds on the regional hydrology model described in EIS Appendix 9A, Hydrological Modelling Summary Report. The regional hydrological model calculates flows at a watershed scale over time and a range of climatic and Project conditions. The fluvial sediment transport calculates hydraulics and sediment transport for a single watercourse based on flows calculated by the regional hydrological model.

The fluvial sediment transport model report is organized as follows:

- Section 9B2, communicates the study areas related to the hydrology effects assessment and supporting fluvial sediment transport modelling.

- Section 9B3 provides an overview of sediment transport processes for context.
- Section 9B4 describes the methods, including modelling steps, input data, and constraints.
- Section 9B5 presents results associated with the modelling study objectives.
- Section 9B6 describes sensitivity analyses completed to support the modelling study.
- Section 9B7 discusses study limitations and approaches to mitigating uncertainty.
- Section 9B8 summarizes key findings of this study.

9B1.3 Modelling Study Objectives

The key objectives of the hydraulic and sediment transport modelling work are as follows:

- Characterize the existing hydraulics and sediment transport mechanisms for a range of flow conditions representative of the current hydrological regime.
- Support quantitative assessment of Project effects.
- Support quantitative assessment of cumulative effects.
- Quantify change to the fluvial sediment transport regime that may occur because of climate change.

9B2 STUDY AREAS

The study area for the fluvial sediment transport model is situated within the study areas adopted for the hydrology effects assessment.

9B2.1 Hydrology Assessment Study Areas

The study areas for the hydrological assessment include the following:

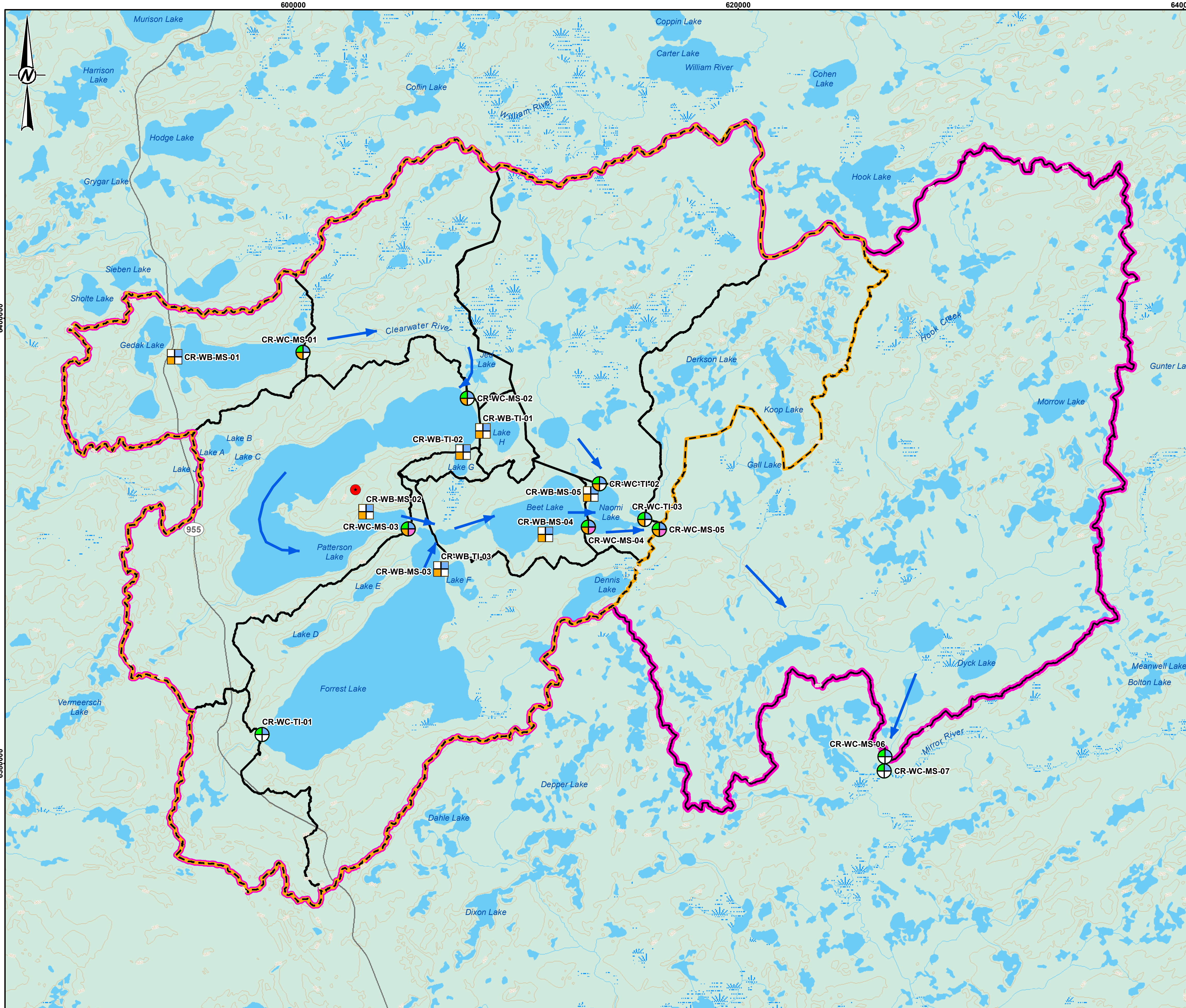
- **Local study area:** the Clearwater River watershed to Naomi Lake outlet; and
- **Regional study area (RSA):** the Clearwater River watershed above the Mirror River confluence.

The Project would be located adjacent to Patterson Lake near the headwaters of the Clearwater River system at Broach Lake. The Upper Clearwater River flows from Broach Lake through a series of lakes including Patterson, Forrest, Beet, and Naomi lakes from upstream to downstream. From Naomi Lake, the Clearwater River flows 20 km southeast before reaching the Mirror River confluence. The Clearwater River between Naomi Lake and Dell Lake transitions to intermittent braiding of multiple channels interrupted by occasional riffles and rapids. Between Dell Lake and the Mirror River confluence, the Clearwater River is broad and shallow, with a sand substrate and emergent macrophyte (i.e., aquatic plants that have roots on streambeds or lake beds) vegetation. Below the Mirror River confluence, the Clearwater River deepens with higher flow volumes from the Mirror River, and the channel form changes to meandering within a well-defined river valley. Farther downstream, the Clearwater River flows through Lloyd Lake, which is just upstream of the Clearwater River Provincial Park; the downstream end of the park is at the Saskatchewan-Alberta border.

Based on hydrological characteristics of the region and a high-level framing of the potential effects of the Project, the local study area is defined as the Clearwater River watershed to the Naomi Lake outlet (Figure 9B-1). The Clearwater River watershed above the Naomi Lake outlet drains an area of 685 km^2.

The RSA for hydrology includes waterbodies and watercourses within the Clearwater River watershed above the Mirror River confluence, which includes the local study area (Figure 9B-1). The Clearwater River watershed above the Mirror River confluence drains an area of 1,076 km^2. The spatial extent of the Clearwater River watershed above the Mirror River confluence is expected to provide an ecologically relevant RSA for the EA. The hydrometric stations in the RSA are shown in Figure 9B-1.

The fluvial sediment transport model targeted the Clearwater River between Patterson and Forrest lakes, as this reach has the potential to be most influenced by proposed Project activities.



LEGEND

- FLOW DIRECTION
- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- HYDROLOGY LOCAL STUDY AREA
- HYDROLOGY REGIONAL STUDY AREA
- WATERSHED
- METEOROLOGICAL STATION

WATERBODY HYDROMETRIC STATIONS

- DISCHARGE
- SURVEYED BENCHMARK (GEODETIC DATUM)
- WATER SURFACE ELEVATION

WATERCOURSE HYDROMETRIC STATIONS

- DISCHARGE
- SURVEYED BENCHMARK (GEODETIC DATUM)
- TOTAL SUSPENDED SOLIDS AND BEDLOAD
- WATER SURFACE ELEVATION

0 5 10

1:175,000 KILOMETRES

REFERENCE(S)

1. PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021. UPDATED JUNE 8, 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

BASELINE HYDROMETRIC MONITORING WITHIN THE REGIONAL STUDY AREA

CONSULTANT

wsp

PROJECT		20144150	PHASE	3105 - 3
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-10	**FIGURE 9B-1**	
CHECK	RWP	2023-02-10		
REVIEW	NPS	2023-02-10		

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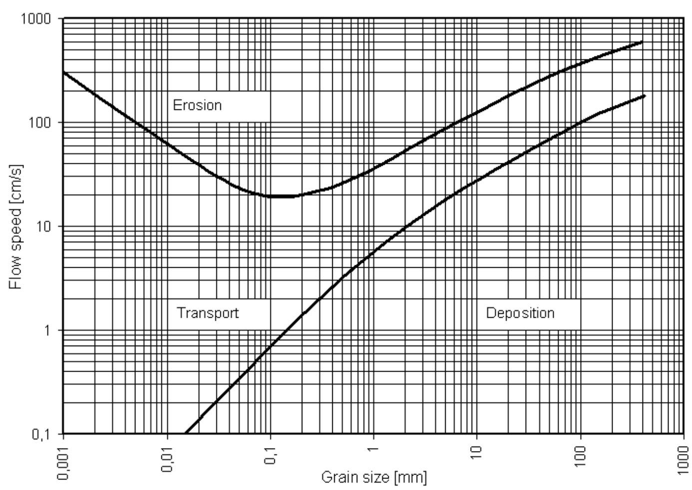
9B3 OVERVIEW OF SEDIMENT TRANSPORT PROCESSES

A watercourse can be broken into reaches, which are sections of the watercourse along which similar conditions exist. As water is conveyed downstream by a watercourse, a portion of its energy is expended moving and rearranging material from the bed and banks. Over time, there is ongoing inflow and outflow of sediment in each reach of a watercourse, and this sediment transport can be broadly broken down into three stages: the initiation of motion, downstream transport, and deposition. To initiate sediment motion, a critical energy level must be reached. Once in motion, sediment is transported downstream and deposited when the stream no longer has the energy to transport it. Deposition generally occurs when the energy available in the stream for transporting the sediment decreases or the sediment load drastically increases. In general, the energy required to initiate motion and transport sediment is greater for larger, heavier particles such as gravel and cobbles than for smaller, lighter particles such as clays or silts.

Modelling sediment transport relies on simplified numerical representations of these processes; the numerical representations also aid in understanding the relationships among variables. Most standard relationships are physically or empirically based and typically assume independent behaviour of non-cohesive particles. Hjulstrom (1935) presented curves to summarize sediment transport mechanisms based on flow speed (i.e., velocity) and particle size. The curves are valuable tools to understand the general conditions under which different sediment will erode, be transported, and be deposited. The Hjulstrom curves presented in Figure 9B-2 show the prevailing mechanism for different grain sizes based on the speed of flow (i.e., velocity).

Figure 9B-2: Hjulstrom Curves for Relationships between Velocity and Particle Size



Source: Hjulstrom 1935.

Fluvial sediment transport varies over time and space. Several sediment transport mechanisms may be active at any given time at a single stream cross-section; for example, sediment may be eroding where erosive potential is highest at the deepest point of the channel or on the outside bank of a river bend, while depositing on the inside of a meander bend where flow velocities are lower. Also, sediment eroded from the bed that is transported downstream may in turn be replaced by material transported from upstream.

During flood events, when high velocities coincide with elevated water depths, scouring in a downstream direction is expected, but erosion loss may be replaced by sediment deposition originating from upstream as the flood waters recede. Thus, the channel bed may experience scour during a flood event but maintain a stable equilibrium that is not aggrading (i.e., increasing in elevation) or degrading (i.e., decreasing in elevation) over a longer period.

9B4 METHODS

This subsection discusses the overall approach to model development, testing, and application for characterizing existing conditions in the Base Case as well as the information that forms the foundation for the assessment of Project effects compared to the Base Case. The methods presented communicate the model spatial and temporal extents, model metadata and input data, as well as approaches for model parameterization, calibration, and the scenarios that ultimately guide its application to fulfill the study objectives (Section 9B1.3).

9B4.1 Spatial Domain

The spatial domain of the model was the approximately 1 km reach of the Clearwater River between the outlet of Patterson Lake to where it empties into Forrest Lake; this section consists of the Upper Reach and Lower Reach of the Clearwater River and is identified as the study reach for the model (Table 9B-1). A notable feature within the spatial domain is the Access Road Bridge which crosses the Upper Reach approximately 80 m downstream of Patterson Lake. The Upper Reach flows from Patterson Lake about 580 m downstream before it bifurcates into the two channels that constitute the Lower Reach. The North Channel is 170 m long and relatively narrow and deep. The South Channel is 300 m long and relatively wide and shallow.

In this study, hydrometric gauge station refers to the Clearwater River below Patterson Lake (CR-WC-MS-03) monitoring station shown in Figure 9B-3 and described in Annex IV.3, Geomorphology Characterization Report. Thirty cross-sections that cover the entire study reach were populated to represent the geometry of the channel in the model. The cross-sections are used in the model to represent two-dimensional geometry at each cross-section location. River stations were used to describe the location of each cross-section, decreasing from upstream to downstream.

The software, HEC-RAS, requires that the river station (i.e., longitudinal distance from the end point) is measured from the downstream boundary. Accordingly, the river station distance of 0 m corresponds to the downstream boundary and the furthest upstream cross-section has the highest magnitude river station.

Table 9B-1: Key Boundary Locations Defining Spatial Domain of Model

Reach	Boundary Location	Coordinates[a]	
		Easting (m)	Northing (m)
Upper Reach	Upstream end of Upper Reach	605081	6390570
Bifurcation point	Junction point that marks the downstream end of the Upper Reach and upstream end of the Lower Reach	605422	6390409
Lower Reach	Downstream end of North Channel	605538	6390414
	Downstream end of South Channel	605659	6390301

a) All coordinates are in Universal Transverse Mercator Zone 12, North American Datum 1983.

9B4.2 Temporal Domain

The temporal domain adopted for modelling is a steady-state (i.e., instantaneous) or a quasi-unsteady-state time series over one year, depending on the question being answered by the model run. The steady-state mode was used to characterize conditions at a single flow condition, such as a daily or instantaneous peak flood flow derived using the regional hydrology model (Appendix 9A). The steady-state model runs were used to evaluate projected water levels in the channel under different (i.e., high and low) flow conditions. The quasi-unsteady-state model runs were used to simulate fluvial sediment transport. The quasi-unsteady-state had a temporal domain of one year on a daily time step, based on hydrographs (i.e., a graph of discharge over time) (Section 9B4.6.5) for floods with 2-, 5-, 10-, 20-, 50-, and 100-year return periods. These discrete simulations were selected to represent each potential effect from the Project over the entire life of the Project, consistent with the timelines presented in EIS Section 9.

LEGEND

- CR-WC-MS-03 STATION
- BOUNDARY POINT
- FLOW DIRECTION

0 100 200

1:3,000 METRES

REFERENCE(S)

1. IMAGERY OBTAINED FROM THE CLIENT, IMAGERY DATE: 2019.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

SPATIAL EXTENT OF THE HYDRAULIC MODEL

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-10	**FIGURE 9B-3**	
CHECK	RWP	2023-02-10		
REVIEW	NPS	2023-02-10		

9B4.3 Model Scenarios

Assessment cases for the EA included a Base Case, Application Case, and Reasonably Foreseeable Development (RFD) Case. The assessment cases and effects assessment are discussed in Section 9 of the EIS. Watercourse flow rates simulated using the Regional Hydrological Model (Appendix 9A) are used as input to the hydraulic model to characterize sediment transport during the assessment cases and scenarios listed below. Use of simulated watercourse flow rates is addressed in greater detail in Section 9B4.6.

The hydrological model is calibrated based on historical monitoring data and then used for effects assessment to inform conditions related to each assessment case as well as to evaluate the incremental change resulting from changes to hydrology under climate change. It has been configured as follows for each case:

- **Base Case (Existing Conditions):** The conditions that exist in the receiving environment prior to initiating the Project. This model consists of ambient hydrological processes with no Project interactions.
- **Application Case:** The predictions of the combined effects of the previous and existing projects/activities and natural factors in the Base Case plus the effects from the Project.
- **Reasonably Foreseeable Development Case** for hydrology represents predictions of the combined effects of the Base Case, Application Case, and RFDs that have not yet been approved, as well as considerations for climate change. The assessment of the RFD Case was analyzed and classified based on the following scenarios:
  - **Reasonably Foreseeable Development Case:** includes the Application Case plus the Fission Patterson Lake South Property (Section 9.6.2). The RFD Case includes the Base Case, Application Case, and Fission Patterson Lake South Property effects under historical climate conditions.
  - **Climate change scenario:** includes the effect of climate change as discussed in Section 9.4 without the inclusion of Project or Fission Patterson Lake South Property effects. The climate change scenario used in the RFD Case (including climate change) represents projected climate change for the 2050s.
  - **Reasonably Foreseeable Development Case (including climate change):** includes the combined effects of the RFD Case and climate change scenarios (Section 9.6.3).

These scenarios are expected to provide the information required to satisfy the anticipated expectations of Indigenous and local communities, provincial regulators, and the federal Canadian Nuclear Safety Commission.

9B4.4 Software

The Hydrologic Engineering Center of the US Army Corps of Engineers developed a river analysis system platform called HEC-RAS for simulating one-dimensional steady flow, one- and two-dimensional unsteady flow, sediment transport and mobile bed computations, and water quality (USACE 2018). The program has been commonly used for hydraulic analysis and flood modelling in North America. HEC-RAS version 5.0.7, an industry standard for fluvial sediment transport simulation, was used for developing one-dimensional steady and quasi-unsteady flow models for hydraulic and sediment transport analysis for the study reach. ArcGIS mapping software (ESRI 2018) was also used to create required channel’s geometry files for the HEC-RAS model.

9B4.5 Model Structure and Configuration

A one-dimensional model was developed in HEC-RAS to analyze open channel hydraulics and sediment transport in the spatial domain. The key components of models developed in HEC-RAS are the geometry data, which represent the physical geometry and characteristics of the spatial domain, and the flow data, which can be steady state or dynamic (i.e., unsteady or quasi-unsteady state). Water surface profiles and hydraulic parameters are simulated in HEC-RAS by solving the energy equation between the geometric cross-sections. The model was calibrated based on field measurements of discharge and WSE. Steady-state hydraulic simulations calculated the channel's wetted depth, wetted width, and flow velocity for a given discharge. The sediment transport processes were simulated under continuous flow conditions under a quasi-unsteady state.

9B4.6 Model Input Data

The channel geometry, flow profiles, boundary conditions, water temperature, bed gradation (i.e., particle size distribution), and sediment influx at the upstream end of the channel were the required model input parameters. The following subsections describe the studies, analysis, and references used to develop model inputs.

9B4.6.1 Site Reconnaissance and Survey

The site reconnaissance and stream channel survey were completed at the study reach on 2 October 2018 and 3 October 2018 using Real Time Kinematic Global Positioning System survey equipment. Survey cross-sections are shown in Figure 9B-4. The field program included topographic information collection, water-level surveys, flow measurements, water sampling for the analysis of total suspended solids (TSS), channel geomorphology characterization, and site photograph collection. Representative photos of the study reach are provided in Figure 9B-5 and Figure 9B-6).

The key observations made during the site reconnaissance include the following:

- Both the left and the right downstream floodplains consist of medium to dense brush and trees.
- Signs of bank erosion were present along the channel on the outside of a bend or meander.
- In the Lower Reach, the North Channel is narrower and deeper than the South Channel. Observed variability in the channel's hydraulic properties is presented in Table 9B-2.

Table 9B-2: Observed Channel Characteristics at Clearwater River below Patterson Lake

Reach	Length (m)	Width (m)	Bed Slope (m/m)	Depth (m)	Wetted Perimeter (m)
Upper Reach	580	8-15	0.0003-0.001	0.5-1.50	9-18
Lower Reach North Channel	170	3-8	0.0003-0.001	0.8-1.30	5-11
Lower Reach South Channel	300	5-10	0.0004-0.002	0.5-1.10	6-12

LEGEND

- CR-WC-MS-03 STATION
- BOUNDARY POINT
- STREAM SURVEY POINT
- FLOW DIRECTION

0 100 200

1:3,000 METRES

REFERENCE(S)

1. IMAGERY OBTAINED FROM THE CLIENT, IMAGERY DATE: 2019.
PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT

NexGen Energy Ltd.

ROOK I PROJECT

TITLE

LOCATION OF GEODETIC CROSS SECTIONS

CONSULTANT

wsp

PROJECT		20144150	PHASE	3314 - 6
DESIGN	JH	2020-03-13	SCALE AS SHOWN	REV. 0
GIS	NO	2023-02-10	FIGURE 9B-4	
CHECK	RWP	2023-02-10		
REVIEW	NPS	2023-02-10		

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Figure 9B-5: View of Clearwater River below Patterson Lake (Upper Reach) on 3 October 2018 Facing Downstream

Figure 9B-6: View of Clearwater River below Patterson Lake (Lower Reach – North Channel) on 3 October 2018 Facing Downstream

9B4.6.2 Discharge and Sediment Transport Measurements

The discharge, TSS, and sediment bed load were measured in the Upper Reach of the Clearwater River below Patterson Lake at a cross-section near the Access Road Bridge as part of the Project hydrometric monitoring program. The detailed procedure adopted for these measurements is provided in Annex IV.2, Hydrometric Monitoring Characterization Report. The field sediment transport measurements made during 2018 and 2019 are summarized in Table 9B-3. The measured TSS near the upstream end of the channel was very low (Table 9B-3), suggesting that sediment influx to the channel at the upstream boundary was negligible, as would be expected for a lake-dominated system. The bed substrate is composed of medium- to fine-grained sand, and this reach has been observed to actively transport sediment as noted in Annex IV.2, Section 5.4, Sediment, and Annex IV.3, Section 5.3.2, Channel Erosion Susceptibility.

Table 9B-3: Suspended and Bed Load Sampling Results in 2018 and 2019

Hydrometric Station	Date	TSS (mg/L)	Bed Load (mg/L)	Bed Load Sampling Duration (s)	Daily Load (Tonnes)	Discharge (m^3/s)	Mean Velocity (m/s)
Clearwater River below Patterson Lake (CR-WC-MS-03)	04 August 2018	<1	Not detected	3,600	Not detected	1.156	0.250
	01 October 2018	<1	Not detected	3,600	Not detected	0.983	0.253
	18 May 2019	<1	0.0021	60,480	0.0083	1.461	0.318
	04 June 2019	<1	0.0028	49,800	0.0102	1.332	0.282
	30 June 2019	<1	0.0010	86,400	0.0031	1.167	0.234
	03 May 2020	n/d	Not detected	88,500	Not detected	1.56	0.241
	08 June 2020	<1	0.0000	138,420	0.0002	2.22	0.311
	14 July 2020	1	0.0002	69,120	0.0049	2.35	0.307
	25 August 2020	<1	0.0003	69,900	0.0090	2.32	0.294
	28 September 2020	<1	0.0001	75,000	0.0041	2.16	0.232

Source: Annex IV.2.
Note: Not detected indicates that there was insufficient mineral sediment weight collected to submit to the laboratory for bed load analysis.
n/d = no data; TSS = total suspended solids; < = less than.

9B4.6.3 Geometry Data

The geometry of the channel was defined by topographic cross-sections including elevations for the stream bed, water level, channel banks, vegetation, ground, roads, and structures (e.g., bridges and culverts). The model geometry was populated with 17 cross-sections in the Upper Reach, 5 in the Lower Reach-North Channel, and 8 in the Lower Reach-South Channel. The floodplain roughness parameter was estimated from reference values (Chow 1959) based on observed vegetation characteristics, and lower boundary conditions (i.e., normal depths) for the channels were calculated based on survey in October 2018.

9B4.6.4 Steady-State Flow Data

Steady state (i.e., a constant snapshot) flow data representing extreme flow conditions, including floods and low flow conditions, were taken from the regional hydrological model (Appendix 9A) and input to the HEC-RAS model. The regional hydrology model was run on a daily time step over a 43-year period to generate flows under varying natural climatic conditions. First, the model was run for the existing Base Case conditions. The regional hydrology model was then modified to reflect potential changes in the regional hydrology associated with each assessment case and for additional scenarios. Outputs from the regional hydrology model were analyzed using frequency analysis techniques to estimate floods and low flows corresponding to different return periods.

Flood Flows

Estimated high and low flow conditions for the Clearwater River below Patterson Lake, based on flood frequency analysis of hydrological model simulations, are summarized in Table 9B-4. The magnitude of flood flows in the Clearwater River below Patterson Lake does not vary greatly for varying return periods (Table 9B-4). This relatively consistent magnitude is largely the result of attenuation of flood volumes by Patterson Lake as well as subsurface storage throughout the Patterson Lake watershed.

Table 9B-4: Simulated Annual Peak Flows for Clearwater River below Patterson Lake

Average Return Period (Years)	Exceedance Probability (%)	Annual Mean Daily Peak Flow (m^3/s)				
		Base Case	Application Case	Reasonably Foreseeable Developments Case	Cumulative Development Scenario	Climate Change Scenario
2	0.5	1.89	1.92	2.05	1.95	2.00
5	0.2	2.38	2.42	2.60	2.43	2.56
10	0.1	2.63	2.67	2.90	2.67	2.87
20	0.05	2.84	2.87	3.14	2.87	3.12
50	0.02	3.05	3.07	3.40	3.07	3.39
100	0.01	3.19	3.19	3.56	3.19	3.56

Source: Appendix 9A.

Extreme Low Flows

Estimated extreme low flow conditions for the Clearwater River below Patterson Lake, based on flood frequency analysis of hydrological model simulations, are summarized in Table 9B-5. Persistent extreme low flow conditions are characterized in this case by the minimum annual low flows, averaged over consecutive-day periods, with a certain average return period. Watercourse flow rates are often referred to as discharge and represented by the symbol Q. The seven-day low flow with an average return period of "N" years, or 7QN, is a common low flow statistic used in hydrology. One of the most used low flow statistics is the 7Q10, or seven-day low flow with an average return period of ten years, which is commonly used as an engineering design low flow value and is often referenced for water quality in assessment of the aquatic environment. The return period and annual exceedance probability are the mathematical inverses of one another. In any given year, there is a 10% probability that the lowest consecutive seven-day average flow will be less than the 7Q10 flow (Dingman 2002). In other words, the 7Q10 is the lowest streamflow for seven consecutive days that would be expected to occur once every ten years. Values for 7QN, including the 7Q10, for the Base Case in the Clearwater River below Patterson Lake are presented in Table 9B-5.

Table 9B-5: Base Case Annual Minimum 7-Day Mean Discharge for Clearwater River below Patterson Lake

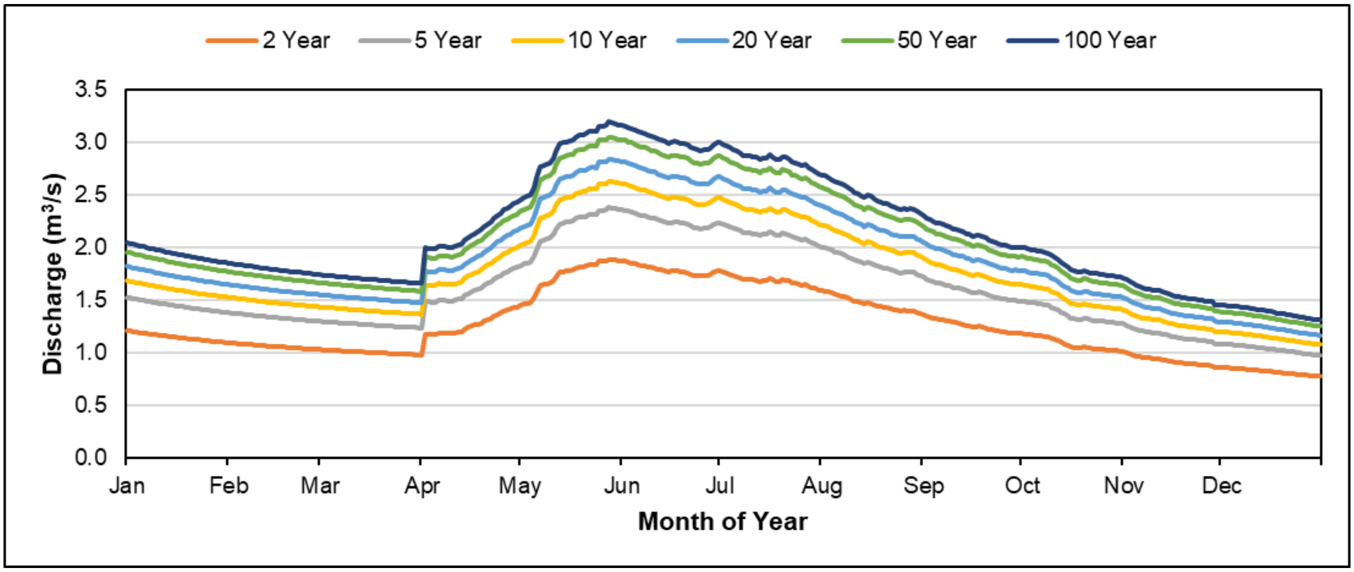
Average Return Period (Years)	Exceedance Probability (%)	Annual 7-Day Low Flow (m^3/s)
		Base Case
2	0.5	0.851
5	0.2	0.635
10	0.1	0.539
20	0.05	0.470
50	0.02	0.407
100	0.01	0.374

9B4.6.5 Quasi-unsteady-state Flow Data

Time series discharge, referred to in HEC-RAS as quasi-unsteady-state flow data, is a required input for sediment transport modelling using HEC-RAS. An annual daily hydrograph derived from hydrological model simulations for 1998, which was a flood year, was adjusted using a multiplier to match the hydrograph peak to the daily flood flow peak for return periods of 2, 5, 10, 20, 50, and 100 years (Figure 9B-7). The daily hydrographs for 2-, 5-, 10-, 20-, 50- and 100-year floods flows were used to run quasi-unsteady-state simulations in HEC-RAS for estimating sediment transport dynamics.

The flood flow hydrographs shown in Figure 9B-7 were adjusted for the peak flows of different assessment cases and used for modelling.

Figure 9B-7: Simulated Flood Flow Hydrographs based on 1998 for Clearwater River below Patterson Lake



9B4.6.6 Water Temperature

Daily water temperature is needed to accompany the quasi-unsteady flow data in the fluvial sediment transport model. Water temperature was measured using a Solinst Levelogger installed at the hydrometric gauge station CR-WC-MS-03 between August 2018 and October 2019 at the hydrometric station Clearwater River below Patterson Lake (CR-WC-MS03) and the daily water temperature data, shown in Figure 9B-8, were used to represent daily temperatures in each simulated flood year. Given that the reach is an outflow from a relatively large lake, annual variability in water temperature is not expected to be large enough to affect fluvial sediment transport predictions.

Figure 9B-8: Water Temperature Adopted for Clearwater River below Patterson Lake as Model Input

9B4.6.7 Bed Substrate Particle-Size Distribution

A bed substrate sample from the straight run reach at river station 630 m, near the Access Road Bridge, was collected and sent for laboratory grain size analysis. Based on the laboratory analysis for grain size, the bed is composed of medium- to fine-grained sand. The particle-size distribution is summarized in Table 9B-6 with detailed data provided in Attachment 9B-1, Particle-Size Distribution at Clearwater River below Patterson Lake. At this location in the straight run reach, the bed was characterized by a typical ripple bed form pattern, which was supported and verified by the bed form charts presented in Maidment (1994) associated with medium- to fine- grained sand. The uniformity of the bed form pattern observed in the straight run reach at river station 630 m, verifies that the bed substrate is uniform. Similar bed form patterns were observed in the straight run reaches throughout the spatial domain. The specific gravity of medium- to fine-grained sand is 2.65 (i.e., 1 L of sand would have a mass of 2.65 kg). The specific gravity is used to support interpretation of sediment transport results, which are presented in units of mass, converted into volumes for context and communication.

Table 9B-6: Bed Substrate Characteristics

Watercourse	Hydrometric Station	Sample Number	D_{15} (mm)	D_{50} (mm)	D_{85} (mm)
Clearwater River below Patterson Lake	CR-WC-MS-03	SL6312	0.177	0.282	0.393

D_{15} = equivalent grain diameter at which 10% of the sample is finer by weight; D_{50} = equivalent grain diameter at which 50% of the sample is finer by weight; D_{85} = equivalent grain diameter at which 85% of the sample is finer by weight.

9B4.6.8 Sediment Transport Module Parametrization

Parameterization of the sediment transport module involves an appropriate selection of transport function, sorting method, and bank locations prone to erosion for computing efficiency. The sediment transport function is used for simulating non-linear transport processes, and different functions can produce very different results based on the conditions of their development. Eight available methods in HEC-RAS were reviewed against the physical setting and typical particle size for the study reach; the Copeland method (Copeland and Thomas 1989) was subsequently adopted.

The sorting method determines sediment availability for transport from the stream's bed. The Copeland Ex7 method (Copeland 1993) was selected for this reach. This method forms an armour layer limiting the erosion for deeper layers more slowly compared to the other methods and is therefore suitable for sand beds like the study reach. Bank erosion was limited to the outside bend of meanders to improve modelling efficiency and to be consistent with field observations (Annex IV.3).

9B4.6.9 Sediment Influx at the Upstream Boundary

A sediment influx at the upstream boundary is a required input to a sediment transport model developed in HEC-RAS. For the sediment transport model for the Clearwater River below Patterson Lake, the influx of sediments at the upstream boundary was defined by a sediment rating curve that relates sediment concentration with discharge. A measured sediment rating curve at the upstream boundary is a typical requirement for modelling sediment transport processes in HEC-RAS. The field measurements of daily sediment load (i.e., daily mass flux of sediment) near the upstream end of the channel during hydrometric monitoring program for the Project, presented in Annex IV.2, were used to develop the sediment load rating curve presented in Table 9B-7.

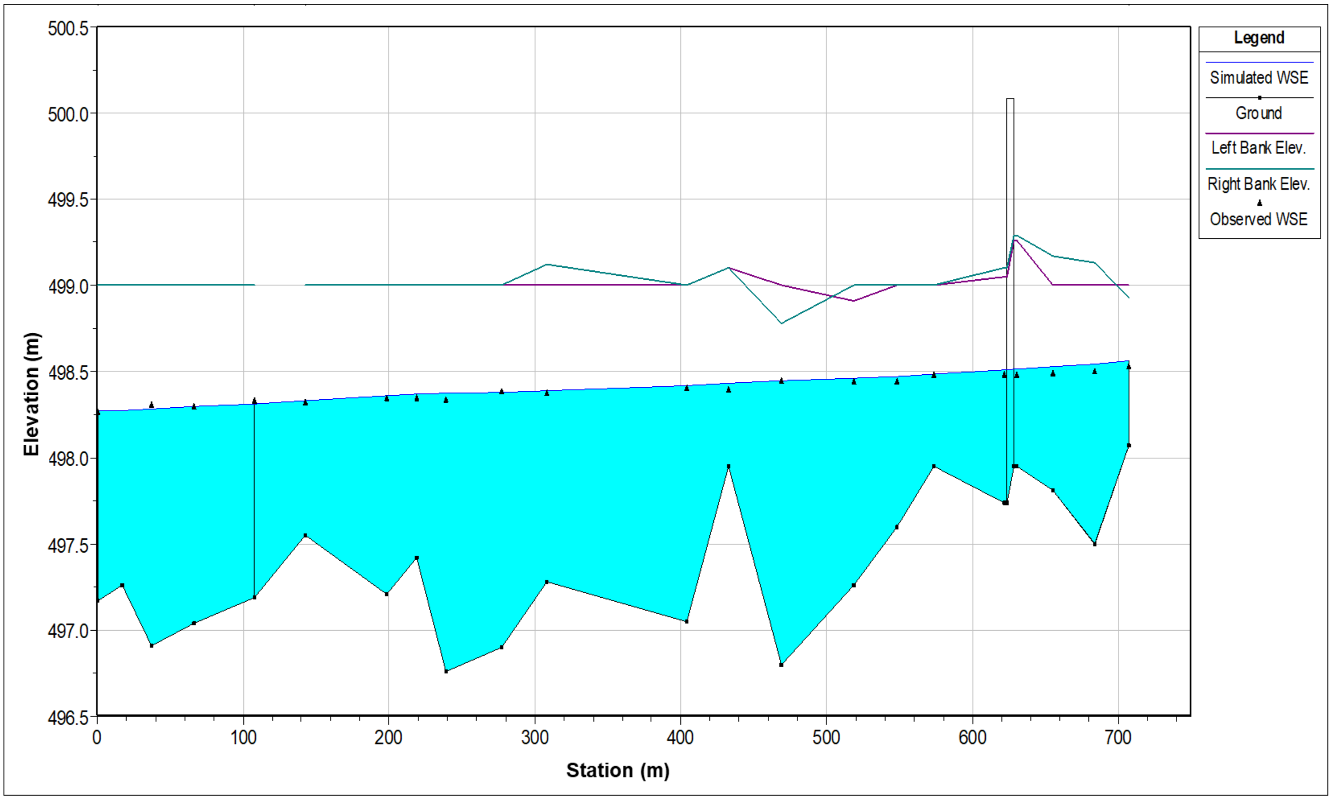
Table 9B-7: Sediment Load Rating Curve for Influx at Upstream End of Spatial Domain

Discharge (m^3/s)	Sediment Load (Tonnes per Day)
0.00	0.00
1.5	0.005
3.0	0.01
6.0	0.02

9B4.6.10 Model Calibration

The one-dimensional hydraulic model was calibrated against the water levels measured on 2 October 2018 and 3 October 2018 at each survey cross-section by changing the roughness coefficient of the channel. Discharge in the channel was measured as 0.98 m^3/s at station CR-WC-MS-03 during the field survey on 29 September 2018 at 17:50. The WSEs simulated by the calibrated model matched well with observations. The results presented in Figure 9B-9 are for the Upper Reach along with the Lower Reach North Channel. The flow distribution based on model simulations from the main channel at its bifurcation was found to be 0.62 m^3/s at the North Channel and 0.36 m^3/s at the South Channel. This calibrated model was then used to assess projected changes in water levels under different flow conditions.

Figure 9B-9: Observed and Model Simulated Water Surface Elevation at Clearwater River below Patterson Lake on 2 October 2018 and 3 October 2018



WSE = water surface elevation.

9B5 MODEL RESULTS

This subsection discusses the modelling study results as they relate to the objectives noted in Section 9B1.3. The presented results summarize the simulation of the hydraulic and sediment transport conditions under the Base Case, Application Case, and RFD Case as well as under climate change scenarios.

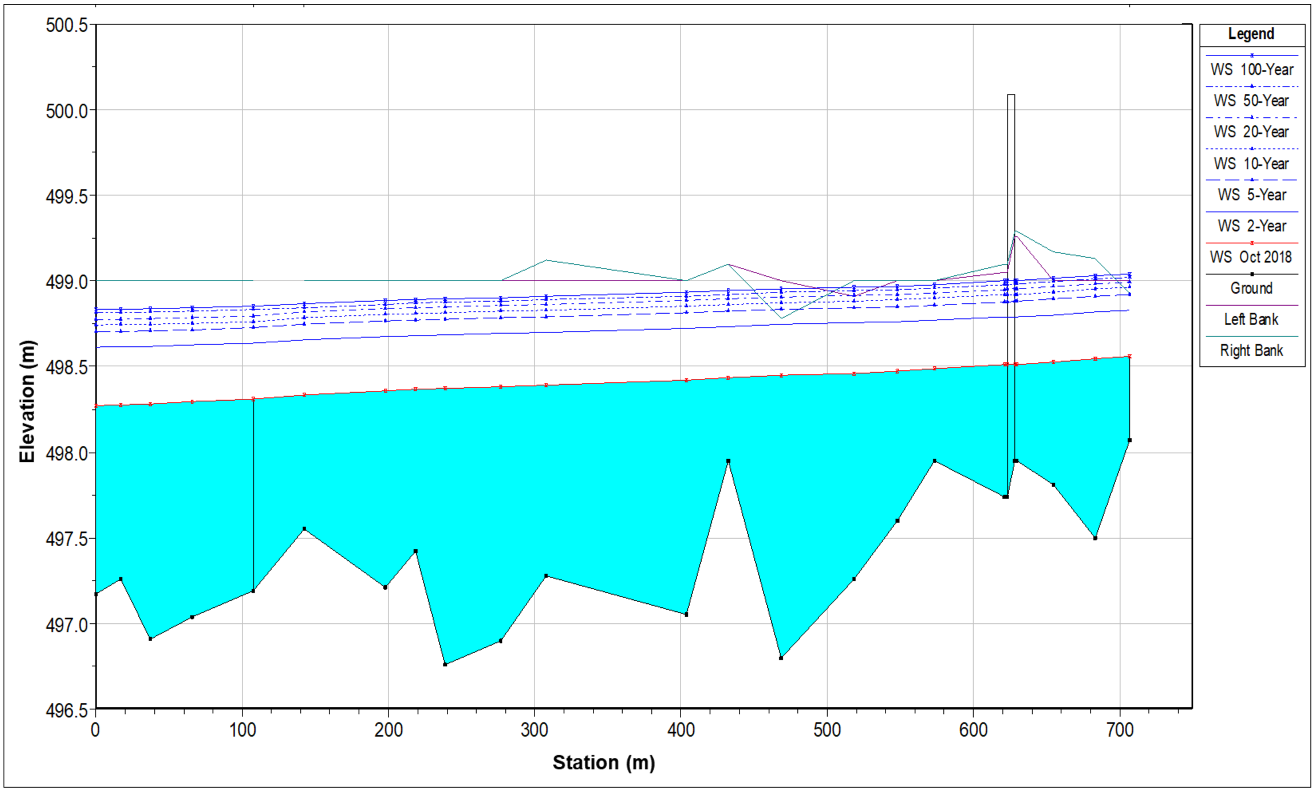
9B5.1 Base Case

Existing hydraulic and fluvial sediment transport conditions are summarized under the Base Case.

Watercourse Hydraulics

The steady-state results for 2-, 5-, 10-, 20-, 50-, and 100-year return period floods are presented in Figure 9B-10. The simulated WSE remained within the channel for a 2-year flood but overtops the channel banks near the upstream end of the channel for all the other flood profiles. The low chord elevation of a bridge is the lowest point of the bridge superstructure that the Clearwater River WSE would reach in a flood condition. The Access Road Bridge low chord elevation, 500.068 m, was well above the water level for floods of any return period evaluated. The mean water depth, flow velocity, and top width simulated by the model for the key flood profiles are summarized in Table 9B-8.

Figure 9B-10: Base Case Simulation Water Surface Elevation Profiles Results for Flood Flows



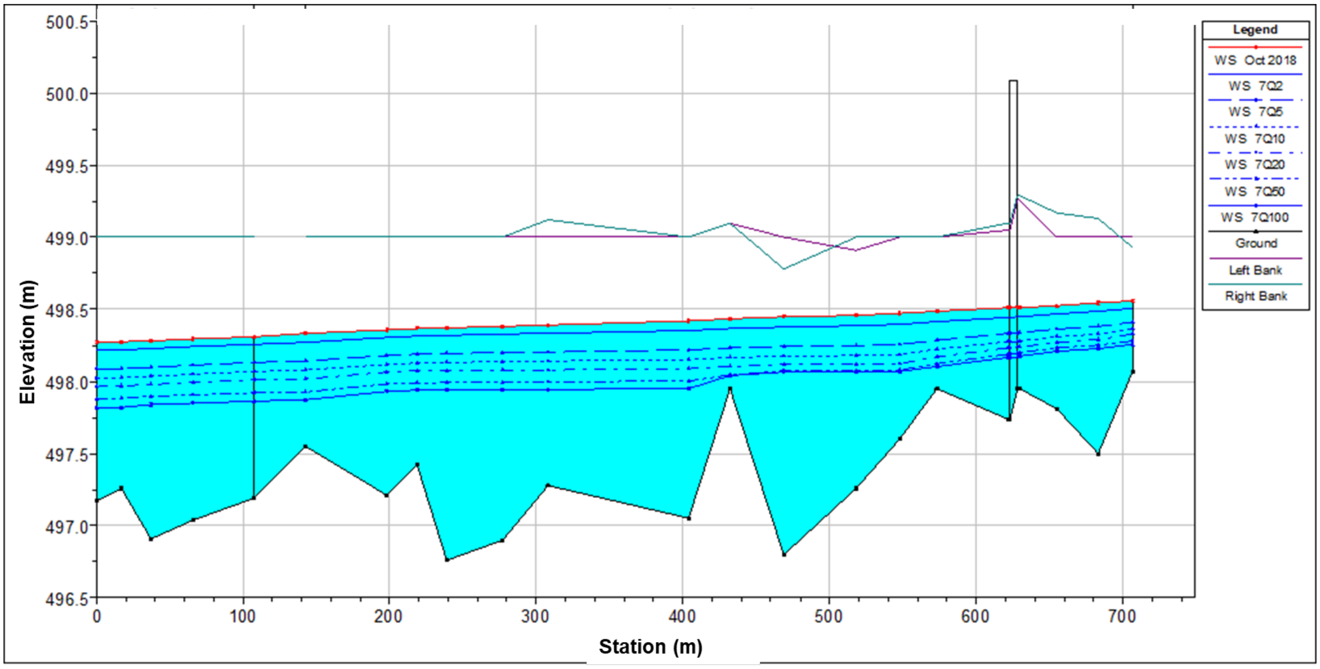
Note: Station distance 0 m corresponds to downstream boundary of the model domain.
WS = water surface.

Table 9B-8: Base Case Simulated Flood Flow Characteristics at Clearwater River below Patterson Lake

Return Period	Annual Mean Daily Peak Flow (m^3/s)	Mean Depth (m)	Flow Velocity (m/s)	Top Width (m)
2	1.89	1.26	0.138	23.3
5	2.38	1.35	0.144	26.0
10	2.63	1.39	0.148	27.2
20	2.84	1.42	0.151	28.1
50	3.05	1.45	0.155	33.6
100	3.19	1.47	0.156	38.1

The simulated WSEs for a seven-day average low flow for return periods of 2, 5, 10, 20, 50, and 100 years (i.e., 7Q2, 7Q5, 7Q10, 7Q20, 7Q50, and 7Q100) are shown in Figure 9B-11. The mean water depth in the channel, top width, and flow velocity for low flood profiles are summarized in Table 9B-9.

Figure 9B-11: Base Case Low Flow Water Surface Elevation Profiles



Note: Station distance 0 m corresponds to downstream boundary of the model domain.
WS = water surface.

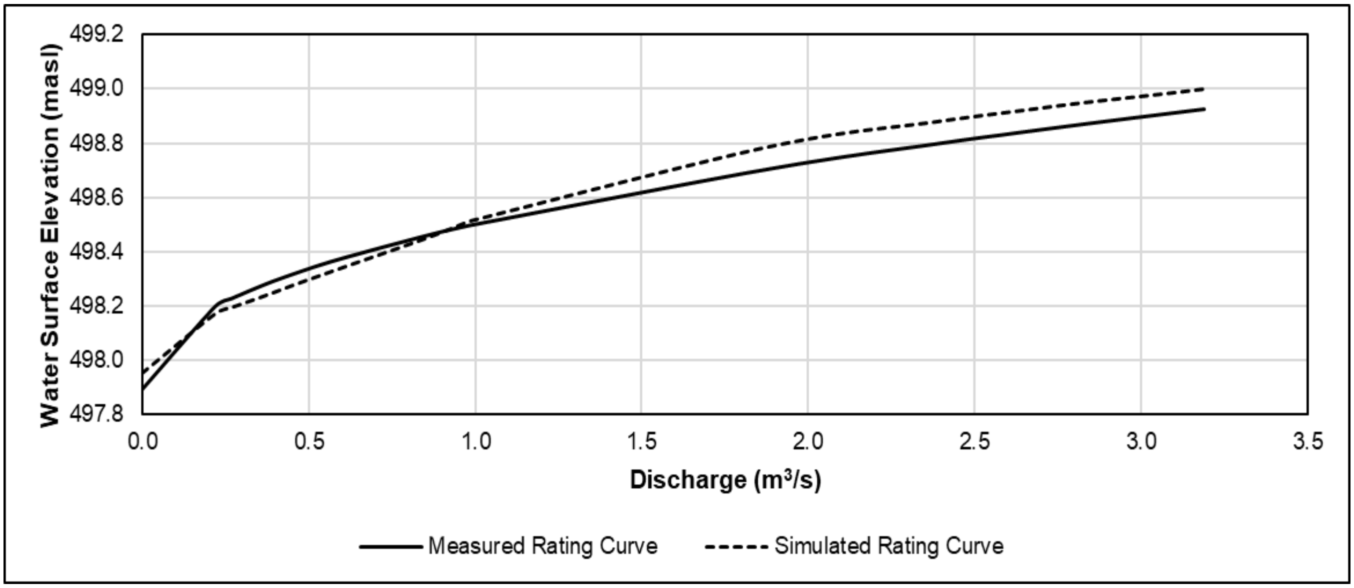
Table 9B-9: Base Case Hydraulics Simulated for 7QN Low Flow Profiles

Return Period	Annual 7-Day Low Flow (m^3/s)	Mean Depth (m)	Flow Velocity (m/s)	Top Width (m)
2	0.85	0.892	0.145	12.0
5	0.59	0.762	0.144	9.37
10	0.46	0.698	0.140	8.15
20	0.37	0.641	0.151	7.17
50	0.27	0.568	0.148	6.04
100	0.22	0.527	0.133	5.40

7QN = seven-day low flow with an average return period of “N” years.

The rating curve developed by the HEC-RAS model for the cross-section at hydrometric gauge station CR-WC-MS-03, located near the Access Road Bridge, represents the relationship between WSE at the station and its discharge. This stage-discharge rating curve is shown in Figure 9B-12, along with the measured rating curve at the same location. For context, the WSE at CR-WC-MS-03 associated with the mean annual flood of 1.89 m^3/s would be 498.79 metres above sea level (masl), and water levels would range from 498.28 masl during the 7Q10 low flow (0.46 m^3/s) to 499.04 masl during the 100-year flood (3.19 m^3/s), based on the calculated rating curve by the hydraulic model.

Figure 9B-12: Simulated and Measured Rating Curves for Hydrometric Gauge Station CR-WC-MS-03



masl = metres above sea level.

Fluvial Sediment Transport

The simulated cumulative mass change along the channel (i.e., longitudinal mass change) is shown in Figure 9B-13 from upstream (i.e., river station 700 m) to downstream (i.e., river station 0 m). Based on the model, the overall erosion in the channel of the Upper Reach increases with increases in stream discharge. For example, average erosion of 81 tonnes was simulated by the model for a two-year flood and 217 tonnes for a 100-year flood at the Upper Reach. The overall deposition in the Lower Reach also rises with increases in stream discharge (Figure 9B-13). The longitudinal cumulative mass change at the junction point and the downstream ends of the channel and mean annual daily peak discharge are summarized in Table 9B-10. A positive value indicates net deposition, whereas a negative value represents net erosion in the reach. Overall, the Upper Reach channel experiences degradation, while the eroded sediments are deposited in the Lower Reach channels. In the Lower Reach channels, more sediment is deposited in the South Channel than the North Channel; the North Channel is the preferential pathway for transport of eroded sediments into Forrest Lake. Sediment transported through the North Channel is deposited where the Clearwater River empties into Forrest Lake. In the 2-year return period flood, 23 tonnes or 8.7 m^3 of sediment are simulated to leave the downstream boundary of the model and be deposited in the Forrest Lake – North Basin at the mouth of the North Channel where the Clearwater River empties into Forrest Lake.

Table 9B-10: Estimated Combined Sediment Load from the Upper Reach and the North and South Channel of the Lower Reach under a Range of Flood Conditions

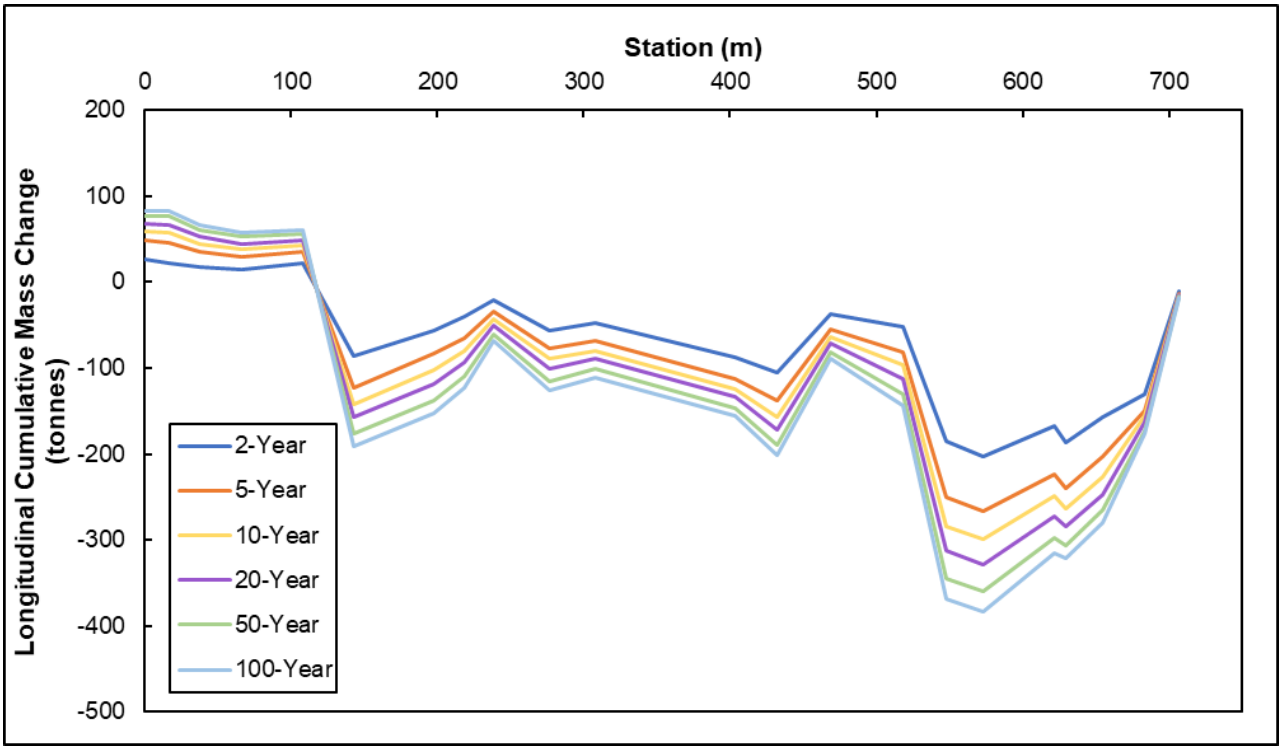
Return Period	Annual Mean Daily Peak Flow (m^3/s)	Longitudinal Cumulative Mass Change (Tonnes)[(a)]		
		Upper Reach (Junction Point)	Lower Reach (Downstream End of the North Channel)	Lower Reach (Downstream End of the South Channel)
2	1.89	-86	27	36
5	2.38	-123	48	54
10	2.63	-143	60	63

Table 9B-10: Estimated Combined Sediment Load from the Upper Reach and the North and South Channel of the Lower Reach under a Range of Flood Conditions

Return Period	Annual Mean Daily Peak Flow (m^3/s)	Longitudinal Cumulative Mass Change (Tonnes)[(a)]		
		Upper Reach (Junction Point)	Lower Reach (Downstream End of the North Channel)	Lower Reach (Downstream End of the South Channel)
20	2.84	-157	67	70
50	3.05	-177	77	80
100	3.19	-191	84	87

a) "+" symbol corresponds to sediment deposition and "-" to erosion.

Figure 9B-13: Model Simulated Sediment Transport in the Channel at Clearwater River below Patterson Lake



Note: Station 0 m corresponds to downstream boundary of the channel at the North Arm.

9B5.2 Climate Change Scenario

The Climate Change Scenario simulates conditions considering mean projected climate change for the 2050s. The estimated fluvial sediment transport under the mean climate change scenario for a range of floods is summarized in Table 9B-11.

Table 9B-11: Mean Climate Change Scenario Sediment Load from the Upper Reach and Lower Reach

Return Period (Years)	Annual Mean Daily Peak Flow (m^3/s)	Upper Reach		Lower Reach (North Channel)		Lower Reach (South Channel)	
		Longitudinal Cumulative Mass Change (Tonnes)[a]	Change Relative to Existing Conditions (%)[b]	Longitudinal Cumulative Mass Change (Tonnes)[a]	Change Relative to Existing Conditions (%)[b]	Longitudinal Cumulative Mass Change (Tonnes)[a]	Change Relative to Existing Conditions (%)[b]
2	2.00	-93	8.1	31	14.8	40	11.1
5	2.56	-135	9.8	55	14.6	60	11.1
10	2.87	-160	11.9	69	15.0	72	14.3
20	3.12	-184	17.0	80	19.4	84	20.0
50	3.39	-211	19.2	92	19.5	97	21.3
100	3.56	-227	18.9	100	19.1	105	20.7

a) "+" mass change corresponds to sediment deposition and "-" to erosion.
b) "+" percent change represents an increase and "-" percent represents a decrease in percentage.

9B5.3 Application Case

The Application Case simulates the Base Case plus the effects from the Project. The Project is expected to result in a net discharge of water to the receiving environment, due primarily to dewatering of the underground mine workings during Operations, which is predicted to result in small but undetectable increases in WSEs and watercourse flow rates in the receiving environment (Appendix 9A). Mean monthly flows at the Clearwater River below Patterson Lake are expected to increase between 1.3% to 1.9% and the annual mean increase is predicted to be 1.6%. The estimated Application Case sediment transport masses for a range of floods are summarized in Table 9B-12.

Table 9B-12: Application Case Sediment Load from the Upper Reach and Lower Reach

Return Period (Years)	Annual Mean Daily Peak Flow (m^3/s)	Upper Reach		Lower Reach (North Channel)		Lower Reach (South Channel)	
		Longitudinal Cumulative Mass Change (Tonnes)[a]	Change Relative to Existing Conditions (%)[b]	Longitudinal Cumulative Mass Change (Tonnes)[a]	Change Relative to Existing Conditions (%)[b]	Longitudinal Cumulative Mass Change (Tonnes)[a]	Change Relative to Existing Conditions (%)[b]
2	1.92	-88	2.3	28	3.7	37	2.8
5	2.41	-126	2.4	50	4.2	55	1.9
10	2.67	-146	2.1	62	3.3	65	3.2
20	2.87	-160	1.9	69	3.0	72	2.9
50	3.07	-179	1.1	78	1.3	81	1.3
100	3.19	-191	0.0	84	0.0	87	0.0

a) "+" mass change corresponds to sediment deposition and "-" to erosion.
b) "+" percent change represents an increase and "-" percent represents a decrease in percentage.

9B5.4 Reasonably Foreseeable Development Case Conditions

9B5.4.1 Reasonably Foreseeable Development Case

The RFD Case simulates conditions considering other developments that have not yet been approved, namely the Fission Patterson Lake South Property, under historical climate. The estimated sediment transport masses under the Cumulative Development Scenario for a range of floods are summarized in Table 9B-13.

Table 9B-13: Reasonably Foreseeable Developments Case Sediment Load from the Upper Reach and Lower Reach

Return Period (Years)	Annual Mean Daily Peak Flow (m^3/s)	Upper Reach		Lower Reach (North Channel)		Lower Reach (South Channel)	
		Longitudinal Cumulative Mass Change (Tonnes)[a]	Change Relative to Existing Conditions (%)[b]	Longitudinal Cumulative Mass Change (Tonnes)[a]	Change Relative to Existing Conditions (%)[b]	Longitudinal Cumulative Mass Change (Tonnes)[a]	Change Relative to existing Conditions (%)[b]
2	1.95	-90	4.7	29	7.4	38	5.6
5	2.43	-127	3.2	51	6.3	56	3.7
10	2.67	-146	2.1	62	3.3	65	3.2
20	2.87	-160	1.9	69	3.0	72	2.9
50	3.07	-179	1.1	78	1.3	81	1.2
100	3.19	-191	0.00	84	0.0	87	0.00

a) "+" mass change corresponds to sediment deposition and "-" to erosion.
b) "+" percent change represents an increase and "-" percent represents a decrease in percentage.

9B5.4.2 Reasonably Foreseeable Development Case (including Climate Change)

The RFD Case (including climate change) simulates conditions considering other developments that have not yet been approved, namely the Fission Patterson Lake South Property, as well as natural factors and climate change, which may interact with the Project and other developments to affect hydrology. The estimated sediment transport masses under the RFD Case for a range of floods are summarized in Table 9B-14. The majority of the change noted in Table 9B-14 is the result of changes associated with the mean climate change scenario rather than effects of cumulative developments. The change associated with the mean climate change scenario without any development effects is presented in Section 9B5.2. The change associated with cumulative developments under the historical climate is presented as the RFD Case in Section 9B5.4.

Table 9B-14: Reasonably Foreseeable Development Case (including Climate Change) Sediment Load from the Upper and Lower Reach

Return Period (Years)	Annual Mean Daily Peak Flow (m^3/s)	Upper Reach		Lower Reach (North Channel)		Lower Reach (South Channel)	
		Longitudinal Cumulative Mass Change (Tonnes)[(a)]	Change Relative to Existing Conditions (%)[(b)]	Longitudinal Cumulative Mass Change (Tonnes)[(a)]	Change Relative to Existing Conditions (%)[(b)]	Longitudinal Cumulative Mass Change (Tonnes)[(a)]	Change Relative to Existing Conditions (%)[(b)]
2	2.05	-97	12.8	33	22.2	41	13.9
5	2.60	-140	13.8	58	20.8	62	14.8
10	2.90	-162	13.2	70	16.7	73	15.9
20	3.14	-186	18.5	81	20.9	85	21.4
50	3.40	-212	19.8	93	20.8	97	21.3
100	3.56	-227	18.9	100	19.1	105	20.7

a) "+" mass change corresponds to sediment deposition and "-" to erosion.
b) "+" percent change represents an increase and "-" percent represents a decrease in percentage.

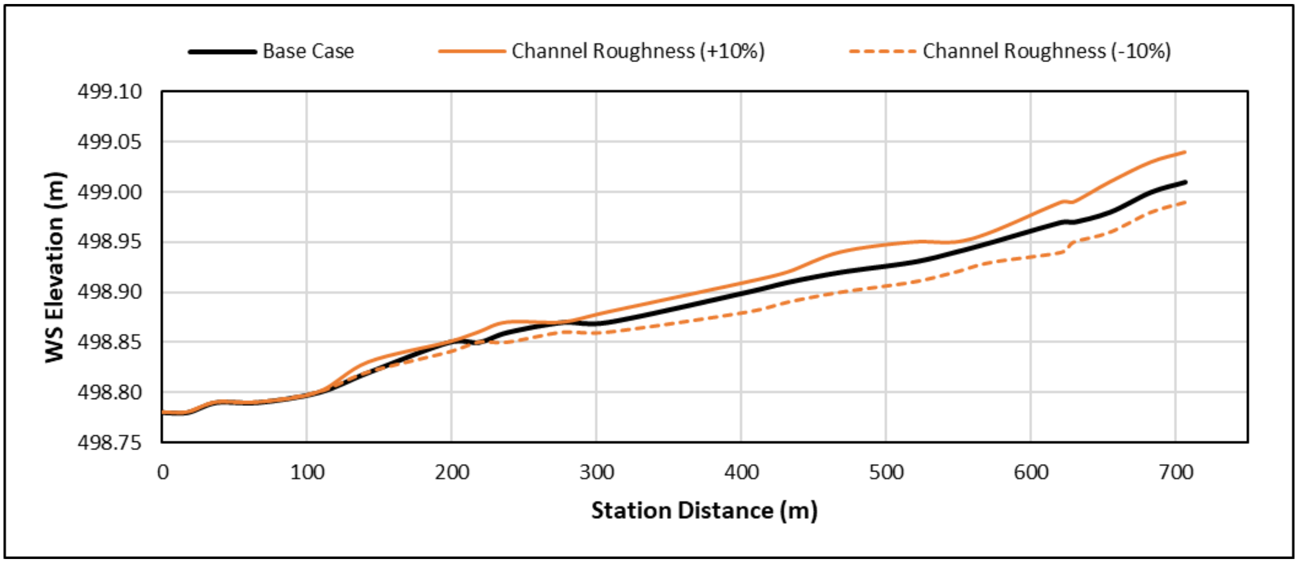
9B6 SENSITIVITY ANALYSIS

9B6.1 Sensitivity to Calibrated Hydraulic Parameters

A sensitivity analysis was completed to evaluate uncertainty in parameterization of the hydraulic model. As noted in Section 9B4.6.10, Model Calibration, the model was calibrated against measured values of WSE at a known discharge by optimizing the channel roughness parameter. The sensitivity of simulated water levels to variations in channel roughness was assessed because calibration parameters, such as channel roughness, can be a source of uncertainty. The channel roughness was varied by ±10% to test the model sensitivity to reasonably foreseeable variations in actual channel roughness and the simulated water levels were compared against the calibrated scenario (without sensitivity) for a 100-year flood.

The HEC-RAS model simulated profiles of WSEs at the Clearwater River below Patterson Lake through the Upper Reach and the downstream North Channel are shown in Figure 9B-14. This graph shows the calibrated scenario and sensitivity scenarios for higher channel roughness (+10%) and lower channel roughness (-10%). The highest river station distance represents the upstream edge of the reach on the x-axis. The water levels are sensitive to the channel roughness in the Upper Reach of the channel but are relatively insensitive in the Lower Reach. An increase in channel roughness results in raising the water levels in the channel and a decrease in channel roughness results in lowering the water levels in the channel. Overall, an average change in WSE was projected to be 11 mm to 12 mm based on the specified changes in channel's roughness, which means that the model is relatively insensitive to reasonable variations in channel roughness.

Figure 9B-14: Sensitivity of Water Surface Elevation to Channel's Roughness and Lower Boundary Conditions (Defined by Normal Depth)

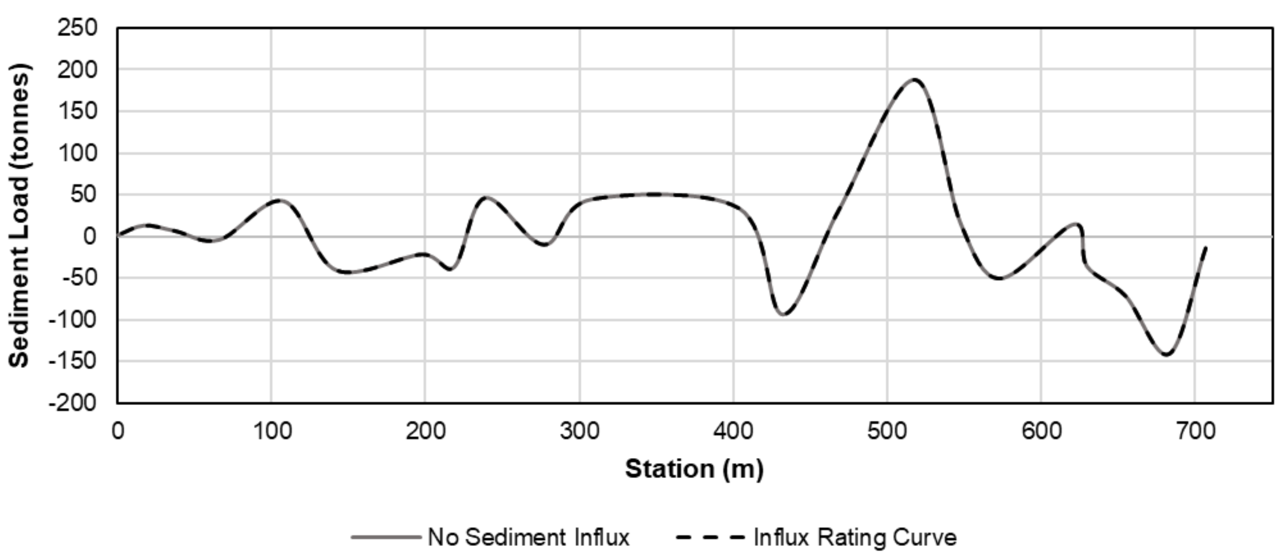


WS = water surface.

9B6.2 Sensitivity to Sediment Influx at Upstream Boundary

The model simulations for the sediment load rating curve at the upstream boundary were compared with the calibration scenario of no influx to better understand the influence of sediment influx at the upstream boundary. The results of the comparison, shown in Figure 9B-15, indicate that the net sediment load of the channel is insensitive to sediment influx at the upstream boundary. As a result, the adoption of the measured sediment load rating curve, described in Section 9B4.6.9, is not expected to be a meaningful source of uncertainty.

Figure 9B-15: Simulated Sediment Load for a 10-Year Flood Flow Hydrograph for Different Influx Conditions



9B7 UNCERTAINTIES

The purpose of the hydraulic and sediment transport modelling is to characterize existing conditions and predict the future conditions for hydraulics and sediment transport immediately downstream of the Project. There is some uncertainty in the model used to characterize hydraulic conditions and sediment transport. The reach has a low gradient and is bounded by two large waterbodies. As a result, the hydraulics of the channel are relatively insensitive to the changes in flows anticipated to result from the Project and uncertainty in the assessment is considered to be low.

The following are key sources of uncertainty:

- **Model Parameterization:** Processes of sediment transport, deposition, and erosion are complex and modelling only provides an indication of the magnitude of the processes. Uncertainty in model parameterization was mitigated by completing sensitivity analyses to quantify how results would change had different assumptions been made when parameterizing the model. The sensitivity analyses indicate that the model results would be unchanged had reasonably different parameters had been selected.
- **Low-Flow Conditions during Calibration:** The hydraulic model was calibrated based on water levels surveyed on 2 October 2018 and 3 October 2018. Characterization of existing hydrological conditions and preliminary hydraulic modelling both suggest that low flow conditions (i.e., below the 25th percentile) were encountered during the model calibration period (i.e., October 2019). Because hydrometric monitoring data were only available for a lower flow period, the model parameters and particularly roughness for the floodplain had to be based on reference values (Chow 1959).
- **TSS Measurement:** The measured TSS near the upstream end of the channel was very low suggesting that sediment influx to the channel at the upstream boundary was low. However, the TSS measurements potentially did not capture a minor influx of sediments into the channel that may occur by longshore drift along the shoreline of Patterson Lake. A sensitivity analysis (Section 9B6.2) confirmed that the model results were not sensitive to uncertainty in the sediment influx at the upstream boundary.

9B8 KEY FINDINGS

The following conclusions are drawn based on this sediment transport modelling assessment:

- A fit-for-purpose, one-dimensional hydraulic model was developed to characterize the existing fluvial sediment transport regime for the reach of the Clearwater River between Patterson Lake and Forrest Lake over a range of climatic conditions. The existing conditions model was calibrated for discharge based on measurements collected on 2 October 2018 and 3 October 2018. The performance of the hydraulic model is partly verified by the similarity of the rating curve simulated using the hydraulic model to the open water rating curve developed during baseline monitoring (Annex IV.1).
- Fluvial sediment transport was assessed for the Clearwater River below Patterson Lake along the reach from Patterson Lake to the north end of Forrest Lake. Changes in sediment transport assessed at one location in the Upper Reach and in both the Lower Reach – South Channel and Lower Reach – North Channel.

- The Base Case simulations characterize existing hydraulic and sediment transport conditions for the Clearwater River below Patterson Lake.
  - The average WSE of Patterson Lake, associated with the mean annual flow, is estimated to be 498.83 masl. The WSE of Patterson Lake is expected to range from 498.28 masl during extremely dry conditions, as represented by the 7Q50 low flow, to 499.04 masl during the 100-year flood.
  - The WSE remained within the channel for a two-year flood but overtops the channel banks near the upstream end of the channel for all the other flood profiles. The low chord elevation (i.e., 500.068 m), which is the bottom of the bridge superstructure, was well above the water level for a flood of any return period evaluated.
  - Sediment transport processes are active in the Clearwater River between Patterson Lake and Forrest Lake. In the Lower Reach, the North Channel is the preferential pathway for the transport of eroded sediments. Sediment transported through the North Channel is deposited where the Clearwater River empties into Forrest Lake. In a two-year return period flood year, 23 tonnes (equivalent to a volume of 9 m^3) of sediment is eroded from the Upper Reach and deposited in Forrest Lake.
- The Application Case was simulated to estimate the expected conditions during the different Project phases under current climate conditions. With a slight increase in mean annual maximum daily flows, estimated sediment transport is also expected to increase slightly as measured by cumulative mass change along the reach. Small (2%) erosional losses of sediment are expected in the Upper Reach, though the changes may not be measurable relative to existing conditions. However, this erosional loss is offset by a 3% increase in sediment deposition in the lower reaches, which may also not be measurable. The net balance of sediment transport for the entire reach is predicted to be a loss of sediment to Forrest Lake at the Clearwater River inflow, but this loss is the same magnitude for the Application Case as the Base Case.
- The RFD Case was simulated to estimate cumulative effects of Project activities and Fission Patterson Lake South Property activities with historical climate.
- The RFD Case (including climate change) was simulated to estimate the expected Project activities and Fission Patterson Lake South Property activities, as well as projected climate for the 2050s, to establish cumulative effects on receiving environment hydrology.

CLOSING

WSP Canada Inc. (WSP) is pleased to submit this report to NexGen in support of the environmental assessment for the Rook I Project. For details on the limitations and use of information presented in this report, please refer to the Study Limitations subsection following this page. If you have any questions or require additional details related to this study, please contact the undersigned.

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REFERENCES

Chow VT. 1959. Open Channel Hydraulics. New York, NY. McGraw-Hill Inc.

Copeland R. 1993. Numerical modeling of hydraulic sorting and armoring in alluvial rivers. Location: The University of Iowa.

Copeland RR, Thomas WA. 1989. Thomas, Corte Madera Creek sedimentation study: numerical model investigation. US Army Engineer Waterways Experiment Station, Vicksburg, MS. TR-HL-89-6.

Dingman SL. 2002. Physical hydrology. 2nd ed. Long Grove, IL: Waveland Press Inc.

ESRI (Earth Systems Research Institute). 2018. ArcGIS ArcMap (Version 10.6.1.9270).

Hjulstrom F. 1935. Studies of the morphological activity of rivers as illustrated by the River Fyris. Bulletin of the Geological Institution of the University of Upsala 25:221-527.

Maidment D. 1994. Handbook of hydrology. Toronto, ON: McGraw-Hill Inc.

USACE (US Army Corps of Engineers). 2018. Hydrologic Engineering Center – River Analysis System. HEC-RAS (5.0.7). Available at https://www.hec.usace.army.mil/software/hec-ras/.

Attachment 9B-1 Particle-Size Distribution at Clearwater River below Patterson Lake

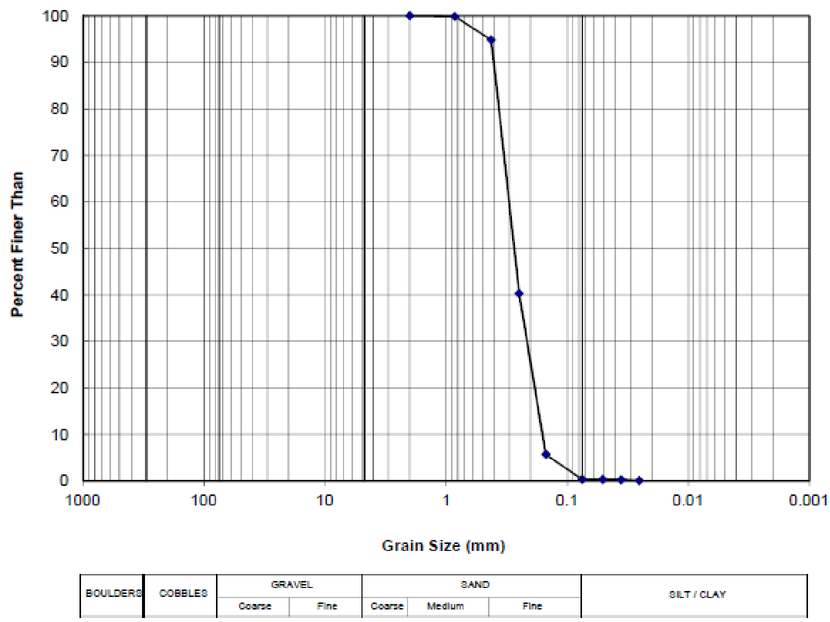
GRAIN SIZE ANALYSIS

(Mechanical & Hydrometer)

Project #: 1899581 Phase: 3
Short Title: NexGen / Rook I Project / Env Baselines
Tested by: T.B. Date: August 28, 2018

Sample #: SL6312
Source: Sampled below Patterson Lake.
Date Sample Received: August 5, 2018

Graphical Analysis



Grain Size Analysis Results:

Opening (mm)	Percent Passing (%)
51	100
38	100
25	100
19	100
9.5	100
4.75	100
2.0	100
0.850	100
0.425	95
0.250	40
0.150	5.7
0.075	0.4
0.051	0.4
0.036	0.3
0.025	0.1

Comments:

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

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Reviewed by: ____________