

Rook I Project

Environmental Impact Statement

Section 11 Fish and Fish Habitat

Submitted to:

Canadian Nuclear Safety Commission
Saskatchewan Ministry of Environment

Submitted by:

NexGen Energy Ltd.
3150-1021 W Hastings St
Vancouver, BC
V6E 0C3

November 2024

Executive Summary

Section Purpose

Section 11 of the Environmental Impact Statement (EIS) provides a comprehensive assessment of potential effects of the Rook I Project (Project) on fish and fish habitat. This assessment included consideration of both potential effects from the Project and cumulative effects from the Project and other reasonably foreseeable developments (RFDs). The fish and fish habitat assessment used widely accepted scientific practices and incorporated Indigenous and Local Knowledge.

Four fish species (i.e., lake trout, lake whitefish, walleye, and northern pike) represented valued components (VCs) in the Environmental Assessment (EA). The selection of these four VCs was based on the respective roles and linkages of each species in the ecosystem and food web, the high traditional and cultural importance of these species to local communities, and the species' presence within nearby waterbodies and watercourses. Additionally, these VCs were selected because they are strong indicators of broader species assemblages and ecosystems, and therefore are suitable for assessing both potential population-level effects and determining potential Project effects on overall biodiversity.

The assessment of potential effects on fish and fish habitat was informed by the assessments completed for air quality, hydrogeology, hydrology, and surface water quality, as well as the results of the Project ecological risk assessment (EcoRA). The fish and fish habitat assessment provided information that was used to support other VC assessments such as wildlife and wildlife habitat, human health, Indigenous land and resource use, and other land and resource use.

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 fish and fish habitat 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 km². 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 km². 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, Forrest Lake, Beet Lake, and Naomi Lake. From Naomi Lake, the Clearwater River flows an additional 20 km southeast before reaching the Mirror River confluence. The LSA and RSA used for the assessment of fish and fish habitat are the same spatial boundaries as those used for other aquatic environment components (e.g., hydrology, surface water quality).

Existing Conditions (Section 11.3)

Fish and fish habitat conditions in the LSA and RSA were evaluated for several waterbodies, including Broach Lake, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake, and sections of the Clearwater River mainstem. In total, 17 fish species were documented within these waterbodies.

The most abundant large-bodied species captured included white sucker, lake whitefish, yellow perch, longnose sucker, northern pike, walleye, burbot, and lake trout. Commonly captured small-bodied species included trout perch, spottail shiner, and lake chub. This species list is characteristic of northern temperate waterbodies and watercourses in Saskatchewan (Langhorne 2001). Of the 17 species identified, none were classified as species with a designated conservation status by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2021), aquatic species listed under the *Species at Risk Act*, or would be considered rare or unique to the area based on a review of Saskatchewan's Conservation Data Centre taxa lists (SKCDC 2021a).

The results of fish community sampling indicated that the four fish VCs are widely distributed throughout the LSA, with northern pike being the most ubiquitous (i.e., found everywhere) species captured. Lake whitefish, walleye, and northern pike were captured in all larger waterbodies sampled, as well as in the Clearwater River. Lake trout were somewhat less prevalent than the other VC species and were captured only in lake habitats.

Characteristics of surveyed lakes within the LSA include the following:

- surface areas between 0.6 km² and 42.8 km²;
- average depths between 1.4 m and 26.5 m;
- mostly oligotrophic, indicating low levels of nutrients, deep and clear water conditions, and limited amounts of algae;
- riparian zones (i.e., the area along the edge of watercourses and water bodies) that typically consist of trees, shrubs, grasses, and sedges;
- bottom substrates predominantly composed of sand, rock, and organic matter; and
- abundant areas of rocky substrate identified within the littoral zones.

Characteristics of the Clearwater River mainstem within the LSA:

- generally shallow (i.e., <1 m deep);
- meandering channels with predominantly slow-moving glide (i.e., flat-water) habitat;
- limited deeper areas with slower-moving pool habitat and faster-flowing riffle and run habitat;
- riparian zones that typically consist of trees, shrubs, grasses, and sedges; and
- bottom substrates predominantly composed of sand with limited areas of rock and organic matter.

Lower trophic level communities such as plankton and benthic invertebrates were also characterized. Phytoplankton and zooplankton biomass and abundance was typically low in the sampled lakes, which is characteristic of northern oligotrophic lakes. Phytoplankton and zooplankton richness (i.e., the number of taxa present) and diversity were both moderate to high. The average density and richness of benthic invertebrates was also low and within the range typically observed for northern oligotrophic lakes, whereas diversity was moderate to high.

Potential Effects and Proposed Mitigations (Section 11.4)

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

Project activities that would have the potential to affect fish and fish habitat during the Project lifespan include:

- changes in Patterson Lake surface water quality from effluent treatment plant and sewage treatment plant discharges;
- runoff from the Project footprint;
- Project-related air and dust emissions;
- runoff and seepage from the waste rock storage areas (WRSAs);
- long-term solute transport from the underground tailings management facility (UGTMF) and WRSAs;
- sediment release during in-water construction and from ground disturbance;
- changes to water flows and levels from site water management activities (e.g., water withdrawals, dewatering of the underground mine); and
- altered surface runoff conditions.

An additional potential Project effect is direct physical habitat loss and disturbance associated with the construction and operation of a fresh water intake, treated effluent diffuser, and treated sewage outfall in Patterson Lake. These Project components and activities also have the potential to change the availability of riparian zone vegetation adjacent to Patterson Lake.

Similar activities that could affect fish and fish habitat 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 fish VCs could be avoided or reduced to negligible, thereby removing the pathway.

Potential effects on fish VCs due to changes in surface water quality during the Project lifespan could be minimized by diverting water generated from undisturbed catchments adjacent to the Project footprint around the site, and by collecting and treating contact water (i.e., water that may have been altered by Project activities) as necessary prior to release to the environment. Proposed mitigations, such as the use of erosion and sediment control best management practices, limiting the disturbance area of Project components, and reclaiming and revegetating disturbed areas, would reduce effects on fish and fish habitat. Additionally, water management infrastructure would be designed to reuse and recycle water wherever possible to minimize the amount of fresh water withdrawn from Patterson Lake and reduce effects on downstream fish habitat.

Infrastructure such as the fresh water intake, treated effluent diffuser, and treated sewage outfall would be designed to minimize the physical footprint and associated habitat loss or disturbance in Patterson Lake. This in-water infrastructure would be located to avoid sensitive or unique habitats in Patterson Lake, to the extent feasible, and would be designed to minimize effects on fish and fish habitat. The fresh water intake would be fitted with a fish screen to minimize the potential for fish to be drawn into the intake. Where possible, in-water construction associated with these developments would be scheduled to avoid sensitive spawning and egg-incubation periods for fish in Patterson Lake. NexGen would work with Fisheries and Oceans Canada to determine the need for a *Fisheries Act* Authorization application and offsetting plan for any of the proposed water management infrastructure.

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 fish and fish habitat from the following pathway:

- runoff and seepage from the WRSAs and groundwater flow from the UGTMF may alter surface water quality in Patterson Lake after Closure and adversely affect fish habitat availability, survival, and reproduction.

This pathway was carried forward into the residual effects analysis.

Residual Effects Analysis (Section 11.5)

A residual effects analysis was conducted to determine the potential effects on fish and fish habitat 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 three measurement indicators:

- habitat availability;
- habitat distribution; and
- survival and reproduction.

The residual effects analysis used a precautionary approach to assess the potential Project-related effects on fish VCs. The evaluation of effects on fish VCs was directly informed by the predictions generated other assessments, which included a similar level of conservatism:

- the surface water quality assessment;
- aquatic health assessment; and
- the EcoRA.

The RFD Case made similar assumptions and considered aspects of the Fission Patterson Lake South Property associated with site runoff from both an above-ground tailings management facility and a covered waste rock storage facility after closure as outlined in the Fission (2019) prefeasibility study.

The residual effects analysis for fish and fish habitat focused on describing the potential effects on fish and lower level trophic organisms that may occur due to changes in water quality after Closure and in the far future. The primary source of loading for constituents in the far future would be the seepage load through the groundwater flow path from stored mine waste on the Project footprint. Changes to water quality in the far future could alter the health of fish and lower trophic organisms that form the fish food base and the subsequent suitability of fish habitat in affected waterbodies and watercourses. These changes could also adversely affect the survival and reproduction of fish VC populations in the RSA or LSA.

In both the Application Case and RFD Case, concentrations of certain metals were predicted to increase in the receiving environment during the far-future modelling timeframe. Of these metals, only copper was predicted to exceed both water quality guidelines for the protection of aquatic life and reference values used in the EcoRA and aquatic health assessment. Therefore, the residual effects analysis focused on assessing the potential effects associated with exposure to elevated copper concentrations in the water column.

Predicted residual effects on fish VC habitat availability, habitat distribution, and survival and reproduction are summarized below, as well as climate change and biodiversity in relation to this assessment. Overall, the outcome of the residual effects analysis for the Application Case and RFD Case were very similar, and the predicted effects described below apply to both assessment cases.

Habitat Availability

The assessment indicated limited potential for changes in habitat availability due to exposure to predicted copper concentrations in Patterson Lake after Closure and in the far future. The results of the EcoRA and aquatic health assessment indicated that predicted copper concentrations would be unlikely to result in population-level and/or community-level effects on lower trophic organisms and forage fish. Additionally, the effects, if realized, would be spatially limited to Patterson Lake North Arm – West Basin. Therefore, adverse effects on the viability and suitability of habitats for use by fish VCs are considered unlikely, and any changes in habitat availability would unlikely be measurable.

Habitat Distribution

Fish would be able to continue using the habitats present and move between habitats to carry out their life processes (e.g., spawning, rearing, overwintering). No effects on habitat arrangement or the spatial distribution and movement of fish in Patterson Lake are expected to occur.

Survival and Reproduction

The survival and reproduction of fish VCs could be directly affected by exposure to copper in the water column or indirectly by changes in habitat availability resulting from potential effects on the lower trophic food base for fish, as described above.

The EcoRA and aquatic health assessment results indicated that effects on the health of fish due to direct exposure to copper in the water column, and therefore survival and reproduction, are not expected for predator fish (e.g., lake trout, walleye, northern pike) and are unlikely for forage fish (e.g., lake whitefish). As described above, only limited effects on the available food supply for fish are possible due to exposure of lower trophic level organisms and forage fish species to predicted copper concentrations. Additionally, these effects would be spatially limited to Patterson Lake North Arm – West Basin. Broad scale changes to the fish food base are not expected to occur. Therefore, any changes in habitat quality are considered unlikely to measurably affect the survival and reproduction of fish VCs.

Climate Change

Climate change effects on fish and fish habitat were considered through the inclusion of a climate change scenario in the surface water quality assessment, which informed the residual effects analysis for fish VCs. Projected future climate extremes indicate a future that is likely to be warmer and wetter on an annual basis. The results of the climate change sensitivity scenario indicated that, based on hydrological projections, climate change effects on surface water quality would be minor within the LSA and RSA. These minor changes in hydrologic conditions did not result in changes to constituent concentrations. Therefore, there would be no change to the predicted effects for fish VCs as outlined above.

Effects on Biodiversity

Effects on aquatic biodiversity were evaluated based on the completed fish VC assessment. The EcoRA and aquatic health assessment results indicated that, after Closure and in the far future, limited effects would be possible on individual taxa or species that may be sensitive to elevated copper concentrations in Patterson Lake.

However, based on the predicted level of exposure and limited spatial extent of elevated copper concentrations, population-level effects are not expected to occur. Therefore, the predicted effects of the Project and RFDs on aquatic biodiversity were considered negligible.

Significance Determination (Section 11.5)

The weight of evidence from the analysis predicts that changes to the habitat availability, habitat distribution, and survival and reproduction of fish VCs (i.e., lake trout, lake whitefish, walleye, northern pike) in the RSA would be within the resilience and adaptability limits for these VCs. The residual effects on fish VCs in the Application Case are predicted to be **not significant**.

The incremental and cumulative effects resulting from the Project, previous and existing developments, and the Fission Patterson Lake South Property on fish and fish habitat are also predicted to be **not significant**.

Prediction Confidence and Uncertainty (Section 11.6)

Overall, there was a moderate to high degree of confidence in the predictions related to the fish and fish habitat assessment. The degree of prediction confidence related to changes in fish VCs from water quality changes were higher during the Project lifespan than for predictions after Closure and in the far future. However, conservatism considered in other assessments and technical support documents, which provided the basis for the fish and fish habitat assessment (i.e., surface water quality assessment, aquatic health assessment, and EcoRA), improved the overall level of confidence that effects were not underestimated and were more likely overestimated.

Monitoring and Follow-Up (Section 11.7)

The Environmental Protection Program, Environmental Monitoring Plan, and associated environmental monitoring would be implemented to verify effects predictions and effectiveness of mitigation on fish and fish habitat, identify unanticipated effects, and apply adaptive management, if required. Monitoring would also be used to address residual uncertainty by evaluating changes to fish and fish habitat, including lower trophic level community conditions (e.g., benthic invertebrates), in the receiving environment.

Key components of aquatic ecology and environmental monitoring are expected to include water and sediment quality, benthic invertebrates, and fish. The Environmental Monitoring Plan would be developed in accordance with the Metal and Diamond Mining Effluent Regulations, the federal *Fisheries Act*, and conditions established through Project authorizations issued by the Canadian Nuclear Safety Commission and Saskatchewan Ministry of Environment.

Abbreviations and Units of Measure

Abbreviation	Definition
BLM	biotic ligand model
BNDN	Birch Narrows Dene Nation
BRDN	Buffalo River Dene Nation
BSA	baseline study area
CanNorth	CanNorth Environmental Services Ltd.
CCME	Canadian Council of Ministers of the Environment
CNSC	Canadian Nuclear Safety Commission
COPC	constituent of potential concern
CPUE	catch per unit effort
CRDN	Clearwater River Dene Nation
DFO	Fisheries and Oceans Canada
DL	detection limit
DO	dissolved oxygen
EA	Environmental Assessment
EEM	environmental effects monitoring
EcoRA	ecological risk assessment
EIS	Environmental Impact Statement
ENV	Saskatchewan Ministry of Environment
ERA	environmental risk assessment
ETP	effluent treatment plant
HDPE	high density polyethylene
HQ	hazard quotient
JWG	Joint Working Group
LSA	local study area
MDMER	Metal and Diamond Mining Effluent Regulations
MLR	multiple linear regression
MN-S	Métis Nation – Saskatchewan
NexGen	NexGen Energy Ltd.
NPAG	non-potentially acid generating
PAG	potentially acid generating
pH	potential of hydrogen; measure of the acidity or alkalinity of a solution on a scale of 0 to 14
Project	Rook I Project
RFD	reasonably foreseeable development
RMZ	regulated mixing zone
RSA	regional study area
RSWQM	regional surface water quality model
SARA	<i>Species at Risk Act</i>
SDI	Simpson's Diversity Index
SEI	Simpson's Evenness Index
STP	sewage treatment plant
TP	total phosphorus
TRV	toxicity reference value
TSD	technical support document
TSP	total suspended particulate
TSS	total suspended solids
UGTMF	underground tailings management facility
VC	valued component

Abbreviation	Definition
WRSA	waste rock storage area
YNLRO	Ya'thi Néné Lands and Resources Office

Unit	Definition
%	percent
°C	degrees Celsius
µg/L	micrograms per litre
µm	micron
µS/cm	microsiemens per centimetre
cm	centimetre
g	gram
g/m ²	grams per square metre
ha	hectare
kg	kilogram
km	kilometre
km/h	kilometres per hour
km ²	square kilometre
m	metre
m ²	square metre
m ³ /d	cubic metres per day
m ³ /h	cubic metres per hour
mg	milligram
mg/L	milligrams per litre
mGy/d	milligrays per day
mm	millimetre
mm/s	millimetres per second
org/L	organisms per litre
org/m ²	organisms per square metre

Table of Contents

11	FISH AND FISH HABITAT	11-1
11.1	Introduction	11-1
11.1.1	Project Summary	11-5
11.1.2	Purpose and Approach to the Assessment	11-7
11.2	Component Methods	11-8
11.2.1	Incorporation of Indigenous and Local Knowledge	11-8
11.2.2	Valued Components, Measurement Indicators, and Assessment Endpoints	11-10
11.2.3	Spatial Boundaries	11-19
11.2.4	Temporal Boundaries	11-25
11.2.5	Assessment Cases	11-26
11.2.6	Existing Conditions	11-27
11.2.7	Project Interactions and Mitigations	11-37
11.2.8	Residual Effects Analysis	11-38
11.2.9	Residual Effects Classification and Determination of Significance	11-39
11.2.10	Prediction Confidence and Uncertainty	11-42
11.2.11	Monitoring, Follow-Up, and Adaptive Management	11-42
11.3	Existing Conditions	11-43
11.3.1	Fish Habitat.....	11-43
11.3.2	Lake Trophic Status.....	11-51
11.3.3	Lower Trophic Communities.....	11-51
11.3.4	Fish Communities	11-58
11.3.5	Species of Conservation Concern	11-65
11.3.6	Fish Valued Component Life Histories	11-65
11.4	Project Interactions and Mitigations.....	11-71
11.4.1	No Pathways.....	11-78
11.4.2	Secondary Pathways.....	11-83
11.4.3	Primary Pathways.....	11-115
11.5	Residual Effects Analysis	11-116
11.5.1	Approach	11-117
11.5.2	Application Case.....	11-123
11.5.3	Reasonably Foreseeable Development Case.....	11-132
11.5.4	Residual Effects Classification and Determination of Significance	11-137
11.5.5	Effects on Biodiversity	11-140
11.6	Prediction Confidence and Uncertainty	11-142
11.7	Monitoring, Follow-Up, and Adaptive Management	11-145
11.8	Key Findings	11-148
11.9	References	11-151

List of Figures

Figure 11.1-1:	Location of the Rook I Project	11-3
Figure 11.1-2:	Regional Area of the Rook I Project	11-4
Figure 11.1-3:	Linkage Diagram of Project Effects on Fish and Fish Habitat Valued Components and Influence on other Valued Components	11-5
Figure 11.1-4:	Layout of Infrastructure and Facilities for the Rook I Project	11-6
Figure 11.2-1:	Aquatic Environment Baseline Study Area	11-23
Figure 11.2-2:	Fish and Fish Habitat Assessment Study Areas	11-24
Figure 11.2-3:	Waterbodies and Watercourses Sampled during the Aquatic Environment Baseline Study	11-31
Figure 11.4-1:	Conceptual Locations of In-Water Developments in Patterson Lake	11-92
Figure 11.4-2:	Predicted Phosphorus Concentrations in Patterson Lake in the Application Case	11-99
Figure 11.5-1:	Summary of Key Information Sources Considered in the Fish and Fish Habitat Residual Effects Assessment	11-117
Figure 11.5-2:	Cobalt and Copper Concentrations Predicted by the Regional Surface Water Quality Model, Application Case	11-125
Figure 11.5-3:	Predicted Copper Concentrations relative to No Effect and Low Effect Thresholds derived by the Biotic Ligand Model and Multiple Linear Regression Model, Patterson Lake North Arm – West Basin and South Arm, Application Case and Reasonable Upper Bound Scenario	11-128
Figure 11.5-4:	Cobalt and Copper Concentrations Predicted by the Regional Surface Water Quality Model, Reasonably Foreseeable Development Case	11-134
Figure 11.5-5:	Predicted Copper Concentrations relative to No Effect and Low Effect Thresholds derived by the Biotic Ligand Model and Multiple Linear Regression Model, Patterson Lake North Arm – West Basin, Reasonably Foreseeable Development Case	11-135

List of Tables

Table 11.2-1:	Species Considered for Selection as Valued Components	11-15
Table 11.2-2:	Valued Components, Rationale, Measurement Indicators, and Assessment Endpoints	11-19
Table 11.2-3:	Spatial Boundaries for Assessment of Fish Valued Components	11-22
Table 11.2-4:	Summary of Sampling Components by Waterbody and Watercourse	11-32
Table 11.2-5:	General Water Quality Classification of Waterbodies and Watercourses in the Baseline Study Area	11-33

Table 11.2-6:	A General Trophic Classification of Waterbodies.....	11-35
Table 11.2-7:	Definitions Applied to Effects Criteria Classifications for the Assessment of Fish and Fish Habitat.....	11-40
Table 11.3-1:	Existing Concentrations of Total Phosphorus Concentrations and Trophic Classification by Waterbody	11-51
Table 11.3-2:	Summary of Fish Species Captured in the Local and Regional Study Areas	11-60
Table 11.3-3:	Morphology and Catch Data for Lake Trout for Fishing Efforts in the Local and Regional Study Areas	11-66
Table 11.3-4:	Morphology and Catch Data for Lake Whitefish for Fishing Efforts in the Local and Regional Study Areas	11-68
Table 11.3-5:	Morphology and Catch Data for Walleye for Fishing Efforts Local and Regional Study Areas	11-69
Table 11.3-6:	Morphology and Catch Data for Northern Pike for Fishing Efforts in the Local and Regional Study Areas	11-71
Table 11.4-1:	Potential Effects Pathways for Fish and Fish Habitat	11-73
Table 11.4-2:	Modelled Concentrations of Total Phosphorus and Predicted Trophic Classification by Waterbody during Rook I Project Operations	11-100
Table 11.5-1:	Summary of Water Quality and Exposure Threshold Values Applied for Copper in the Surface Water Quality Assessment, Ecological Risk Assessment, and Aquatic Health Assessment of the Potential for Adverse Effects of Predicted Far-Future Copper Concentrations in Patterson Lake	11-121
Table 11.5-2:	Classification of Residual Effects on Lake Trout, Lake Whitefish, Walleye, and Northern Pike Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case in the Far Future	11-138

List of Appendices

Appendix 11A	Aquatic Health Assessment of the Potential for Adverse Effects of Predicted Far-Future Copper Concentrations in Patterson Lake
--------------	--

11 FISH AND FISH HABITAT

11.1 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 11.1-1). 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 11.1-2), with on-site worker accommodation serviced by fly-in/fly-out access.

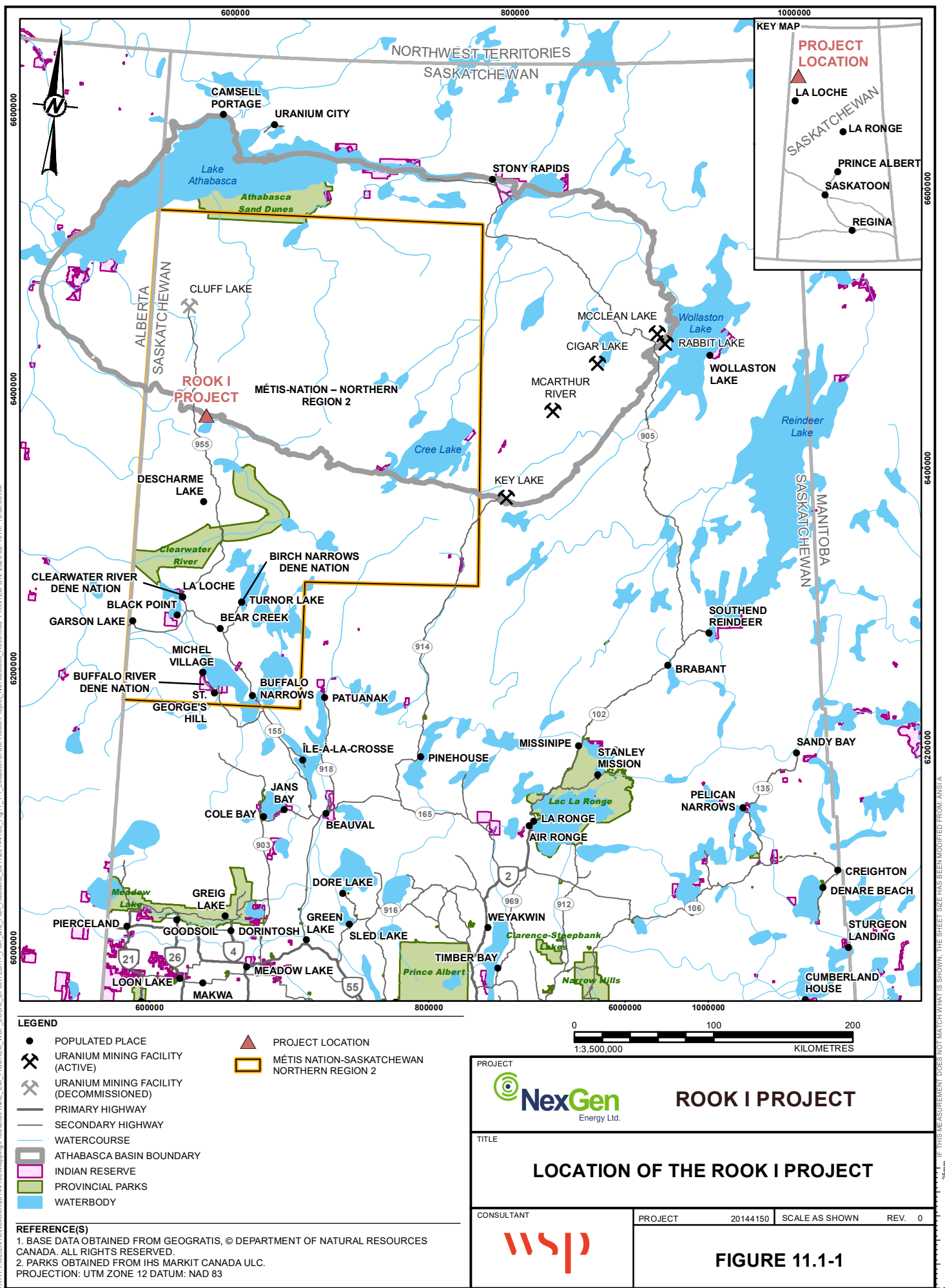
Section 11, Fish and Fish Habitat, of the Environmental Impact Statement (EIS) characterizes the potential residual effects of the Project on fish and fish habitat, which are attributes or components of the aquatic environment. Fish and fish habitat represent valued components (VCs) for the Environmental Assessment (EA). The Project has the potential to cause adverse effects on fish VCs primarily through changes in surface water quality resulting from operational discharges and long-term solute transport from the underground tailings management facility (UGTMF) and waste rock storage areas (WRSAs). In addition, the Project could affect fish and fish habitat due to direct habitat loss and disturbance associated with the development of a fresh water intake, treated effluent diffuser, treated sewage outfall, and associated pipelines in Patterson Lake. Changes to water flows and water levels resulting from site water management activities and altered surface runoff conditions also have the potential to affect fish VCs. Baseline data (Annex V.1, Aquatic Environment Baseline Report; Annex V.2, Overwintering Fish Habitat Report; Annex V.3, Naomi Lake Bathymetry Report) and information from the assessments completed for air quality (Section 7.2, Air Quality), hydrogeology (Section 8, Hydrogeology), 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), as well as the results of the ecological risk assessment (EcoRA) completed for the Project (Technical Support Document [TSD] XXI, Environmental Risk Assessment), were used to form the basis for the fish and fish habitat assessment.

Fish and fish habitat are protected under the federal *Fisheries Act*. For the purpose of the assessment, and consistent with the *Fisheries Act*, “fish” is defined as fish species that occur in the area surrounding the Project and includes eggs and juvenile stages of fish. The definition of “fish habitat” in the *Fisheries Act* is “*water frequented by fish and any other areas on which fish depend directly or indirectly to carry out their life processes, including spawning grounds and nursery, rearing, food supply and migration areas.*”

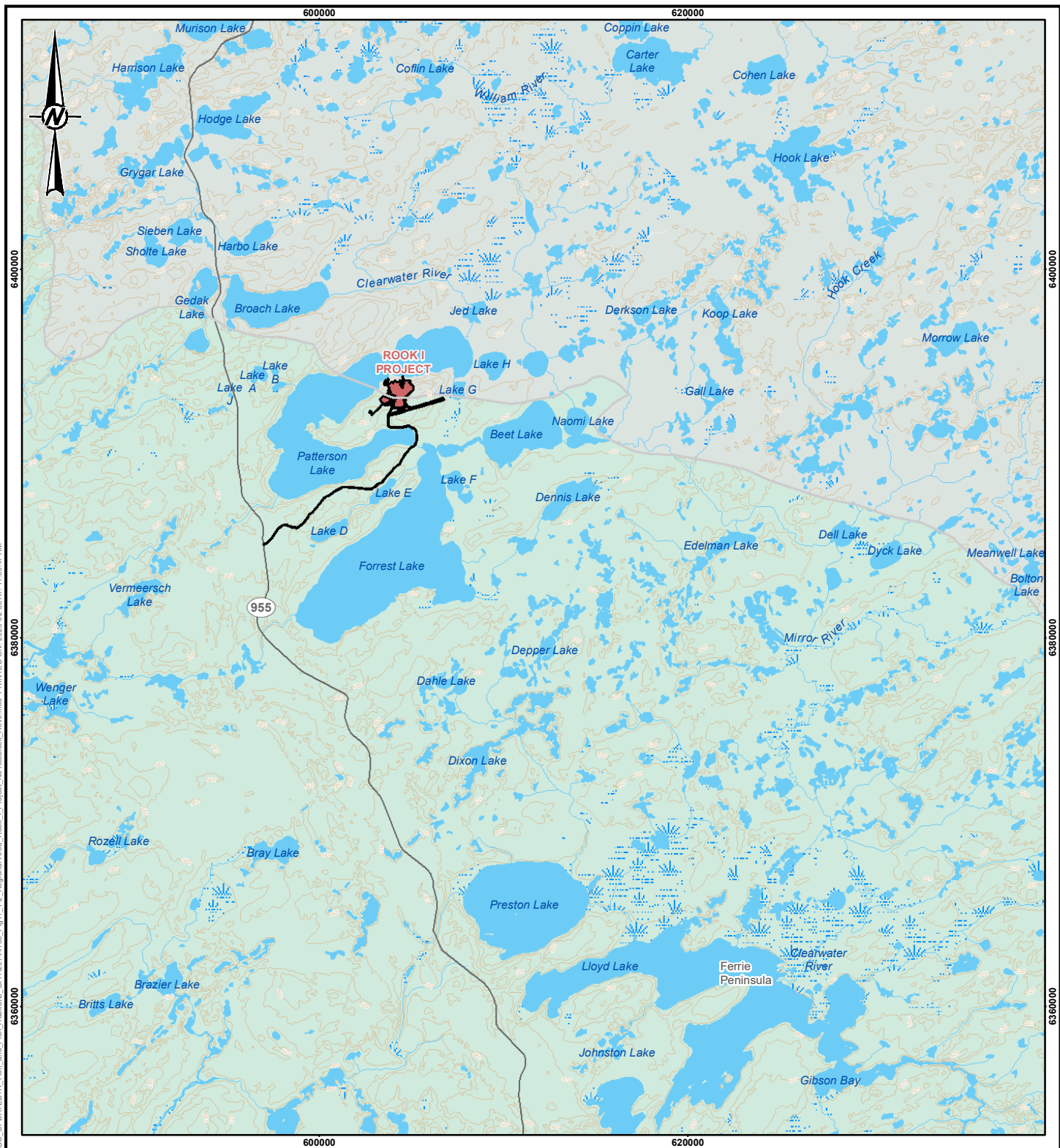
Fish have an important role in the function of the aquatic food web. Consumption of lower trophic level organisms, such as plankton (i.e., algae and small crustaceans in the water) and benthic invertebrates (i.e., small animals that live in or on the bottom substrate), by fish contributes to regulation of trophic structure and, thus, influences the stability, resilience, and food web dynamics of aquatic ecosystems. Therefore, plankton and benthic invertebrates provide important supporting information for assessing effects to fish and fish habitat and are described and characterized herein. Fish are also important food items for higher trophic level organisms in both aquatic and terrestrial ecosystems. Therefore, the results of the fish and fish habitat assessment provide information that was used to support the assessment of wildlife and wildlife habitat (Section 14, Wildlife and Wildlife Habitat).

Fish are an important resource culturally, economically, and traditionally to local Indigenous communities, and are an important contributor to tourism and recreation in the surrounding region. Changes to the health and productivity (e.g., growth and abundance) of fish and fish habitat could adversely influence the people that rely on these resources for their livelihood, subsistence, and culture. Therefore, the fish and fish habitat assessment provides information that was used to support the assessments of socio-economic VCs, particularly those discussed in 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 11.1-3, illustrates how proposed Project activities could result in a direct or indirect effect on fish and fish habitat, and the VCs that could be influenced through changes to fish and fish habitat.

RTM: ICLIENTS\NexGen\20144150\Maping\Products\FINAL_ES_FIGURES_WSP_LOGO_UPDATED\11_Fig_and_Fish_Habitat\8_5x1020144150_Fig11-1-1_Location-of-the-Rook-I-Project_NorthernRegion.mxd PRINTED ON: 2023-02-10 AT: 10:35:09 AM



\\N:\GIS\Projects\20141410\MapInfo\Products\FINAL_EIS_FIGURES\WSP\LOGO_UPDATED\11_Fish_and_Fish_Habitat08_06120144100_Fig11-2_RegionalArea_Rook_I_Project_NoTitleblock_Rev0.mxd PRINTED ON: 2023-02-08 AT: 11:39:47 AM



LEGEND

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

REFERENCE(S)

- PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021.
 - BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
- PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT



ROOK I PROJECT

TITLE

REGIONAL AREA OF THE ROOK I PROJECT

CONSULTANT



PROJECT

20144150

SCALE AS SHOWN

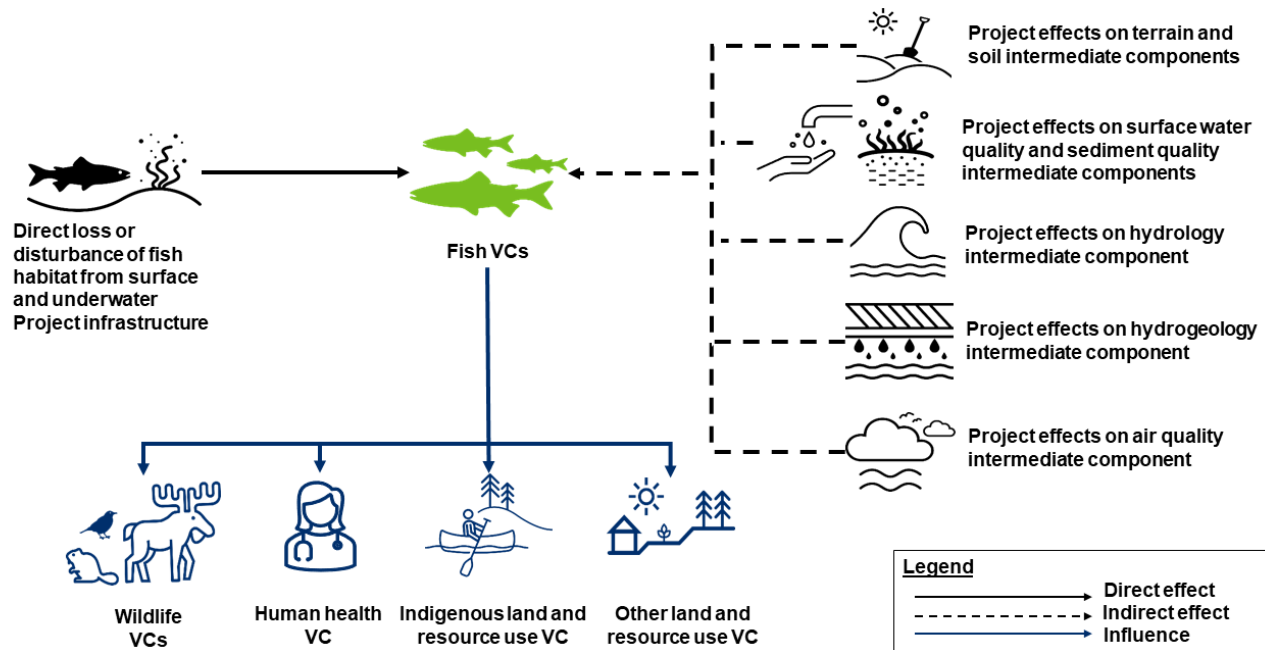
REV. 0

FIGURE 11.1-2

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

25mm

Figure 11.1-3: Linkage Diagram of Project Effects on Fish and Fish Habitat Valued Components and Influence on other Valued Components



VC = valued component

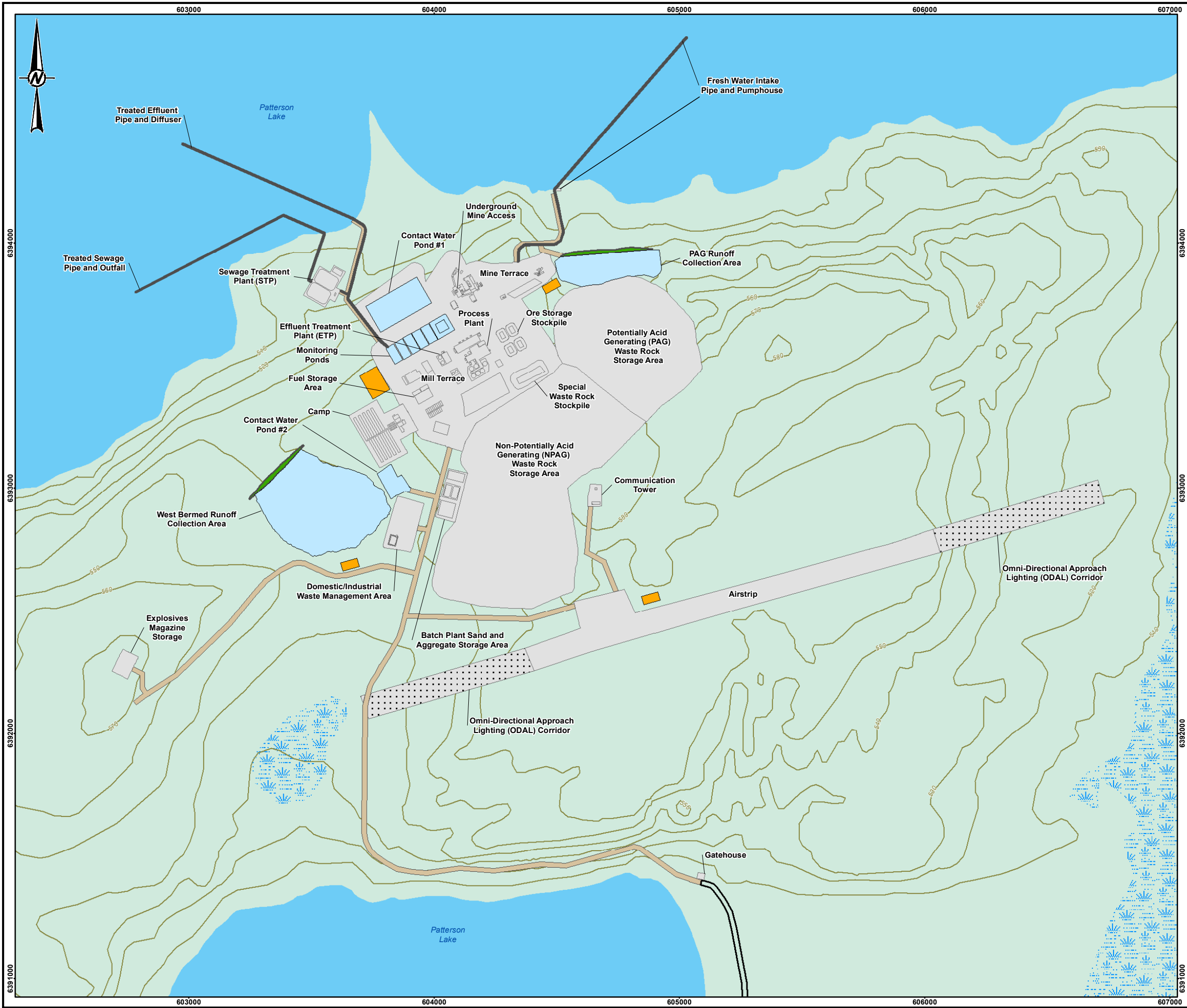
11.1.1 Project Summary

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 11.1-4):

- 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 rock¹ and ore storage stockpiles;
- surface and underground water management infrastructure, including water management ponds, effluent treatment plant (ETP), and sewage treatment plant (STP);
- 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.

¹Special waste rock is mine rock that is mineralized with insufficient grade to be considered ore (i.e., greater than 0.03% of triuranium octoxide [U₃O₈] and less than 0.26% U₃O₈). All special waste would be temporarily stored in the special waste rock stockpile.

\\01\clients\NexGen\20144150\Mapping\Process\FINAL_ES_FIGURES\WSP-LOGO_UPDATED011_Fish_and_Fish_Habitat\7x1120144150_Fig11.1-4_Layout-of-Infrastructure-and-Facilities_Rook_I_Project_Northing.mxd PRINTED ON: 2023-02-08 AT: 11:38:40 AM



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  ROOK I PROJECT			
TITLE LAYOUT OF INFRASTRUCTURE AND FACILITIES FOR THE ROOK I PROJECT			
CONSULTANT 	PROJECT 20144150	SCALE AS SHOWN	REV. 0
FIGURE 11.1-4			

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

11.1.2 Purpose and Approach to the Assessment

The purpose of Section 11 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 fish and fish habitat. 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 fish and fish habitat 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 11.2, Component Methods): presents the specific approaches and methods used to measure and assess the effects of the Project on fish and fish habitat 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 11.3, Existing Conditions): describes and characterizes existing conditions to provide context and a basis for evaluating potential changes to fish and fish habitat caused by the Project.

Step 3 – Evaluate Project interactions and mitigations (Section 11.4, Project Interactions and Mitigations): identifies Project components and/or activities with the potential to affect fish and fish habitat and provides 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 fish and fish habitat 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 11.5, Residual Effects Analysis): evaluates and describes the potential Project effects on fish and fish habitat 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 subsection also completes an analysis of residual cumulative effects from the Project, other previous and existing projects and activities, and RFDs.

Step 5 – Classify residual effects and determine significance (Section 11.5): 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 was determined using the results of the residual effects analysis and classification. Significance was 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 11.6, Prediction Confidence and Uncertainty): 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 11.7, Monitoring, Follow-up, and Adaptive Management): 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.

11.2 Component Methods

11.2.1 Incorporation of Indigenous and Local Knowledge

Indigenous and Local Knowledge included in the assessment of fish and fish habitat 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 fish and fish habitat 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 [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

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.

- TSD VI (YNLR), Provision of Athabasca Denesųliné 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 fish and fish habitat 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 fish and fish habitat assessment in the following ways:

- **Component Methods – Valued Components:** Indigenous and Local Knowledge was considered in the selection of the fish VCs and reflects species identified by Indigenous Groups and LPA communities that are important for traditional purposes. Traditional fishing is valued for cultural purposes, is an important part of traditional diets and contributes to health, and plays a key role in the intergenerational transmission of knowledge (Section 11.2.2.1).

- **Component Methods – Spatial Boundaries:** Indigenous and Local Knowledge supported the spatial boundaries used in the assessment, which includes a portion of the Clearwater River system and connecting waterbodies. Indigenous and Local Knowledge has highlighted the interconnectedness of the region's waterways and the Clearwater River as a holistic river system that has many large lakes that are connected and integral to the river and cannot be viewed in isolation (Section 11.2.3.2).
- **Component Methods – Sampling Locations:** While Indigenous and Local Knowledge was primarily received after the aquatic environmental baseline program was underway, the waterbodies that were sampled were identified as culturally important to Indigenous Groups and LPA communities and used for traditional fishing. The Patterson Lake area was identified as a culturally significant area where fishing has been practiced for generations. Therefore, the locations used to represent existing conditions generally align with Indigenous and Local Knowledge (Section 11.2.6.1).
- **Existing Conditions – Fish Communities:** Fish species observed or fished in the waterbodies and the Clearwater River in the Baseline Study Area, and observations of trends in populations, were included in the discussion of fish communities (Section 11.3.4).
- **Project Interactions and Mitigation:** Indigenous and Local Knowledge helped to inform the scoping of Project interactions, pathway analysis, and consideration of mitigation measures (Section 11.4). This includes observations and experiences of land users related to the cumulative effects of air pollution from industry, including mining activities, on water quality, fish populations, and aquatic health.
- **Monitoring, Follow-Up, and Adaptive Management:** Feedback provided by Indigenous Groups during engagement, including recommendations, was considered in the development of monitoring and follow-up activities (Section 11.7). 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 fish and fish habitat raised by Indigenous Groups and LPA community members, are included in the applicable sections of this assessment.

11.2.2 Valued Components, Measurement Indicators, and Assessment Endpoints

11.2.2.1 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 2021a). 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 considerations (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;
- species conservation status or concern (e.g., rarity, sensitivity, uniqueness);
- 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.

Seventeen fish species were identified as being present in local waterbodies and watercourses during the aquatic baseline surveys completed for the Project (Section 11.3.4, Fish Communities). None of the fish species identified are classified as provincially or federally listed species or as species with a designated conservation status by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2021). In addition, review of distribution data for aquatic species listed under the federal *Species at Risk Act* (SARA) did not identify the presence of any federally listed fish species in the area of the Project (Government of Canada 2021; DFO 2019a). Therefore, protected species are not expected to occur in waterbodies and watercourses potentially affected by the Project (Section 11.3.4), and having a federally, or provincially, designated conservation status was not a relevant criterion in the selection of VCs for fish and fish habitat. Additionally, none of the fish species identified during the baseline study would be considered rare or unique to the area based on a review of Saskatchewan's Conservation Data Centre taxa lists (Section 11.3.4; SKCDC 2021a), which provide rankings of species rarity for taxa documented to occur in the province.

Selection of fish VCs was informed by Indigenous and Local Knowledge shared during community engagement sessions for the Project in La Loche, Turnor Lake, Buffalo River, and Buffalo Narrows (Section 2 and Section 3), in JWG meetings, and in the IKTLU Studies (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; TSD VI: YNLR). Emphasis was placed on aligning fish VCs with species that are targeted or identified as important to Indigenous Groups and LPA community members.

Indigenous Groups spoke of the importance of fishing for subsistence, survival, and livelihood, and highlighted fishing as an important aspect of community and cultural life (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; TSD VI: YNLR). The importance of commercial fishing in the area surrounding the Project was also noted by Indigenous Groups, with some community members making their living fishing and selling to buyers in the community (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.2: CRDN; BRDN-JWG 2021a).

The CRDN described how “southern Denesūliné peoples, living . . . within the Upper Churchill River watershed and the southern reaches of the Athabasca Basin primarily depended on fish and more solitary big game animals” (TSD V.2: CRDN). Since fish are a mainstay in the diets of CRDN members, cabins and harvesting camps are typically located near lakes that provide a good supply of fish (TSD V.2: CRDN).

The MN-S consider the Region 2 territory as a vital source of food which provides members “a shared identity, sense of community and permanence” (TSD IV: MN-S). Community members still rely on the land and its resources, and it is estimated that approximately 70% of their food comes from hunting, trapping, fishing, and gathering (TSD IV: MN-S). Fish are an integral part of MN-S members’ traditional diet. Fish are also an important part of the traditional diets for BNDN and BRDN members, and consuming fish promotes good health and is important for community wellbeing (TSD II: BNDN; TSD III: BRDN). The BNDN commented that fishing traditions are learned from Elders and relatives and have been passed down through the generations and are an important aspect of BNDN members’ identities and land use. The YNLR also rely on a variety of fish species for traditional purposes (TSD VI: YNLR).

The BNDN and BRDN reported that fishing traditions include more than just catching and eating fish, but also include cultural activities such as community gatherings, and spending time with others while out on the land (TSD II: BNDN; TSD III: BRDN).

Showing respect for, and giving thanks to the water and resources through ceremonies is an important aspect of traditional fishing (TSD III BRDN; TSD V.2: CRDN; MN-S-JWG 2019a). For example, at harvesting cultural camps, CRDN Elders and teachers select a location next to a lake which is known to have fish, and a prayer and offerings are made to the water are made (TSD V.2: CRDN). The importance of collectively processing and sharing traditional foods, including fish, with extended family and the wider community was also noted by Indigenous Groups as a key cultural practice (TSD II: BNDN; TSD V.2: CRDN).

When we dry fish is fall time. When we go there, we go for two, three weeks. Then we fish nets, And then we’ll make dry fish to eat there....Dry meat as well there There’s my family and [another] family are all there Probably about 10 - 15 people there. And then people that come on a visit, they’ll come and eat with us. (TSD V.2: CRDN)

The BNDN and BRDN noted that specialized knowledge and skills are required to fish successfully, such as understanding the seasonal patterns of fish and where to find prime fishing locations (TSD II: BNDN; TSD III: BRDN). Indigenous and Local Knowledge related to fish and fishing is passed down to younger generations, including cultural protocols, fishing locations and techniques, how to process and store fish, assessing the health of fish and the benefits of consuming traditional foods (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.2: CRDN; TSD VI: YNLR; MN-S-JWG 2020). The intergenerational transmission of knowledge is often experiential, learned from Elders and relatives while out on the land, and therefore requires access to land and high quality, abundant resources (TSD II: BNDN; TSD III: BRDN).

[My mother] used to make [mesh] nets by herself [using string]. . . . there were [no] store-bought nets. We used to set nets for the dogs, I worked with my dad. We pulled a lot of fish for us and for the dogs. (TSD VI: YNLR)

I’ve been [fishing] – well, ever since I remember, I was fishing. And then ever since I was old enough to do it on my own, I started for myself and never quit ever since. (TSD II: BNDN)

Well my dad [taught me to fish] . . . and my grandpa. (TSD II: BNDN)

Fishing plays an important role in the relationship Indigenous Groups have with their traditional lands, especially in their connection to the lakes and rivers in the region (TSD II: BRDN). Their long history of fishing in the same lakes and rivers over generations contributes to sense of place which is “intricately connected to land and place”, is tied to people’s attachment and affiliation with the land, and is an expression of identity and familiarity (TSD II: BNDN; TSD III: BRDN). Sense of place “depends on particular places... along with their particular features (physical, social, and symbolic) and the values and activities these features foster and enable” (TSD II: BNDN).

Indigenous Groups and LPA community members indicated that land users target a variety of fish species in lakes in the area of the Project (Table 11.2-1):

- The CRDN identified grayling, (Arctic grayling [*Thymallus arcticus*]), jackfish (northern pike [*Esox lucius*]), herring (cisco; *Coregonus artedii*), lake trout (*Salvelinus namaycush*), ling cod (burbot [*Lota lota*]), pickerel (walleye [*Sander vitreus*]), suckers (white sucker [*Catostomus commersonii*] and/or longnose sucker [*Catostomus catostomus*]), and minnows as species that are considered important to community members (TSD V.1: CRDN; TSD V.2: CRDN).
- Members of the MN-S identified all manner of fish, including trout, whitefish, jack (jackfish, or northern pike), pickerel, suckers, burbot, and catfish³ as being consumed (TSD IV: MN-S; MN-S-JWG 2019a).
- Members of the BNDN pursue and rely on a variety of fish species, including lake trout, whitefish (lake whitefish [*Coregonus clupeaformis*]), jackfish, pickerel (walleye), suckers, and mariah (burbot) (TSD II: BNDN; BNDN-JWG 2019).
- Members of the BRDN described fishing for lake whitefish, lake trout, jackfish, pickerel, and perch (yellow perch [*Perca flavescens*]), and highlighted the importance of Patterson Lake as providing high quality fishing, particularly for species such as lake trout and lake whitefish (TSD III: BRDN; BRDN-JWG 2019a; BRDN-JWG 2020).
- The YNLR identified lake trout, whitefish, northern pike, suckers, and pickerel as species that are considered important to community members (TSD VI: YNLR).

A species-specific approach was considered for the selection of VCs for fish and fish habitat. This is consistent with the approach used for other higher trophic level species in the wildlife and wildlife habitat assessment (Section 14). For the EIS, four fish species were ultimately selected as VCs for assessing the effects of the Project on fish and fish habitat (Table 11.2-1): lake trout, lake whitefish, walleye, and northern pike (Table 11.2-1). These four species were identified as VCs, in part, because they were frequently noted by Indigenous Groups and LPA communities during engagement, including LPA community information sessions (NexGen 2019), JWG Meetings (BNDN-JWG 2019; BNDN-JWG 2020; BRDN-JWG 2019a; BRDN-JWG 2020; MN-S-JWG 2019b), and in IKTLU Studies (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; TSD VI: YNLR) as having high value and traditional and cultural importance. Finally, these species represent important ecosystem processes within the local aquatic environment, as they are relatively abundant in Patterson Lake, other nearby lakes, and/or in the Clearwater River, and occupy various habitat niches and trophic positions in the food web.

³ Biological species identification is uncertain. Catfish are not known to occur in the area of the Project; however, the comment may have been referring to burbot, which have a similar appearance to catfish because of the barbel (feeler) on the chin.

A few fish species noted during engagement and captured during the baseline surveys were excluded from the list of VCs (e.g., white sucker, longnose sucker, burbot, yellow perch, cisco, Arctic grayling). These species were excluded, in part, because they were mentioned relatively infrequently by communities during engagement compared to species retained as VCs (Table 11.2-1). In addition, these species occupy a similar niche, ecological space, and functional role to species retained as VCs. For example, burbot, though identified as important to some Indigenous Groups (e.g., TSD II: BNDN; TSD V.1: CRDN; TSD V.2: CRDN; MN-S-JWG 2019a), was excluded as a VC because its life history (i.e., pattern of survival and reproduction) and functional role in the aquatic food web overlaps with that of lake trout, which is also a representative pelagic (i.e., inhabiting the water column, being neither close to the bottom nor near the shore) predator, and lake whitefish, which is also a representative bottom dwelling species (Table 11.2-1). Additional rationale for excluding certain fish species identified during engagement as VCs is provided in Table 11.2-1.

Table 11.2-1: Species Considered for Selection as Valued Components

Species	Presence Confirmed by Baseline Surveys ^(a)	Provincially Tracked (Rank) ^(b)	Federally Listed (Schedule 1 SARA)	Comments from Indigenous Groups	Included as a VC	Rationale
Lake trout (<i>Salvelinus namaycush</i>)	Confirmed	No (S5)	No	- Targeted by Indigenous Groups and LPA community members (TSD II: BNDN; TSD III: BRDN; TSD V.1: CRDN; TSD V.2: CRDN; NexGen 2019) - Patterson Lake provides good fishing for lake trout (BRDN-JWG 2020) - Lake trout is fished in Patterson Lake (TSD II: BNDN; MN-S-JWG 2019b; NexGen 2019) - People travel to Patterson Lake for the opportunity to fish for lake trout (BRDN-JWG 2020) - Important for subsistence purposes (BRDN-JWG 2020)	Yes	- Captured in large lakes in the area, including Patterson Lake (Annex V.1) - Less prevalent in waterbodies in the area of the Project compared to other fish VCs (Annex V.1), but highly valued by Indigenous land users - Representative species for cold water fish and fish habitat - Completes its life history in lakes and is therefore suitable for assessing potential changes to lake habitats
Lake whitefish (<i>Coregonus clupeaformis</i>)	Confirmed	No (S5)	No	- Targeted by Indigenous Groups and LPA community members (TSD II: BNDN; TSD III: BRDN; TSD VI: YNLR; TSD V.2: CRDN; BNDN-JWG 2019; BNDN-JWG 2020; BRDN-JWG 2019a; NexGen 2019) - Patterson Lake provides good fishing for lake whitefish (BRDN-JWG 2020) - Important for subsistence (TSD III: BRDN) - Integral to traditional diet (TSD IV: MN-S); used to make pemican (TSD IV: MN-S) - A lot of lakes have lake whitefish (BNDN-JWG 2020); fished in Patterson Lake (TSD II: BNDN) - Considered a delicacy (TSD III: BRDN; TSD V.2: CRDN) - A bottom feeder and good to include (BNDN-JWG 2019)	Yes	- Abundant and widely distributed in local waterbodies, including the Clearwater River mainstem (Annex V.1) - Representative species for cold water fish and fish habitat. Completes most of its life history in lakes, with occasional movements into streams, and is therefore, suitable for assessing potential changes to lake habitats - Important prey of lake trout and walleye, which have been included as VCs; therefore, lake whitefish represent an important food web linkage to other VCs - Receptor for the EcoRA
Walleye (<i>Sander vitreus</i>)	Confirmed	No (S5)	No	- Targeted by Indigenous Groups and LPA community members (TSD II: BNDN; TSD III: BRDN; TSD V.1: CRDN; TSD V.2: CRDN; BNDN-JWG 2019; NexGen 2019) - Important for subsistence (TSD III: BRDN); integral to traditional diet (TSD IV: MN-S) - Abundance of walleye has increased (BNDN-JWG 2019) - Walleye population is healthy (BNDN-JWG 2019) - Fished in Patterson Lake (TSD II: BNDN; MN-S-JWG 2019b; NexGen 2019)	Yes	- Abundant and widely distributed in local waterbodies and watercourses (Annex V.1) - Representative species for cool water fish and fish habitat. Completes its life history in either lacustrine pelagic habitats or in riverine habitats and is therefore suitable for assessing potential changes to both lake and riverine habitats
Northern pike (<i>Esox lucius</i>)	Confirmed	No (S5)	No	- Targeted by Indigenous Groups and LPA community members (TSD II: BNDN; BNDN JWG 2020; TSD VI: YNLR; TSD III: BRDN; TSD V.2: CRDN; BNDN-JWG 2019; NexGen 2019) - Important for subsistence (TSD III: BRDN); integral to traditional diet (TSD IV: MN-S) - Fished in Patterson Lake (TSD II: BNDN; MN-S-JWG 2019b)	Yes	- Abundant and widely distributed in local waterbodies and watercourses (Annex V.1) - Representative species for cool water fish and fish habitat, and as a littoral predator. Species is also suitable for assessing potential changes to watercourse habitats - Receptor for the EcoRA
White sucker (<i>Catostomus commersonii</i>)	Confirmed	No (S4)	No	- Targeted by Indigenous Groups (TSD II: BNDN; TSD V.1: CRDN; TSD V.2: CRDN; TSD VI: YNLR) - Integral to traditional diet (TSD IV: MN-S) - Fished in Patterson Lake (TSD II: BNDN)	No	- Abundant and widely distributed in local waterbodies and watercourses (Annex V.1) - Represented by lake whitefish. The species occupies a similar niche, ecological space, and functional role as lake whitefish, which is also a representative bottom dwelling and forage species and has been included as a VC - Number of comments received from communities about the importance of sucker species was minimal compared to lake whitefish
Longnose sucker (<i>Catostomus catostomus</i>)	Confirmed	No (S5)	No		No	
Burbot (<i>Lota lota</i>)	Confirmed	No (S5)	No	Targeted by Indigenous Groups (TSD II: BNDN; TSD V.1: CRDN; TSD V.2: CRDN; MN-S-JWG 2019a)	No	- Moderately abundant and widely distributed in local waterbodies and watercourses (Annex V.1) - Life history and functional role as a pelagic predator overlaps with that of lake trout, which has been included as a VC. Functional role as a bottom dwelling species overlaps with lake whitefish, which has been included as a VC - Number of comments received from communities about the importance of burbot was minimal compared to lake trout and lake whitefish
Yellow perch (<i>Perca flavescens</i>)	Confirmed	No (S5)	No	- Targeted by Indigenous Groups (BRDN-JWG 2020) - Fishing on Patterson Lake includes harvest of yellow perch (BRDN-JWG 2020)	No	- Abundant and widely distributed in local waterbodies (Annex V.1) - Represented by lake trout. Functional role as a littoral forage species overlaps with other VCs; yellow perch is a direct competitor with lake trout and salmonid species for planktonic food and smaller fish prey - Number of comments received from communities about the importance of yellow perch was minimal compared to species that have been included as VCs

Table 11.2-1: Species Considered for Selection as Valued Components

Species	Presence Confirmed by Baseline Surveys ^(a)	Provincially Tracked (Rank) ^(b)	Federally Listed (Schedule 1 SARA)	Comments from Indigenous Groups	Included as a VC	Rationale
Cisco (<i>Coregonus artedii</i>)	Confirmed	No (S5)	No	Targeted by Indigenous Groups (TSD V.1: CRDN; TSD V.2: CRDN)	No	- Infrequently captured during the 2018 and 2019 baseline surveys (Annex V.1). Cisco were captured in only one of eight lakes surveyed (Broach Lake). Therefore, not representative of effects in the RSA - Functional role as a pelagic forage species overlaps with that of lake whitefish, which has been included as a VC - Number of comments received from communities about the importance of cisco was minimal compared to lake whitefish
Arctic grayling (<i>Thymallus arcticus</i>)	Confirmed	No (S5)	No	- Targeted by Indigenous Groups (TSD V.2: CRDN) - Not specifically mentioned in surveys for VC selection. However, Arctic grayling is targeted by Indigenous and non-Indigenous land users in northern Saskatchewan	No	- Infrequently captured during the 2018 and 2019 baseline surveys (Annex V.1). A single Arctic grayling was captured during the baseline surveys, in the Clearwater River downstream of Naomi Lake. Therefore, this species is not representative of effects in the RSA - Functional role as forage species overlaps with that of lake whitefish, which has been included as a VC. Additionally, there is overlap with northern pike, which has been included as a VC, and is considered suitable for assessing potential changes to watercourse habitats - Number of comments received from communities about the importance of Arctic grayling was minimal compared to species that have been included as VCs

a) Based on Annex V.1 Aquatic Environment Baseline Report. All large-bodied fish species captured during the baseline surveys were initially considered in the VC selection process.
b) Provincial Rank Definitions (SKCDC 2021a): S4 – Apparently secure; S5 – Secure/Common.
VC = valued component; EcoRA = ecological risk assessment; SARA = *Species at Risk Act*.

In summary, fish VCs were selected to capture a range of potential effects of the Project on fish and fish habitat, while simultaneously avoiding redundancy by selecting one representative species when multiple species occupy a similar ecological niche and/or functional role in the aquatic food web. To avoid missing functional roles or ecological processes not associated with a specific indicator species, species with a variety of habitat requirements and representing different trophic positions were selected. In addition, ecological health risks were examined in the ecological risk assessment (EcoRA), which is a component of the environmental risk assessment (ERA) (TSD XXI). In the EcoRA, aquatic species were examined to determine the sensitivity of fish and other aquatic biota to exposure of chemical substances and metals that may result from changes in surface water quality. Aquatic species or receptors included benthic invertebrates, zooplankton (i.e., microscopic animals that live suspended in the water), phytoplankton (i.e., algae that live suspended in the water), lake whitefish, and northern pike. Two of these receptors are VCs in the fish and fish habitat assessment (i.e., lake whitefish, northern pike; Table 11.2-1), and the others were evaluated in terms of their importance as food for fish and as a component of fish habitat (i.e., benthic invertebrates, zooplankton, phytoplankton). Results from the EcoRA completed for the Project (TSD XXI) were used to support the assessment of fish VCs and associated habitat.

Fish VCs selected for the Project are as follows:

- **Lake trout:** Lake trout is an important species ecologically, culturally, and socio-economically, and is targeted by both Indigenous and non-Indigenous land users. The species typically occurs in relatively deep waterbodies with cold water (Scott and Crossman 1973; Evans et al. 2002; Richardson et al. 2001; McPhail 2007). During the baseline surveys, lake trout were captured in all the large lakes in the area of the Project, including Patterson Lake (Annex V.1). The species is a long-lived, top trophic level consumer (i.e., found at the top of the aquatic food web) that is primarily piscivorous (i.e., fish-eating) but may also consume crustaceans and insects. The species is suitable for assessing how potential changes in the aquatic food base may affect species at the top of the food web. Lake trout spawn during the fall and typically rely on rocky shoals in lakes for spawning (Scott and Crossman 1973; Richardson et al. 2001; McPhail 2007).
- **Lake whitefish:** Lake whitefish is an important species ecologically, culturally, and socio-economically, and is targeted by Indigenous Groups and valued by LPA communities. Lake whitefish typically occur in lakes with cold water and is primarily a bottom-dwelling species; however, the species may occasionally be pelagic or occur in riverine (i.e., in river or watercourse) environments (McPhail and Lindsey 1970; Scott and Crossman 1973; Ford et al. 1995). The species is abundant and widely distributed in waterbodies in the area of the Project, including the Clearwater River mainstem (Annex V.1). The species is a mid-trophic level consumer (i.e., found in the middle of the aquatic food web) and feeds primarily on benthic-dwelling organisms. The species is suitable for assessing how potential changes to sediment quality and benthic invertebrates may affect fish. Lake whitefish spawn during the fall and typically rely on rocky shoals in lakes for spawning; however, spawning may also occur in rivers (Scott and Crossman 1973).
- **Walleye:** Walleye is an important species ecologically, culturally, and socio-economically, and is targeted by both Indigenous and non-Indigenous land users. Walleye occur in lakes and large rivers and are typically pelagic, moving into deeper water in the summer (Colby et al. 1979; McPhail 2007; Paragamian 1989; Scott and Crossman 1973). The species is abundant and widely distributed in waterbodies in the area of the Project, including the Clearwater River mainstem (Annex V.1). The species is a long-lived, top trophic level consumer that is primarily piscivorous but will also consume invertebrates. The species is suitable for assessing how potential changes in the aquatic food base may affect species at

the top of the food web. Walleye spawn in the late spring, primarily along gravel, boulder, or cobble along nearshore areas of lakes, or nearby tributaries (Scott and Crossman 1973).

- **Northern pike:** Northern pike is an important species ecologically, culturally, and socio-economically, and is targeted by both Indigenous and non-Indigenous land users. The species prefers relatively shallow, vegetated (i.e., weedy), clear waters in lakes and streams with a slow to moderate current (Scott and Crossman 1973; Harvey 2009). The species is abundant and widely distributed in waterbodies in the area of the Project, including in the Clearwater River (Annex V.1). The species is an upper trophic level consumer that is primarily piscivorous but will also consume invertebrates. Northern pike spawn in early spring soon after the ice melts in inundated or submerged vegetation along the floodplains and nearshore areas of rivers, streams, marshes, or shallow areas of lakes (Scott and Crossman 1973; Inskip 1982).

Additional information and description of the biology and life history characteristics of fish species selected as VCs is provided in Section 11.3.6, Fish Valued Component Life Histories.

11.2.2.2 *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). Several measurement indicators were identified and used for the fish and fish habitat assessment (Table 11.2-2). Importantly, the measurement indicators for fish VCs are connected to intermediate components in the EA such as air quality, hydrogeology, hydrology, and surface water quality. Accordingly, the results of the air quality (Section 7.2), hydrogeology (Section 8), hydrology (Section 9), and surface water quality and sediment quality (Section 10) assessments are fundamental to understanding the total effects of the Project on the fish VCs (Section 6.3.3, Intermediate Components). Results from the EcoRA completed for the Project (TSD XXI) are also incorporated into the assessment for fish VCs.

The measurement indicators for the fish VCs are defined as follows:

- **Habitat availability** (i.e., habitat quantity and quality): amount and suitability of available habitat occupied by fish. Includes consideration of the following indicators:
 - hydrology, including water levels in waterbodies and flow velocities and stream channel parameters (e.g., wetted widths) in watercourses;
 - surface water quality, including temperature, dissolved oxygen (DO) levels, suspended sediment concentrations, and the concentrations of major ions, nutrients, metals, and radionuclides; and
 - lower trophic levels, including plankton and benthic invertebrates, which provide the base of the food web.
- **Habitat distribution** (i.e., habitat arrangement and connectivity): arrangement and connectivity of habitat (e.g., habitat fragmentation) and the spatial distribution and movement of fish.
- **Survival and reproduction:** fish populations or population structure related to survival and/or recruitment (i.e., the process by which new individuals are added to a population due to factors such as spawning success).

Each measurement indicator was evaluated quantitatively where sufficient information existed to support a numerical assessment, and qualitatively where necessary.

11.2.2.3 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 significance of effects from the Project and other human developments on fish VCs is evaluated by linking changes in measurement indicators to the influence on self-sustaining and ecologically effective fish populations (Table 11.2-2). Details on the application of self-sustaining and ecologically effective populations as a significance threshold is provided in Section 11.2.9, Residual Effects Classification and Determination of Significance. The compilation and interpretation of the results from analyzing changes in measurement indicators provides lines of evidence that collectively provide a determination of whether the assessment endpoints are maintained or achieved (Section 6.3.2). The results from the EcoRA completed for the Project provide another important line of evidence in the determination of significance of effects on fish VCs (Section 6.3.4, Environmental Risk Assessment Receptors).

Table 11.2-2: Valued Components, Rationale, Measurement Indicators, and Assessment Endpoints

VCs	Rationale	Measurement Indicators	Assessment Endpoint
▪ Lake trout ▪ Lake whitefish ▪ Walleye ▪ Northern pike	▪ Traditional and/or current food source ▪ Socio-economic/cultural importance ▪ Ecological importance ▪ Relatively abundant in nearby lakes and/or the Clearwater River	▪ Habitat availability (i.e., habitat quantity and quality) ▪ Habitat distribution (i.e., habitat arrangement and connectivity) ▪ Survival and reproduction	▪ Self-sustaining and ecologically effective fish populations

VC = valued component.

11.2.3 Spatial Boundaries

Spatial boundaries for the fish and fish habitat component were defined separately for the aquatic resource environmental baseline study and the effects assessment completed for the EIS. The spatial boundary applied to the baseline surveys was selected based on an early understanding of the Project description and activities, whereas the boundaries defined for the effects assessment were based on a more advanced understanding of the Project description, footprint, and potential for effects on fish VCs. This subsection provides a description and rationale for the spatial boundaries applied during the baseline surveys and in assessing effects from the Project on fish VCs.

11.2.3.1 Baseline Study Area

The aquatic environment baseline study area (BSA) represents the area established in Annex V.1, Aquatic Environment Baseline Report. In Annex V.1, the BSA is referred to as the “aquatic study area”; however, the convention “BSA” has been applied herein for clarity and to distinguish it from the study areas considered in the fish and fish habitat effects assessment in the EIS (Section 11.2.3.2, Effects Assessment Study Areas). As described in Annex V.1:

The BSA was selected based on the watershed designated for treated effluent release, knowledge of information needed for an EA and long-term monitoring for similar developments, and consideration of potential cumulative effects.

The detailed rationale used to define the BSA is presented in Annex V.1. The BSA is shown in Figure 11.2-1 and includes the following:

- Waterbodies in close proximity to the proposed Project site: Patterson Lake and adjoining sections of the Clearwater River mainstem, Lake G, and Lake H.
- Waterbodies located along the flow path of the proposed treated effluent discharge: Patterson Lake, Forrest Lake, Beet Lake, Naomi Lake, Lloyd Lake, and adjoining sections of the Clearwater River.
- Waterbodies that could potentially be considered for reference areas during operational monitoring: Broach Lake and Hodge Lake. However, during the EA, Broach Lake was removed as a reference area as it would potentially be affected by the proposed Project as a result of air emissions and related deposition (Section 7.2).

11.2.3.2 *Effects Assessment Study Areas*

The assessment of fish and fish habitat was completed using the same spatial boundaries as those for other aquatic environment components (i.e., hydrology and surface water quality) and consists of a local study area (LSA) and regional study area (RSA) (Table 11.2-3; Figure 11.2-2). The selection of the LSA and RSA considered VC-specific and ecosystem-centred attributes and boundaries as well as the predicted maximum spatial extent of Project effects and other existing and future activities/developments (CEA Agency 2018).

The selection of spatial boundaries for the LSA and RSA was based on the physical and biological properties of VCs. Spatial scales relevant for the population or fisheries unit under examination are needed to assess project effects on fish VCs (Randall et al. 2013). Spatial scales for estimating effects on the assessment endpoint for fish VCs (Section 11.2.2, Valued Components, Measurement Indicators, and Assessment Endpoints) considered the geographic area that may potentially contribute to the fishery or self-sustaining population. The Project would be located near the headwaters of the Clearwater River system, which flows through several waterbodies, including Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake. Several smaller lakes and tributary habitats are also present adjacent to the Clearwater River mainstem, within the contributing watershed area.

The approach used to select spatial boundaries aligns with 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 2021b; BRDN-JWG 2019a; BRDN-JWG 2020; 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 . . . in a circle. And . . . 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 CRDN describe the Clearwater River as a holistic river system in which Patterson Lake and Forrest Lake, and downstream lakes (e.g., Beet Lake), are intrinsically connected to and integral to the river (TSD V.2: CRDN). Similarly, Patterson Lake and other lakes are viewed by the CRDN as connected to the network of waterbodies and watercourses in the area, rather than as discrete and separate waterbodies (TSD V.2: CRDN; CRDN-JWG

2021). 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 that members use (TSD IV: MN-S). As noted by a member of the CRDN:

It's all connected, the water, in there. And there. Where's the lake [Patterson], here. Right here. All the way, it's all connected. Lloyd Lake. . . . All this . . . here, that's all connected together. . . . all the way to the Clearwater; goes to the Mackenzie. It's all connected together That's all one river. Patterson, through Forrest, Beet Lake. The river starts here to Clearwater.
(TSD V.2: CRDN)

The entire watershed boundary of the Clearwater River upstream of the predicted maximum spatial extent of effects was considered in the delineation of study areas, as all suitable habitats in this area may potentially be used by fish VCs to live out their life histories and these areas may be important for the maintenance of self-sustaining VC populations. For example, fish populations may utilize tributary or mainstem river habitat as spawning or rearing habitat, whereas lake habitats may provide adult feeding and overwintering habitat. The use of a watershed-based approach provides the necessary context for interpreting the effects of the Project on fish VCs and is suitable for capturing potential population-level effects, as well as for determining Project effects on overall biodiversity. Additionally, the approach represents the use of both VC-specific and ecosystem-centred approaches to defining the spatial boundaries of assessment.

The LSA and RSA capture the areas where potential hydrologic and surface water quality effects from the Project may occur and may affect fish and fish habitat measurement indicators. Additionally, the spatial extent of the LSA and RSA considers pathways of exposure to constituents of potential concern (COPCs) from the Project, which were evaluated in the EcoRA (TSD XXI), including from air and dust emissions and subsequent deposition, treated effluent discharge, surface runoff, seepage from facilities, and long-term solute transport from the UGTMF and WRSAs.

The LSA for the fish and fish habitat assessment is defined as the area where both potential direct effects and local-scale indirect effects from the Project could occur. Loss of fish habitat associated with the Project's proposed fresh water intake is an example of a direct environmental effect. Potential indirect environmental effects might include changes to habitat quantity from altered stream flow or changes to habitat quality or fish survival and reproduction resulting from sediment release or treated effluent discharge. The LSA for fish and fish habitat is defined by the Clearwater River watershed boundary up to the Naomi Lake outlet (Figure 11.2-2), which covers a surface area of 68,530 ha (685 km²). There are five larger lakes in the LSA (i.e., Broach, Patterson, Forrest, Beet, and Naomi lakes), as well as several smaller waterbodies including Lake G and Lake H. For assessment purposes, Patterson Lake is divided into a North Arm and South Arm, as shown in Figure 11.2-2. The North Arm is further divided into the West Basin and East Basin. Similarly, Forrest Lake is divided into a North Arm and South Arm (Figure 11.2-2). Further details regarding the delineation of basins within these waterbodies is provided in Section 9.3.2.1, Waterbodies.

The RSA is the largest scale at which data were collected, compiled, and analyzed, and includes indirect effects that may extend beyond the LSA (CEA Agency 2018). The RSA for the fish and fish habitat component is expected to be large enough to capture the maximum predicted spatial extent of combined direct and indirect effects from the Project on fish and fish habitat. Cumulative and incremental Project effects are also expected to be captured within the RSA. The RSA includes the LSA and is defined by the Clearwater River watershed boundary upstream of the Mirror River confluence, which represents a surface area of 107,490 ha (1,076 km²). The rationale for selecting the Mirror River confluence as the downstream point defining the fish and fish habitat

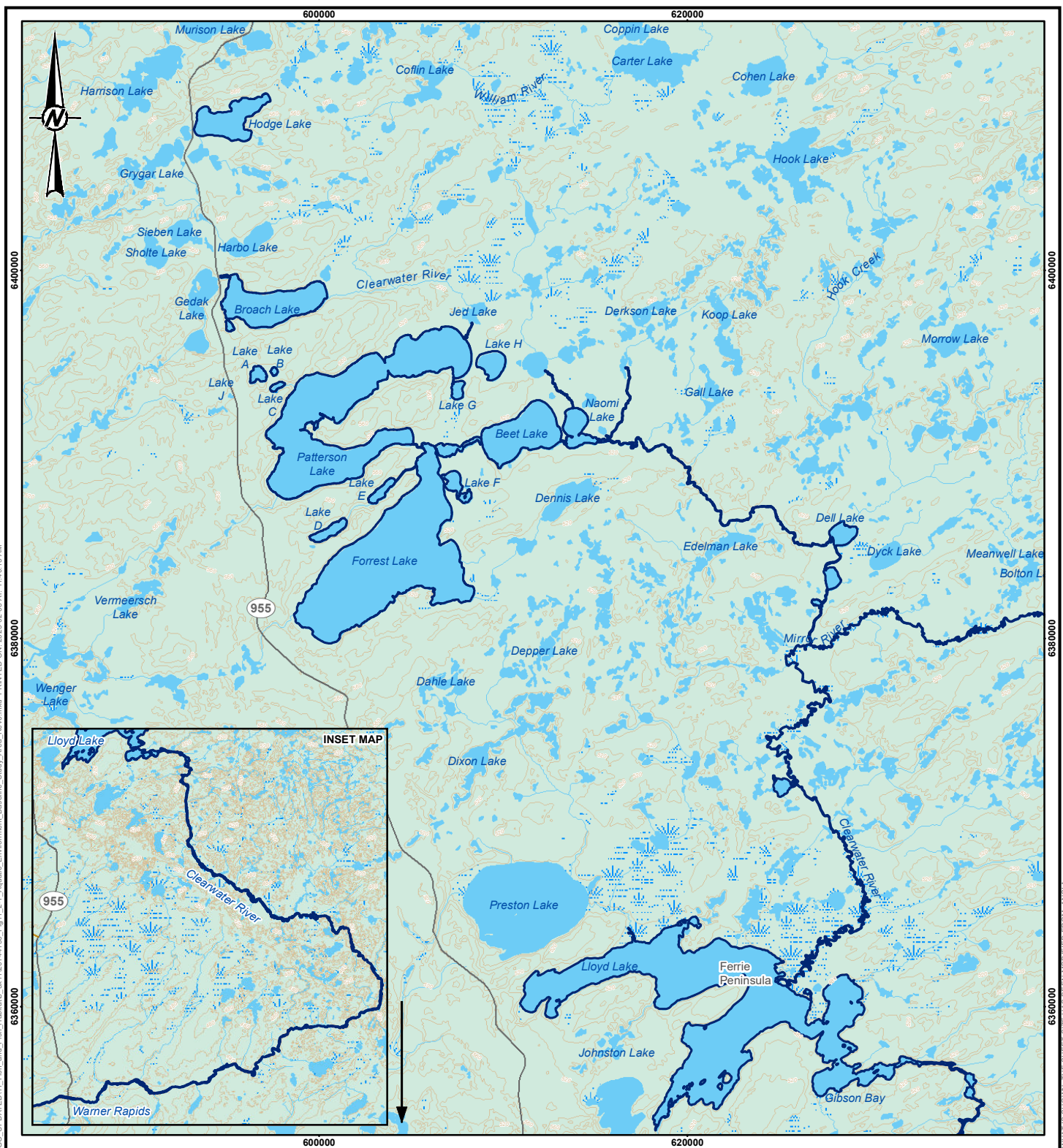
RSA is that the potential changes in surface water quantity and quality from the Project would not be greater-than-negligible downstream of this confluence due to the three-fold increase in drainage area and flows, which provide dilution and attenuation of effects associated with potential Project-related changes in hydrology and surface water quality.

Table 11.2-3: Spatial Boundaries for Assessment of Fish Valued Components

Study Area	Area	Description/Rationale
LSA	68,530 ha (685 km ²)	- Includes the Clearwater River watershed boundary upstream of the Naomi Lake outlet - Defined by the expected extent of the direct and local-scale indirect effects from the Project - Provides local context for assessing the residual effects on fish VCs
RSA	107,490 ha (1,076 km ²)	- Watershed draining to the Clearwater River above the Mirror River confluence - Provides broader scale context to capture and assess Project effects and is linked to aquatic-related exposure pathways in the EcoRA - Provides a large enough area to assess the cumulative effects on fish VCs and is the scale at which significance is determined

LSA = local study area; RSA = regional study area; EcoRA = ecological risk assessment; VC = valued component.

\\N:\GIS\Projects\NexGen\01441501\Map\Map\FIG11.2-1_Aquatic Environment Baseline Study Area_Rev0.mxd PRINTED ON: 2023-02-08 AT: 11:40:15 AM



LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA
- AQUATIC SAMPLED WATERBODY

REFERENCE(S)

- CANNORTH (CANADA NORTH ENVIRONMENTAL SERVICES). 2020. ROOK I PROJECT AQUATIC AND TERRESTRIAL ENVIRONMENT BASELINE REPORT.
 - PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021.
 - BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
- PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT



ROOK I PROJECT

TITLE

AQUATIC ENVIRONMENT BASELINE STUDY AREA

CONSULTANT



PROJECT	20144150	PHASE	3107 - 2
DESIGN	JL	2023-02-08	SCALE AS SHOWN
GIS	NO	2023-02-08	REV. 0
CHECK	KM	2023-02-08	FIGURE 11.2-1
REVIEW	KM	2023-02-08	

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

25mm

11.2.4 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 scope of the assessment is intended to evaluate the shorter- and longer-term changes from the Project and the associated Project-specific and cumulative effects on fish VCs. The duration of potential effects on fish VCs is discussed in the effects assessment (Section 11.4 and Section 11.5).

For some pathways of effects, residual effects on fish VCs were evaluated across all phases of the Project, but not necessarily for each specific phase. For example, effects on fish and fish habitat associated with development of the Project's proposed fresh water intake are anticipated to begin during Construction and continue through Operations, until effects are reversed following Active Closure Stage activities.

Where applicable, residual effects on fish VCs may be assessed in terms of environmental modelling outputs generated by intermediate components that may have a linkage to potential effects on fish VCs (i.e., air quality, hydrology, and surface water quality). For example, the hydrology component (Section 9) summarizes modelled changes in lake levels and watercourse flow rates in terms of mean annual and monthly surface water elevations and flow rate at assessment nodes along the Clearwater River mainstem during each Project phase. Where applicable, environmental modelling outputs generated by intermediate components may be referenced in the

fish and fish habitat assessment when interpreting effects on measurement indicators defined for fish VCs, which include consideration of indicators of surface water quantity and quality.

Similarly, the surface water quality component (Section 10) summarizes the results of environmental modelling for the downstream receiving environment (i.e., Patterson Lake and downstream waterbodies and watercourses) in terms of mean annual COPC concentrations for individual lakes or lake basins along the Clearwater River flow path, for each Project phase, to illustrate variation in the aquatic environment over time. For surface water quality, and the potential for corresponding effects on fish VCs, the duration of effects from the Project may occur well beyond Closure and were therefore also assessed for the far future. The far-future projection for surface water quality was considered in the fish and fish habitat assessment when evaluating potential effects on aquatic health and corresponding changes to habitat availability and the survival and reproduction measurement indicators. The far-future projection encompasses the long-term period of extremely slow migration of COPCs from the UGTMF and WRSAs to the environment, and potential for aquatic receptors to be exposed to COPCs. While it is not possible to accurately predict any process thousands of years into the future, the far-future projection is a reasonable representation of the return to steady-state conditions. Additional details and rationale for the defining the far-future projection is provided in the surface water quality assessment (Section 10.2.4, Temporal Boundaries).

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.

11.2.5 Assessment Cases

The concept of assessment cases was applied to the fish and fish habitat 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 fish VCs. Assessment cases for the Project included a Base Case, Application Case, and RFD Case.

Base Case for fish and fish habitat 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, drought) on the environment and fish and fish habitat. As such, existing conditions represent the cumulative effects of historical and current environmental pressures that have influenced the observed condition and patterns of the fish VCs (CEA Agency 2018).

Application Case for fish and fish habitat 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 fish VCs.

Reasonably Foreseeable Development Case for fish and fish habitat 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 the VCs.

A key criterion for selecting other projects to include in the RFD Case was that the projects must cause similar effects on fish VCs 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 11.2-2). 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 specifically mentioned the risk of cumulative effects from the Project and the nearby proposed Patterson Lake South Property (CRDN 2019a).

As a scenario within the RFD Case (where applicable), potential effects from climate change, including how natural factors (e.g., changes in precipitation and surface water flows) may be altered resulting from climate change, was considered within the assessment. Indigenous Groups indicated concerns about cumulative effects from human development, government policies and climate change (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN).

The fish and fish habitat assessment includes a quantitative and qualitative analysis of predicted changes on measurement indicators and associated effects from the Fission Patterson Lake South Property on fish VCs. In addition, potential changes from natural disturbance factors and climate change are qualitatively discussed for fish VCs.

11.2.6 Existing Conditions

The fish and fish habitat assessment describes and characterizes existing conditions for fish and lower trophic organisms in the LSA and RSA to provide context and a basis for evaluating potential changes from the Project. The existing conditions represent the expected conditions that exist in 2021 and prior to Project initiation. Existing conditions were evaluated quantitatively where information was available, and qualitatively where necessary, using the most up-to-date information available to provide context. The information used to characterize fish populations and fish habitat was based on a desktop review of existing information and results from field surveys completed between 2015 and 2020.

Sources and data used to characterize existing conditions for fish and fish habitat were as follows:

- *Aquatic Environment Baseline Report* (Annex V.1): This report was the primary information source used to characterize existing conditions for fish and fish habitat in the LSA and RSA. It summarizes baseline conditions for fish and fish habitat based on field surveys completed between 2018 and 2020.
- *Overwintering Fish Habitat Field Program Results Summary Report for the Rook I Project* (Annex V.2 Overwintering Fish Habitat Report): This report presents the results of a supplementary study to the Aquatic Environment Baseline Report (Annex V.1). It summarizes winter fish habitat conditions in watercourses potentially affected by the Project based on field surveys completed in 2019.
- *Naomi Lake Bathymetry Report* (Annex V.3). This report presents the work completed in 2019 to map the bathymetry of Naomi Lake to support water modelling and fish habitat assessments.
- *Background Surface Water Quality Characterization* (Appendix 10A, Surface Water Quality Modelling Report, Attachment 10A-1): This report presents baseline conditions for surface water quality during field surveys completed between 2015 and 2020. The specific relevance of this report in characterizing existing conditions for fish and fish habitat was to describe baseline lake productivity conditions (i.e., lake trophic status, as described in Section 11.2.6.1, Sampling Locations and Activities) in the LSA and RSA. Detailed information related to existing water and sediment quality conditions is provided in Section 10.
- Various technical reports and databases developed by government resource agencies, such as Fisheries and Oceans Canada (DFO) and ENV (e.g., Saskatchewan Conservation Data Centre's Hunting, Angling, and Biodiversity Information of Saskatchewan database; SKCDC 2021b). These resources were reviewed to provide additional information on fish species presence/absence and distribution in the LSA and RSA.
- Species at risk resources:
 - *Aquatic Species at Risk Map* (DFO 2019a): The DFO aquatic species at risk map provides a compilation of critical habitat and distribution data for aquatic species listed under the SARA within Canadian waters. This mapping tool was used to identify the possible presence of federally listed Species at Risk in the LSA and RSA.
 - Saskatchewan Conservation Data Centre's taxa lists (SKCDC 2021a): This online resource maintained by ENV and Nature Saskatchewan provides a centralized database on the status, location, and ecology of Saskatchewan species, including provincially threatened and endangered species in the province. This database was used to identify the possible presence of species of conservation concern.

The aquatic environment baseline sampling program (Annex V.1) was designed to collect information from waterbodies and watercourses located in the BSA (Section 11.2.3, Spatial Boundaries; Figure 11.2-1); however, results are summarized in the existing conditions section (Section 11.3) only for waterbodies and watercourses that are located in the LSA and RSA defined for the fish and fish habitat effects analysis (Section 11.2.3), with emphasis on fish habitats that would be most affected by the Project and the fish species selected as VCs (Section 11.2.2). Full details for the aquatic environment baseline study are presented in Annex V.1. The existing conditions summary for fish and fish habitat in the LSA and RSA includes the following:

- characterization of fish habitat conditions in the waterbodies and watercourse sections in the defined LSA and RSA, including spawning, nursery, rearing, feeding, and overwintering habitats;
- characterization of trophic status of waterbodies and description of lower trophic communities, including plankton and benthic invertebrate communities, as a food source for fish and indicator of habitat productivity;

- description of the fish populations comprising the local fish communities;
- description of habitat use and how fish populations complete their life history activities; and
- description of the biology and life history characteristics of the fish VC populations.

Information on existing fish and fish habitat conditions in the LSA and RSA is summarized both in terms of general conditions that are relevant to all fish VCs (i.e., lake trout, lake whitefish, walleye, and northern pike), and where feasible, specifically for individual VCs. For example, information on basic physical habitat conditions (e.g., water depth, composition of bottom substrates) and lower trophic level communities is summarized once for all fish VCs. Where available, species-specific information on fish species distribution, morphometry (i.e., body size), and presence of suitable habitats is provided for individual VCs.

11.2.6.1 *Sampling Locations and Activities*

The aquatic environment baseline sampling program was designed to collect information from waterbodies and watercourses located in the BSA (Annex V.1). Sampling activities focused on summarizing fish habitat conditions, including information on lower trophic level communities, and fish populations in Patterson Lake and downstream waterbodies on the Clearwater River flow path, as well as in adjoining mainstem sections of the Clearwater River. Sampling also occurred in smaller waterbodies located adjacent to the Clearwater River mainstem and in tributary habitats (Table 11.2-3; Figure 11.2-3). Notably, the naming conventions used for certain watercourse sections surveyed by Canada North Environmental Services (CanNorth) during the aquatic environment baseline (Annex V.1) differed from those used in the EIS main sections. Differences in naming conventions used between the Annex V.1 and the EIS main sections are summarized in Table 11.2-4.

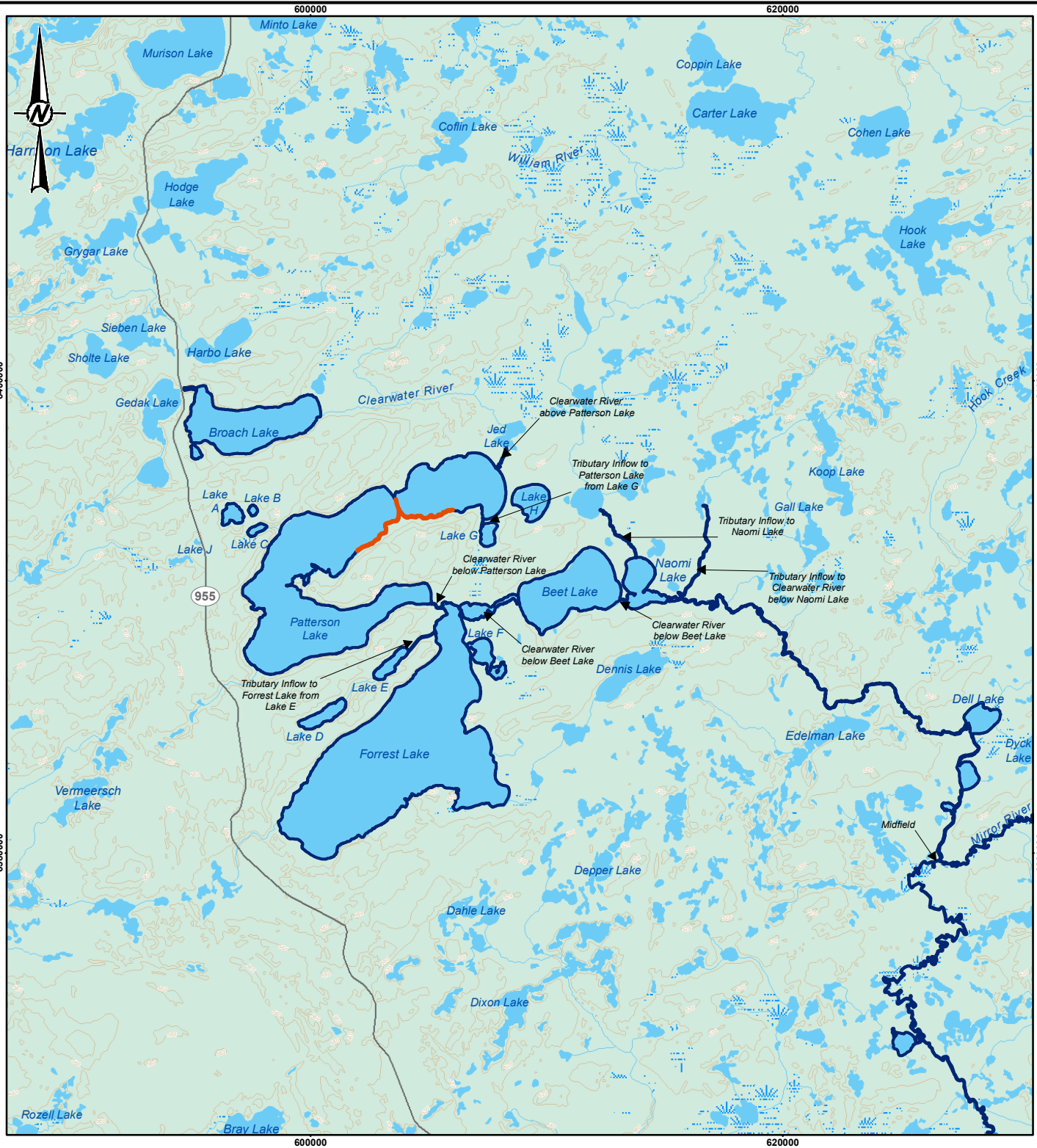
Sampling activities and survey types completed within each waterbody and watercourse are defined in Table 11.3-1. A detailed description of the sampling locations and timing of individual sampling and survey types is included in Annex V.1. An overview of the sampling methods used to conduct each survey type is provided in Sections 11.2.6.2 to 11.2.6.5; details are included in Annex V.1.

As the Project is proposed to be located adjacent to Patterson Lake, the intensity of sampling for the aquatic environment baseline was greatest in Patterson Lake. Additionally, while Patterson Lake as a whole was surveyed for all aquatic components (i.e., lower trophic communities, fish habitat, fish populations), more detail was given for some surveys within an approximately 5 km long section of the lake shoreline located immediately north of the proposed Project location. This area of the Patterson Lake shoreline adjacent to the Project, referred to in Annex V.1 as “Patterson Lake – Mine Site Area” (Figure 11.2-3), was subject to greater sampling intensity due to its proximity to the proposed Project site, and because the area is intersected by the proposed locations for the treated effluent diffuser, fresh water intake, and treated sewage outfall.

The waterbodies sampled in the aquatic environment baseline study, including Broach, Patterson, Forrest, Beet, and Naomi lakes, are culturally important to Indigenous Groups and used for harvesting, occupancy, and travel (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). The Clearwater River was identified as an ancestral water route that is still used presently to access traditional use areas (TSD IV: MN-S; TSD V.2: CRDN). The CRDN reported that the Patterson Lake, Forrest Lake, Beet Lake, and other lakes further downstream are intrinsically connected and integral to the Clearwater River (TSD V.2: CRDN), and the MN-S highlighted Patterson Lake as being central to the river system for the entire area because it feeds the lakes to the south (TSD IV: MN-S).

The Patterson Lake and Forrest Lake area is particularly significant to the CRDN and have sustained CRDN members for generations (TSD V.1: CRDN). The MN-S have described the Patterson Lake area as being 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). The CRDN view Patterson Lake and Forrest Lake as one large lake with a narrow constriction, rather than two separate waterbodies (TSD V.1: CRDN; TSD V.2: CRDN).

FILE: I:\ENVS\NexGen\0144150\Maping\Products\FINAL_EIS_FIGURES_WSP_LOGO_UPDATED\11_Fish_and_Fish_Habitat\11.2\11.2-3_Waterbodies_Sampled_Aquatic_Environment_Baseline_Study_Area_Rev0.mxd PRINTED ON: 2023-02-08 AT: 11:37:47 AM

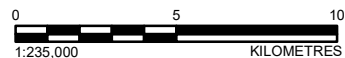


LEGEND

- ELEVATION CONTOUR (20 m INTERVAL)
- SECONDARY HIGHWAY
- WATERCOURSE
- WATERBODY
- WETLAND
- WOODED AREA

BASELINE AQUATIC STUDY AREA

- PATTERSON LAKE SHORELINE ADJACENT TO PROJECT
- AQUATIC SAMPLED WATERBODY



REFERENCE(S)

- CANNORTH (CANADA NORTH ENVIRONMENTAL SERVICES), 2020. ROOK I PROJECT AQUATIC AND TERRESTRIAL ENVIRONMENT BASELINE REPORT.
 - PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021.
 - BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
- PROJECTION: UTM ZONE 12 DATUM: NAD 83

PROJECT



ROOK I PROJECT

TITLE

WATERBODIES AND WATERCOURSES SAMPLED DURING AQUATIC ENVIRONMENT BASELINE STUDY

CONSULTANT



PROJECT	20144150	PHASE	3107 - 2
DESIGN	JL	2023-02-08	SCALE AS SHOWN
GIS	NO	2023-02-08	REV. 0
CHECK	KM	2023-02-08	FIGURE 11.2-3
REVIEW	KM	2023-02-08	

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

Table 11.2-4: Summary of Sampling Components by Waterbody and Watercourse

Waterbody or Watercourse ^(a)			In Situ Water Quality	Plankton	Benthic Invertebrates	Fish Habitat	Spring Spawning	Fall Spawning	Overwintering Habitat	Fish Community
Waterbody	Broach Lake		✓	✓	✓	✓	X	X	✓	✓
	Lake H		✓	X	✓	✓	X	X	✓	✓
	Lake G		✓	X	✓	✓	✓	X	✓	✓
	Patterson Lake		✓	✓	✓	✓	✓	✓	✓	✓
	Patterson Lake Shoreline Adjacent to Project (Patterson Lake – Mine Site Area)		X	X	✓	✓	✓	✓	✓ ^(b)	✓
	Forrest Lake		✓	✓	✓	✓	✓	✓	✓	✓
	Beet Lake		✓	✓	✓	✓	✓	✓	✓	✓
	Naomi Lake		✓	✓	✓	✓	✓	✓	✓	✓
Watercourse	Clearwater River	Clearwater River above Patterson Lake (Jed Creek)	✓	X	X	✓	✓	✓	X	✓
		Clearwater River below Patterson Lake (Patterson Creek)	X	X	X	✓	✓	✓	✓	✓
		Clearwater River above Beet Lake (Beet Channel)	X	X	X	✓	✓	X	✓	✓
		Clearwater River below Beet Lake (Beet Creek)	✓	X	X	✓	✓	X	✓	✓
		Clearwater River below Naomi Lake (Clearwater River Nearfield)	✓	X	✓	✓	✓	X	✓	✓
		Clearwater River above the Mirror River Confluence (Clearwater River Midfield 1)	✓	X	X	✓	X	X	✓	✓
	Clearwater River tributaries	Tributary inflow to Naomi Lake (Naomi Creek)	X	X	X	✓	✓	X	✓	✓
		Tributary inflow downstream of Naomi Lake (Clearwater Creek)	X	X	X	✓	✓	X	✓	✓

a) An alternative naming convention was used in Annex V.1 Aquatic Environment Baseline Report compared to that used in the EIS main sections. The naming convention used in Annex V.1 is shown in parentheses.

b) Overwintering fish habitat surveys occurred in the vicinity of the proposed locations for the treated effluent discharge and fresh water intake for mine/mill.

✓ = survey or sampling completed; X = survey or sampling not completed.

11.2.6.2 Fish Habitat Surveys

Fish habitat assessments were completed to characterize the existing fish habitat conditions in the BSA. Surveys were completed during spring, summer, and fall 2018 and during winter and summer 2019 in the waterbodies and watercourses listed in Table 11.2-4. Three types of surveys were completed: general fish habitat surveys, spawning habitat surveys, and overwintering habitat surveys. Information on in situ water quality was also collected to support the characterization of fish habitat conditions in the BSA.

In Situ Water Quality

In situ water quality parameters (i.e., water temperature, specific conductivity, DO, pH) and Secchi depth (i.e., a measure of water clarity or transparency) were measured in a subset of waterbodies and watercourses sampled in the BSA (Table 11.2-4). Water quality conditions are an important component of fish habitat, as described in Section 11.2.2.2, Measurement Indicators. Water temperature, conductivity, DO, and pH were measured using a multi-parameter water quality meter. Existing conditions were characterized based on the parameter ranges presented in Table 11.2-5.

Table 11.2-5: General Water Quality Classification of Waterbodies and Watercourses in the Baseline Study Area

Parameter	Parameter Classification	Parameter Range	Description
Secchi depth (i.e., water clarity or transparency)	Poor	<1 to <2 m	Transparency can be affected by the colour of the water, algae, and suspended sediments. Transparency decreases as colour, suspended sediments, or algal abundance increases (Wetzel 2001).
	Moderate	≥2 to ≤6 m	
	High	>6 m	
pH	Acidic	0 to <7	Most aquatic organisms can tolerate waters with a pH between 6.0 and 9.0 (Wetzel 2001).
	Neutral	7	
	Basic (i.e., alkaline)	>7 to 14	
DO	Low	<6.5 mg/L	Adequate amounts of DO are required to support fish and other organisms in aquatic systems. The DO ranges were based on the CCME water quality guidelines for the protection of aquatic life (CCME 2021; CCME 1999), which consist of guideline values for the protection of aquatic life for both “early” life stages of fish (i.e., embryo/alevin; 9.5 mg/L) and other life stages of fish (6.5 mg/L; CCME 1999).
	Moderate	6.5 to 9.5 mg/L	
	High	>9.5 mg/L	
Specific conductivity	Low	0 to 200 µS/cm	Conductivity is an indirect measure of the salinity of the water. Fish and other organisms that live in fresh water cannot tolerate large increases in salinity. Low conductivity can be an indicator of relatively undisturbed or background conditions. Mid-range conductivity is the normal background for most major rivers. High conductivity is an indicator of saline conditions (Wetzel 2001).
	Moderate	>200 to 1,000 µS/cm	
	High	>1,000 to 10,000 µS/cm	

DO = dissolved oxygen; µS/cm = microsiemens per centimetre; >= greater than; ≥ = greater than or equal to, ≤ = less than or equal to, <= less than; CCME = Canadian Council of Ministers of the Environment.

General Fish Habitat

General fish habitat surveys included characterization of baseline fish habitat conditions in waterbodies and watercourses in the BSA. The surveys were completed during the spring, summer, or fall depending on the waterbody or watercourse. The purpose of the surveys was to characterize existing spawning, nursery, rearing, feeding, and overwintering habitat conditions, and to document potentially sensitive habitats that may be present adjacent to or downstream of the Project. Additionally, the surveys provided information to inform the selection of locations for in-water developments such as the proposed fresh water intake, treated effluent diffuser, and treated sewage outfall. More detailed information on spawning and overwintering fish habitat conditions was obtained during the spawning and overwintering habitat surveys described below.

Each waterbody was divided into a series of habitat sections based on physical characteristics. Habitat surveys included assessment of the upland, riparian, and littoral zones of the surveyed areas. The upland zone refers to the area of higher, dry ground located adjacent to a waterbody or watercourse, the riparian zone refers the transitional area between the upland area and the waterbody or watercourse shoreline, and the littoral zone refers to the nearshore area of a waterbody. Information on bottom substrate composition (i.e., silt/clay, sand, gravel, cobble, boulder, or organic material) and channel characteristics (e.g., presence of riffle, run, pool, and glide habitats) was also collected. Riffles are areas of high-velocity flow and relatively shallow depth and a turbulent water surface. Runs are areas of moderate to high-velocity flow, largely non-turbulent water, and are deeper than riffles. Glides are characterized by very low, near-laminar flow (i.e., smooth flow as opposed to turbulent flow), high channel uniformity, and a lack of scour in the channel bed. Pools are deep areas with the lowest flow velocity relative to other habitat unit types and are formed by scour within the channel bed. The habitat surveys also included characterization of the density of emergent aquatic vegetation (i.e., aquatic plants that grow with their roots under water but their leaves and stems above the water surface) and submergent aquatic vegetation (i.e., aquatic plants that have their roots, leaves, and stems below the water surface), and the amount and type of fish cover present. Cover for fish is defined as aspects of the physical environment that provide resting places or protection from predators and can include physical features such as areas of undercut bank and the presence of woody debris. Additional explanation and definitions for habitat descriptors used in the fish habitat surveys, along with descriptions of the qualitative ranges used to describe the conditions, are provided in Annex V.1, Appendix C, Table 57.

Spawning Habitat

Spring and fall spawning surveys were completed to document the specific locations in the BSA that are used for spawning by large-bodied fish species, including the four fish VCs. Spring spawning surveys were completed during mid- to late May and specifically targeted spring spawning species, including northern pike and walleye. Fall spawning surveys were completed during late September to mid-October and targeted fall spawning species, including lake whitefish and lake trout.

Spawning surveys consisted of fish sampling and egg searches. The purpose of the fish sampling was to determine the spawning condition of captured fish and locate areas where fish in ripe (i.e., ready) spawning condition were most likely to spawn. The fish capture methods used during the surveys included hoop netting, gill netting, and angling. In conjunction with fishing efforts, egg searches were completed to confirm fish use the habitats as spawning habitat. Methods used to target the capture of eggs included vegetation sweeps, egg suctioning, and kick netting.

Habitats were rated for spawning habitat suitability based on known spawning habitat characteristics that are described in the scientific literature. Habitat suitability models were developed for individual species, where available. Habitat suitability models were used to predict fish use through modelling of specific environmental variables, such as water depth and substrate type. Information collected from the spawning surveys for each waterbody or watercourse was incorporated into the habitat suitability models. Habitat suitability ratings were defined as follows: not suitable, marginally suitable, moderately suitable, and most or highly suitable. Annex V.1, Section 9.2.2.2, Spawning Habitat Suitability Index, provides additional detail information regarding the assumptions used to develop the habitat suitability ratings, along with the list of supporting scientific literature considered.

Overwintering Habitat

Overwintering habitat surveys were completed to document winter habitat conditions in watercourses in the BSA. Overwintering habitat is often one of the most important habitat types for fish, particularly in northern regions, which may experience extended periods of ice cover and limited flow. Adequate winter habitat is limiting in many systems and is often an important factor affecting the distribution and abundance of fish in an environment (Cunjak 1996). Overwintering habitat surveys were completed in March 2019 during late ice-cover conditions. The survey targeted the late-winter low flow period, which would represent the most severe winter conditions for fish in these habitats. The surveys included collection of information on under-ice DO concentrations, ice thickness, snow depth, under-ice water depth, and discharge. Any distinguishing habitat features that may influence winter habitat utilization by fish were also noted (e.g., open, ice-free areas, or deep pools). Additional information on overwintering habitat surveys can be found in Annex V.2.

11.2.6.3 Lake Trophic Status

Trophic status is an accepted and widely used means of classifying lakes and describing lake processes in terms of the productivity of the system (Wetzel 2001). In this context, productivity refers to the amount and rate of production (e.g., by phytoplankton) that occurs in an ecosystem over time. Waterbodies are usually categorized into one of three classes: oligotrophic; mesotrophic; or eutrophic (Wetzel 2001). In general, waters with low productivity are classified as oligotrophic, waters with high productivity as eutrophic, and waters with intermediate productivity as mesotrophic. Further sub-classes may also be defined, such as ultra-oligotrophic, oligo-mesotrophic, meso-eutrophic, and hyper-eutrophic (CCME 2004). The trophic status of a waterbody can be assessed based on the concentration of the limiting nutrient (e.g., phosphorus) in a system. The limiting nutrient is that which limits biological productivity. Patterson Lake and the major lakes south of the Project are phosphorus-limited systems (Annex V.1).

The trophic status of each major waterbody in the BSA was evaluated by examining open-water (i.e., May to October) total phosphorus (TP) concentrations. Trophic status was determined using the Canadian Council of Ministers of the Environment (CCME 2004) trophic classification scheme for Canadian waterbodies and watercourses, which is based on TP concentrations in the water column. Following this classification scheme, waterbodies with low TP concentrations can be classified as ultra-oligotrophic (i.e., less than 0.004 mg/L) or oligotrophic (i.e., 0.004 mg/L to 0.01 mg/L); waterbodies with moderate TP concentrations can be classified as mesotrophic (i.e., 0.01 mg/L to 0.02 mg/L) or meso-eutrophic (i.e., 0.02 mg/L to 0.035 mg/L); and waterbodies with high TP concentrations can be classified as eutrophic (i.e., 0.035 mg/L to 0.1 mg/L) or hyper-eutrophic (i.e., greater than 0.1 mg/L; Table 11.2-6).

Table 11.2-6: A General Trophic Classification of Waterbodies

Trophic Classification	TP (mg/L)
Ultra-oligotrophic	<0.004
Oligotrophic	0.004 to 0.01
Mesotrophic	0.01 to 0.02
Meso-eutrophic	0.02 to 0.035
Eutrophic	0.035 to 0.1
Hyper-eutrophic	>0.1

Source: CCME 2004.

>= greater than; <= less than; TP = total phosphorus.

11.2.6.4 Lower Trophic Community Sampling

11.2.6.4.1 Plankton

Plankton is a general term referring to small, usually microscopic organisms that live suspended in the water. Plankton can be subdivided into two different groups: phytoplankton and zooplankton. Phytoplankton refers to the algal component of the plankton community, ranging between 2 µm and 20 µm in size. Zooplankton refers to microscopic animals that live suspended in the water. In general, phytoplankton provide the food base for zooplankton, which in turn are an important food source of many fish species, including early life history stages of piscivorous species. Additional information on the ecology of the dominant zooplankton and phytoplankton groups in the LSA and RSA is provided further below.

Plankton sampling occurred in a subset of waterbodies during open-water conditions in September and October 2018 and included sampling for phytoplankton and zooplankton (Table 11.2-4). The purpose of the plankton sampling was to characterize the phytoplankton and zooplankton communities in the BSA. Phytoplankton samples were collected using a depth-integrated tube sampler from within the euphotic zone (i.e., the region within the water column where photosynthesis typically occurs, defined as twice the Secchi depth). Each sample was a composite of two net hauls through the water column. Zooplankton samples were collected using an 80 µm mesh Wisconsin plankton net with a 20 cm diameter mouth size and consisted of a composite of two hauls drawn vertically through the water column. Phytoplankton and zooplankton samples were analyzed by a qualified taxonomist for taxonomic composition, density (i.e., abundance), and biomass (i.e., weight), or biovolume for phytoplankton. For phytoplankton, biovolume was converted to biomass assuming unit specific gravity.

Phytoplankton and zooplankton taxonomic richness (i.e., the number of individual taxa present, calculated at the family level); Simpson's Diversity Index (SDI; a measure of diversity which considers both the number of family level taxa [richness] and the evenness of distribution of individuals among taxa in a sample); and Simpson's Evenness Index (SEI; a measure of the equitability of distribution of individuals among taxa within the community) were also calculated. Phytoplankton and zooplankton community composition based on major group abundance (i.e., phylum, class, or order, depending on the group) were also calculated.

11.2.6.4.2 Benthic Invertebrates

The term benthic invertebrate is a general term referring to bottom-dwelling organisms (e.g., worms, snails, clams, crustaceans, insects) living on or within the sediments of waterbodies and watercourses. Benthic invertebrates are an important link in aquatic food webs. Most are herbivores, detritivores (i.e., feeding on dead, organic material), or filter-feeders, deriving much of their energy from algae, aquatic plants, and decaying organic material; however, some benthic invertebrates are predators, typically feeding upon other invertebrates. Many fish species, including early life history stages of piscivorous species, rely upon benthic invertebrates as a food source.

Benthic invertebrate samples were collected from a subset of waterbodies and watercourses during September and October 2018 (Table 11.2-4). The objective of the benthic invertebrate sampling was to collect baseline data on benthic invertebrate communities within the BSA. Benthic invertebrate samples were collected using an Ekman dredge (i.e., a grab-sampling device intended for use in soft sediments) as composites of five individual grabs and sieved using a 500 µm mesh. Benthic invertebrate samples were analyzed for abundance, biomass, and community composition. Additional community metrics calculated at the family level included richness, SDI,

and SEI (Section 11.2.6.4.1, Plankton, for descriptions of each metric). Benthic invertebrate community composition based on major group abundance was also calculated.

11.2.6.5 Fish Community Sampling

Fish community surveys targeted specific areas within the BSA (Table 11.2-4). Fish community surveys were completed during the spring, summer, or fall depending on the waterbody or watercourse. The purpose of the fish community surveys was to assess species presence, abundance, community composition, and morphometry (i.e., body size including length and weight). Fish capture methods used during the fish community surveys included angling, boat and backpack electrofishing, minnow trapping, gill netting, and dip netting. Catch-per-unit-effort (CPUE) was calculated for the boat and backpack electrofishing effort conducted in waterbodies and watercourses. Catch-per-unit effort is a measure of relative abundance that relates the number of fish captured to the effort spent fishing for a particular gear type (e.g., time spent electrofishing). It can be used to define relative abundance and compare abundances between sites. Fork length (i.e., length from nose to the indent of the caudal/tail fin), or total length where applicable, and weight were measured during selected surveys. Length and weight data for the fish VCs are summarized in the fish VC life history descriptions (Section 11.3.6).

11.2.6.6 Fish Valued Component Life Histories

Species-specific summaries were prepared for each of the four fish VC species (i.e., lake trout, lake whitefish, walleye, northern pike) and are presented in Section 11.3.6 to support the characterization of existing conditions in the LSA and RSA. These summaries are based on a literature review of the biology of the selected VC species and basic information on life history requirements (e.g., preferred habitat conditions, spawning requirements, feeding ecology). Additionally, the available fish and fish habitat baseline information was reviewed to generate species-specific summaries of fish species distribution, catch, morphometry, and documented fish use of habitat types (i.e., spawning, nursery, rearing, feeding) in the LSA and RSA.

11.2.7 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 the fish VCs (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 fish VCs.

Potential pathways from Project activities to fish VCs 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 fish VCs (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 fish.
- **Secondary pathway:** The pathway could result in a measurable but minor environmental change relative to existing conditions or guideline values, but this change is sufficiently small that it would have a negligible residual effect on fish. 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 fish.

Project interactions determined as no pathway or secondary pathways were not carried forward for further assessment (Section 6.7.3). Pathways that 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 fish VCs were carried forward to the residual effects analysis and residual effects classification (Section 11.5).

Where direct effects on fish habitat cannot be avoided or minimized, NexGen would determine through consultation with DFO where there is a harmful alteration, disruption, or destruction of fish habitat, as defined by the federal *Fisheries Act*, and would implement offsetting measures to counterbalance any residual loss through positive contributions to the aquatic ecosystem. Offsetting was not assumed to remove pathways but was considered as a factor that could be used to reduce the residual effects of a pathway on a fish VC. If required, a fish habitat offsetting plan would be developed in consultation with DFO and with engagement of the local communities, and ultimately, authorized by DFO with the goal of maintaining or improving fisheries productivity in the LSA and RSA.

11.2.8 Residual Effects Analysis

The residual effects analysis measures and describes the effects of the Project on fish VCs relative to existing conditions. The residual effects analysis was conducted using spatial boundaries (Section 11.2.3 Spatial Boundaries) and temporal boundaries (Section 11.2.4, Temporal Boundaries) identified for the assessment. The analysis used conservative assumptions and integrated information from intermediate components that may have a linkage to potential effects on fish VCs (e.g., surface water quality [Section 10]) and from relevant TSDs (e.g., TSD XXI). Where applicable, environmental modelling outputs generated in these assessments were used to provide information and context to support the interpretation of potential residual effects on fish VCs.

Residual effects are described for each of the measurement indicators for the primary pathways identified for fish VCs in the LSA and RSA (Section 11.4.3, Primary Pathways). The residual effects analysis was completed for the Application Case and the RFD Case.

The Application Case represents predictions of the cumulative effects of the previous and existing conditions (i.e., Base Case) combined with the effects from the Project. The Application Case is 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 additional RFDs in the study areas, and natural disturbance factors such as climate change.

The residual effects analyses for the Application Case and the RFD Case were completed by estimating and predicting changes to fish VC measurement indicators. Residual effects of the Project are those effects that remain after implementation of all mitigation. Predictions were summarized both in terms of general changes in measurement indicators that are applicable to all fish VCs, and where feasible, specific changes that are applicable to individual fish VCs (i.e., lake trout, lake whitefish, walleye, northern pike). Predicted changes in measurement indicators are very similar among the four species selected as VCs; therefore, instead of repeating similar information on a VC-by-VC basis, the effects were most efficiently summarized collectively for VCs with individual differences noted, where feasible. For example, potential changes to the health of lower trophic level organisms can affect all fish VCs by changing the available food base, and therefore habitat availability for fish. However, the magnitude and specific type of effect may differ among the fish VCs depending on their individual feeding ecology. These similarities and differences were accounted for in the effects analysis.

The residual effects analysis for each primary pathway and VC used logical reasoning to describe anticipated changes to each measurement indicator caused by the Project. This narrative description of anticipated effects was the foundation for the residual effects classification and significance determination detailed in Section 11.2.9.

11.2.9 Residual Effects Classification and Determination of Significance

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 each VC. 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 and significance determination. 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 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 11.2-7.

Table 11.2-7: Definitions Applied to Effects Criteria Classifications for the Assessment of Fish and Fish Habitat

Criterion	Rating	Definition
Direction	Positive	Change in measurement indicator results in net improvement or benefit to the fish VC
	Neutral	Change in measurement indicator results in net balance to the fish VC
	Negative	Change in measurement indicator results in net degradation or loss to the fish VC
Magnitude	Qualitative narrative or numeric quantification	Change in measurement indicator is described by effect size (e.g., quantitative, or qualitative description of change in VC habitat availability or survival and reproduction)
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 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 hot, dry climatic conditions)
	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; VC = valued component.

While most criteria could be assigned categorical ratings for fish VCs, predicted effect sizes were provided in specific terms (i.e., narrative or numeric quantification) in the residual effects characterization (Table 11.2-7). 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. For example, characterizing magnitude solely using an ordinal scale (i.e., low, moderate, or high) for fish VCs 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 they fail to consider context. Depending on ecological context, and context from the cumulative effects from previous and existing developments and activities that also interact with a VC, a 20% change from existing conditions in the study area may be required to cause a high magnitude effect for one VC, whereas a 2% change in the study area may be sufficient to cause a high magnitude effect for another VC (Section 6.9.1, Residual Effects Classification).

The significance of adverse residual effects on fish VCs was evaluated using the assessment endpoints as significance thresholds defined for each VC. In general, the determination of significance followed the approach provided in Section 6.9.2, Significance Determination. For fish VCs, the threshold used for significance was the maintenance of self-sustaining and ecologically effective populations at the scale of the RSA. The RSA was set using ecological boundaries at a scale suitable for the application of cumulative effects management strategies for fish VCs, and is therefore an appropriate and relevant scale for evaluating population integrity for fish VCs.

Self-sustaining fish populations are populations that will be maintained into the future with a low risk of extirpation (i.e., loss of a species or population within a defined geographic area). Self-sustaining populations are healthy and viable populations which are, by definition, robust, and capable of withstanding environmental change and accommodating stochastic population processes (Reed et al. 2003). Stochastic population processes refer to chance events such as floods or droughts that can affect population dynamics. Maintaining viable populations is a conservation target frequently applied by conservation biologists and resource managers (Fahrig 2001; Nicholson et al. 2006; Ruggiero et al. 1994; With and Crist 1995). An ecologically-effective population differs from a self-sustaining population if the number of individuals needed to maintain ecological function is greater than the number required to maintain a viable population for the long term.

The ability of a VC to accommodate disturbance was evaluated using the concepts of ecological adaptability and resilience. Adaptable fish species are those that can change their behaviour, physiology, or population characteristics (e.g., reproduction rate) in response to a disturbance such that the integrity of the population remains more or less unchanged. Adaptable species can accommodate substantial disturbance and sometimes thrive in highly modified environments, whereas species with low adaptability can accommodate little or no disturbance.

Resilience is a concept that is distinct from, yet closely related to, adaptability. Biological populations often have inertia, meaning a tendency to resist changes away from current density (Murdoch 1970), and would continue to function after disturbance up to the point where the disturbance becomes severe and long enough that the population undergoes a fundamental change. Adaptability influences the duration and magnitude of effect required for this to happen, whereas resilience defines the ability of a species' population or ecosystem to recover from disturbance. Highly resilient fish species have the potential to recover quickly from disturbance (e.g., after reclamation is achieved or an important mortality source removed), whereas species with low resilience would recover more slowly or may not recover at all (Vasconcelos et al. 2017).

Resilience, adaptability, and existing conditions provide important ecological context for the determination of significance. Existing conditions represent the combined effects of previous and current human activities and natural factors that have shaped the observed condition or patterns of each VC in the LSA and RSA. These conditions represent the starting point for assessing Project effects and were considered as context to help define how close each VC might be to its resilience limits when making the significance determination for the Project, and for future projects or natural factors, if applicable.

Ideally, effect threshold values for adaptability and resilience of a VC are known, and changes in measurement indicators can be quantified accurately and with a high degree of confidence to evaluate whether or not these have been exceeded. However, critical thresholds such as the amount or distribution of habitat required to maintain a self-sustaining population or the specific number of individuals required to maintain an ecologically effective population size, are rarely available for fish VCs. Overall, a detailed and transparent account of whether the predicted effects of the Project could be significant by causing a critical threshold to be exceeded was prepared for each VC by combining available scientific literature, data collected in the LSA and RSA, and logical reasoning (i.e., a weight of evidence or reasoned narrative approach). The determination of significance was also placed in context of how changes from the Project and RFDs could influence biodiversity (Section 6.3.5, Biodiversity). Fish VCs and measurement indicators were reviewed holistically to evaluate the potential for effects on biodiversity.

Confidence in the significance prediction was identified and discussed for each VC as part of the reasoned narrative. If uncertainty was high about where a threshold for a significant effect would occur in the range of potential values, and if the effect could be assessed as significant or not significant, a precautionary approach was applied, and the effect was identified as significant. Additional follow-up actions to reduce uncertainty were proposed.

11.2.10 Prediction Confidence and Uncertainty

The purpose of the assessment is to predict the future conditions for fish and fish habitat 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 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 fish and fish habitat and the way they were addressed are presented as part of this assessment (Section 11.6).

11.2.11 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 the installation of a silt fence, 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 effect 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).

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.

11.3 Existing Conditions

The existing environment for fish VCs is a summary of biological and environmental information collected in the LSA and RSA (Section 11.2.3). Detailed information on existing conditions for fish and fish habitat is provided in Annex V. Summaries of fish habitat conditions, including lake trophic status, lower trophic level community conditions, and fish communities are provided to characterize the Base Case against which Project effects are evaluated. Additionally, summaries outlining the biology and life history of the four fish VC species in the LSA and RSA are provided. Information related to hydrology and water and sediment quality in the LSA and RSA is provided in Section 9 and Section 10, respectively.

11.3.1 Fish Habitat

The following sections summarize the existing fish habitat conditions for each waterbody or watercourse assessed (Table 11.2-4; Figure 11.2-3) in the LSA and RSA (Figure 11.2-1). Results from habitat surveys completed for the aquatic environment baseline study (i.e., general fish habitat assessments, spring and fall spawning surveys, overwintering habitat surveys) are discussed. Detailed descriptions of the areas surveyed, including representative photographs and figures summarizing the habitat conditions within each waterbody or watercourse, are provided in Annex V.1 and Annex V.2.

The Project would be located adjacent to Patterson Lake, within the Clearwater River watershed. The headwaters of the Clearwater River are traditionally known to be situated north of Patterson Lake (CRDN 2019a). The Clearwater River flows from its headwaters at Broach Lake through a series of lakes including Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake, with a channel that is shallow, flat, and meandering (Figure 11.2-3). From Naomi Lake, the Clearwater River flows an additional 20 km southeast before reaching the Mirror River confluence. 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.

11.3.1.1 Waterbodies

Broach Lake

Broach Lake is located upstream of the proposed Project at the headwaters of the Clearwater River. The lake has a surface area of 9.3 km², a maximum depth of 82 m, and a mean depth of 26 m. During summer sampling, the average Secchi depth was 7.4 m, indicating high water clarity. Summer DO concentrations were high, averaging 10.3 mg/L, and pH was neutral, averaging 7.0. Conductivity was low, averaging 39.2 microsiemens per centimetre (µS/cm), indicating low salinity, or background conditions (Wetzel 2001).

The upland landscape consists of mature mixed forest stands. The riparian zone consists of forest stands vegetated with trees, shrubs, grasses, and sedges. The littoral zone is predominantly composed of cobble and/or boulder substrates and sections of sand. Aquatic vegetation cover is sparse to non-existent, and large woody debris is sparse. The main types of cover for fish are rock and overhanging vegetation.

Under-ice DO concentrations were observed to be high (average = 10.0 mg/L), indicating there is suitable overwintering habitat present for all species and life stages of fish.

The lake bottom predominantly consists of clean, rocky substrates (i.e., areas where the rock is relatively clear of accumulated silt or algae); these areas provide spawning habitat for fish species that prefer to spawn on rocky substrates, including walleye, lake whitefish, and lake trout. Sparse aquatic vegetation in most areas limits suitability for northern pike spawning.

Lake H

Lake H is located adjacent to the east shore of Patterson Lake North Arm – East Basin and discharges to Patterson Lake via a tributary stream. Lake H has a surface area of 1.7 km², a maximum depth of 8.2 m, and a mean depth of 1.4 m. The clarity of the water in Lake H was observed to be poor, with an average Secchi depth of 1.1 m during summer sampling. Summer DO concentrations were moderate, averaging 8.2 mg/L, and pH was slightly alkaline, averaging 7.7. Conductivity was low, averaging 38.5 µS/cm.

Nearly the entire upland zone has been burned as a result of forest fires in the area. The riparian zone consists of wet sandy beaches that have been colonized by dense grasses and sedges or of a band of rock with burnt trees and regenerating shrubs. The dominant substrate type in the littoral zone is sand, which is mixed with small amounts of organic matter. The littoral zone of the southwest portion of the lake is composed of rocky substrates, which are covered in a layer of silt and algae. Variable amounts of emergent aquatic vegetation are common, although floating vegetation is also occasionally present. Cover for fish consists of moderate to dense amounts of aquatic vegetation and undercut banks, sparse amounts of overhanging vegetation, and sparse amounts of large woody debris.

The results of winter water quality sampling in Lake H indicated that DO is naturally low during ice covered conditions (average = 2.2 mg/L). These conditions would limit fish use of the lake as overwintering habitat, particularly for species (e.g., lake whitefish and lake trout) and life stages (e.g., fry and alevin) that require high DO concentrations.

Spawning habitat for walleye, lake whitefish, and lake trout is limited due to a lack of clean, rocky substrates and the presence of aquatic vegetation and organic matter. Two shoreline areas were assessed as moderately to mostly suitable for spawning by northern pike due to the presence of moderate to dense amounts of sedge and sparse to moderate amounts of large woody debris.

Lake G

Lake G is located adjacent to the east shore of Patterson Lake North Arm – East Basin, and discharges to Patterson Lake via a tributary stream. Lake G has a surface area of 0.59 km², a maximum depth of 3.4 m, and a mean depth of 1.4 m. The water clarity was observed to be poor in Lake G, with an average Secchi depth of 0.8 m during summer. Summer DO concentrations were moderate, averaging 8.7 mg/L; pH was alkaline, averaging 8.0; and conductivity was low, averaging 38.2 µS/cm.

The upland landscape consists of mature, mixed, or coniferous forest stands, and the riparian zone is vegetated with trees, shrubs, and grasses extending to the shoreline. The dominant substrate found in the littoral zone is

sand; in some areas, small amounts of gravel, cobble, or organic matter are mixed with the sand. Cover for fish is abundant, with dense amounts of large woody debris, undercut banks, and overhanging vegetation, and sparse to dense amounts of mainly emergent aquatic vegetation.

The results of winter water quality sampling in Lake G indicated that DO is low during ice-covered conditions (average = 3.45 mg/L). These conditions would limit use of the lake by fish as overwintering habitat, particularly by species and life stages that require high DO concentrations.

Dense amounts of sedge are present along the shoreline in the north and south areas of the lake, making these areas highly suitable for northern pike spawning. The east side of the lake features substrates composed of sand, combined with small amounts of gravel or cobble, and was assessed as marginally suitable for walleye, lake whitefish, and lake trout.

Patterson Lake

Patterson Lake is located along the Clearwater River flow path, downstream of Broach Lake, and upstream of Forrest Lake. Patterson Lake has a surface area of 38.2 km², a maximum depth of 52.7 m, and a mean depth of 14.3 m. Patterson Lake is divided into the North Arm and South Arm (Figure 11.2-2). The North Arm is further divided into the West Basin and East Basin, which are separated by a narrow, shallow sand bar. The North Arm – West Basin is the deepest (i.e., 52.7 m) of the three areas of Patterson Lake.

The average Secchi depth during the summer ranged between 5.2 m and 8.7 m depending on the basin, indicating moderate to high water clarity. These results are supported by Indigenous and Local Knowledge from the CRDN about the clarity of Patterson Lake and from the BNDN and BRDN (BRDN-JWG 2019b) about lakes generally in the area of the Project:

This is all really clear, clean water too. Patterson's really clean. All this. Like this river, in here, like this connects Beet and all this stuff here. Right in this area here, until it gets to the Clearwater, is really really clear water . . . It's pretty clear into here . . . But here (tli kli na*/Where the Rivers Meet) it's all really clean clear good water. Like, Patterson, Forrest, all that, is really good water. (TSD V.2: CRDN)

Well, if it's not as clear as it was back then . . . [there's]probably [something] wrong. Because all these lakes here are just crystal-clear water . . . If you start seeing algae and all that and just – something's not right because these are all rock and sand lakes – sand bottom, rock. (TSD II: BNDN).

Summer DO concentrations were moderate to high, ranging between 6.4 mg/L and 10.1 mg/L. The pH of the water was neutral to slightly alkaline, ranging between 7.0 and 7.3. Conductivity was low, ranging between 31.2 µS/cm and 39.7 µS/cm.

The upland landscape is composed of a mature coniferous forest and some areas of burnt, regenerating, mixed, or deciduous stands. In the littoral zone, cobble and boulder are the dominant sediment types, followed by sand or a sand/gravel mixture. Limited areas of organic matter and gravel were also identified. Aquatic vegetation cover is sparse or absent. Dense rock cover and dense overhanging vegetation are the main types of fish cover present.

Under-ice DO concentrations were lower overall in the North Arm – East Basin (average = 6.4 mg/L) and higher in the North Arm – West Basin and South Arm (average = 10.1 mg/L and 9.3 mg/L, respectively). These results indicate that all three areas of the lake would provide suitable overwintering habitat for some species; however, overwintering habitat conditions for species and life stages that require higher DO levels may be more suitable in the West Basin and South Arm.

The lake bottom predominantly consists of clean, rocky substrates. These areas provide moderately to highly suitable spawning habitat for lake trout, lake whitefish, and walleye. A rock shoal with clean substrate and good water circulation is present on a point located in the North Arm of the lake, making this area highly suitable for spawning for these species. Two locations had dense emergent vegetation and were assessed as highly suitable for northern pike spawning.

Surveys were also conducted along the Patterson Lake shoreline adjacent to the proposed Project. The surrounding upland along this shoreline consists of mature mixed forest with small patches of deciduous and coniferous forest, and regenerating forest stands. The riparian zone consists of shrubs and trees. The dominant substrate in the littoral zone in approximately half of the survey area consists of sand, while the other half consists of rocky substrates (i.e., gravel, cobble, boulder), or a mixture of sand, cobble, and boulder. Rocky substrates, where present, are often covered in a thin layer of silt. Organic matter is limited to only a few areas. Aquatic vegetation cover is sparse. There were limited amounts of cover for fish. Where present, cover mainly consists of large woody debris, rock cover, and overhanging vegetation.

Similar to the rest of Patterson Lake, high quality northern pike spawning habitat is lacking along the Patterson Lake shoreline adjacent to the Project. Sand and rocky substrate and sparse amounts of emergent vegetation provide marginal spawning habitat in only a few areas. Approximately half of the surveyed area provides moderately to highly suitable spawning habitat for lake trout, lake whitefish, and walleye due to the presence of rocky substrates or a mixture of sand, cobble, gravel, and boulder substrates.

Forrest Lake

Forrest Lake is located along the Clearwater River flow path, downstream of Patterson Lake and upstream of Beet Lake. Forrest Lake has a surface area of 40.1 km², a maximum depth of 52.7 m, and a mean depth of 30.5 m. The clarity of the water during summer sampling varied from poor to high depending on the location and ranged between 1.2 m and 11.8 m. Summer DO concentrations were high, averaging 9.8 mg/L; pH was slightly alkaline, averaging 7.4; and conductivity was low, averaging 44 µS/cm.

The upland zone is composed mainly of mature coniferous forest, and some area of wetlands. The riparian vegetation is composed of trees, shrubs, grasses, and sedges. The substrate predominantly consists of cobble and/or boulder or areas of sand, with organic matter, gravel/cobble, or mixture of sand and rock substrates also being present. Aquatic vegetation cover is limited, and large woody debris is sparse. Vegetation is present mainly in the northern portion of the lake and in a bay on the east side. The main cover types for fish are overhanging vegetation and rock.

Under-ice DO concentrations were observed to be high (average = 9.8 mg/L), indicating there is suitable overwintering habitat present for all species and life stages of fish.

The northwest portion of Forrest Lake contains dense emergent vegetation beds that were assessed as moderately to highly suitable for northern pike spawning. Clean cobble and/or boulder substrates are present in several areas and provide moderately or highly suitable spawning habitat for lake trout, lake whitefish, and walleye.

Beet Lake

Beet Lake is located along the Clearwater River flow path, downstream of Forrest Lake and upstream of Naomi Lake. Beet Lake has a surface area of 8.9 km², a maximum depth of 33.7 m, and a mean depth of 10.7 m. The water clarity was high during summer sampling, with an average Secchi depth of 6.2 m. Summer DO concentrations were high, averaging 10.4 mg/L; pH was slightly alkaline, averaging 7.2; and conductivity was low, averaging 45 µS/cm.

The upland area is occupied by recently burned forest stands, though a few regenerating and mature stands are also present. The riparian zone vegetation is composed of grasses, shrubs, and trees. The substrate in the littoral zone is primarily composed of sand, with mixtures of gravel, cobble, and/or the presence of boulder substrates. Aquatic vegetation is sparse. The main cover types for fish are overhanging vegetation and rock. Large woody debris and undercut bank were present in moderate to dense amounts in some areas.

Under-ice DO concentrations were observed to be moderate (average = 7.9 mg/L), indicating there is suitable overwintering habitat present for fish, except species and life stages requiring high DO levels.

Spawning habitat for northern pike is limited or absent due to the lack of emergent vegetation. Areas with mostly sand substrate were assessed as marginally suitable as spawning habitat for walleye and lake whitefish. Some of the rocky areas present in the lake had clean or mostly clean rock substrate and were assessed as moderately suitable spawning habitat for lake trout, lake whitefish, and walleye.

Naomi Lake

Naomi Lake is located downstream of Beet Lake along the Clearwater River flow path. Naomi Lake has a surface area of 2.4 km², a maximum depth of 8.4 m, and a mean depth of 1.8 m. The water clarity was high during summer sampling, with an average Secchi depth of 6.2 m. Summer DO concentrations were moderate, averaging 7.6 mg/L; pH was slightly acidic, averaging 6.9; and conductivity was low, averaging 26 µS/cm.

The upland landscape consists of mature or burnt coniferous forest stands and the riparian zone is occupied by forest stands, with trees, shrubs, grasses, and sedges. The substrate in the littoral zone is a mixture of nearly entirely sand and organic matter, and very limited areas of cobble and boulder. Overhanging vegetation is the most abundant type of cover for fish and was present in dense or moderately dense amounts. Aquatic vegetation is also moderately abundant as cover for fish. Large woody debris and undercut cover are sparse, while rock cover is typically absent.

Habitat conditions in Naomi Lake were assessed as either not suitable or marginally suitable for spawning for lake trout, lake whitefish, and walleye due to a lack of clean, rocky substrate. The organic and sandy substrate with sometimes abundant or moderately abundant vegetation and large woody debris is more appropriate for northern pike spawning.

11.3.1.2 Clearwater River Mainstem

Clearwater River above Patterson Lake

A 100 m long section of the Clearwater River above Patterson Lake was surveyed immediately upstream of the Patterson Lake inflow. The DO concentrations in this section of the Clearwater River were moderate during summer, averaging 8.8 mg/L; pH was neutral, averaging 7.0; and conductivity was low, averaging 24.5 μ S/cm. Mature or burnt coniferous stands occupy the upland zone, while wetlands composed primarily of shrubs, grasses, and sedges are present in the riparian zone. River bottom substrates primarily consist of sand, with small amounts silt/clay, organic matter, and gravel. Mean wetted width is 8 m to 18 m, and mean depth in the centre of the channel was shallow (i.e., 0.3 m to 0.4 m). The surveyed section is composed primarily of glides. Cover for fish includes dense overhanging vegetation with moderate amounts of undercut banks. Sparse to moderate amounts of large woody debris and aquatic vegetation are also present.

The surveyed section is considered to provide good quality overwintering habitat for all life stages and species of fish due to high winter DO concentrations (average = 11.3 mg/L), abundant overhead cover, and ice-free, flowing water conditions.

Occasional areas with dense vegetation beds provide highly suitable spawning habitat for northern pike. Due to the very limited amounts of rocky substrates, the habitat is not considered suitable or only marginally suitable for lake trout, lake whitefish, and walleye.

Clearwater River below Patterson Lake

A 1 km long section of the Clearwater River was surveyed between the Patterson Lake outflow and Forrest Lake inflow. In this section of the Clearwater River, the river is composed of a single channel, except for near its entry into Forrest Lake, where the river branches into a “Y”, separating into two channels. The existing bridge crossing of the site access road is located within this section of the Clearwater River.

Mature coniferous or mixed stands occur in the upland zone and riparian zone along this section of the Clearwater River. Sand is the dominant substrate; however, relatively fast flowing waters with more rocky substrates also occur. Mean wetted width is between 3 m and 15 m, except for the two channels that branch off entering Forrest Lake where the wetted width in each channel is approximately 25 m. Mean depth in the centre of the channel is shallow (i.e., 0.4 m to 1.2 m). The surveyed section is composed predominantly of runs, although riffles, glides, and pools also occur. Cover for fish includes dense overhanging vegetation and undercut banks, with some sections of large woody debris, aquatic vegetation, or rock.

The surveyed section was considered to provide good quality overwintering habitat for all life stages and species of fish due to high DO concentrations (average = 13.6 mg/L), abundant overhead cover, and ice-free, flowing water conditions.

Due to the relatively fast flowing waters near the Patterson Lake outflow and rocky substrates, the area is considered suitable for lake whitefish and walleye spawning. The slow-moving glides and pools with dense vegetation beds provide highly suitable spawning habitat for northern pike. The habitat is considered unsuitable for lake trout spawning.

Clearwater River above Beet Lake

A 1.5 km long section of the Clearwater River above Beet Lake was surveyed between the Patterson Lake outflow and Beet Lake inflow. The upland landscape in the surveyed section of the Clearwater River is predominantly occupied by coniferous forest stands. The vegetation in the riparian zone is composed of trees, shrubs, grasses, and sedges. The substrate in the littoral zone is primarily composed of sand or organic matter, with limited areas of cobble and/or boulder. Water depths at approximately 5 m from shore are typically between 0.2 m and 0.5 m. The main cover types for fish are overhanging vegetation and undercut banks. Aquatic plant cover is usually sparse or moderate.

The surveyed section is considered to provide good quality overwintering habitat for all life stages and species of fish due to high DO concentrations (average = 12.9 mg/L), abundant overhead cover, and ice-free, flowing water conditions.

Clean, rocky substrates are mostly absent; therefore, the spawning habitat is unsuitable, or marginally suitable, for lake trout, lake whitefish, and walleye. Dense vegetation beds in the surveyed section are suitable for northern pike spawning.

Clearwater River below Beet Lake

An approximately 500 m long section of the Clearwater River was surveyed between the Beet Lake outflow and the Naomi Lake inflow. Summer DO concentrations in this section of the Clearwater River were observed to be moderate, averaging 8.4 mg/L; pH was slightly alkaline, averaging 7.5; and conductivity was low, averaging 43.1 $\mu\text{S}/\text{cm}$. Mature coniferous stands are present in the upland zone. The riparian zone is forested, with the vegetation composed of trees, shrubs, grasses, and sedges. The bottom substrate is composed of organic matter, silt/clay, and sand. Mean wetted width is 13 m to 20 m, and mean depth at the centre of the channel is near 1 m. The surveyed section consists predominantly of slow-moving glides. Cover for fish includes dense amounts of large woody debris and undercut banks, with moderate amounts of aquatic vegetation.

Frequent water depths greater than 1 m and high winter DO concentrations (average = 11.9 mg/L) at this site indicate the presence of good quality overwintering habitat for all life stages and species of fish within the surveyed section.

The moderate to dense amounts of emergent vegetation with slow-moving waters provide highly suitable spawning conditions for northern pike. The absence of rocky substrates indicate habitat is marginally suitable for lake whitefish and walleye spawning and not suitable for lake trout.

Clearwater River below Naomi Lake

A 4 km long section of the Clearwater River was surveyed beginning at the outlet of Naomi Lake. Summer DO concentrations in this section of the Clearwater River were observed to be moderate, averaging 9.3 mg/L; pH was slightly alkaline, averaging 7.6; and conductivity was low, averaging 36.9 $\mu\text{S}/\text{cm}$. The upland zone consists of mature coniferous forest stands, and the riparian zone consists of forest extending to the bank, with trees, shrubs, grasses, and sedges present. The bottom substrate consists of sand with smaller amounts of silt/clay and organic matter, and gravel, cobble, and boulder. Water depths at 5 m from the shoreline are moderately shallow, ranging from 0.3 m to 1.4 m. Most areas within the section consist of glides, with limited areas of riffle habitat. The main cover types for fish are overhanging vegetation, and aquatic vegetation.

The surveyed section is considered to provide good suitability overwintering habitat for some life stages and species of fish based on the moderate DO levels (average = 7.9 mg/L), and ice-free, flowing water conditions

encountered at the site. Overwintering habitat may be more limiting for sensitive species or life stages (e.g., embryos or newly hatched trout) that require higher DO concentrations.

Dense vegetation beds occur often along this section and provide suitable spawning habitat for northern pike. The surveyed section was assessed as unsuitable or marginally suitable as spawning habitat for lake whitefish and walleye due to the general lack of clean rock. However, limited areas of highly suitable spawning habitat for these species were identified. The habitat is considered unsuitable for lake trout spawning.

Clearwater River above the Mirror River Confluence

An approximately 800 m long section of the Clearwater River was surveyed upstream of the Mirror River confluence. Summer DO concentrations in this section of the Clearwater River were observed to be moderate, averaging 7.8 mg/L; pH was slightly alkaline, averaging 7.3; and conductivity was low, averaging 32.4 μ S/cm. The surrounding upland consists of mature coniferous forest, and the riparian zone consists of wetlands vegetated with trees, shrubs, grasses, and sedges. The bottom substrate is predominantly sand mixed with organics, with limited areas of cobble/gravel. Dense amounts of submergent macrophytes are present. Cover for fish consists of aquatic vegetation and overhanging vegetation and limited amounts of large woody debris and undercut banks.

Approximately half of the surveyed section is considered to be moderately to highly suitable spawning habitat for northern pike due to the presence of dense beds of sedge and shallow water depths. Moderately suitable spawning habitat for lake trout, lake whitefish, and walleye was identified in the upstream portion of the surveyed section where sand, gravel, and cobble substrates are present.

11.3.1.3 Clearwater River Tributaries

Tributary Inflow to Naomi Lake

The tributary inflow to Naomi Lake flows south into Naomi Lake at the north end of the lake. An approximately 150 m long section of the tributary was surveyed. The upland area consists of a mature mixed forest stand, with a forested riparian vegetation consisting of trees, shrubs, grasses, and sedges. The bottom substrate consists of organics with small amounts silt/clay and sand. Mean wetted width is 15 m, and mean depth in the centre of the channel is shallow (i.e., 0.4 m). Beaver (*Castor canadensis*) activity was evident during surveying, but fish passage was possible. The surveyed section is composed predominantly of pool habitat with a small amount of glide habitat. Dense aquatic vegetation, overhanging vegetation, and moderate amounts of undercut bank are the main sources of cover for fish. Sparse amounts of large woody debris are present.

The overwintering habitat potential is considered to be suitable for species and life stages of fish that are tolerant of moderate DO concentrations encountered at this site during the winter survey (average = 8.8 mg/L) but may be more limiting for more sensitive species or life stages that require higher DO concentrations. Dense vegetation beds provide suitable spawning habitat for northern pike. Rocky substrates are absent; therefore, the surveyed section is considered to be marginally suitable for lake whitefish and walleye spawning and not suitable for lake trout.

Tributary Inflow Downstream of Naomi Lake

The tributary inflow downstream of Naomi Lake flows south into the Clearwater River. An approximately 150 m long section of the tributary was surveyed upstream of the confluence with the Clearwater River. The upland area consists of mature coniferous forest stands. The riparian zone is forested with vegetation consisting of trees, shrubs, grasses, and sedges. The bottom substrate consists of sand and organic matter. Mean wetted width ranges between 5 m and 22 m, and mean depth in the centre of the channel is shallow (i.e., 0.5 m to 0.6 m). The surveyed section consists of slow-moving pools and glides. Dense aquatic vegetation and moderate amounts of overhanging vegetation are the predominant types of cover for fish.

The vegetation beds present in the surveyed section, combined with slow-moving waters, provide moderately suitable spawning habitat for northern pike. Rocky substrates are absent; therefore, the surveyed section is considered as unsuitable, or at best, marginally suitable for lake trout, lake whitefish, and walleye spawning.

11.3.2 Lake Trophic Status

Open-water concentrations of TP were typically measured at or below the analytical detection limit (DL) of 0.01 mg/L in all waterbodies surveyed, including Broach Lake, Lake H, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake (Table 11.3-1). These waterbodies were classified as oligotrophic based on the CCME (2004) classification system (Section 11.2.6.1). The exception was Lake G, which was classified as mesotrophic, based on TP concentrations ranging between 0.01 mg/L and 0.02 mg/L.

Table 11.3-1: Existing Concentrations of Total Phosphorus Concentrations and Trophic Classification by Waterbody

Waterbodies	Existing Conditions			
	TP (mg/L)			Trophic Status
	Min.	Mean	Max.	
Broach Lake	<0.01	<0.01	0.01	Oligotrophic
Patterson Lake	<0.01	<0.01	<0.01	Oligotrophic
Lake H	<0.01	<0.01	0.02	Oligotrophic
Lake G	<0.01	0.01	0.02	Mesotrophic
Forrest Lake	<0.01	<0.01	<0.01	Oligotrophic
Beet Lake	<0.01	<0.01	<0.01	Oligotrophic
Naomi Lake	<0.01	<0.01	<0.01	Oligotrophic

Note: A method detection limit of 0.01 mg/L was used for the open-water monitoring results (Annex V.1).

<= less than; TP = total phosphorus.

11.3.3 Lower Trophic Communities

The following sections provide a summary of lower trophic level community conditions for each waterbody or watercourse assessed in the LSA and RSA, including information related to phytoplankton, zooplankton, and benthic invertebrates. Detailed results for community metrics are provided in Annex V.1.

Based on the results for all waterbodies, sampled phytoplankton abundance ranged from 4.3 million cells per litre to 12.2 million cells per litre, biomass ranged from 0.09 µg/L to 1.83 µg/L, and richness ranged from 18 to 27 taxa. The SDI⁴ was moderate to high, ranging from 0.63 to 0.79, and the SEI⁵ was low, ranging between 0.10 and 0.21.

The dominant major phytoplankton groups identified in the BSA were:

- **Cyanobacteria (Cyanophycota in Annex V.1), commonly known as blue-green algae:** Cyanobacteria can out-compete other groups when there are increases in available phosphorus, a limiting nutrient for algae in fresh water (Schindler 1974), because most Cyanobacteria species are capable of fixing atmospheric nitrogen (i.e., changing free nitrogen to nitrate, nitrite, or ammonia; Wehr and Sheath 2003). However, if there is a substantial nitrogen load to a waterbody, it can cause continued phosphorus limitation, which reduces the competitive advantage of Cyanobacteria over other groups of phytoplankton.
- **Chrysophyceae or chrysophytes (Chrysophyta in Annex V.1), commonly known as golden-brown algae:** Chrysophytes are known to frequently dominate or co-dominate phytoplankton biomass (i.e., mass of living algal material at a given area in a given period of time) in clear oligotrophic waterbodies with low temperature, light, alkalinity (0 mg/L to 60 mg/L, calcium carbonate), conductivity (less than 50 µS/cm), and nutrient concentrations (Wehr and Sheath 2003).
- **Bacillariophyceae or diatoms (Bacillariophyta in Annex V.1):** Diatoms have high silica requirements for cell wall development (Wehr and Sheath 2003). Silica is often a limiting nutrient for diatom growth in many waterbodies (Wehr and Sheath 2003); however, if there are sustained inputs of silica (i.e., greater than 100 µg/L; Reynolds 2006), diatom growth is not inhibited, and this major group can constitute a large proportion of the phytoplankton community.
- **Chlorophyceae or chlorophytes (Viridiplantae in Annex V.1, commonly known as green algae):** Chlorophytes are a ubiquitous group present in waterbodies with differing nutrient and salinity concentrations; generally, increased salinity does not inhibit chlorophyte growth (Wetzel 2001).

The remaining phytoplankton groups contribute less than 5% to the overall abundance (Annex V.1) and are not considered dominant groups.

Sampled zooplankton abundance ranged between 33 organisms per litre (org/L) and 65 org/L, biomass ranged from 0.06 mg/L to 0.30 mg/L, and richness typically ranged between 7 taxa and 13 taxa. The SDI was moderate to high, ranging from 0.40 to 0.80, and the SEI was low to moderate in all areas, ranging between 0.17 and 0.49.

The dominant major zooplankton groups identified in the BSA were:

- **Cladocera or cladocerans, small crustaceans commonly known as water fleas:** Cladocerans are generally found in eutrophic, phytoplankton-rich waterbodies, while their abundance is often low in oligotrophic waterbodies (de Bernardi et al. 1987). Cladocerans are filter feeders that graze on phytoplankton, bacteria, and detritus (i.e., dead organic material). Cladocerans are a favourite prey for macroinvertebrates and fish and are an important group in waterbodies with regard to energy transfer along the food chain because of their short generation times and their high reproductive efficiency (de Bernardi et al. 1987).

⁴ Simpson's Diversity Index values range between 0 and 1 (Renkonen 1938); values between 0 and 0.25 indicate low diversity, values between 0.25 and 0.75 indicate moderate diversity, and values greater than 0.75 indicate high diversity.

⁵ Simpson's Evenness Index values range between 0 and 1 (Renkonen 1938); values between 0 and 0.25 indicate low evenness, values between 0.25 and 0.75 indicate moderate evenness, and values greater than 0.75 indicate high evenness.

- **Calanoida and Cyclopoida (or calanoid and cyclopoid copepods), small crustaceans commonly known as copepods:** Copepods are generally the dominant members of the zooplankton in waterbodies and are a major food source for small fish. Cyclopoid and calanoid copepods are examined separately because calanoid copepods are typically herbivorous, feeding on phytoplankton, while cyclopoid copepods are typically omnivorous, feeding on phytoplankton and small zooplankton (Brönmark and Hansson 1998). Calanoid copepods are almost exclusively pelagic (i.e., open-water), while cyclopoid copepods are dominated by littoral (i.e., nearshore) species, although a few pelagic species of cyclopoid copepods can account for a major component of the planktonic community.
- **Rotifera or rotifers (i.e., Collotheceae, Flosculariaceae, and Ploima in Annex V.1), commonly known as wheeled animals:** Rotifers are generally sessile (i.e., fixed in place) and associated with the nearshore area; however, the few planktonic taxa that do exist can form a major component of the zooplankton community. Rotifers filter feed on food particles less than 12 µm in diameter such as bacteria, small algae, and detritus. Their food requirements are high in relation to their small size (Wetzel 2001).

Most waterbodies sampled had average benthic invertebrate densities that ranged between 1,000 organisms per square metre (org/m²) and 5,000 org/m². Average taxon richness ranged between 8 taxa and 16 taxa per sample in most areas. In more than half of the locations surveyed, average SDI was moderately high, ranging between 0.61 and 0.77. Average SEI was low to moderate, measuring lower than 0.35 in most study areas.

Major benthic invertebrate groups identified in waterbodies and watercourses were:

- **Chironomidae, or chironomids, a member of the group Diptera, or dipterans (i.e., true or two-winged flies), and commonly known as midges:** All larval (i.e., immature forms) chironomids are aquatic and are found in all types of aquatic habitats (Clifford 1991). They are often the dominant aquatic family of dipterans. Some chironomids can withstand low oxygen levels and can live in the oxygen-poor substrata of some deep lakes. Chironomid larvae can be very important in aquatic food chains. Some larvae are predacious, but most are omnivorous.
- **Amphipoda, an order of crustacean, especially the genera *Gammarus* sp. and *Hyaella* sp.:** These amphipods, especially *Gammarus* sp., are sometimes found in large numbers in almost all unpolluted standing waters, primarily in shallow waterbodies and occasionally in slow-moving watercourses (Clifford 1991). *Gammarus* sp. and *Hyaella* sp. are commonly known as scuds and fresh water shrimp and often occur together. They feed mainly on dead animal and plant matter, but some are active carnivores.
- **Oligochaeta, or oligochaetes, commonly known as aquatic earthworms:** Oligochaetes are found in a variety of aquatic habitats (Clifford 1991). Some oligochaetes can tolerate low oxygen levels and may be found in large numbers in polluted habitats. The oligochaete gut is one-way and terminates at the posterior end of the body. Most fresh water oligochaetes feed by passing mud and debris through the gut and extracting organic matter from this material (Clifford 1991).
- **Non-Unionidae Mollusca, or small bivalves, commonly known as fingernail clams:** Fingernail clams are usually found in small watercourses (Clifford 1991). The two sides (i.e., valves) of the shell are the most conspicuous feature of these bivalves. The two valves interlock with each other by teeth. Bivalves are filter feeders, and the gills are very important in feeding. Water containing minute food material (e.g., organic detritus, algae, and zooplankton) enters the mantle cavity and adheres to gill filament surfaces.

- **Ephemeroptera, or ephemeropterans, commonly known as mayflies:** Ephemeropterans have a very brief adult life span; usually adults live less than three days (Clifford 1991). Larvae are found in both unpolluted standing water and unpolluted running water. They achieve their greatest diversity in watercourses and can be an important food item for fish. Mayfly larvae are mainly detritivores, but they might eat substantial amounts of algae, especially diatoms. A few species are entirely carnivorous.
- **Trichoptera, or trichopterans, commonly known as caddisflies:** Caddisfly larvae often construct cases or fixed retreats in which the larvae live (Clifford 1991). Cases can be of a variety of plant or mineral matter or both, depending on the caddisfly. Caddisfly larvae are found in all types of unpolluted aquatic habitats. Most are omnivorous or herbivorous, but some are predacious.

11.3.3.1 Waterbodies

Broach Lake

Phytoplankton

Phytoplankton abundance (9,904,790 cells per litre) and biomass (0.21 µg/L) in Broach Lake were low and within the range characteristic of other oligotrophic temperate waterbodies (Levine and Schindler 1999) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were 22 taxa counted, with a moderate SDI of 0.69, indicating a relatively diverse community. The SEI was low (0.15), indicating the community was represented by only a few taxa. At the major group level (i.e., phylum or class), the community was dominated by Cyanobacteria (92%).

Zooplankton

Zooplankton abundance (35 org/L) and biomass (0.19 mg/L) in Broach Lake were low and within the range characteristic of other oligotrophic temperate waterbodies (Yan 1986) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were 10 taxa counted, with a moderate SDI value of 0.40, indicating a relatively diverse community. The SEI was low (0.17), indicating the community was represented by only a few taxa. At the major group level (i.e., phylum or order), the community was dominated by cyclopoid copepods (76%), followed by cladocerans (26%) and rotifers (17%).

Benthic Invertebrates

Total invertebrate density (average = 1,329 org/m²) and family-level richness (average = 8 taxa) in Broach Lake were low, and similar to subarctic lakes on the Canadian Shield (De Beers 2019, 2021b; Golder 2020). The average biomass was 2.3 g/m². The SDI was moderate, averaging 0.69, indicating a relatively diverse community. The SEI was also moderate, averaging 0.44, indicating the community was represented by a moderate number of taxa. The community was dominated by Chironomidae (51%) followed by Mollusca (24%).

Lake H

Benthic Invertebrates

Total invertebrate density (average = 297 org/m²) and family-level richness (four taxa) in Lake H were low, and similar to subarctic lakes on the Canadian Shield (De Beers 2019, 2021b; Golder 2020). The SDI was moderate, averaging 0.47, indicating a relatively diverse community. The average biomass was 1.8 g/m². The SEI was also moderate, averaging 0.58, indicating the community was represented by a moderate number of taxa. The community was dominated by Chironomidae (67%) followed by Oligochaeta (15%).

Lake G

Benthic Invertebrates

Total invertebrate density (average = 23,581 org/m²) and family-level richness (average = 15 taxa) in Lake G were moderate and similar to subarctic lakes on the Canadian Shield (De Beers 2019, 2021b; Golder 2020). The average biomass was 52.3 g/m². The SDI was moderate, averaging 0.50, indicating a relatively diverse community. The SEI was low, averaging 0.15, indicating the community was represented by few taxa. The community was dominated by Chironomidae (70%) followed by non-Unionidae Mollusca (13%).

Patterson Lake

Phytoplankton

Phytoplankton abundance (12,244,628 org/L) and biomass (0.61 µg/L) in Patterson Lake were low and within the range characteristic of other oligotrophic temperate waterbodies (Levine and Schindler 1999) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were 18 taxa counted, with a moderate SDI of 0.64, indicating a relatively diverse community. The SEI was low (0.15), indicating the community was represented by only a few taxa. At the major group level (i.e., division or class), the community was dominated by Cyanobacteria (82%), followed by chrysophytes (13%).

Zooplankton

Zooplankton abundance (52 org/L) and biomass (0.06 mg/L) in Patterson Lake were low and within the range characteristic of other oligotrophic temperate waterbodies (Yan 1986) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were eight taxa counted, with a high SDI value of 0.84, indicating a diverse community. The SEI was moderate (0.49), indicating the community was represented by a moderate number of taxa. At the major group level (i.e., phylum or order), the community was dominated by rotifers (62%), followed by cladocerans (26%) and cyclopoid copepods (11%).

Benthic Invertebrates

Total invertebrate density (average = 5,510 org/m²) and family-level richness (11 taxa) in Patterson Lake were low, and similar to subarctic lakes on the Canadian Shield (De Beers 2019, 2021b; Golder 2020). The average biomass was 4.7 g/m². The SDI and SEI were moderate, averaging 0.59 and 0.27, respectively, indicating a relatively diverse community. The community was dominated by Chironomidae (51%), followed by non-Unionidae Mollusca (24%).

Total invertebrate density and family-level richness from samples collected along the Patterson Lake shoreline adjacent to the proposed Project were low, averaging 2,097 org/m² and 14 taxa, respectively. The average biomass was 2.7 g/m². The SDI was high, averaging 0.76, indicating a diverse community. The SEI was moderate, averaging 0.31, indicating the community was represented by a moderate number of taxa. The community was dominated by non-Unionidae Mollusca (35%) followed by Chironomidae (29%).

Forrest Lake

Phytoplankton

Phytoplankton abundance (4,297,915 org/L) and biomass (0.09 µg/L) in Forrest Lake were low and within the range characteristic of other oligotrophic temperate waterbodies (Levine and Schindler 1999) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were 27 taxa counted, with a moderate SDI of 0.63, indicating a relatively diverse community. The SEI was low (0.10), indicating the community was represented by only a few taxa. At the major group level (i.e., division or class), the community was dominated by Cyanobacteria (89%).

Zooplankton

Zooplankton abundance (46 org/L) and biomass (0.21 mg/L) in Forrest Lake were low, and within the range characteristic of other oligotrophic temperate waterbodies (Yan 1986) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were seven taxa counted, with a moderate SDI (0.58) and moderate SEI (0.34), indicating a relatively diverse community. At the major group level (i.e., phylum or order), the community was dominated by cyclopoid copepods (55%) followed by rotifers (40%).

Benthic Invertebrates

Total invertebrate density (average = 8,897 org/m²) and family-level richness (14 taxa) in Forrest Lake were low, and similar to subarctic lakes on the Canadian Shield (De Beers 2019, 2021b; Golder 2020). The average biomass was 24.3 g/m². The SDI and SEI were moderate, averaging 0.67 and 0.278, respectively, indicating a relatively diverse community. The SEI was moderate, averaging 0.27, indicating the community was represented by a few taxa. The community was dominated by Chironomidae (37%), followed by non-Unionidae Mollusca (24%) and Amphipoda (21%).

Beet Lake

Phytoplankton

Phytoplankton abundance (10,666,491 org/L) and biomass (1.07 µg/L) in Beet Lake were low, and within the range of other oligotrophic temperate waterbodies (Levine and Schindler 1999) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were 21 taxa counted, with a moderate SDI of 0.67, indicating a relatively diverse community. The SEI was low (0.14), indicating the community was represented by only a few taxa. At the major group level (i.e., division or class), the community was dominated by Cyanobacteria (72%), followed by chrysophytes (11%) and diatoms (10%).

Zooplankton

Zooplankton abundance (144 org/L) and biomass (0.30 mg/L) in Beet Lake were low and within the range of other oligotrophic temperate waterbodies (Yan 1986) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were 12 taxa counted, with a moderate SDI value of 0.68, indicating a relatively diverse community. The SEI was low to moderate (0.26), indicating the community was represented by a few taxa. At the major group level (i.e., phylum or order), the community was dominated by cyclopoid copepods (51%), followed by rotifers (27%) and cladocerans (22%).

Benthic Invertebrates

Total invertebrate density (average = 2,445 org/m²) and family-level richness (average = 14 taxa) in Beet Lake were low and similar to subarctic lakes on the Canadian Shield (De Beers 2019, 2021b; Golder 2020). The average biomass was 3.2 g/m². The SDI was moderate, averaging 0.61, indicating a relatively diverse community. The SEI was low, averaging 0.18, indicating the community was represented by few taxa. The community was dominated by the Chironomidae (50%) followed by non-Unionidae Mollusca (38%).

Naomi Lake

Phytoplankton

Phytoplankton abundance (11,836,802 org/L) and biomass (1.83 µg/L) in Naomi Lake were low, and within the range of other oligotrophic temperate waterbodies (Levine and Schindler 1999) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were 23 taxa counted, with a moderate SDI of 0.67, indicating a relatively diverse community. The SEI was low (0.21), indicating the community was represented by only a few taxa. At the major group level (i.e., division or class), the community was dominated by Cyanobacteria (59%), followed by chrysophytes (18%), and diatoms (12%).

Zooplankton

Zooplankton abundance (65 org/L) and biomass (0.09 mg/L) in Naomi Lake were low, and within the range of other oligotrophic temperate waterbodies (Yan 1986) and subarctic lakes on the Canadian Shield (De Beers 2021a, 2021b; Golder 2020). There were 11 taxa counted, with a high SDI value of 0.80, indicating a diverse community. The SEI value was moderate (0.45), indicating the community was represented by a moderate number of taxa. At the major group level (i.e., phylum or order), the community was dominated by rotifers (42%), followed by cyclopoid copepods (36%), and cladocerans (19%).

Benthic Invertebrates

Total invertebrate density (average = 2,428 org/m²) and family-level richness (average = 5 taxa) in Naomi Lake were low, and similar to subarctic lakes on the Canadian Shield (De Beers 2019, 2021b; Golder 2020). The average biomass was 5.2 g/m². The SDI and SEI were moderate, averaging 0.68 and 0.60, respectively, indicating a relatively diverse community. The community was dominated by the Chironomidae (47%), followed by the Oligochaeta (25%), and non-Unionidae Mollusca (15%).

11.3.3.2 Clearwater River Mainstem

Clearwater River below Naomi Lake

Total invertebrate density and family-level richness at the Clearwater River below Naomi Lake survey location were moderate and low, respectively, averaging 41,168 org/m² and 15 taxa. The average biomass was 47 g/m². The SDI was moderate, averaging 0.48, indicating a relatively diverse community. The SEI was low, averaging 0.14, indicating the total invertebrate density was represented by few taxa. The community was dominated by the Chironomidae (68%) followed by the Amphipoda (22%).

11.3.4 Fish Communities

The following sections describe fish community composition in each waterbody and watercourse evaluated in the LSA and RSA (Table 11.2-4). Where available, the results of spring and fall spawning surveys are described. Detailed fish capture results, including information on relative abundance, fish morphometry (i.e., lengths and weights), and any abnormalities identified during sampling, are included in Annex V.1.

A total of 6,045 fish were captured during the aquatic environment baseline surveys during all fish studies completed in 2018 and 2019. A list of the fish species captured in the LSA and RSA waterbodies and watercourses is provided in Table 11.3-2. This list includes species captured by CanNorth during the aquatic environment baseline surveys, as well as any additional species that have been previously documented in the LSA and RSA (Section 11.2.6), based on a review of existing information, including Hunting, Angling, and Biodiversity Information of Saskatchewan (SKCDC 2021b), and other relevant sources (e.g., Saskatchewan Parks and Renewable Resources [1991]). In total, 17 fish species were identified. Overall, the list of fish species documented in the LSA and RSA is characteristic of northern temperate waterbodies and watercourses in Saskatchewan (Langhorne 2001).

During the spring spawning survey, 1,213 fish were captured, of which 94% were spring spawning species. More than half of the spring spawning species (i.e., 67%) were in active spawning condition. A total of 515 fish were captured during the fall spawning surveys, of which 94% were fall spawning species. More than 83% of the fall spawning species were in active spawning condition. These results indicate that the timing of the surveys (i.e., 18 May 2018 to 30 May 2018, and 30 September 2018 to 14 October 2018) overlapped with active spawning conditions in the LSA and RSA.

An LPA community member commented that there are fewer fish in the lakes in the area of the Project (NexGen 2019) and a member of the MN-S also noted less fish in the lakes in general (TSD IV: MN-S). The CRDN have reported that fish populations in Patterson Lake and Forrest Lake have decreased following exploratory drilling on the lake during the late 1970s and 1980s, and that fish populations in the lake have never fully recovered (TSD V.2: CRDN).

Back in the day, like I think it was 70s they [were] drilling in that lake [Patterson] There wasn't—there was no fishing after that. Nothing! I would say...70s to 80s.... And I fished in that lake one time after they've been drilling. I fished in that lake. Two weeks, I don't think I took 400 lbs of fish out of there. I used about 50 nets. Because there was no fish! After they did the drilling, 1970s, nothing. No fish....[The fish] come back, but not as much as before....I've never tried [fishing in Patterson Lake] again after that. (TSD V.2: CRDN)

As presented in Section 11.2.2, Patterson Lake was also noted as important for high quality fishing by members of the BRDN (TSD III: BRDN; BRDN-JWG 2019a; BRDN-JWG 2020). This observation was supported by the baseline field studies that verified the presence and spawning activity of lake trout, lake whitefish, northern pike, walleye, slimy sculpin, and sucker spp. (Annex V.1). The Indigenous and Local Knowledge shared and baseline studies indicate there have been changes in fish populations over time from previous disturbance, but that the value of fish and fishing in Patterson Lake is currently considered to be high.

11.3.4.1 Waterbodies

Broach Lake

A total of 515 fish were captured in Broach Lake, consisting of 11 species: burbot; cisco; lake trout; lake whitefish; longnose sucker; ninespine stickleback (*Pungitius pungitius*); northern pike; slimy sculpin (*Cottus cognatus*); spottail shiner (*Notropis hudsonius*); white sucker; and yellow perch. Broach Lake had an electrofishing catch per unit effort (CPUE) of 4.05 fish/minute. Longnose sucker (number of individuals [n] = 200) and white sucker (n = 136) were the most common species captured. Broach Lake was the only waterbody where cisco (n = 32) was captured. The CRDN reported fishing for trout in Broach Lake (TSD V.2: CRDN). The MN-S identified Broach Lake as a general harvesting area (TSD IV: MN-S), and the YNLR noted that Broach Lake is an important area for fish (TSD VI: YNLR).

Lake H

A total of 147 fish were captured in Lake H, consisting of four species: burbot, northern pike, spottail shiner, and yellow perch. Lake H had an electrofishing CPUE of 12.62 fish/minute. Spottail shiner (n = 90) was the most common species captured, followed by yellow perch (n = 47), northern pike (n = 7) and burbot (n = 3).

Lake G

A total of 22 fish were captured in Lake G during the fish community surveys, consisting of two species: northern pike (n = 21) and burbot (n = 1). Lake G had an electrofishing CPUE of 0.56 fish/minute. During the spring spawning survey completed in Lake G, no fish were captured, and no eggs were found.

Table 11.3-2: Summary of Fish Species Captured in the Local and Regional Study Areas

Species	Provincially Tracked (Rank) ^(a)	Federally Listed (Schedule 1 SARA)	Waterbody							Watercourse							
			Broach Lake	Lake H	Lake G	Patterson Lake	Forrest Lake	Beet Lake	Naomi Lake	Clearwater River						Clearwater River Tributaries	
										Clearwater River above Patterson Lake	Clearwater River below Patterson Lake	Clearwater River above Beet Lake	Clearwater River below Beet Lake	Clearwater River below Naomi Lake	Clearwater River above the Mirror River Confluence	Tributary Inflow to Naomi Lake	Tributary Inflow Downstream of Naomi Lake
Arctic grayling (<i>Thymallus arcticus</i>)	No (S5)	No	X	X	X	X	X	X	X	X	X	X	X	✓	X	X	X
Burbot (<i>Lota lota</i>)	No (S5)	No	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X	✓	✓	✓	✓
Cisco (<i>Coregonus artedii</i>)	No (S5)	No	✓	X	X	✓ ^(c)	X	X	X	X	X	X	X	X	X	X	X
Johnny darter (<i>Etheostoma nigrum</i>)	No (S5)	No	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lake chub (<i>Couesius plumbeus</i>)	No (S5)	No	X	X	X	✓	✓	✓	X	X	✓	X	X	X	X	X	X
Lake trout (<i>Salvelinus namaycush</i>)	No (S5)	No	✓	X	X	✓	✓	✓ ^(b)	X	X	X	X	X	X	X	X	X
Lake whitefish (<i>Coregonus clupeaformis</i>)	No (S5)	No	✓	X	X	✓	✓	✓	✓	✓	✓	✓	✓	X	X	✓	X
Longnose sucker (<i>Catostomus catostomus</i>)	No (S5)	No	✓	X	X	✓	✓	✓	X	✓	✓	X	✓	✓	X	✓	X
Ninespine stickleback (<i>Pungitius pungitius</i>)	No (S5)	No	✓	X	X	✓	✓	X	X	X	X	✓	X	✓	✓	X	X
Northern pike (<i>Esox lucius</i>)	No (S5)	No	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Slimy sculpin (<i>Cottus cognatus</i>)	No (S5)	No	✓	X	X	✓	✓	✓	✓ ^(b)	X	✓	X	✓	X	✓	X	X
Spottail shiner (<i>Notropis hudsonius</i>)	No (S5)	No	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	X	✓	X	X	X
Trout perch (<i>Percopsis omiscomaycus</i>)	No (S5)	No	X	X	X	✓	✓	✓	✓	✓	✓	X	X	X	X	X	X
Walleye (<i>Sander vitreus</i>)	No (S5)	No	✓ ^(c)	X	X	✓	✓	✓	✓	✓	✓	X	✓	✓	X	✓	X
White sucker (<i>Catostomus commersonii</i>)	No (S4)	No	✓	X	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X	✓
Yellow perch (<i>Perca flavescens</i>)	No (S5)	No	✓	✓	X	✓	✓	✓	✓	X	X	✓	✓	✓	X	X	X
Pearl dace (<i>Margariscus margarita</i>)	No (S5)	No	X	X	X	✓ ^(c)	X	X	X	X	X	X	X	X	X	X	X

a) Provincial Rank Definitions (SKCDC 2021a; SKCDC 2021b):
▪ S4 – Apparently secure; S5 – Secure/Common.

b) Species not captured during CanNorth aquatic environment baseline study; however, eggs of this species were identified during egg searches completed during the CanNorth aquatic environment baseline study.

c) Species previously documented in LSA/RSA (Source: Saskatchewan Parks and Renewable Resources 1991).

SARA = *Species at Risk Act*, LSA = local study area; RSA = regional study area; ✓ = species documented during CanNorth aquatic environment baseline study or based on the results of a literature review of species presence in the LSA and RSA; X = species not documented during CanNorth aquatic environment baseline study or based on the results of a literature review of species presence in the LSA and RSA.

Patterson Lake

A total of 1,697 fish were captured in Patterson Lake, consisting of 13 species: burbot, lake chub, lake trout, lake whitefish, longnose sucker, ninespine stickleback, northern pike, slimy sculpin, spottail shiner, trout perch, walleye, white sucker, and yellow perch. Patterson Lake had an electrofishing CPUE of 4.06 fish/minute. Trout perch (n = 984) was the most common species captured, followed by spottail shiner (n = 183), lake whitefish (n = 109), and white sucker (n = 105). Patterson Lake and Forrest Lake had the highest number of individual species captured of the waterbodies surveyed.

During the spring spawning survey, 63 fish were captured, including four spring spawning species: longnose sucker (n = 3), northern pike (n = 11), white sucker (n = 17), and yellow perch (n = 8). Of these, 92% were in active spawning condition. During the fall spawning survey, 43 lake whitefish were captured, of which 74% were in active spawning condition. Egg searches identified 6,030 eggs, consisting of eggs of lake trout, lake whitefish, northern pike, slimy sculpin, and walleye, and unidentified sucker species (i.e., eggs could not be identified to species and could be either white sucker or longnose sucker).

A total of 514 fish were captured during fish sampling along the Patterson Lake shoreline adjacent to the proposed Project, consisting of nine species: burbot, lake whitefish, longnose sucker, ninespine stickleback, northern pike, spottail shiner, white sucker, trout perch, and yellow perch. Electrofishing CPUE adjacent to the Project was 3.43 fish/minute. The most abundant species in this area were trout perch (n = 202), spottail shiner (n = 118), and yellow perch (n = 34). Lake trout and walleye were not captured; however, eggs of both species were found.

The results of field studies in Patterson Lake were corroborated by Indigenous and Local Knowledge shared by Indigenous Groups and LPA community members. The CRDN, BNDN, BRDN and MN-S identified Patterson Lake as an important area for fishing (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). The YNLR identified Patterson Lake as an important area for fish (TSD VI: YNLR). The CRDN noted that the Patterson Lake area has an abundance of resources and is intensively used by community members for harvesting. The BNDN noted that Patterson Lake supports numerous key fish species of historically high quality and large size (TSD II: BNDN). Species that are fished in Patterson Lake include lake trout (BRDN-JWG 2020; TSD II: BNDN; NexGen 2019), whitefish (TSD II: BNDN), walleye (TSD II: BNDN; NexGen 2019), suckers (TSD II: BNDN), and northern pike (TSD II: BNDN; NexGen 2019).

Forrest Lake

A total of 674 fish were captured in Forrest Lake, consisting of 13 species: burbot, lake chub, lake trout, lake whitefish, longnose sucker, ninespine stickleback, northern pike, slimy sculpin, spottail shiner, trout perch, walleye, white sucker, and yellow perch. Forrest Lake had an electrofishing CPUE of 3.61 fish/minute. Trout perch (n = 375) was the most common species captured and lake whitefish (n = 44) was the most common large-bodied species.

During the spring spawning survey, 23 fish were captured, including three spring spawning species: longnose sucker (n = 5), northern pike (n = 11), and white sucker (n = 1). Of these, 17% were in active spawning condition. During the fall spawning survey, 27 lake whitefish were captured, of which 70% were in active spawning condition. Egg searches identified 1,730 eggs, consisting of eggs of lake trout, lake whitefish, northern pike, slimy sculpin, and walleye, as well as unidentified sucker species.

The results of field studies in Forrest Lake were corroborated by Indigenous and Local Knowledge shared by Indigenous Groups. The CRDN, BNDN, and MN-S fish in Forrest Lake (TSD II: BNDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). The YNLR identified Forrest Lake as an important area for fish (TSD VI: YNLR). The CRDN reported that Patterson Lake and Forrest Lake is an important lake for both traditional and commercial fishing (TSD V.1: CRDN).

Beet Lake

A total of 404 fish were captured in Beet Lake, consisting of 11 species: burbot, lake chub, lake whitefish, longnose sucker, northern pike, slimy sculpin, spottail shiner, trout perch, walleye, white sucker, and yellow perch. Beet Lake had an electrofishing CPUE of 4.84 fish/minute. Spottail shiner was the most common species (n = 138) captured, followed by trout perch (n = 91). Yellow perch (n = 40) was the most common large-bodied species present. Although no lake trout were captured, eggs were found during the fall spawning survey, confirming the species presence in the waterbody.

During the spring spawning survey, 30 fish were captured, including three spring spawning species: longnose sucker; northern pike; and white sucker. Of these fish, 46% were in active spawning condition. During the fall spawning survey, 13 lake whitefish were captured, of which, 85% were in active spawning condition. Egg searches identified 498 eggs, consisting of eggs of lake trout, lake whitefish, walleye, and unidentified sucker species.

The MN-S reported fishing in Beet Lake (TSD IV: MN-S), and the YNLR identified Beet Lake as an important area for fish (TSD VI: YNLR).

Naomi Lake

A total of 1,697 fish were captured in Naomi Lake, consisting of eight species: burbot, lake whitefish, northern pike, spottail shiner, trout perch, walleye, white sucker, and yellow perch. Naomi Lake had an electrofishing CPUE of 3.41 fish/minute. Spottail shiner (n = 75), yellow perch (n = 67), lake whitefish (n = 48), northern pike (n = 42), and white sucker (n = 40) were the most common species captured. Although no slimy sculpin were captured, eggs were found during the spring spawning survey, confirming the species presence.

During the spring spawning survey, seven fish were captured, of which northern pike (n = 6 in unknown spawning condition) was the only spring spawning species. During the fall spawning survey, 44 lake whitefish were captured, of which 84% were in active spawning condition. Egg searches identified 265 eggs, consisting of eggs of northern pike, slimy sculpin, walleye, and unidentified sucker species. Egg searches were not conducted during the fall survey due to near shore ice buildup.

The MN-S reported fishing in Naomi Lake (TSD IV: MN-S), and the YNLR identified Naomi Lake as an important area for fish (TSD VI: YNLR).

11.3.4.2 Clearwater River Mainstem

Clearwater River above Patterson Lake

A total of 687 fish were captured in Clearwater River above Patterson Lake, consisting of eight species: burbot, lake whitefish, longnose sucker, northern pike, spottail shiner, trout perch, walleye, and white sucker. This section of river had an electrofishing CPUE of 22.11 fish/minute. Walleye (n = 311), lake whitefish (n = 170), white sucker (n = 90), and trout perch (n = 59) were the most common species captured.

During the spring spawning survey, 403 fish were captured. The most abundant spring spawning species captured was walleye (n = 310), of which 65% were in active spawning condition. During the fall spawning survey, 168 lake whitefish were captured, of which, 94% were in active spawning condition. Egg searches identified 123 eggs, consisting of eggs of northern pike, walleye, and unidentified sucker species.

The CRDN and MN-S reported fishing in the Clearwater River (TSD IV: MN-S; TSD V.2: CRDN), and the YNLR identified the Clearwater River as an important area for fish (TSD VI: YNLR).

Clearwater River below Patterson Lake

A total of 320 fish were captured in the Clearwater River below Patterson Lake, consisting of 10 species: lake whitefish, northern pike, spottail shiner, trout perch, white sucker, longnose sucker, lake chub, slimy sculpin, walleye, and burbot. This section of river had an electrofishing CPUE of 2.59 fish/minute. Lake whitefish (n = 208) and northern pike (n = 69) were the most common species captured.

During the spring spawning survey, 99 fish were captured, including four spring spawning species: longnose sucker, northern pike, white sucker, and walleye. Of these fish, 71% were in active spawning condition. During the fall spawning survey, 43 lake whitefish were captured, of which 74% were in active spawning condition. Egg searches identified 232 eggs, consisting of eggs of lake whitefish, northern pike, walleye, and unidentified sucker species.

Clearwater River above Beet Lake

A total of 295 fish were captured in the Clearwater River above Beet Lake, consisting of six species: lake whitefish, northern pike, spottail shiner, white sucker, ninespine stickleback, and yellow perch. This section of river had an electrofishing CPUE of 5.83 fish/minute. Spottail shiner (n = 217) and yellow perch (n = 43) were the most common species captured.

Northern pike (n = 5) was the only spring spawning species captured during the spring spawning survey. Only one of the individuals captured (20%) was in active spawning condition. No eggs were found during egg searches.

Clearwater River below Beet Lake

A total of 192 fish were captured in the Clearwater River below Beet Lake, consisting of seven species: longnose sucker, northern pike, lake whitefish, walleye, white sucker, yellow perch, and slimy sculpin. This section of river had an electrofishing CPUE of 1.34 fish/minute. Longnose sucker (n = 145), northern pike (n = 22), and lake whitefish (n = 15) were the most common species captured.

During the spring spawning survey, 183 fish were captured. The most abundant species in active spawning condition was longnose sucker ($n = 111$), of which 71% were in active spawning condition. The abundance of spawning longnose suckers captured during the spring spawning survey aligns with Indigenous and Local Knowledge shared by the CRDN, who noted that the section of the river which connects Beet Lake to the Clearwater River is full of red (spawning) suckers in the spring (Figure 25; TSD V.2: CRDN).

This river, in here . . . this connects Beet . . . Right in this area here, until it gets to the Clearwater, is really really clear water and full . . . it's red of suckers in the spring. If you go down in the spring it's just red; there's so many . . . when you go over them you'll feel them on the boat there's so many suckers in there sometimes. (TSD V.2: CRDN)

Egg searches identified 150 eggs, consisting of eggs of northern pike, walleye, and yellow perch, and unidentified sucker species.

Clearwater River below Naomi Lake

A total of 203 fish were captured in the Clearwater River below Naomi Lake, consisting of nine species: white sucker, northern pike, spottail shiner, walleye, burbot, yellow perch, longnose sucker, ninespine stickleback, and Arctic grayling. This section of river had an electrofishing CPUE of 1.47 fish/minute. White sucker ($n = 83$), northern pike ($n = 66$), and spottail shiner ($n = 14$) were the most common species captured. The Clearwater River below Naomi Lake survey location was the only location where Arctic grayling ($n = 1$) was captured.

During the spring spawning survey, 192 fish were captured, which included four spring spawning species: northern pike, longnose sucker, white sucker, and walleye. Of these fish, 57% were in active spawning condition. Egg searches identified 192 eggs, consisting of eggs of Arctic grayling, northern pike, and unidentified sucker species.

Clearwater River above the Mirror River Confluence

A total of 12 fish were captured in the Clearwater River at the surveyed location above the Mirror River confluence, consisting of four species: burbot, northern pike, ninespine stickleback, and slimy sculpin. This section of river had an electrofishing CPUE of 0.65 fish/minute. Slimy sculpin ($n = 5$) and northern pike ($n = 4$) were the most common species captured.

11.3.4.3 Clearwater River Tributaries

Tributary Inflow to Naomi Lake

A total of 22 fish were captured at the tributary inflow to Naomi Lake survey location, consisting of five species: burbot, lake whitefish, longnose sucker, northern pike, and walleye. The inflow had an electrofishing CPUE of 2.59 fish/minute. Longnose sucker ($n = 9$), northern pike ($n = 5$), and walleye ($n = 5$) were the most common species captured. The overall number of fish captured at this location was likely limited due to damage to nets by bears, which allowed fish to escape. The nets were not deployed at this location for the remainder of the survey.

During the spring spawning survey, nine fish were captured, which included two spring spawning species: northern pike and walleye. A total of 67% of the individuals were in active spawning condition. Egg searches identified 226 eggs, consisting of eggs of northern pike and unidentified sucker species.

Tributary Inflow Downstream of Naomi Lake

A total of 205 fish were captured at the tributary inflow to Naomi Lake survey location, consisting of three species: burbot, northern pike, and white sucker. This tributary had an electrofishing CPUE of 1.41 fish/minute. White sucker ($n = 187$) was the most common species captured.

During the spring spawning survey, a total of 230 fish were captured, including northern pike ($n = 11$) and white sucker ($n = 219$). Of the fish captured, 81% were in active spawning condition. Egg searches identified 50 eggs, consisting of eggs of northern pike and unidentified sucker species.

11.3.5 Species of Conservation Concern

Seventeen fish species were identified in the LSA and RSA (Table 11.3-2). Of these, none were classified as provincially or federally listed species or species with a designated conservation status by the Committee on the Status of Endangered Wildlife in Canada (Table 11.3-2; COSEWIC 2021). In addition, review of distribution data for aquatic species listed under SARA did not identify the presence of any provincially or federally listed species in the LSA or RSA (Government of Canada 2021; DFO 2019a; SKCDC 2021a). Therefore, protected species are not expected to occur in waterbodies and watercourses potentially affected by the proposed Project.

11.3.6 Fish Valued Component Life Histories

11.3.6.1 Lake Trout

Lake trout primarily inhabit deep, cold, well-oxygenated waterbody habitats (Scott and Crossman 1973; Evans et al. 2002; Richardson et al. 2001; McPhail 2007). Lake trout is a highly valued and sought-after fish species in Canada's inland waters (Scott and Crossman 1973). Lake trout were captured in all the large waterbodies in the LSA, including Broach Lake, Forrest Lake, Hodge Lake, Lloyd Lake, and Patterson Lake.

Northern populations of lake trout are especially long lived, and fish older than 20 years old are common. The species spawns in the fall (i.e., September or October) when water temperatures fall below approximately 10°C (Scott and Crossman 1973; Richardson et al. 2001; McPhail 2007). Northern populations typically grow slowly and mature between the ages of 7 and 10 years. Spawning occurs at night, with females depositing eggs over beds of large boulder or rubble. The fertilized eggs settle into the interstitial spaces within the substrate to incubate. Lake trout eggs are relatively large (i.e., 4 mm to 5 mm), and fecundity (i.e., maximum potential offspring in a lifetime) is low compared to other fish species (McPhail 2007). Eggs remain in the substrate over winter, and hatch during spring.

Spawning habitat for lake trout is readily available in the LSA (Annex V.1). Moderate to high quality spawning habitat was observed throughout Patterson Lake, including in the shoreline area surveyed in detail near the proposed Project. Moderate to high quality spawning habitat for lake trout was also identified in Broach Lake, Lake H, Forrest Lake, Beet Lake, and in the Clearwater River Downstream of Naomi Lake. Incubating eggs of lake trout were found in Patterson Lake, Forrest Lake, and Beet Lake during fall spawning surveys. No vegetation was present in any of the areas where eggs were found, and substrates were composed mostly of gravel, cobble, and boulders.

Nursery and early-stage rearing habitat for lake trout is similar to that of spawning habitat, as the larvae do not disperse until the yolk sac is absorbed approximately one month after hatching. The prevalence of spawning habitat for lake trout in the LSA indicates that nursery and early-stage rearing habitat is available. Young lake

trout feed in the shallows for several months before they are large enough to venture into deeper water. However, in some northern waterbodies, where water temperatures remain low throughout the year, lake trout may remain in nearshore areas for months to years (Martin 1956; Scott and Crossman 1973). There is evidence that adults in some populations return to their natal spawning sites (Scott and Crossman 1973).

Lake trout are predacious and feed on zooplankton, aquatic and terrestrial invertebrates, and fish (Scott and Crossman 1973). The food types consumed are dependent upon life stage, season, and availability. Young lake trout feed primarily upon plankton and aquatic insect larvae until they reach an adequate size to prey on fish, such as cisco. Adult lake trout often have a preferred diet of cisco, which were found in conjunction with lake trout exclusively in Broach Lake; however, other fish species such as lake whitefish, yellow perch, stickleback, trout perch, and longnose sucker are common prey items. A variety of small- and large-bodied prey species were captured during baseline surveys, indicating that suitable feeding habitat exists in the waterbodies where lake trout occur. Seasonal changes in diet are common and are often associated with water temperature. For example, in the spring, adults may feed on forage fish and terrestrial insects in shallow water, or near the waterbody surface. If the waterbody warms and stratifies, the cold, denser water sinks to the lake bottom and the lake trout follow it down as a refuge from the higher water temperatures in the upper layer of the waterbody. Under these conditions in waterbodies, lake trout may switch to feeding on plankton.

The morphology and catch data for lake trout based on fishing efforts in the LSA and RSA are presented in Table 11.3-3. A total of 33 lake trout were captured during baseline sampling. Of the 33 lake trout captured, 3 were captured in Patterson Lake. In Patterson Lake, lake trout ranged in size from 57.7 cm to 59.4 cm for length and 2,620 g to 3,300 g for weight (Table 11.3-3).

Table 11.3-3: Morphology and Catch Data for Lake Trout for Fishing Efforts in the Local and Regional Study Areas

Waterbody	N	Length (cm)				Weight (g)			
		Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
Broach Lake	14	53.4	6.6	47.5	69.8	1,750	904	940	4,050
Patterson Lake	3	58.6	0.9	57.7	59.4	3,033	363	2,620	3,300
Forrest Lake	14	57.4	5.8	46.2	66.0	1,949	455	1,080	2,620

N = number; SD = standard deviation.

11.3.6.2 Lake Whitefish

Lake whitefish are found throughout much of Saskatchewan (McPhail and Lindsey 1970; Scott and Crossman 1973). The species commonly occurs in waterbodies but is also found in larger watercourses. Lake whitefish is one of the most valuable commercial fresh water fish species in Canada (Scott and Crossman 1973). Lake whitefish are widely distributed throughout the LSA and were captured in both waterbody and watercourse habitats. Lake whitefish were captured in all the large waterbodies surveyed, including Broach Lake, Forrest Lake, and Patterson Lake. Lake whitefish were also captured in Naomi Lake and in the Clearwater River at the surveyed sections above and below Patterson Lake and Beet Lake.

Northern populations of lake whitefish spawn about every two or three years (Scott and Crossman 1973). Spawning usually occurs from mid-September to mid-October in northern regions (Richardson et al. 2001) but may occur as early as late summer and as late as December. Spawning may occur in waterbodies or watercourse environments, over large boulders to gravel and occasionally sand (Richardson et al. 2001). Spawning usually takes place in

shallow water areas, but deeper spawning has been reported (Scott and Crossman 1973). Eggs are released over substrate (Scott and Crossman 1973) and settle into crevices where they incubate for several months before hatching in approximately March to May (Richardson et al. 2001).

Spawning habitat for lake whitefish is readily available in the LSA (Annex V.1). Moderate to high quality spawning habitat was observed throughout Patterson Lake, including in the shoreline area surveyed in detail near the proposed Project. Moderate to high quality spawning habitat for lake whitefish was also identified in Broach Lake, Lake H, Forrest Lake, Beet Lake, and in the Clearwater River at the sections surveyed below Patterson Lake, below Naomi Lake, and above the Mirror River confluence. During fall spawning surveys, incubating lake whitefish eggs were found in Patterson Lake, including along the Patterson Lake shoreline adjacent to the proposed Project, as well as in Forrest Lake, Beet Lake, and the Clearwater River at the section surveyed below Patterson Lake. The highest lake whitefish egg densities occurred in areas with no vegetation cover and substrates composed of gravel, cobble, and boulder (Annex V.1).

Newly hatched lake whitefish may form aggregations (i.e., groups) along steep shorelines characterized by the presence of boulders, rocks, and gravel stretching out into the deeper waters. Lake whitefish generally leave shallow nearshore areas to move into deeper open waters by early summer, to depths of 5 m to 10 m over substrates of boulder, cobble, gravel, and sand (Lane et al. 1996). These types of habitats were present throughout most waterbodies in the LSA, providing suitable nursery and early stage rearing habitat for lake whitefish. This species was found to be abundant and widely distributed throughout the LSA, indicating that habitat is not limiting.

Adult lake whitefish tend to leave the spawning grounds shortly after spawning and return immediately to deep water habitat to overwinter (Ford et al. 1995). They are often found at depths greater than 10 m for most of the year and can occur at depths greater than 100 m (McPhail and Lindsey 1970). Despite being primarily bottom dwelling, they may be occasionally found in the pelagic (i.e., open-water) zone of waterbodies (Ford et al. 1995).

The diet of lake whitefish includes snails, clams, aquatic insects, plankton, and small fish (Scott and Crossman 1973). Examinations of the stomach contents of lake whitefish captured during the aquatic environment baseline study (Annex V.1) revealed the presence of unidentified, digested invertebrates as well as what appeared to be fish eggs. Copepods and cladocerans are a major part of the young lake whitefish diet and by early July, bottom-dwelling organisms begin to enter their diet. As the young move into deeper waters, their diet closely resembles that of adult lake whitefish but still includes zooplankton. Lake whitefish are preyed upon by lake trout and other piscivores in both the juvenile and adult life stages (Scott and Crossman 1973).

Morphology and catch data for lake whitefish based on fishing efforts in the LSA and RSA are presented in Table 11.3-4. A total of 637 lake whitefish were captured during baseline sampling in the LSA or RSA. Of these, 109 were captured in Patterson Lake. In Patterson Lake, lake whitefish ranged in size from 15.1 cm to 48.2 cm for length and 20 g to 1,260 g for weight (Table 11.3-4).

Table 11.3-4: Morphology and Catch Data for Lake Whitefish for Fishing Efforts in the Local and Regional Study Areas

Waterbody/Watercourse		N	Length (cm)				Weight (g)			
			Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
Waterbody	Broach Lake	16	38.0	14.0	4.1	48.3	1,057	225	640	1,420
	Patterson Lake	109	35.3	5.3	15.1	48.2	598	230	20	1,260
	Forrest Lake	44	40.7	6.5	3.9	49	1,017	311	500	1,960
	Beet Lake	24	39.8	5.6	25.6	48.2	880	361	120	1,520
	Naomi Lake	48	42.8	2.3	35.8	48.3	1,071	176	740	1,620
Clearwater River	Clearwater River above Patterson Lake	170	37.1	2.8	32.7	55.3	675	149	440	1,420
	Clearwater River below Patterson Lake	208	41.8	28.0	18.0	440.2	741	189	80	1,240
	Clearwater River below Beet Lake	1	40.6	n/a	40.6	40.6	680	n/a	680	680
	Clearwater River below Naomi Lake	15	42.1	1.9	38.4	45	1,071	224	740	1,600
Clearwater River tributary	Tributary inflow to Naomi Lake above the Mirror River Confluence	2	44.3	0.1	44.2	44.3	1,190	42	1,160	1,220

N = number; SD = standard deviation; n/a = not applicable.

11.3.6.3 Walleye

Walleye primarily inhabit large waterbodies and watercourses where the depth or turbidity of the water provides cover from bright sunlight (Scott and Crossman 1973). Walleye is a highly valued and sought-after fish species in Canada's inland waters (Scott and Crossman 1973). Walleye were captured in both waterbody and watercourse habitats, including Patterson, Forrest, Beet, and Naomi lakes, and in the Clearwater River at the surveyed sections above and below Patterson Lake, Beet Lake, and Naomi Lake.

In watercourses, walleye move into still pools that are up to 3.5 m deep or into shallow current breaks and regions with slight currents over gravel, cobble, and boulder substrates (Colby et al. 1979; McPhail 2007; Paragamian 1989; Scott and Crossman 1973). Male walleye reach maturity at two to four years and females at three to six years (Scott and Crossman 1973). Spawning occurs in the early spring, shortly after ice breaks up, when water temperatures reach 6.7°C to 8.9°C (Scott and Crossman 1973). Northern populations may not spawn every year if water temperatures are not favourable (Scott and Crossman 1973). Spawning in watercourses occurs at night in rocky areas below rapids and impassable falls (Scott and Crossman 1973). Eggs fall into crevices of the substrate where they remain for 12 to 18 days before hatching (Scott and Crossman 1973).

Spawning habitat for walleye is readily available in the LSA. Moderate to high quality spawning habitat was observed throughout Patterson Lake, including in the shoreline area surveyed in detail adjacent to the proposed Project. Moderate to high quality spawning habitat for walleye was also identified in Broach Lake, Lake H, Forrest Lake, Beet Lake, and in the Clearwater River at the sections surveyed below Patterson Lake, below Naomi Lake, and above the Mirror River confluence. Incubating eggs of walleye were widespread and were found in Patterson Lake, including along the Patterson Lake shoreline adjacent to the proposed Project, as well as in Forrest Lake, Beet Lake, Naomi Lake, and the Clearwater River at the sections surveyed above and below

Patterson Lake and Beet Lake during spring spawning surveys. Walleye eggs were predominantly found in cobble/gravel substrates.

Nursery and early-stage rearing habitat for walleye is similar to spawning habitat, as the larvae do not disperse until the yolk sac is absorbed. Egg yolk absorption takes approximately 10 to 15 days, after which the young disperse into the upper strata of open water. By late summer, the young-of-the-year move into deeper waters and can be found at depths ranging from 6 m to 9 m (Scott and Crossman 1998). Deeper waters to which the young-of-the-year walleye can migrate are readily available in LSA waterbodies and watercourses, indicating that nursery and early-stage rearing habitat is not limiting.

Walleye feed throughout the day in turbid waters (i.e., water lacking clarity due to suspended material), but in clear water, feeding is restricted to twilight or nighttime (Scott and Crossman 1973). Adult walleye tend to feed on any species of fish and invertebrates that are readily available; however, some populations of walleye, even as adults, feed almost exclusively on emerging larval or adult mayflies or chironomids for part of the year (Scott and Crossman 1998). During the first six weeks of development, walleye diet consists primarily of copepods, cladocerans, invertebrates, and small-bodied fish. As the young walleye shift in size, the diet shifts very quickly from invertebrates to fish. Small-bodied fish species such as lake chub, ninespine stickleback, slimy sculpin, spottail shiner, and trout perch, which all comprise a typical walleye diet, were found throughout the LSA and RSA. The abundance of small-bodied fish and invertebrates provided suitable and abundant prey for walleye in all life stages. Juvenile walleye are preyed upon by a variety of predator fish, including adult walleye (Scott and Crossman 1973).

Morphology and catch data for walleye based on fishing efforts in the LSA and RSA are presented in Table 11.3-5. A total of 336 walleye were captured during baseline sampling in the LSA or RSA. However, a large majority of the walleye documented were captured in the Clearwater River above Patterson Lake (n = 298; Table 11.3-5). Of the 336 walleye captured, 10 were captured in Patterson Lake. In Patterson Lake, walleye ranged in size from 26.6 cm to 66.5 cm for length and 140 g to 2,720 g for weight (Table 11.3-5).

Table 11.3-5: Morphology and Catch Data for Walleye for Fishing Efforts Local and Regional Study Areas

Waterbody/Watercourse		N	Length (cm)				Weight (g)			
			Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
Waterbody	Patterson Lake	10	47.0	14.7	26.6	66.5	1,267	935	140	2,720
	Forrest Lake	1	52.5	n/a	52.5	52.5	1,700	n/a	1,700	1,700
	Beet Lake	4	35.7	15.9	12.7	49.4	847	352	560	1,240
	Naomi Lake	6	42.9	7.5	29.0	50.0	677	402	80	1,080
Clearwater River	Clearwater River above Patterson Lake	298	50.3	6.1	31.2	71.3	1,559	562	420	3,860
	Clearwater River below Patterson Lake	1	61.3	n/a	61.3	61.3	1,560	n/a	1,560	1,560
	Clearwater River below Beet Lake	5	54.1	7.7	46.5	62.1	1,844	549	1,200	2,420
	Clearwater River below Naomi Lake	6	42.1	6.8	28.6	46.8	761	260	280	980
Clearwater River tributary	Tributary inflow to Naomi Lake above the Mirror River Confluence	5	48.4	5.1	41.8	55.6	1,416	483	720	2,080

N = number; SD = standard deviation; n/a = not applicable.

11.3.6.4 Northern Pike

Northern pike occurs throughout Saskatchewan and inhabits fresh water waterbodies and watercourses. The species is most commonly found in nearshore areas of waterbodies and slow-moving watercourses that are relatively shallow (i.e., less than 4 m) and contain vegetative cover (Harvey 2009). Where northern pike are found in watercourses, they are likely to seek out areas with low velocities, such as side channels, back waters, or sloughs. Northern pike is a popular species among recreational anglers.

Northern pike were documented in all waterbodies and watercourses surveyed during the aquatic environment baseline study, making the species the most ubiquitous among the four fish VCs. Northern pike were captured in Broach Lake, Lake G, Lake H, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake. The species was captured in all sections of the mainstem Clearwater River surveyed, as well as in all Clearwater River tributaries.

Northern pike spawning occurs in spring, usually in April to early May, after the ice has melted and water temperatures have reached approximately 4.4°C to 11.1°C (Scott and Crossman 1973). Individuals may ascend tributaries to spawn, and typically seek out flooded marshes or shallow areas that contain abundant aquatic or terrestrial vegetation (Inskip 1982). Each female is generally accompanied by one or two males. Females broadcast (i.e., release) their adhesive eggs over vegetation; eggs are fertilized as they are released from the female (Scott and Crossman 1973; Stewart and Watkinson 2004). The eggs sink and stick to vegetation or the substrate. Hatching occurs approximately two weeks later (Billard 1996). After emerging, the young attach themselves to nearby vegetation and remain relatively inactive for 6 to 10 days, until the yolk sac is absorbed (Harvey 2009; Scott and Crossman 1973).

The results of the aquatic environment baseline study (Annex V.1) indicated a general lack of highly suitable spawning habitat for northern pike in the surveyed waterbodies; however, each of these waterbodies contained limited areas that were deemed at least marginally suitable for spawning, except for Beet Lake. Limited areas of moderate to high quality spawning habitat were observed in Broach Lake, Patterson Lake, Lake H, Lake G, and Forrest Lake. All the surveyed sections of the Clearwater River mainstem and tributary habitats in the LSA and RSA were found to contain moderately to highly suitable spawning habitat for northern pike. During spring spawning surveys, incubating eggs were widespread and were found in Patterson Lake, including along the Patterson Lake shoreline adjacent to the proposed Project, as well as in Forrest Lake, Naomi Lake, and the Clearwater River at the sections surveyed above and below Patterson Lake, below Beet Lake, below Naomi Lake, and above the Mirror River Confluence. Northern pike eggs were found in areas that contained dense vegetation cover.

Nursery and early-stage rearing habitat for northern pike is generally the same as that of spawning habitat, as larvae tend to remain immobile after hatching until the yolk sac is absorbed. The young-of-the-year are also reported to utilize the same type of habitat sought for spawning, and prefer silt or organic substrate, emergent macrophytes or flooded vegetation, and woody debris at depths of less than 1 m (Inskip 1982; Scott and Crossman 1998). The types of habitats also provide abundant nursery and early-stage rearing habitat for northern pike in the LSA and RSA. Habitat availability was also evident by the widespread distribution of northern pike in the LSA and RSA.

Young-of-the-year northern pike start out on a diet of zooplankton. As they grow larger, they rely more heavily on aquatic insects and small fish (Scott and Crossman 1973). Adult northern pike are opportunistic predators; they typically hide within aquatic vegetation and ambush potential prey (Harvey 2009). Northern pike are primarily piscivorous but have been known to consume a variety of prey, including crayfish, frogs, aquatic

mammals, and birds (Stewart and Watkinson 2004). Examination of the stomach contents of northern pike captured from several of the waterbodies within the LSA and RSA during the aquatic environment baseline study (Annex V.1) revealed that fish, invertebrates, and even small birds or waterfowl are part of the diet.

Morphology and catch data for northern pike for fishing efforts in the LSA and RSA are presented in Table 11.3-6. A total of 388 northern pike were captured during baseline sampling. Of these, 22 were captured in Patterson Lake. In Patterson Lake, northern pike ranged in size from 5.9 cm to 82.6 cm for length and 760 g to 4,220 g for weight (Table 11.3-6).

Table 11.3-6: Morphology and Catch Data for Northern Pike for Fishing Efforts in the Local and Regional Study Areas

Waterbody/Watercourse		N	Length (cm)				Weight (g)			
			Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
Waterbody	Broach Lake	14	65.3	22.6	12.4	103.5	3,231	2,547	580	9,200
	Lake H	7	38.6	16.2	15.6	55.6	464	387	30	960
	Lake G	21	29.5	16.0	11.8	54.8	620	342	200	1,240
	Patterson Lake	22	49.9	22.8	5.9	82.6	1,813	1,123	760	4,220
	Forrest Lake	30	54.1	24.0	7.8	105.0	2,044	2,117	60	9,060
	Beet Lake	27	55.1	15.3	10.9	73.9	1,521	598	630	2,660
	Naomi Lake	42	35.5	18.0	6.6	72.9	834	499	80	2,500
Clearwater River mainstem	Clearwater River Above Patterson Lake	18	58.1	11.7	26.8	71.0	1,847	682	520	3,000
	Clearwater River Below Patterson Lake	69	55.8	15.7	18.3	100.0	1,549	1,103	66	7,880
	Clearwater River Above Beet Lake	26	31.5	21.6	8.7	78.5	1,084	1,074	70	3,800
	Clearwater River Below Beet Lake	21	53.8	16.7	6.4	68.8	1,463	374	780	2,140
	Clearwater River Below Naomi Lake	66	48.9	7.7	18.3	68.5	891	388	300	2,900
	Clearwater River Above the Mirror River Confluence	4	12.5	5.5	8.7	20.5	35	20	20	65
Clearwater River tributaries	Tributary inflow to Naomi Lake	5	41.8	10.2	32.6	58.0	596	369	320	1,220
	Tributary inflow downstream of Naomi Lake	16	40.4	14.1	15.2	64.0	632	455	90	1,680

N = number; SD = standard deviation.

11.4 Project Interactions and Mitigations

The pathway analysis identified potential adverse effects of the Project on fish VCs, identified practicable mitigation for these potential effects, and determined whether any of the potential effects could be sufficiently mitigated such that they are not expected to cause a residual adverse effect. As described in Section 11.2.7, Project Interactions and Mitigations, the pathway analysis assigned each potential effect as:

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

The pathway analysis is summarized in Table 11.4-1. 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 11.5. Effects pathways apply to all Project phases and all fish VCs unless otherwise noted.

The environmental design features and mitigations in Table 11.4-1 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 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 11.7). 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 11.4-1: Potential Effects Pathways for Fish and Fish Habitat

Path ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
F-01	Project components/activities that may change surface water and sediment quality and aquatic health after Closure and in the far future : - WRSAs - storage of tailings in the UGTMF and backfilled stopes	Changes in surface water quality from WRSAs and UGTMF after Closure: Runoff and seepage from the WRSAs and groundwater flow from the UGTMF may alter surface water quality in Patterson Lake after Closure and adversely affect fish habitat availability, survival, and reproduction	Install engineered cover of compacted clean material and growth medium layer on PAG WRSA and install growth medium cover on NPAG WRSA - Use engineered cemented paste backfill and tailings to control source concentrations Apply binder to reduce permeability in backfill and tailings Revegetate NPAG and PAG WRSAs during reclamation to limit TSS in surface runoff - Develop and implement a Preliminary Decommissioning and Reclamation Plan	Primary pathway
F-02	Project components/activities that may cause temporary disturbance to fish habitat, including riparian habitat, in the vicinity of the existing access road crossing location of the Clearwater River during Construction, Operations, and Closure : - use of a crane to move heavy equipment and infrastructure across the Clearwater River - land clearing and site access development - reclamation and revegetation of disturbed areas	Disturbance at river crossing: Movement of heavy equipment and infrastructure across the Clearwater River at the existing access road crossing location may adversely affect fish habitat availability, survival, and reproduction	Employ a crane to move heavy equipment and infrastructure across the Clearwater River only in instances where loads exceed the legal rating or capacity of the bridge and options for reducing load size/weight are not feasible or practical (e.g., dismantling equipment, breaking down a load into smaller units) Minimize the footprint of work areas adjacent to the Clearwater River, and associated ingress/egress, to limit the area of disturbance. Fording of the Clearwater River, or activities that could result in a direct disturbance to the bed or banks of the river, would not occur - To the extent practical, construct work areas to avoid critical or sensitive habitat (e.g., riparian zones) following best practices and regulatory requirements Implement DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2019b) to minimize potential adverse effects on aquatic resources Install appropriate erosion and sediment control measures, as required. Regularly inspect erosion and sediment control measures to confirm they are functioning as planned, and perform any required maintenance, as needed - Confirm heavy equipment (e.g., crane) used on site is properly maintained and is free of leaks - Inspect loads to be moved across the Clearwater River for leaks - If an upgrade to the existing Clearwater River bridge is required, avoid any permanent disturbance below the high-water mark of the Clearwater River - Implement a Project-specific Environmental Protection Program - Develop and implement a Preliminary Decommissioning and Reclamation Plan to decommission and transfer the site to the province under the Institutional Control Program	Secondary pathway
F-03	Project components/activities that may divert water from its natural course and influence hydrological processes and water balance during Construction, Operations, and Closure : - 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 and special waste rock, and ore - treated effluent discharge following treatment at ETP - domestic treated sewage discharge following treatment at sewage treatment plant	Altered site drainage affecting water levels and flow: Altered site drainage, runoff, and discharge may cause changes to water levels and flows and channel/bank stability in downstream waterbodies and watercourses and affect fish habitat availability and distribution	- Design and install appropriate site drainage and water containment and conveyance structures on site - Provide adequate contact water storage capacity to allow controlled rate of release during both routine and non-routine operation scenarios Install appropriate erosion and sediment control measures, as required - Regularly inspect erosion and sediment control measures to confirm they are functioning as planned, and perform any required maintenance, as needed Install and operate an ETP and a STP to reduce release of COPCs (e.g., major ions, metals, radionuclides) to the environment and discharge treated effluent and treated sewage to Patterson Lake - Design new roads such that the alignments minimize water crossings and avoid potentially sensitive habitat to the extent possible Limit the Project footprint to the extent practical using practices such as: - optimizing use of cleared areas for Project activities - using existing road infrastructure, including the existing access road and bridge crossing - storing tailings underground - designing an efficient infrastructure footprint (i.e., buildings clustered together) - Implement progressive reclamation and revegetation of disturbed areas no longer required Reclaim and revegetate areas where non-permanent Project facilities have been decommissioned Recycle and reuse process water to reduce fresh water intake and release to Patterson Lake, to the extent practical	Secondary pathway
F-04	- additional infrastructure (e.g., roads, airstrip, existing exploration camp, maintenance shop, and offices) - removal of infrastructure - reclamation and revegetation of facilities and infrastructure	Water use affecting water levels and flows: Water supply requirements (potable and process) for the Project may cause changes to water levels and flows and channel/bank stability, which can affect fish habitat availability and distribution	- Adhere to guidance from regulators such as DFO as to the allowable rate and timing of water withdrawals from the point of supply Apply DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2019b) to minimize potential adverse effects on aquatic resources Monitor water flows in the downstream aquatic environment at the outlet of Patterson Lake and apply adaptive management if changes in flows are larger than predicted and are affecting fish habitat - Implement a Project-specific Mine Waste Management Plan - Implement a Project-specific Environmental Protection Program and a Project-specific Environmental Monitoring Plan - Develop and implement a Preliminary Decommissioning and Reclamation Plan to decommission and transfer the site to the province under the Institutional Control Program	Secondary pathway
F-05		Changes to sediment transport: Changes to water flows may alter channel sediment transport conditions in the Clearwater River downstream of Patterson Lake, which can affect fish habitat availability and distribution		Secondary pathway

Table 11.4-1: Potential Effects Pathways for Fish and Fish Habitat

Path ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
F-06	Project components/activities that may cause sediment release during Construction, Operations, and Closure: - land clearing, site preparation, and construction of facilities and infrastructure - handling and storage of waste rock, special waste rock, and ore - removal of infrastructure - reclamation and revegetation of facilities and infrastructure	Sediment release: Sediment release during in-water construction and from ground disturbance may alter fish habitat availability, survival, and reproduction in downstream waterbodies and watercourses	- Where feasible, locate Project footprint components and associated construction activities away from waterbodies and watercourses to avoid or minimize the potential for sediment transfer to the surface water environment Minimize timeframes for site clearing and activities that expose soils, to the extent practical - To the extent practical, work in sensitive areas (i.e., erosive soils, wetland features, and fish habitats) would be scheduled to avoid periods that may result in high flow volumes and/or increase erosion and sedimentation (e.g., spring freshet) - Install appropriate erosion and sediment control measures, as required - Regularly inspect erosion and sediment control measures to confirm they are functioning as planned, and perform any required maintenance, as needed - 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 Minimize areas of vegetation clearing and soil disturbance Minimize steepness and length of slopes of disturbed areas and stockpiled soils Avoid placing soil stockpiles near waterbodies (i.e., maintaining 150 m buffer from waterbodies and watercourses), and near natural drainage features, unless required for temporary storage - Establish appropriate site drainage - Where feasible, preserve natural drainage features to minimize alteration to drainage conditions in the area - Minimize interaction between the surface water system and erodible soils Apply DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2019b) to minimize potential adverse effects on aquatic resources - Where possible, schedule in-water activities to avoid work during DFO's <i>Saskatchewan Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat</i> (DFO 2013a). Restricted activity periods for fish are as follows: - fall/winter spawning fish in northern Saskatchewan with lake trout present (1 September to 15 July) - spring spawning fish in northern Saskatchewan without lake sturgeon (1 May to 15 July) - Implement progressive reclamation and revegetation of disturbed areas no longer required Reclaim and revegetate areas where non-permanent Project facilities have been decommissioned - Implement a Project-specific Mine Waste Management Plan - Implement a Project-specific Environmental Protection Program - Implement a Project-specific Environmental Monitoring Plan - Develop and implement a Preliminary Decommissioning and Reclamation Plan to decommission and transfer the site to the province under the Institutional Control Program	Secondary pathway
F-07	Project components/activities that contribute to emissions and deposition of fugitive dust during Construction, Operations, and Closure: - land clearing, site preparation, and construction of facilities and infrastructure - underground shaft and mine development - site traffic - transportation of personnel and material to and from the site - handling and storage of waste rock, special waste rock, and ore - additional infrastructure (e.g., maintenance shop, offices) - non-hazardous waste incineration - removal of infrastructure - reclamation and revegetation of facilities and infrastructure	Air and dust emissions affecting water quality: Air and dust emissions, including emissions of criteria air contaminants and fugitive dust, and subsequent deposition (e.g., particulate matter, metals, and radionuclides) may cause changes to surface water quality, which may adversely affect fish habitat availability, survival, and reproduction in local waterbodies and watercourses	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 - Establish and enforce speed limits on site and access roads to reduce dust production Optimize haul routes to reduce fuel consumption and emissions from equipment - Primarily use liquified natural gas for power generation Use and maintain emissions control devices on combustion-based equipment Maintain mobile mining equipment and vehicles and monitor for leaks - Evaluate opportunities to reduce fuel combustion requirements of infrastructure and equipment, to the extent practical, during detailed design. - Conduct regular equipment maintenance 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 Effluent and Emissions Plan - Implement a Project-specific Environmental Monitoring Plan that includes ambient air monitoring and adaptive management based on ambient air quality standards	Secondary pathway

Table 11.4-1: Potential Effects Pathways for Fish and Fish Habitat

Path ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
F-08	Project components/activities that may result in direct physical changes to fish habitat during Construction, Operations, and Closure : - fresh water intake for potable and process water - treated effluent discharge pipe and diffuser - treated sewage outfall - associated pipelines	<u>Loss or alteration of fish habitat:</u> Physical loss or alteration of fish habitat in Patterson Lake from the Project footprint, including the fresh water intake, treated effluent diffuser, treated sewage outfall, may affect fish habitat availability	Design in-water developments so that the structures minimize adverse effects on fish and fish habitat and avoid a harmful alteration disruption or destruction of fish habitat, as defined by the federal <i>Fisheries Act</i>, to the extent practical - If required, develop a fish habitat offsetting plan in consultation with DFO and with engagement of the local Indigenous communities - Design and locate shoreline developments (e.g., site roads, shoreline infrastructure, physical footprints of the conveyance pipes for the fresh water intake, treated effluent diffuser, and treated sewage outfall) to minimize riparian vegetation loss and/or disturbance, to the extent practical Revegetate temporarily disturbed areas with suitable, native species after construction activities are complete Minimize the physical footprint of in-water developments (i.e., fresh water intake, treated effluent diffuser, and treated sewage outfall) to the extent practical - To the extent practical, locate in-water developments to avoid potentially sensitive or unique fish habitats Apply DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2019b) to minimize potential adverse effects on aquatic resources - Implement a Project-specific Environmental Protection Program - Develop and implement a Preliminary Decommissioning and Reclamation Plan with government and Indigenous communities to decommission and transfer the site to the province under the Institutional Control Program	Secondary pathway
F-09	Project components/activities that may result in risk of injury/mortality to fish during Construction, Operations and Closure : - installation of fresh water intake, treated effluent diffuser, and treated sewage outfall, associated pipelines, and associated maintenance activities - removal of infrastructure	<u>Disturbance during in-water construction:</u> In-water construction and related activities for the fresh water intake, treated effluent diffuser, and treated sewage outfall can cause injury or mortality to fish, including fish eggs, and disturb fish habitats in Patterson Lake, which may adversely affect fish habitat availability, survival, and reproduction	- To the extent practical, locate in-water developments (i.e., proposed fresh water intake, treated effluent diffuser, and treated sewage outfall) away from sensitive or unique fish habitats Design in-water components of site water management infrastructure (i.e., proposed fresh water intake, treated effluent diffuser, and treated sewage outfall) to minimize the potential for adverse effects on the aquatic environment and such that discharged flow does not interact with sediment, to the extent practical - Where possible, schedule in-water activities to avoid work during DFO's <i>Saskatchewan Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat</i> (DFO 2013a). Restricted activity periods for fish are as follows: - fall/winter spawning fish in northern Saskatchewan with lake trout present (1 September to 15 July) - spring spawning fish in northern Saskatchewan without lake sturgeon (1 May to 15 July) - Employ construction methods that avoid or minimize the potential to cause injury or mortality to fish or disturb nearby habitats, to the extent practical. Assemble in-water structures on shore, where practical, and float into position in Patterson Lake, and then submerged and anchored on the lake bottom - Construct in-water developments in adherence with the conditions of any permits or authorizations that may be issued for the Project from the appropriate regulatory agencies Apply DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2019b) to minimize potential adverse effects on aquatic resources - Implement a Project-specific Environmental Protection Program	Secondary pathway
F-10		<u>Impingement and entrainment of fish in the fresh water intake:</u> Impingement and entrainment of fish in the fresh water intake may cause injury or mortality to fish and affect the survival of fish	Locate the fresh water intake in an area and depth of water that avoids sensitive or unique fish habitats, to the extent practical Locate the intake screen above the bottom of the waterbody to prevent entrainment of sediment and aquatic organisms associated with the bottom area - Design and install a fish screen on the fresh water intake in Patterson Lake to avoid or reduce entrainment or impingement of fish. Pump intake screens would be designed in accordance with DFO's <i>Freshwater Intake End-of-Pipe Fish Screen Guideline</i> (DFO 1995) - Develop and implement a Preliminary Decommissioning and Reclamation Plan to decommission and transfer the site to the province under the Institutional Control Program	Secondary pathway
F-11	Project activities that directly alter fish habitat during Construction, Operations, and Closure : operation of the treated effluent diffuser	<u>Habitat disturbance from treated effluent diffuser:</u> The area of water turbulence around the treated effluent diffuser may affect local fish habitat availability in Patterson Lake	- Locate proposed treated effluent diffuser away from sensitive or unique habitats, to the extent practical - Locate the diffuser discharge ports above the lake bed to avoid or minimize erosion - Discharge pumped contact water through an engineered diffuser to minimize effects from changes in velocity - Develop appropriate discharge flow rates and monitor treated effluent flow to address erosion concerns - Develop and implement a Preliminary Decommissioning and Reclamation to decommission and transfer the site to the province under the Institutional Control Program	Secondary pathway

Table 11.4-1: Potential Effects Pathways for Fish and Fish Habitat

Path ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
F-12	Project activities that change access for Indigenous and other land users during Construction, Operations, and Closure : - development and improvement of access road and site roads - removal of infrastructure - reclamation and revegetation of facilities and infrastructure	Public access affecting survival: Changes in public access to recreational fishing areas on the Clearwater River and in Patterson Lake, and increased density of people (e.g., Project staff and contractors) in the area, may affect the survival of fish	Use existing roads, where feasible. Development of new public roads would not be required; the existing road from Highway 955 would be upgraded (i.e., widened to a surface width of 8 m) to support increased traffic volume and heavy vehicle/equipment use, allow for two-way traffic travel, and improve safety - Transport employees and contractors to site by aircraft, or by bus from La Loche until the on-site airstrip is operational, to limit the opportunity for people to fish along the access road for the Project Install a gate at the site entrance (i.e., gatehouse) to control public access - Implement progressive reclamation and revegetation of disturbed areas no longer required Reclaim and revegetate areas where non-permanent Project facilities have been decommissioned - Develop and implement a Preliminary Decommissioning and Reclamation Plan to decommission and transfer the site to the province under the Institutional Control Program - Work with local Indigenous Groups and communities to develop fishing policies that consider both fisheries protection and traditional use activities	Secondary pathway
F-13	Project components/activities that may change water and sediment quality and aquatic health during Construction, Operations, and Closure : - 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 and special waste rock, and ore - surface water management activities (e.g., water withdrawal, diversion, collection, storage, and treatment) - treated effluent discharge following treatment at ETP - domestic waste water discharge following treatment at STP - removal of infrastructure - reclamation and revegetation of facilities and infrastructure	Project activities affecting water and sediment quality and aquatic health: Project activities and discharge (e.g., treated effluent and treated sewage discharge, runoff from the Project footprint, air and dust emissions, and runoff and seepage from the WRSAs) may cause changes to water and sediment quality during Construction, Operations, and Closure and adversely affect fish habitat availability, survival, and reproduction	Install engineered cover of compacted clean material and growth medium layer on PAG WRSA and install growth medium cover on NPAG WRSA Segregate PAG material from NPAG material and store separately - Collect, store, and routinely monitor contact water to confirm discharge water meets water quality criteria appropriate for release - Confirm discharge meets water quality discharge criteria prior to release to the environment Develop a site-specific ETP and STP to reduce release of COPCs (e.g., major ions, metals, radionuclides) to the environment - Collect contact water, monitor, and treat where necessary Monitor treated effluent and treated sewage flow and quality - Locate proposed treated effluent diffuser away from sensitive or unique habitats, to the extent practical - Design the treated effluent diffuser and treated sewage outfall to provide effective mixing and dilution of the effluent to limit the area of the receiving environment affected by mine discharge Recycle and reuse process water to reduce fresh water intake and release to Patterson Lake, to the extent practical Limit seepages from the PAG WRSA through the use of an engineered physical liner under the storage area Limit seepages from the special waste storage area with double liner and leak detection system - Implement a Project-specific Mine Waste Management Plan - Implement a Project-specific Environmental Protection Program - Implement a Project-specific Environmental Monitoring Plan that includes monitoring in the vicinity of the Project, as required, in accordance with licence requirements and the federal MDMER to monitor the potential effects of Project discharges on water and sediment quality, and on the fish population and benthic invertebrate community - Develop and implement a Preliminary Decommissioning and Reclamation Plan to decommission and transfer the site to the province under the Institutional Control Program	Secondary pathway
F-14		Nutrient changes from Project activities: Project activities and discharge (e.g., treated effluent and treated sewage discharge, runoff from the Project footprint, and air and dust emissions) may change nutrient concentrations in the aquatic receiving environment, and affect fish habitat availability, survival, and reproduction during Construction, Operations, and Closure		Secondary pathway
F-15		Temperature and dissolved oxygen changes from Project activities: Project activities and discharge (e.g., development of the Project footprint, surface water management activities including pumping and storage of contact water, water withdrawals, and treated effluent discharge) may change the temperature and DO regime of receiving waters, which can alter fish habitat availability, survival, and reproduction		No pathway
F-16		TSS changes from Project activities: Discharge of treated effluent can increase TSS concentrations in receiving waters, and affect fish habitat availability, survival, and reproduction		No pathway

Table 11.4-1: Potential Effects Pathways for Fish and Fish Habitat

Path ID	Project Components/Activities	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
F-17	Project components/activities that may cause disturbance to natural drainage features along site and access roads during Construction, Operations, and Closure : - upgrades to the existing access road from Highway 955 - construction of new site roads - installation of cross-drainage structures (e.g., culverts) along site access roads, and associated maintenance activities - removal of infrastructure	<u>Drainage infrastructure affecting habitat and movement:</u> Placement of new or upgraded cross-drainage structures (e.g., culverts) along site and access roads may adversely affect fish habitat availability in downstream fish-bearing environments	- Design new roads such that road alignments minimize the number of water features crossed and avoid sensitive areas to the extent feasible - Design stream crossing structures to limit the area disturbed and in a manner that protects the banks from erosion and maintains the flows Design cross-drainage structures to provide a conveyance for the maximum instantaneous flow resulting from a 1:100-year 24-hour storm event - Construct and install water crossings in a manner that follows best practices and regulatory requirements Inspect culverts regularly and perform maintenance, as required, to prevent blockages from forming and causing ponding or backwater effects - Implement Environmental Protection Program - Develop and implement a Preliminary Decommissioning and Reclamation Plan to decommission and transfer the site to the province under the Institutional Control Program	No pathway
F-18	Project activities that use explosives during Construction and Operations : underground shaft and mine development	<u>Explosives harming fish:</u> Use of explosives near fish-bearing water can affect fish survival and reproduction	Implement DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2019b) to minimize potential adverse effects on aquatic resources Follow DFO's Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998) for setback distances from Patterson Lake. If setback distances are approached, develop site-specific operating mitigations in consultation with DFO - Implement a Project-specific Environmental Protection Program	No pathway

Bolded text represents the key topic of the environmental design features and mitigation.
> = greater than; DFO = Fisheries and Oceans Canada; UGTMF = underground tailings management facility; COPC = constituent of potential concern; ETP = effluent treatment plant; TSP = total suspended particulate; TSS = total suspended solids; STP = sewage treatment plant; MDMER = Metal and Diamond Mining Effluent Regulations; PAG = potentially acid generating; NPAG = non-potentially acid generating; WRSA = waste rock storage area; DO = dissolved oxygen.

11.4.1 No Pathways

The following Project interactions were predicted to result in no pathway to fish VCs and were not carried forward in the assessment.

F-17: Drainage infrastructure affecting habitat and movement:

- Placement of new or upgraded cross-drainage structures (e.g., culverts) along site and access roads may adversely affect fish habitat availability in downstream fish-bearing environments.

Project activities would include upgrades to the existing access road from Highway 955 and the development of new roads on the Project site (Figure 11.1-3). Changes to the existing access road alignment are not planned except to avoid a wetland; however, the road would be widened during Construction to support increased traffic volume and heavy vehicle/equipment use during the Project lifespan. Access and site road development would require the installation of cross-drainage structures (e.g., culverts) or upgrades to existing structures along the road alignments. There are 23 locations along the existing access road where culverts may need to be constructed, replaced, or extended in conjunction with planned upgrades to the road. Additional culverts would also be required for new site roads and on the proposed Project site to provide conveyance of surface runoff within the Project footprint.

A review of geospatial hydrography mapping data (GeoGratis CanVec Series; NRCan 2021) was conducted for the Project footprint. The GeoGratis CanVec Series is a reliable, widely used mapping resource that originates from the best available geospatial data sources covering Canadian territory. These data include detailed delineation of waterbodies, watercourses, and drainage features in Canada (NRCan 2021). Based on the review of the GeoGratis CanVec Series data, none of the planned access road upgrades or new site roads would intersect mapped waterbodies or watercourses. Therefore, any culverts located along the access roads and site roads would provide cross-drainage and prevent upstream ponding but do not cross waterbodies or watercourses with a defined bed and banks that may be habitat for fish. As a result, construction, maintenance, and removal activities related to culverts are not expected to directly affect fish-bearing habitats. Likewise, no change in the distribution of fish habitats within the LSA is expected.

The placement of culverts and associated maintenance activities are not expected to affect fish VC habitat quality in downstream environments, such as Patterson Lake, due to the physical distance between the area of disturbance and fish-bearing habitats and the incorporation of environmental design features and mitigation into the design and maintenance of culverts. In accordance with the Environmental Protection Program: the design of new cross-drainage structures would convey the maximum instantaneous flow resulting from a 1 in 100-year 24-hour storm event and incorporate erosion protection features to prevent localized erosion from high-velocity flows; construction would follow best practices for culvert installations; and culverts would be inspected regularly and maintained to prevent blockages. These measures would limit effects on downstream habitats.

Additionally, the alignments for the existing access road and new site roads would be set back from the Patterson Lake shoreline at most locations (i.e., setback distance typically ranging between 300 m and more than 1 km); there are limited sections with a narrower setback distance, but the distance remains more than 30 m from nearby waterbodies or watercourses, except for ramps and roads needed for installation and maintenance of pipelines and foreshore and lake infrastructure. These setbacks provide a buffer that would prevent effects from construction and operation of proposed roads on downstream fish-bearing environments.

As Project roads and components are not expected to cross water features frequented by fish, installation and/or upgrades to culverts would not affect fish VC habitat quantity or distribution in the LSA. Similarly, effects on downstream, fish-bearing habitats are not expected due to the incorporation of identified environmental design features and mitigations. Therefore, this pathway was determined to have no linkage to effects on lake trout, lake whitefish, walleye, and northern pike and was not carried forward in the assessment.

F-18: Explosives harming fish:

- Use of explosives near fish-bearing water can affect fish survival and reproduction.

Pressure changes and vibrations caused by blasting on land during Project Construction and Operations can cause injury or mortality of fish in nearby Patterson Lake. Post-detonation compression shock waves caused by detonations of explosives near water can cause internal damage to the swim bladder and other soft organs of fish and can cause changes to fish behaviour (Wright 1982; Wright and Hopky 1998; Cott and Hanna 2005; Goddard et al. 2008). The severity of effects is related to the type of explosive, method of detonation, distance away from fish, water depth, and the weight and pattern of the explosive charges. The species, size, and life stage of fish also play a role in the severity of effects of blasting. Fish eggs incubating in spawning beds near blasting zones can be damaged by movement of the substrate in which eggs are imbedded, causing mortality or disrupting development (Wright 1982; Faulkner et al. 2006, 2008). Peak particle velocities (i.e., vibrations) can increase mortality of incubating eggs close to blasting zones (Wright 1982).

The YNLR have expressed concerns about the potential effects of using explosives on fish and other resources.

It would affect the water, and wildlife especially if they have to blast in the water and land. It would also affect the moose, and fish – there is good fish in that area. There are similar mine sites in this area, they say it okay, eventually it does affect the water. It will affect the fish and wildlife.
(TSD VI: YNLR)

Blasting is not planned adjacent to or within waterbodies or watercourses.

All applicable DFO-recommended measures to avoid causing harm to fish from the use of explosives would be followed for the proposed Project (DFO 2019b). The DFO guidelines (Wright and Hopky 1998) and recommendations (Cott and Hanna 2005) for the use of explosives in or near fish-bearing waters provide a maximum allowable limit for overpressure (i.e., peak pressure level; 50 kilopascals) and peak particle velocity (i.e., 13 mm/s). For example, assuming a detonation of a confined explosive with a heavy charge weight of 100 kg, a conservative setback distance of 77 m from the blast location would be applied to avoid effects to fish from pressure changes, and a distance of 150.9 m would be applied to avoid effects to incubating eggs from increased peak particle velocities (Wright and Hopky 1998; Cott and Hanna 2005). Several studies have demonstrated the effectiveness of DFO recommended setback distances for detonations in avoiding effects to fish (Faulkner et al. 2006, 2008).

Blasting for the Project would occur in conjunction with development of the underground mine and UGTMF at the locations of the production shaft and exhaust shaft. All Project blasting would occur on land and not in Patterson Lake. The minimum separation distance between Patterson Lake and the anticipated location of Project blasting is 345 m; however, much of the blasting activity would occur at distances typically greater than away 450 m (UGTMF blasting) to 750 m (production blasting) from Patterson Lake. Peak pressure level and peak particle velocity vibration levels were predicted for Project blasting at the nearest anticipated location to

Patterson Lake. Blasting activities would be located at distances greater than the DFO recommended setback distances referenced above (TSD X, Vibration Effects Analysis Report), and thus avoid harm to fish. If these setback distances are approached, site-specific operating mitigations could be implemented, as required, to protect fish.

Thus, survival and reproduction rates of fish in nearby surface waters would remain unchanged as a result of the use of explosives during Project Construction and Operations. Therefore, the effect of pressure changes and vibrations from blasting on fish is considered as no pathway because blasting would occur at a considerable distance from Patterson Lake. As a result, there are no predicted residual effects on lake trout, lake whitefish, walleye, and northern pike survival and reproduction, and this pathway was not carried forward in the assessment.

F-15: Temperature and DO changes from Project activities:

- Project activities and discharge (e.g., development of the Project footprint, surface water management activities including pumping and storage of contact water, water withdrawals, and treated effluent discharge) may change the temperature and DO regime of receiving waters, which can alter fish habitat availability, survival, and reproduction.

Project components and activities, such as pumping and storage of contact water, treated effluent discharge, and other activities associated with surface water management and site preparation, have the potential to alter the temperature and DO regime of downstream receiving environments and to affect the suitability and availability of habitat for fish VCs in the LSA. Water temperatures or DO levels outside of the preferred range for a fish species can affect survival and reproduction. Changes to water temperature or DO conditions could occur directly through mixing of treated effluent with ambient water, or indirectly, through changes in environmental factors or processes that may mediate the physicochemical characteristics of surface water. For example, changes to surface water flows and levels (Caissie 2006), increases in nutrient concentrations (Wetzel 2001), or losses and/or disturbance to riparian vegetation (Broadmeadow and Nisbet 2004; DeWalle 2010) can be factors affecting the temperature and/or DO regime of surface waters.

Prior to releasing treated effluent to Patterson Lake, mine water and contact water would be captured and stored in treatment ponds at ambient temperatures. Based on the design of the water treatment infrastructure, water storage and treatment are not expected to thermally alter the treated effluent discharge relative to ambient conditions. Effluent would be conveyed to the treated effluent diffuser and treated sewage outfall using above-ground heat-traced pipelines to prevent the effluents from freezing; however, the heat-tracing would not be expected to appreciably raise the temperature of the effluents.

Changes in water temperature and DO conditions in the Patterson Lake receiving environment were assessed in the surface water quality assessment using the approach and conservative assumptions described in Section 10A 6.4.2 of Appendix 10A. The results indicate that increases in water temperature would be less than 1°C at the edge of the regulated mixing zones (RMZs) for the treated effluent diffuser and treated sewage outfall, during both ice-cover and open-water conditions. These predicted increases are considered to be within the natural range of variability for Patterson Lake (Section 10.3) and are not likely to be measurable. Similarly, decreases in DO concentrations were estimated to be less than 0.1 mg/L, and would be within the natural range of variability for Patterson Lake and not likely measurable. Additionally, the treated effluent diffuser and treated sewage outfall would be designed to provide effective mixing and dilution of the treated effluent, such that water temperatures and DO conditions would be well mixed within the adjacent Patterson Lake receiving environment, with no measurable changes from existing conditions (TSD XX, Downstream Use and Impact Study for Proposed

Treated Sewage Discharge Report) beyond the 100 m RMZ. Consequently, the implementation of environmental design features would avoid residual effects on fish habitat quality, such that effects on fish VCs are not expected.

The proposed Project is not expected to adversely affect the function of the riparian zone of Patterson Lake in providing adequate shading of surface water from solar radiation, which can be an important factor moderating water temperature (Broadmeadow and Nisbet 2004; DeWalle 2010). Only very minimal losses or disturbance to riparian vegetation are expected due to the Project, as Project components would generally be located more than 30 m away from waterbodies and watercourses. Additionally, in cases where infrastructure footprints are required within 30 m of a waterbody (e.g., the construction of a fresh water intake pumphouse adjacent to Patterson Lake), the developments would be sited in previously disturbed areas, where feasible. Further assessment and description of predicted riparian habitat losses or disturbance associated with the proposed Project is provided in Section 11.4.2, Secondary Pathways, under pathway F-08: Loss or alteration of fish habitat. Changes to water temperature related to riparian habitat loss would not be expected, but if they were to occur, effects would be localized and limited to shoreline areas immediately adjacent to the disturbances; these localized changes are likely unmeasurable and would not affect the lake as a whole. As a result, there would be no corresponding effects on fish VC populations.

Project-related changes in hydrology are not expected to be of sufficient magnitude to affect the temperature and/or DO regime of surface waters. Changes in hydrologic conditions can affect the local environment by altering environmental variables such as waterbody residence time, turnover conditions, lake inflow/outflow conditions, and other dynamic processes, which are factors that can mediate water temperature and/or DO conditions in receiving waters (Wetzel 2001; Caissie 2006). The results of the hydrology assessment (Section 9.6.1.2) indicate that changes to watercourse flow rates, lake levels, and stream channel parameters are predicted to be small and not measurable at hydrometric stations. Therefore, changes in hydrology are not expected to meaningfully alter the physicochemical characteristics of waterbodies and watercourses or affect fish VC habitat quality.

The results of the surface water quality assessment (Section 10) indicate that proposed Project activities and discharge would result in increased nutrient concentrations in Patterson Lake and other downstream environments, particularly during Operations. An analysis of potential effects from increased nutrient concentrations on fish VCs is provided in Section 11.4.2 under pathway F14: Nutrient changes from Project activities (Table 11.4-1). A minimal (i.e., less than 0.005 mg/L) increase in TP concentration is expected in the receiving environment during the 43-year Project lifespan. With an increase in TP concentration of approximately 0.005 mg/L, a minor corresponding increase in the productivity of phytoplankton may be expected; however, at the predicted magnitude of effect, reductions in DO that could affect habitat use or suitability for fish VCs are not expected (Anderson 2002; Wetzel 2001).

Overall, changes in water temperature and DO conditions are predicted to remain within the natural range of variability for Patterson Lake and are expected to be not measurable in the receiving environment. Consequently, changes to fish habitat availability, survival, and reproduction are not expected. Therefore, this pathway was determined to have no linkage to effects on lake trout, lake whitefish, walleye, and northern pike and was not carried forward in the assessment.

F-16: TSS from Project activities:

- Discharge of treated effluent can increase TSS concentrations in receiving waters and affect fish habitat availability, survival, and reproduction.

Discharge of treated effluent and treated sewage to Patterson Lake has the potential to result in an increase in total suspended solids (TSS; i.e., particles suspended in the water column) and turbidity (i.e., a measure of relative clarity of the water) in the receiving environment. During engagement for the Project, the BNDN expressed concern that the Project could cause changes to water clarity (TSD II: BNDN). An increase in TSS or turbidity has the potential to adversely affect fish habitat quality and the survival and reproduction of fish. Total suspended solids may affect fish by altering their physiology, behaviour, and habitat, all of which may lead to physiological stress and reduced survival or reproduction rates (Bash et. al. 2001). The nature and extent of adverse effects of increased TSS is influenced by both the TSS concentration and the duration of exposure. Fish can typically tolerate lower concentrations of TSS for longer periods and higher concentrations for shorter periods before potentially experiencing harmful effects (Newcombe and Jensen 1996).

Total suspended solids loadings to the receiving environment from the treated effluent discharge are anticipated to be low. The diffuser and outfall designs would provide effective mixing and dilution of the treated effluent, which would limit the area of the receiving environment expected to experience an increase in TSS concentrations. The surface water quality assessment (Section 10) provided a conservative analysis (Appendix 10A, Section 10A6.4.2) estimating effects of discharge on TSS concentrations at the edge of the RMZs for the treated effluent diffuser and treated sewage outfall in Patterson Lake. Total suspended solids concentrations during peak effects (i.e., Operations) are predicted to be 1.8 mg/L and 1.1 mg/L at the edge of the RMZs for the treated effluent diffuser and treated sewage outfall, respectively, during both ice-cover and open-water conditions. These predictions reflect increases of 0.8 mg/L and 0.1 mg/L at the RMZs for the treated effluent diffuser and treated sewage outfall, respectively, relative to baseline values (Appendix 10A). These predicted increases are within the range of natural variability for Patterson Lake (Appendix 10A) and are unlikely to be measurable in the environment.

It is expected that TSS in the effluent would settle within a short distance of the treated effluent diffuser and treated sewage outfall resulting in minor, localized changes to water and sediment quality in the immediate, adjacent receiving environment of Patterson Lake relative to baseline conditions. Settling of sediment on the lake bottom is not expected to adversely affect sensitive or unique fish habitats due to the low magnitude of the predicted TSS increases and because the diffuser and outfall have been sited away from unique or sensitive fish habitats. Additional description and assessment of the effects of in-water developments, including the treated effluent diffuser and treated sewage outfall, on fish habitats in Patterson Lake is provided in Section 11.2.4, Temporal Boundaries.

Surface water quality would be protected and managed in accordance with the Environmental Protection Program. The ETP would be designed to remove TSS such that the concentrations in the treated effluent discharge would be below the maximum authorized monthly mean concentration of 15 mg/L, set out in Schedule 4, Table 1, of the Metal and Diamond Mining Effluent Regulations (MDMER). These criteria are set to be protective of fish and aquatic life. The rate of discharge from the ETP would be managed by having adequate surface water storage capacity to allow for controlled release rates. Effluent from the ETP would be stored in ponds and only released to Patterson Lake in batches after treated effluent is tested to confirm water quality objectives are met.

Site drainage from non-mineralized areas of the site that is not treated in the ETP would have the potential to entrain TSS. However, this water would be collected in sedimentation ponds or discharged through infiltration to remove TSS. For example, runoff from the NPAG WRSA would be collected in site runoff pond #2, (i.e., contact water pond #2) which would then be pumped to the west bermed runoff collection area, after being tested and passing water quality criteria. From the west bermed runoff collection area, water would then infiltrate and report to Patterson Lake via shallow groundwater. This flow pathway would remove virtually all TSS before the water reaches Patterson Lake.

Given that predicted increases in TSS are expected to be minor and localized, discharge of TSS to the receiving environment is not expected to measurably affect fish habitat quality or alter the survival and reproduction of fish VCs. Therefore, this pathway was determined to have no linkage to effects on lake trout, lake whitefish, walleye, and northern pike and was not carried forward in the assessment.

11.4.2 Secondary Pathways

The following Project interactions were predicted to result in secondary pathways to fish VCs and were not carried forward in the assessment.

F-02: Habitat disturbance at river crossing:

- Movement of heavy equipment and infrastructure across the Clearwater River at the existing access road crossing location may adversely affect fish habitat availability, survival, and reproduction.

At certain stages of the proposed Project, it may be necessary to employ a crane to move heavy mobile equipment and infrastructure over the Clearwater River at the existing access road crossing location. The existing Clearwater River bridge along this existing access road is a light duty, clear span structure that accommodates single lane traffic. The structural capacity and width of the bridge would be adequate for most vehicles and equipment accessing the Project site; however, the capacity of the bridge may be insufficient to support some large loads during Construction, Operations, and the Active Closure Stage. Operation of a crane adjacent to the Clearwater River, and movement of heavy equipment and infrastructure over the river, could adversely affect fish VC habitat quality by disturbing riparian vegetation and through the potential for increased erosion and sedimentation and/or water quality effects.

Access to the Project site would be provided by the existing access road from Highway 955. Upgrades to the access road are planned to support increased traffic volume and heavy vehicle/equipment use and to widen the road surface. This additional development of the road would include upgrades to cross-drainage structures to accommodate the wider road width and anticipated use. An upgrade to the Clearwater River bridge is not planned, because in most circumstances, the existing bridge would provide sufficient capacity for the planned use. Therefore, the preferred approach for the Project is to maintain the existing bridge and to use a crane to move equipment over the river in limited instances where loads may exceed the legal rating or capacity of the bridge. An alternative option would be to upgrade the existing bridge to provide additional capacity; however, this approach would be taken only if the preferred approach is not feasible, as determined during detailed design. An assessment of potential effects on fish VCs is provided below for the preferred approach, as well as the alternative option.

Movement of materials over the Clearwater River at the existing bridge location by crane would occur only in instances where loads exceed the legal rating or capacity of the bridge and options for reducing load size/weight are not feasible or practical (e.g., dismantling equipment, breaking down a load into smaller units). The crane would be used to lift and move heavy equipment or materials horizontally over the river, and would operate above the bank, adjacent to the Clearwater River. Fording of the river by the crane and equipment would not occur. Use of a crane adjacent to the river may require the development of site access and staging areas. This could result in a temporary loss of, or disturbance to, riparian vegetation in the immediate work area. There is also potential for increased soil erosion and runoff to surface water due to site preparation activities and heavy equipment operation near the watercourse. Additionally, sediment-laden runoff and the potential for leaks from equipment could alter the chemical properties of the water (e.g., increase turbidity and TSS, introduce hydrocarbons) and adversely affect fish habitat quality, survival, and reproduction.

If feasible, staging areas would be constructed to avoid critical or sensitive habitat (e.g., riparian zones), following best practices and regulatory requirements. The footprint of staging areas would be limited to the extent practical to minimize the area of disturbance. The development of staging areas and operation of the crane would be managed so that the activities do not result in any disturbance to the bed and banks of the river. Crane pads would be used to reduce erosion and disturbance to soils. Disturbed areas would be reclaimed and revegetated after the activities are complete. Construction practices and mitigation measures would follow DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2019b) to minimize adverse effects on aquatic resources.

To prevent deleterious substances from entering the watercourse, the crane and any equipment or infrastructure to be moved over the river would arrive in good working order and be well maintained and free of leaks in accordance with the Environmental Protection Program. The crane would be routinely inspected throughout the duration of use and would be removed from the work area upon completion of the activities, or during extended periods where it is not in use. Standard best management practices and mitigations related to spills would be implemented in accordance with the Emergency Preparedness and Response Program (Section 11.4.1, No Pathways).

In the event that an upgrade to the existing Clearwater River access road bridge is deemed necessary, the bridge would be upgraded to a larger clear span structure that would have no permanent footprint below the high-water mark. The upgraded bridge, if required, would be designed to maintain the natural channel and hydraulic conditions of the Clearwater River. Clearing of riparian vegetation would be limited to the footprint and the immediate work area. Some limited disturbance to the watercourse bed or banks and to riparian vegetation may occur during bridge construction, and there is potential that limited in-water work may be required depending on the final design and plan for construction. Where possible, in-water work would be scheduled outside of the DFO restricted activity timing windows, which are: 1 September to 15 July for fall/winter spawning fish in northern Saskatchewan with lake trout present; and 1 May to 15 July for spring spawning fish in northern Saskatchewan without lake sturgeon (DFO 2013a). Permanent alterations to riparian vegetation may occur due to installation of the bridge footprint (e.g., abutments) on the shoreline. Construction practices and mitigation measures would follow DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2019b) and incorporate design and mitigation guidance from DFO and Saskatchewan government's *Fish Habitat Protection Guidelines: Road Construction and Stream Crossings* (1995) to minimize adverse effects on aquatic resources.

With implementation of best management practices and mitigation, effects on fish VC habitat quality, survival, and reproduction from the use of a crane to transport equipment and infrastructure over the Clearwater River are expected to be of short duration (i.e., primarily limited to periods when the crane is in use) and negligible in

magnitude. In the event that an upgrade to the existing access road bridge is required, the activities would be expected to result in negligible changes to fish habitat availability. Therefore, this pathway was classified as a secondary pathway and not carried forward for further assessment.

F-03: Altered site drainage affecting water levels and flow:

- Altered site drainage, runoff, and discharge may cause changes to water levels and flows and channel/bank stability in downstream waterbodies and watercourses and affect fish habitat availability and distribution.

AND

F-04: Water use affecting water levels and flows:

- Water supply requirements (potable and process) for the Project may cause changes to water levels and flows and channel/bank stability in downstream waterbodies and watercourses, which can affect fish habitat availability and distribution.

AND

F-05: Changes to sediment transport:

- Changes to water flows may alter channel sediment transport conditions in the Clearwater River downstream of Patterson Lake, which can affect fish habitat availability and distribution.

For brevity, the pathways F-03, F-04, and F-05 are discussed together because they share similar potential causes, assessment methods, and mitigations.

Potential effects on fish habitat availability and distribution may occur due to changes in hydrology during Construction, Operations, and the Active Closure Stage. Natural flow regimes are essential for sustaining fish populations and the ecosystem structure and function that supports these populations (DFO 2013b). Fish VC populations in the LSA and RSA could be adversely affected through the alteration of natural lake levels, watercourse flow rates, and the potential for subsequent effects on natural channel and bank conditions. Changes to flow rates can also affect sediment transport conditions in a watercourse by changing the natural loading and movement of sediment and bed material within the watercourse, which can alter the quality and distribution of available habitats for fish.

The Project mechanisms (e.g., fresh water withdrawal) and site water management features, facilities, and activities that could contribute to potential changes in hydrometric conditions in waterbodies and watercourses in the LSA and RSA are described in the hydrology assessment (Section 9.6). Development of the proposed Project footprint would remove drainage area from the Patterson Lake watershed, which would locally alter drainage and runoff conditions to Patterson Lake. Water would be withdrawn from Patterson Lake to supply the site water system for mining and domestic potable water consumption. Non-contact water generated from undisturbed catchments adjacent to the Project footprint would be diverted around the area using diversion ditches and conveyed directly to Patterson Lake. Contact water that may have been physically or chemically altered by construction, mining, or milling activities would be controlled and monitored. Then, depending on water management requirements, water would be either reused, discharged if it meets discharge criteria, or treated at the ETP to ensure it meets discharge criteria prior to release. Treated effluent would be released to Patterson Lake via an engineered diffuser. Treated sewage generated from the use of fresh water or treated

fresh water by domestic sources would be discharged back into Patterson Lake via a treated sewage outfall. These Project activities would result in a net discharge of water to Patterson Lake during Construction, Operations, and the Active Closure Stage.

During engagement for the Project, Indigenous Groups communicated the value of the lakes, rivers, and streams in the area of the Project (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; TSD VI: YNLRO). The YNLRO expressed concern regarding the sustainable and responsible use of water resources and the potential for corresponding effects on aquatic communities (YNLRO 2019).

The Environmental Protection Program developed for the Project outline the mitigation measures and policies that would be used to avoid or minimize effects on downstream water resources and fish habitat (Table 11.4-1). The YNLRO commented about the importance of responsibly managing water on site and recommended that water use for the Project be minimized by recycling and reusing water on site wherever possible (YNLRO 2019). Proposed infrastructure has been designed to reuse and recycle water wherever possible to minimize the amount of fresh water withdrawn from Patterson Lake (Table 11.4-1). Effects on hydrology would also be reduced by the compact design of surface infrastructure, which would limit changes to drainage areas and runoff pathways, as well as the amount of water that needs to be collected and treated. Site water management facilities and systems are designed in a manner that minimizes Closure activities where possible.

An evaluation of Project-related effects on surface water quantity is presented in the hydrology assessment (Section 9.6.1). A summary of the results of this assessment and potential for resulting effects on fish VCs is provided below.

Predicted Changes to Hydrology

The hydrology assessment (Section 9.6.1) quantitatively evaluated the potential Project-related changes in hydrometric measurement indicators, which included water surface elevation (i.e., lake water levels), watercourse flow rates, stream channel parameters (e.g., wetted area), and fluvial sediment transport conditions. These indicators represent important fish habitat parameters that are considered in the evaluation of the habitat availability and habitat distribution measurement indicators for fish VCs (Section 11.2.2; DFO 2013b; Bradford et al. 2014). Residual effects on lake water levels, watercourse flow rates, and stream channel parameters were evaluated via the development of a regional hydrological model. Predicted effects were modelled for each Project phase, and at key evaluation nodes on waterbodies and watercourses downstream of the Project. Potential Project-related changes in fluvial sediment transport conditions were evaluated using a fluvial sediment transport model for the Clearwater River below Patterson Lake. Both the regional hydrological model and sediment transport model considered all potential effect mechanisms in the upstream watershed area, including changes in site drainage conditions, runoff, water collection and storage, discharge, and water supply requirements.

The hydrology assessment results indicated that the proposed Project would result in minor increases in lake water levels and watercourse flow rates in the receiving environment, with the largest increases expected in Patterson Lake and the Clearwater River below Patterson Lake (Section 9.6.1). These increases would propagate downstream but diminish in magnitude as the watershed area and ambient flows increase. Predicted increases in watercourse flow rates could result in minor changes to stream channel parameters and sediment transport conditions in the Clearwater River downstream of Patterson Lake. These predicted changes could affect fish VCs by modifying the amount and suitability of available habitat and the connectivity of habitats in the LSA and RSA.

Project-related changes in hydrometric measurement indicators are predicted to peak during Operations when the proposed Project footprint is fully developed and when water is discharged to Patterson Lake at maximum rates. During Closure, discharge to Patterson Lake would cease, and baseline drainage conditions would be restored. Consequently, Closure activities would result in the reestablishment of natural flow rates, water levels, and volumes at Patterson Lake and its outflow.

Predicted changes in fish VC habitat availability and distribution from modelled changes in lake water levels, watercourse flow rates, stream channel parameters, and fluvial sediment transport conditions are summarized below, with emphasis on changes occurring during Operations, when peak effects are expected to be realized.

Effects from Changes to Lake Levels

Natural fluctuations in water surface elevations are important for the maintenance of fish habitat in waterbodies (DFO 2013b), including potentially sensitive habitats such as shoals and areas of inundated vegetation, which may serve as important spawning and nursery habitats for fish (Snodgrass et al. 1996; Keddy and Reznicek 1986). Proposed Project activities are predicted to result in a small net change in lake water levels during Construction, Operations, and the Active Closure Stage. Peak increases in mean monthly lake levels relative to Base Case conditions would occur during Operations and are estimated to be consistently less than 1 cm for Patterson Lake and less than or equal to 0.5 cm for Forrest, Beet, and Naomi lakes. Expressed as a percentage, these changes would be less than 1.2% for Patterson, Forrest, Beet, and Naomi lakes. These changes are well within the natural variability of lake levels for Patterson Lake and downstream waterbodies and are unlikely to be measurable at any of these waterbodies (Section 9.6.1). The projected increases are not expected to meaningfully alter water depth in potentially sensitive areas, such as identified spawning areas along the Patterson Lake shoreline (Annex V.1; Section 11.3), or in shallow nearshore nursery habitats such that changes to the suitability of these habitats for use by VC fish species would occur. Overall, changes in lake water levels are predicted to have a negligible residual effect on fish habitat availability and distribution in downstream waterbodies.

Effects from Changes to Watercourse Flow Rates

Maintaining characteristics of the natural flow regime in terms of timing, magnitude, and frequency of flow is an important consideration in sustaining the health of riverine ecosystems (Poff et al. 1997; Arthington et al. 2006; Richter et al. 2012). Increases in flow can alter fish habitat availability by changing available habitat area and other characteristics (e.g., flow depth) that can affect the suitability of the habitat for use by fish. Changes in habitat distribution may occur through alteration of flow depth and velocity conditions, which can alter fish passage conditions.

Applicable guidance to avoid or reduce the potential for adverse effects on fish from flow alterations was considered for the Project. A broadly applied “presumptive standard” for evaluating flow departure from natural conditions is presented in Richter et al. (2012), which recommends that a departure from natural flow conditions of less than or equal to 10% would result in a high level of ecological protection whereby the natural structure and function of the ecosystem would be maintained. The DFO *Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada* (2013b) also applies a percent-of-flow approach and recommends that cumulative flow alterations remain within 10% of natural instantaneous flow. Maintaining flows within 10% of natural flow was expected to have a low likelihood of having detectable negative effects on the ecosystem.

Flows in the Clearwater River below Patterson Lake are predicted to increase in response to a net discharge of water to Patterson Lake resulting from proposed Project activities during Construction, Operations, and the Active Closure Stage. Expressed as a percentage relative to Base Case conditions, increases in mean monthly flow would be between 1.3% and 1.9% at the worst-case assessment node on the Clearwater River below Patterson Lake. For the evaluation nodes farther downstream on the Clearwater River, percent increases in mean monthly flow would be less than or equal to 1.4%, with the predicted changes decreasing in magnitude moving in a downstream direction. These changes would not be detectable during operational monitoring and would be within the natural range of variability for the Clearwater River at both daily and seasonal time scales (Section 9.6.1). Consequently, the natural timing of peak flows and the relative seasonal magnitude of flow conditions would remain unchanged. Additionally, no channel or bank stability effects are expected because the magnitude of predicted flow-related effects is small relative to the Base Case. The predicted changes in watercourse flow rates are well within recommended guideline values (i.e., cumulative flow alterations of less than 10% of natural instantaneous flow; DFO 2013b; Richter et al. 2012) for reducing or avoiding negative effects on fish habitat and are therefore expected to have a negligible effect on fish VCs.

Effects from Changes in Wetted Area

Predicted increases in flows downstream of the proposed Project may result in limited changes to stream channel parameters (e.g., wetted area) in the Clearwater River. In riverine environments, changes to habitat size (i.e., areas of available habitat) due to flow alterations can affect the productivity of fish (e.g., growth, population size; Bradford et al. 2014). Changes in stream channel parameters using wetted area as the representative parameter were predicted to be less than 1% at the Clearwater River evaluation nodes at the mean annual flow and would not be large enough in magnitude to be detectable (Section 9.6.1). No effects on fish VCs are expected due to changes in stream channel parameters.

Effects from Changes in Sediment Transport Conditions

Increases in flow may change sediment transport conditions by altering the rate and nature of sediment movement downstream, which can affect fish habitat availability through changes in substrate conditions, channel geomorphology, and distribution of channel unit types (e.g., riffles, runs, pools) within the watercourse (Hassan et al. 2018). Changes in fluvial sediment transport conditions were assessed for the Clearwater River below Patterson Lake along the section from Patterson Lake to the north end of Forrest Lake. Estimated sediment transport, expressed as cumulative mass change along the section, was predicted to increase slightly (i.e., 2%); however, erosional losses in the upstream areas would be largely counterbalanced by increased sediment deposition in the downstream areas (Section 9.6.1). Predicted changes in fluvial sediment transport conditions in the LSA are not expected to be measurable and are not expected to be of a sufficient magnitude to meaningfully alter fish habitat conditions such that residual adverse effects on fish VCs would occur.

Summary

With implementation of mitigation and environmental design features incorporated into the proposed Project, changes to hydrology are expected to be minor and not large enough to be detectable in downstream waterbodies and watercourses. Based on the quantitative outcome of the hydrology assessment, predicted changes in lake water levels, watercourse flow rates, stream channel parameters, and fluvial sediment transport, conditions are not expected to meaningfully affect fish habitat availability and distribution in waterbodies and watercourses downstream of the Project. Therefore, these pathways were determined to have a negligible residual effect on lake trout, lake whitefish, walleye, and northern pike, and were not carried forward in the assessment.

F-06: Sediment release:

- Sediment release during in-water construction and from ground disturbance may alter fish habitat availability, survival, and reproduction in downstream waterbodies and watercourses.

Increases in the concentrations of suspended sediment in surface water can result directly from disturbance and re-suspension of bed material during in-water construction or indirectly from site runoff. These increased concentrations could increase TSS and turbidity in downstream aquatic ecosystems and result in an adverse effect on fish habitat quality, and the survival and reproduction of fish VCs. During engagement for the Project, the BNDN expressed concern that Project activities could adversely affect water clarity in Patterson Lake (TSD II: BNDN).

Exposure to suspended sediment can affect the health of fish and lower trophic organisms, with effects ranging from minor physiological stress to mortality (Coen 1995; Berli et al. 2014). The magnitude of the effect depends on a combination of the suspended sediment concentration, particle size (Muck 2010; Lake and Hinch 1999), and the duration of exposure. Excess suspended sediment can also result in changes in behaviour (Schreck et al. 1997), such as feeding (Berg and Northcote 1985) and predator avoidance (Miner and Stein 1996). Fish can tolerate low TSS concentrations for long periods and high concentrations for short periods without suffering adverse effects (Caux et al. 1997; Newcombe 2003; Fleming et al. 2005). The effects of sediment deposition can include infilling of interstitial spaces between substrate particles that provide habitat for spawning, rearing of fry, or incubation of eggs (Bash et al. 2001; Muck 2010). Infilling of substrates can also affect habitat conditions for benthic invertebrates, which are an important food source for fish. Sediment can cover aquatic plants that can provide habitat for fish, particularly northern pike. The severity of the effect depends on the type of habitat and its use by fish (Bash et al. 2001; Muck 2010).

The main Project activities and mechanisms that may result in sediment release to waterbodies and watercourses are in-water construction activities associated with the installation of water management infrastructure components in Patterson Lake, and runoff from ground disturbance (e.g., site clearing, contouring, excavation) during Construction. Changes in natural erosion and sedimentation conditions may also occur during Operations and Closure of the Project due to altered site runoff conditions. However, the magnitude of predicted effects from sediment release is expected to be greatest during Construction and during the subsequent removal of Project components in the Active Closure Stage.

Sediment release from in-water construction activities may occur as a direct result of installing the proposed fresh water intake, treated effluent diffuser, and treated sewage outfall in Patterson Lake during Construction, associated maintenance activities during Operations, and infrastructure removal during the Active Closure Stage. In-water developments planned for the Project have been designed to reduce adverse effects on the aquatic environment. Construction methods for these structures would be relatively unobtrusive in terms of the potential for sediment to be released to the aquatic environment. Structures would be assembled on shore and floated into position in Patterson Lake and then submerged and weighted to the lake bottom. Pipelines intersecting the Patterson Lake shoreline and riparian zone would be installed above ground, and in-water sections of pipe would be installed on the lake bottom.

The installation methods that would be used for in-water developments typically do not cause extensive entrainment of sediments or high TSS levels, as there is limited potential for disturbance to the lake bed substrate and shoreline areas. Consequently, the potential for sediment-related effects would be lower than for more invasive construction methods, such as activities that require excavation, open-trenching, the use of isolation measures (i.e., to allow work in the dry), or construction of coffer dams (DFO 2019b). However, some degree of disturbance to the lake bed substrate and along shoreline areas would be expected during installation of these Project components, which could result in sediment release and temporary increases in TSS concentrations in water.

The release of suspended particulate matter during the proposed in-water construction and subsequent deposition of sediment on the lake bottom could locally alter substrate conditions and affect fish VC habitat suitability. Effects on fish habitat availability from settling of particulate matter may potentially occur in areas where high quality substrates are found (e.g., clean gravel, cobble, or boulder substrates that are relatively free of silt, organics, and debris). Based on the results of field surveys completed during the aquatic environment baseline study (Annex V.1), the pipes for the proposed fresh water intake and treated sewage outfall would intersect shoreline areas consisting of cobble and boulder substrates (Annex V.1; Figure 11.4-1). Limited and localized effects would be possible in these areas due to sediment release and subsequent deposition. However, meaningful effects from sediment deposition would be unlikely during the effluent diffuser pipe installation, which would intersect an area consisting primarily of sand substrate. Similarly, effects from sediment deposition are not expected in deeper areas of Patterson Lake where silt or organic substrates are more likely to occur.

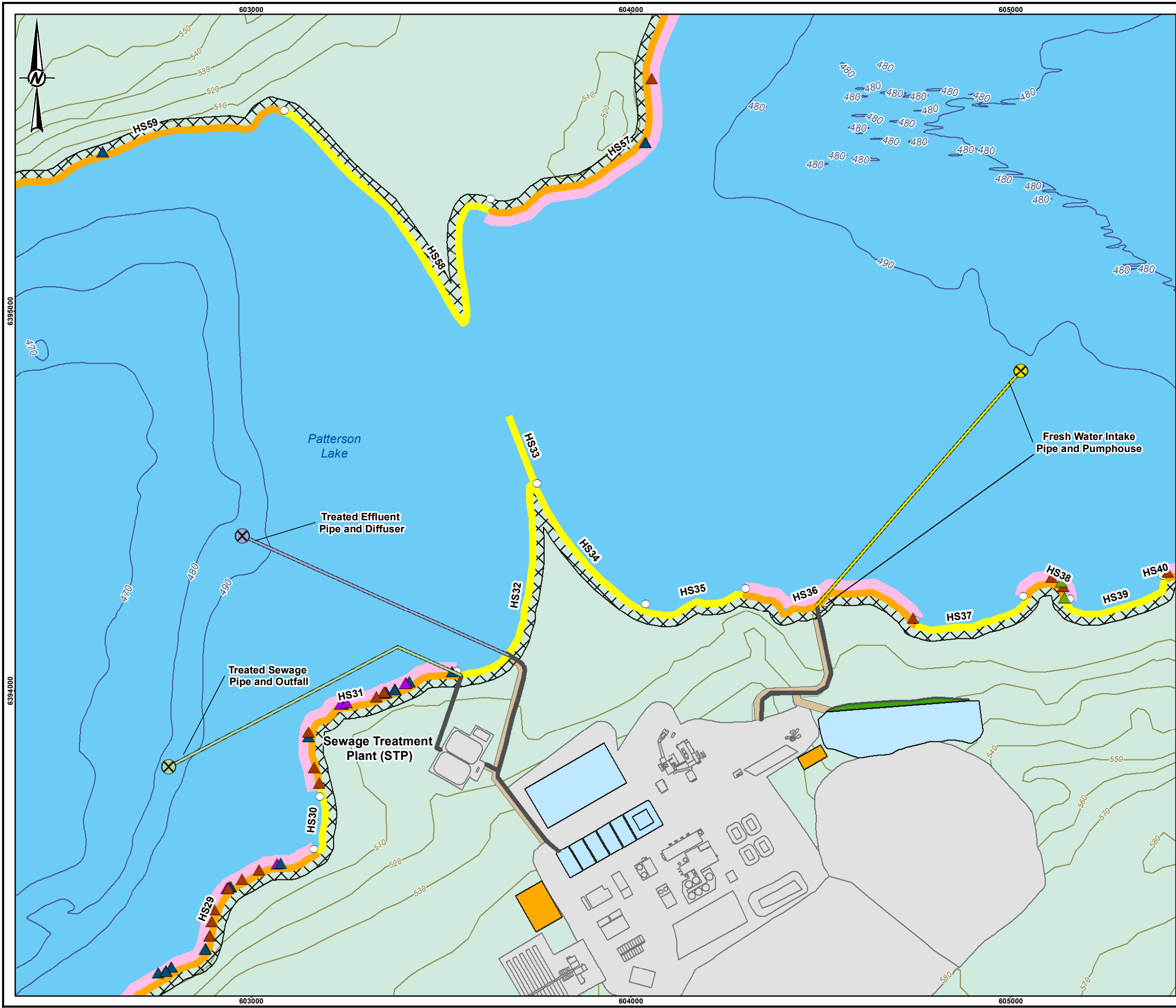
In-water construction activities are expected to occur over short periods of one to two days (i.e., for each development). Consequently, the duration of potential effects would be short and limited to the immediate vicinity of the work area. Similar types of effects could occur during maintenance and removal activities related to the in-water developments. Construction of in-water developments and associated shoreline infrastructure would occur during the open-water season. Where possible, in-water work would be scheduled outside of the DFO restricted activity timing windows, which are: 1 September to 15 July for fall/winter spawning fish in northern Saskatchewan with lake trout present; and 1 May to 15 July for spring spawning fish in northern Saskatchewan without lake sturgeon (DFO 2013a). Any in-water work required outside of the restricted activity timing window would be specified in the Request for Review to be submitted to DFO for the Project; see effect pathway F-08: Loss or alteration of fish habitat. During onshore construction, runoff would be managed, and sediment and erosion controls would be implemented.

Project construction activities, such as land clearing, site preparation, excavation, and construction of facilities and infrastructure, would have the potential to accelerate erosion and runoff into surrounding waterbodies and watercourses by exposing terrestrial soils to wind, rain, and surface water runoff throughout Construction, Operations, and the Active Closure Stage. In general, Project footprint components and associated construction activities would be located at a distance from waterbodies and watercourses, which would avoid or minimize the potential for sediment transfer to the surface water environment. However, construction would occur near or directly adjacent to Patterson Lake in limited instances, including during construction of a new site road along the east shoreline of Patterson Lake South Arm and during installation of on-shore components of the site water system (e.g., construction of the fresh water intake pump house on the south shoreline of Patterson Lake – North Arm East Basin, new site roads for the proposed fresh water intake and treated effluent diffuser).

All construction activities would occur in accordance with the Environmental Protection Program, which would outline management practices that include standard erosion and sediment control measures. Soil erosion from site-clearing, excavation, and construction would be mitigated and managed through the use of standard erosion and sediment control best management practices. The Project footprint would be limited to the smallest practical area of land, and site clearing and activities that expose soils would be completed in the shortest timelines possible. Areas of vegetation clearing and soil disturbance would be minimized, and soil stockpiles would be located away (i.e., greater than 150 m) from any water feature, unless required for temporary storage. Appropriate site drainage would be established, and where feasible, natural drainage features would be preserved to minimize alteration to drainage conditions in the area and limit interaction between surface water and erodible soils. As part of the reclamation process, disturbed areas that are no longer required and where Project infrastructure has been removed, would be progressively reclaimed and revegetated to prevent erosion. Finally, erosion and sediment control measures would be checked on an ongoing basis to verify that control practices are functioning as intended.

Through the described mitigation, the release of sediment from in-water infrastructure construction, including maintenance and removal activities, is expected to result in short-term, localized, and minor changes to fish habitat quality in Patterson Lake. Additionally, implementation of sediment and erosion control best practices, both during Construction and or at other phases when ground disturbance would be required, are expected to effectively minimize the erosion of soils and associated transfer of sediment into nearby waterbodies. Therefore, this pathway is expected to have negligible effects on fish habitat availability and the survival and reproduction of VCs (i.e., lake trout, lake whitefish, walleye, and northern pike) and was not carried forward for further assessment.

PATH: I:\CLIENTS\NexGen\20144150\Mapping\PreJus\FINAL_ES_FIGURES\WSP-LOGO_UPDATED011_Fish_and_Fish_Habitat\7x1120144150_Eg11.4-1_Conceptual_In-Lake_Developments_Habitat_Rev0.mxd PRINTED ON: 2023-02-08 AT: 11:38:15 AM



LEGEND

- BATHYMETRY CONTOUR ELEVATION (10 m)
- ELEVATION CONTOUR (10 m INTERVAL)
- WATERBODY
- WOODED
- INTAKE OR DISCHARGE PIPE
- CONTACT WATER CONTAINMENT
- PROJECT
- SITE ROAD
- TOPSOIL STORAGE
- WATER MANAGEMENT
- LAKE TROUT EGGS
- LAKE WHITEFISH EGGS
- NORTHERN PIKE EGGS
- WALLEYE EGGS
- EFFLUENT TREATED PIPE
- FRESH WATER INTAKE
- SEWAGE TREATED PIPE
- EFFLUENT TREATED PIPE
- FRESH WATER INTAKE PIPE
- SEWAGE TREATED
- GRAVEL/COBBLE/BOULDER
- SAND/GRAVEL SUBSTRATE
- MODERATE TO MOST SUSTAINABLE SPAWNING HABITAT LAKE WHITEFISH, LAKE TROUT AND
- 30m RIPARIAN BUFFER

NOTE(S)

HS = Habitat Section

Information on fish habitat conditions and egg search results were summarized from field data collected by Canada North Environmental Services (CanNorth 2021). Habitat sections were delineated based on physical habitat characteristics, as described in Section 2.8.2.4 of CanNorth 2021. Spawning habitat suitability ratings were defined for each habitat section based on known spawning habitat characteristics that have been described in literature, and where available, habitat suitability models developed for the species. Section 2.8.2.4 of CanNorth 2021 provides detailed information regarding assumptions used to develop the habitat suitability ratings, along with a list of references considered.

REFERENCE(S)

- PROJECT FEATURES OBTAINED FROM NEXGEN, APRIL 6, 2021 AND UPDATED JUNE 8, 2021 .
- BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
- BATHYMETRY CONTOURS DERIVED FROM DATA COLLECTED BY NEXGEN, 2016.

PROJECT

ROOK I PROJECT

TITLE

CONCEPTUAL LOCATIONS OF IN-WATER DEVELOPMENTS IN PATTERSON LAKE

	PROJECT		20144150	PHASE		3314 - 6
	DESIGN	LJ	2020-03-13	SCALE AS SHOWN	REV. 0	
	GIS	NO	2023-02-08	FIGURE 11.4-1		
	CHECK	KM	2023-02-08			
		REVIEW	KM	2023-02-08		

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

F-13: Project activities affecting water and sediment quality and aquatic health:

- Project activities and discharge (e.g., treated effluent and treated sewage discharge, runoff from the Project footprint, air and dust emissions, and runoff and seepage from the WRSAs) may cause changes to water and sediment quality during Construction, Operations, and Closure and adversely affect fish habitat availability, survival, and reproduction.

Effects on fish and lower trophic organisms, including phytoplankton, zooplankton, and benthic invertebrates, could potentially occur due to changes in water and sediment quality during the proposed 43-year period from initial Project Construction to the end of Closure. Sources of constituents to the aquatic receiving environment during Construction, Operations, and Closure of the Project include releases from the ETP and STP, runoff from the Project footprint, Project-related air and dust emissions, and seepage and runoff from the WRSAs. Changes to water and sediment quality can alter fish health and the suitability of fish habitat in affected waterbodies and watercourses, which could adversely affect the survival and reproduction of fish VC populations in the RSA or LSA.

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 2019). Indigenous Groups have expressed concerns regarding potential effects on water quality, and have indicated that they are already experiencing the adverse effects to water quality from industrial developments, including mineral exploration activities and the Cluff Lake Mine, which they believe has impacted 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 2020; CRDN-JWG 2021; MN-S-JWG 2019a; MN-S-JWG 2019b).

During engagement for the Project, Indigenous Groups expressed concerns that Project activities and discharge could pollute Patterson Lake, and by extension, the Clearwater River watershed (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). Patterson Lake is considered by Indigenous Groups to be an integral part of the Clearwater River system (TSD III: BRDN; TSD IV: MN-S; TSD V.2: CRDN), which has its headwaters to the north of the Project (Section 11.3.1, Fish Habitat). The CRDN raised concerns about contaminants entering the food chain within the Clearwater River watershed and adversely affecting fish health (TSD V.1: CRDN; TSD V.2: CRDN; CRDN-JWG 2020; CRDN-JWG 2021). Similar concerns were raised by the BNDN, BRDN, and MN-S related to the effects of water contamination from Project activities to fish populations and health, and in turn to human health (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; BNDN-JWG 2021a; BRDN-JWG 2019b; BRDN-JWG 2020; BRDN-JWG 2021b). Trappers from the 2021 trappers workshop and LPA community members also are concerned about the potential Project effects on water quality and fish in the area of the Project (NexGen 2019).

Potential Project effects on fish habitat availability, survival, and reproduction from changes in surface water quality are assessed below and incorporate the results from the EcoRA completed for the Project (TSD XXI). Potential Project effects on human health are assessed in the human health assessment (Section 15).

The release of constituents of toxicological concern (e.g., metals, radionuclides) to the aquatic receiving environment has the potential to affect the health of fish and lower trophic organisms if the constituent concentrations are at high enough levels to cause toxicological effects (e.g., effects on growth and survival). For fish and lower trophic organisms, contact with water and contaminant uptake from water as a result of feeding on other aquatic organisms represent the main paths of exposure to COPCs in the environment. Direct contact or uptake from sediment is also relevant for benthic invertebrates and bottom-feeding fish such as lake whitefish.

The YNLRO communicated the importance of mitigating and monitoring the potential effects of Project activities and discharge on the Patterson Lake receiving environment (YNLRO 2019). Environmental protection and monitoring plans developed for the Project (e.g., Environmental Protection Program, Environmental Monitoring Plan), which include adaptive management, are expected to reduce the loading of COPCs to the surface water environment and the potential for associated effects on water quality and the health of fish and lower trophic organisms. Biological monitoring of the aquatic receiving environment would occur as a component of the Environmental Monitoring Plan and in accordance with federal and provincial requirements to monitor and manage the potential effects of Project discharges on water and sediment quality and on the fish population and benthic invertebrate community in the vicinity of the Project (Section 11.7).

Design features and mitigation have been incorporated into the Project to reduce potential effects from proposed Project activities that can alter surface water quality (Section 5, Project Description). Non-contact water generated from undisturbed catchments adjacent to the Project footprint would be diverted around the area to reduce the total volume of contact water generated by the Project. Contact water would be collected, stored, and treated as necessary prior to release to the environment. The rate of discharge from the ETP would be managed by having adequate surface water storage capacity to allow for controlled release rates, as required. The YNLRO specifically noted the importance of properly treating and closely monitoring effluent prior to releasing it to the environment (YNLRO 2019). Regulated monitoring of treated discharges from the effluent and sewage treatment plants would be conducted to confirm water quality objectives are met for discharge, including adherence to the limits defined as per Schedule 4 of the MDMER. Potential seepages from the PAG WRSA would be limited during Operations through the use of a liner under the storage area and minimized after Closure by an engineered cover.

An evaluation of Project-related effects on surface water and sediment quality and resulting effects on aquatic health in the receiving environment is presented in the surface water quality assessment (Section 10) and in the EcoRA component of the ERA completed for the Project (TSD XXI). A summary of the results of these assessments and potential for resulting effects on fish VCs is provided below.

Predicted Changes to Surface Water Quality

Potential changes to surface water quality in the receiving environment were predicted via the development of a regional surface water quality model (RSWQM; Section 10.2.8.1.3) used to assess the expected magnitude, extent, and duration of Project effects in waterbodies along the Clearwater River mainstem (i.e., Broach Lake, Lake G, Lake H, Patterson Lake, Forrest Lake, Beet Lake, and Naomi Lake). A description of the source term inputs and COPCs considered in the RSWQM is provided in Section 10.2.8. Constituents of potential concern included metals and radionuclides. In addition to assessing potential Project effects, the RSWQM considered a sensitivity scenario that was representative of reasonable upper bound conditions (Section 10.2.8.1.3). This reasonable upper bound scenario was completed to provide a precautionary, more conservative bound in the surface water quality assessment.

Based on the RSWQM, the concentrations of metals and radionuclides defined as COPCs in the surface water quality assessment (Section 10.2.8) were predicted to increase relative to Base Case concentrations (i.e., existing conditions, as defined in Section 10.2.8) during the 43-year period that includes Construction, Operations, and Closure. The concentrations of metals and radionuclides were predicted to begin increasing in Patterson Lake once active discharge commences and were typically expected to reach peak concentrations at the end of Operations. Increases in the concentrations of COPCs were predicted in all downstream waterbodies in the LSA but would attenuate with increased distance downstream from Patterson Lake. The increase in COPC

concentrations during the proposed Project lifespan would primarily be the result of the active ETP and STP discharges to Patterson Lake during Operations. The concentrations of radionuclides and certain metals were predicted to subsequently decrease following the cessation of Project discharges at Closure. A limited number of metal COPC concentrations were predicted to continue to increase after Closure due to delayed onset of acid generation and groundwater migration from the UGTMF; effects on fish VCs from these predicted increases after Closure and in the far future are assessed in Section 11.5.

Despite COPC metal and radionuclide concentrations increasing in the receiving environment, concentrations during the 43-year period from initial Project Construction to the end of Closure were predicted to remain below Project-specific water quality threshold values in both the Application Case and the reasonable upper bound scenario. Water quality threshold values defined for the Project are described in the surface water quality assessment (Section 10.2.8.2.1) and are based primarily on the Canadian Environmental Quality Guidelines for the Protection of Aquatic Life summary table (CCME 2021) and Saskatchewan's provincial water quality objectives (WSA 2015). These guidelines are intended to provide protection to fresh water life from anthropogenic (i.e., human-caused) stressors such as chemical inputs. These guidelines are based on current, scientifically defensible toxicological data and are meant to protect all forms of aquatic life and all aspects of aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term.

Estimated Health Risks to Aquatic Life

The EcoRA component of the ERA completed for the Project provides an evaluation of the estimated ecological health risks to aquatic receptors potentially affected by the proposed Project. Ecological health risks resulting from changes in surface water quality were examined for aquatic species or receptors, including phytoplankton, zooplankton, benthic invertebrates, northern pike, and lake whitefish. The environmental pathways model, IMPACT, was used to predict concentrations of COPCs identified for the EcoRA in environmental media and potential risks to ecological receptors (TSD XXI, Appendix A, IMPACT Model Report). Based on the screening process undertaken for the EcoRA (TSD XXI, Section 4.2.3, Screening for Constituents of Potential Concern in Aquatic Environment), chloride, sulphate, arsenic, cobalt, copper, uranium, and the radionuclides, uranium-238, uranium-234, thorium-230, radium-226, lead-210, and polonium-210 were selected as COPCs for further assessment within the EcoRA. Constituents selected as COPCs in the EcoRA were predicted to exceed screening criteria in the treated mine effluent or at the edge of the mixing zone, or they are constituents of interest from other uranium mining and milling operations. The above-described radionuclides were carried forward as COPCs for further assessment in the ERA due to public and regulatory interest in these constituents (TSD XXI, Section 4.1, Model Integration).

The EcoRA also included an evaluation of ecological health risks related to changes in sediment quality. Based on the EcoRA screening process, no COPCs in sediment were identified for further evaluation of potential risks for ecological health, and thus toxicity via direct contact with sediment was not considered further.

Exposures of aquatic organisms to radionuclide and non-radionuclide COPCs in surface waters were predicted and assessed. A radiation dose benchmark of 9.6 milligrays per day (mGy/d) was selected for the assessment of effects on aquatic biota, as recommended in the CSA N288.6-22 standard (UNSCEAR 2008; CSA Group 2022). For assessment of non-radiological COPCs, a toxicity reference value (TRV) is used. A TRV is a toxicological index associating specific effects with a level of exposure to a chemical. The ecological risk to aquatic organisms was then estimated by calculating a hazard quotient (HQ) that provides a quantitative estimate of overall risk to a receptor. The HQ was calculated as the ratio between an exposure (i.e., dose) estimate and TRV. An HQ of less than or equal to 1 suggests low risk to the ecological receptor because

exposure estimates do not exceed levels known to cause adverse effects. If the HQ is greater than 1, adverse effects may be possible, and further assessment would be warranted.

The results of the EcoRA indicate that there are no exceedances of the 9.6 mGy/d radiation dose benchmark for aquatic biota in the LSA or RSA for the 43-year period that includes Construction, Operations, and Closure, for both Project effects in the Application Case and in the reasonable upper bound scenario. Similarly, HQs for all non-radiological COPCs (i.e., chloride, sulphate, arsenic, cobalt, copper, uranium) for aquatic receptors are less than 1 during all Project phases.

Effects on Lower Trophic Organisms and Fish Populations

Although the concentrations of COPCs are predicted to increase in waterbodies and watercourses during the Project lifespan, these changes are not expected to result in adverse effects on the health of fish and lower trophic organisms. As all HQs derived for aquatic receptors considered in the EcoRA were less than 1, and predicted radiological doses were well below the benchmark (i.e., 9.6 mGy/d), toxicological effects on aquatic populations or communities are not expected because exposure estimates to COPCs in water and sediment are below levels known to cause adverse effects. Additionally, concentrations of COPCs in the receiving environment (i.e., Patterson Lake outside of the RMZs for the ETP and STP, and in downstream waterbodies) are predicted to remain below water quality thresholds defined for the proposed Project to provide protection for aquatic life in the receiving environment. Therefore, effects on the survival and reproduction of fish VCs are not expected as a result of the predicted changes to water and sediment quality during Construction, Operations, and Closure.

Summary

Based on the results of the surface water quality assessment and EcoRA completed for the proposed Project, predicted COPC concentrations in the aquatic receiving environment would remain below water quality thresholds, and the estimated ecological health risks for radiological and non-radiological COPCs are less than respective screening values for all aquatic receptors assessed. Therefore, this pathway is expected to have negligible effects on fish habitat quality and the health, survival, and reproduction of fish VCs (i.e., lake trout, lake whitefish, walleye, and northern pike) and was not carried forward for further assessment.

F-14: Nutrient changes from Project activities:

- Project activities and discharge (e.g., treated effluent and treated sewage discharge, runoff from the Project footprint, and air and dust emissions) may change nutrient concentrations in the aquatic receiving environment and affect fish habitat availability, survival, and reproduction during Construction, Operations, and Closure.

The release of treated effluent and treated sewage from the ETP and STP, respectively, is anticipated to result in an increase in nutrient concentrations (e.g., nitrogen, phosphorus) in the receiving environment during the 43-year period from initial Construction to the end of Closure (Section 10.5.1.2.2). An increase in nutrient concentrations in Patterson Lake and downstream waterbodies may cause an increase in phytoplankton, which could alter the transfer of food energy through the aquatic food web and affect the food base for fish, ultimately resulting in changes to fish habitat quality and the survival and reproduction of fish VCs in the LSA and RSA.

Food webs represent feeding relationships within a community (Smith and Smith 2009) and the transfer of food energy up the food chain from its source in plants to herbivores, omnivores, and carnivores (Krebs 2009). In a simplified aquatic food web, energy and nutrients move from the phytoplankton at the bottom of the food chain

to the zooplankton consuming them and then to carnivores or omnivores, which can include fish and certain zooplankton or benthic invertebrate taxa. The position of organisms in the food web is represented by trophic level. Phytoplankton are referred to as primary producers, or autotrophs, meaning they obtain nutrients and energy through photosynthesis. Zooplankton and benthic invertebrates that feed on phytoplankton are referred to as primary consumers. Secondary and tertiary consumers are represented by the omnivores and carnivores in the system (i.e., certain zooplankton or benthic invertebrate taxa, and fish) that feed on primary and secondary consumers.

Energy flow through the aquatic food web is strongly influenced by the concentration of nutrients such as nitrogen or phosphorus in the water (Wetzel 2001). Nutrients are essential for phytoplankton growth and therefore, the loading of nutrients to a waterbody can result in an increase in phytoplankton or what is referred to as primary productivity (Krebs 2009; Elser et al. 1990). This increase can result in an increase in food availability for consumer organisms such as zooplankton, benthic invertebrates, and fish (Carpenter et al. 1985). The assimilation and expenditure of energy by consumer organisms is referred to as secondary productivity. Productivity is often measured in terms of energy flow between trophic levels or biomass, a term used to refer to the weight of living organisms in an area (Krebs 2009). Changes in biomass can occur as a result of altered growth rates or reproductive output by individuals and populations.

During engagement for the Project, Indigenous Groups expressed concern that Project activities, including discharge, could result in pollution of Patterson Lake and the lakes and waterways to the south of the Project (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN; BRDN-JWG 2020). Indigenous Groups commented on the clarity of the water in Patterson Lake and potential for changes (TSD II BNDN; TSD V.1: CRDN; McQueen et al. 1990). For example, the BNDN noted:

Well, if it's not as clear as it was back then . . . [there's] probably [something] wrong. Because all these lakes here are just crystal-clear water If you start seeing algae and all that and just – something's not right because these are all rock and sand lakes – sand bottom, rock.
(TSD II: BNDN)

Water clarity can decrease with increased phytoplankton biomass resulting from nutrient increases. The clarity is typical of the oligotrophic lakes in the RSA. Lower clarity can be indicative of more productive lakes but may also be indicative of anthropogenic sources of nutrients.

The Environmental Protection Program and Environmental Monitoring Plan developed for the Project would reduce the load of COPCs, including nutrients such as phosphorus, to the surface water environment and the potential for corresponding effects on the productivity of aquatic organisms. Biological monitoring of the aquatic receiving environment would consider the potential for nutrient enrichment effects on fish and lower trophic organisms (Section 11.7). Effluent characterization for the ETP would include monitoring of phosphorus, as required under the MDMER. The Project design features and mitigations described in the preceding effect pathway (F-13) are also relevant to the management of phosphorus in the receiving environment and would be effective in reducing effects from nutrient loading to the surface water environment.

Effects on aquatic habitat and fish VCs from changes in nutrient concentrations were evaluated using quantitative and qualitative methods. The assessment included consideration of the results of the surface water quality assessment, which presents predictions for nutrient concentrations in the receiving environment during Project phases, review of scientific literature on the effects of nutrient enrichment, and trophic classification of aquatic ecosystems based on nutrient concentrations (CCME 2004). Trophic status is an accepted and widely used means of classifying waterbodies and describing waterbody processes based on the amount of biological

productivity they sustain (Wetzel 2001; additional information about lake trophic status is provided in Section 11.2.6.1, Sampling Locations and Activities).

An evaluation of Project-related effects on nutrient concentrations in the receiving environment is presented in the surface water quality assessment (Section 10). A summary of these results and potential for corresponding effects on fish VCs is provided below.

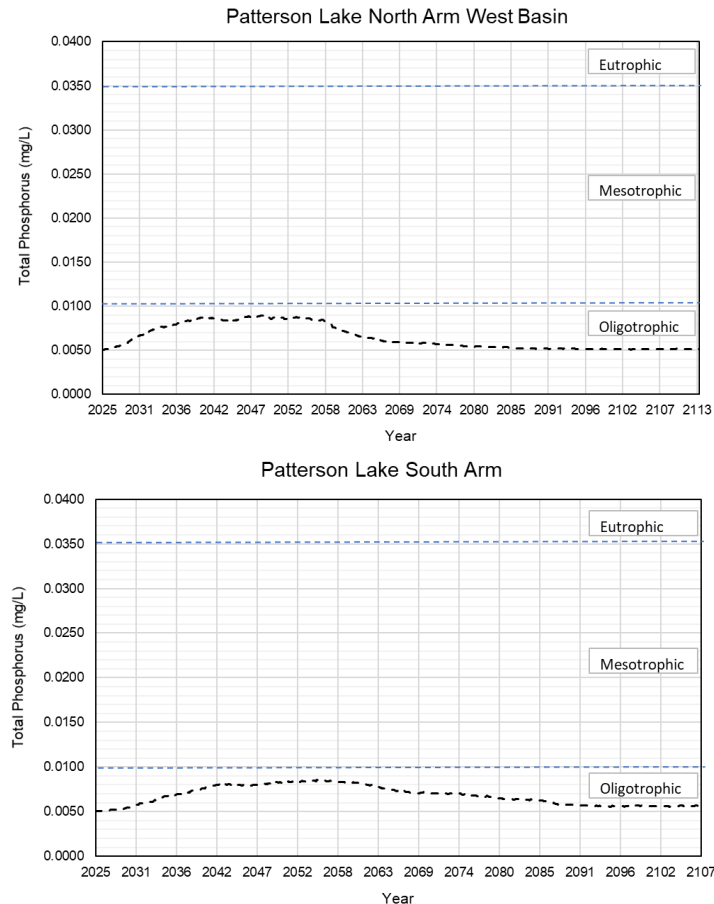
Predicted Total Phosphorus Concentrations

Water quality modelling was used to simulate nutrient concentrations in the receiving environment during Project phases. A summary of the approach used in the surface water quality assessment to model constituent concentrations in the receiving environment via development of a RSWQM (Section 10.2.8) is provided in the assessment of the preceding pathway (F-13). Nutrients defined as COPCs in the RSWQM included ammonia, nitrate, and TP. Patterson Lake is a phosphorus-limited waterbody (Annex V.1; Section 11.3.2), meaning that ecosystem productivity is limited by the amount of phosphorus present in the system compared to other nutrients such as nitrogen; therefore, the analysis of effects from changes in nutrient concentrations was based on predicted TP concentrations.

Based on the RSWQM results, concentrations of TP are predicted to increase relative to Base Case concentrations during the 43-year Project lifespan. The increase in TP begins during Construction when discharge of treated sewage effluent to Patterson Lake North Arm – West Basin commences. Increases in TP concentrations relative to baseline conditions (Table 11.3-1) are predicted in all downstream waterbodies in the LSA with concentrations attenuating with distance downstream from Patterson Lake. Peak concentrations of 0.009 mg/L are predicted in Patterson Lake North Arm – West Basin at the end of Operations (Section 10.5.1.2.2). Concentrations subsequently decrease following the cessation of Project discharges, with steady state conditions, non-distinguishable from Base Case conditions, occurring after Closure (Figure 11.4-2). The magnitude of the predicted increases in TP concentrations are greater in the reasonable upper bound scenario, with peak concentrations of 0.014 mg/L modelled in Patterson Lake North Arm – West Basin by the end of Operations.

The increase in TP during the Project lifespan is primarily the result of the active ETP and STP discharges to Patterson Lake, with treated sewage and effluent discharge from the ETP being the primary source of phosphorus.

Figure 11.4-2: Predicted Phosphorus Concentrations in Patterson Lake in the Application Case



Note: Blue dashed lines represent divisions between lake trophic status based on the CCME (2004) classification system. Based on this system, waterbodies can be classified as oligotrophic, mesotrophic, or eutrophic based on low (i.e., <0.01 mg/L), moderate (i.e., 0.01 mg/L to 0.035 mg/L), and high (i.e., >0.035 mg/L) concentrations of TP, respectively; black dashed line represents predicted TP concentration for the Project.

TP = total phosphorus; <= less than; >= greater than; CCME = Canadian Council of Ministers of the Environment.

Effects on Lake Trophic Status

The trophic status of Patterson Lake and waterbodies downstream in the LSA was evaluated based on existing and predicted concentrations of TP using the CCME (2004) classification system described in Section 11.2.6. Based on this system, waterbodies can be classified as oligotrophic, mesotrophic, or eutrophic based on low (i.e., less than 0.01 mg/L), moderate (i.e., 0.01 mg/L to 0.035 mg/L), and high (i.e., more than 0.035 mg/L) concentrations of TP, respectively (Section 11.2.6). The overall trophic classification of the LSA waterbodies was based on the maximum predicted concentration of TP during the 43-year Project lifespan to provide a conservative estimate of potential Project effects.

The results of the surface water quality baseline study (Annex V.1; Attachment 10A-1; Section 11.3.2) indicate that waterbodies in the LSA would generally be classified as oligotrophic (i.e., characterized by low productivity due to low nutrient concentrations; Section 11.2.6.1; Table 11.4-2). Baseline concentrations of TP during the open-water period were consistently measured at or below the analytical detection limit (DL) of 0.01 mg/L in the LSA waterbodies included in the RSWQM. The exception was Lake G, which is a small, shallow waterbody that

discharges through a tributary stream into Patterson Lake North Arm – East Basin and was classified as mesotrophic based on measured TP concentrations ranging between 0.01 mg/L and 0.02 mg/L.

Throughout the proposed 43-year Project lifespan, Patterson Lake and downstream waterbodies are predicted to remain oligotrophic based on modelled concentrations of TP (Section 10; Table 11.4-2). Lake G would remain within the mesotrophic range. Model predictions, therefore, demonstrate that there would be no change in trophic status as a result of Project-related nutrient releases (Table 11.4-2). Under the most conservative conditions defined by the reasonable upper bound scenario, Patterson Lake North Arm – West Basin downstream to Forrest Lake – North Basin shifts trophic state from oligotrophic to mesotrophic towards the end of Operations but returns to oligotrophic status after Project discharges cease during Closure (Section 10.5.3.1.2). The likelihood that reasonable upper bound scenario conditions would be realized is low given the high level of conservatism considered in the modelling assumptions for this scenario (Section 10.2.8). For example, the uptake of additional bioavailable phosphorus, which would be immediate in a phosphorus-limited system, was assumed not to occur in the mass balance model. The model calculated TP concentrations as if they would accumulate additively, so the predicted concentrations presented here are likely overestimates of change.

Table 11.4-2: Modelled Concentrations of Total Phosphorus and Predicted Trophic Classification by Waterbody during Rook I Project Operations

Waterbodies	RSWQM Predictions – Operations			
	TP (mg/L)			Trophic Status
	Min.	Mean	Max.	
Broach Lake	0.005	0.005	0.005	Oligotrophic
Patterson Lake – North Arm West Basin	0.005	0.006	0.006	Oligotrophic
Patterson Lake – North Arm East Basin	0.005	0.008	0.009	Oligotrophic
Patterson Lake South Arm	0.005	0.007	0.009	Oligotrophic
Lake H	0.005	0.006	0.007	Oligotrophic
Lake G	0.010	0.012	0.013	Mesotrophic
Forrest Lake – North Basin	0.003	0.006	0.007	Oligotrophic
Forrest Lake – South Basin	0.005	0.005	0.005	Oligotrophic
Beet Lake	0.005	0.006	0.007	Oligotrophic
Naomi Lake	0.005	0.006	0.007	Oligotrophic

RSWQM = regional surface water quality model; TP = total phosphorus.

Effects on Lake Ecosystem Productivity

Phosphorus is generally the limiting nutrient for primary production in most Canadian Shield lakes (Schindler 1974; Elser et al. 1990; Power 1992; Dillon et al. 2004) because of its scarcity in bedrock and overburden in Canadian Shield watersheds and efficient retention by upland forests and wetlands (Allan et al. 1993; Devito et al. 1989 cited in Steedman et al. 2004). Therefore, loading of phosphorus to the surface water environment can result in effects on lake ecosystem productivity, wherein an increase in primary production may propagate up the food web and affect the productivity of secondary consumers, which include lower trophic organisms (i.e., phytoplankton, zooplankton, and benthic invertebrates) and fish (Power 1992; Dillon et al. 2004).

In contrast to constituents that can elicit a toxicological response (e.g., metals) at a certain concentration, there is no given threshold or concentration of nutrients at which a nutrient enrichment response can be expected. Theoretically, any input of nutrients to an oligotrophic waterbody could result in some response, such as an increase in phytoplankton biomass. For example, nutrient-enhanced growth of phytoplankton can increase

biomass available for zooplankton to feed upon, which in turn may increase food availability for fish species and invertebrate life stages that feed on zooplankton.

As outlined above, baseline concentrations of TP in most LSA waterbodies were consistently reported at or below the analytical DL of 0.01 mg/L (Table 11.4-2). Notably, the analytical DL used for TP during the baseline monitoring is also the trophic boundary between oligotrophic and mesotrophic conditions (0.01 mg/L; Section 11.2.6.1; Table 11.4-2). A reasonable approximation of baseline conditions can be estimated by multiplying the analytical DL by 0.5 (i.e., estimated baseline TP concentration of 0.005 mg/L). Replacement of non-detectable values with half the analytical DL is a widely used method of dealing with non-detectable data in water quality datasets (USEPA 2002). Based on the maximum predicted TP concentration generated by the RSWQM (i.e., 0.009 mg/L during Operations; Table 11.4-2) and assumed baseline concentration of approximately 0.005 mg/L, a maximum TP concentration increase of less than or equal to approximately 0.005 mg/L could be expected by the end of Operations when peak effects are expected.

Effects on Lower Trophic Organisms

With an increase in TP concentration of approximately 0.005 mg/L in Operations, it is expected that there may be a corresponding increase in primary productivity. In phosphorus-limited systems, such as Patterson Lake, phytoplankton communities can readily respond to even small increases in available phosphorus with increases in algal biomass; however, large shifts in community composition or excessive nuisance algal growth would not be expected at the predicted magnitude of effect (Wetzel 2001). The predicted magnitude of increase in phytoplankton biomass in Patterson Lake may be measurable in phytoplankton community metrics, but effects would be localized and are unlikely to be detectable in downstream waterbodies due to attenuation of TP concentrations with increasing distance downstream (Table 11.4-2). Additionally, available phosphorus inputs from the discharge into Patterson Lake would be readily captured and used by phytoplankton within Patterson Lake. The numerical predictions presented above for TP concentrations conservatively omit this process.

An increase in phytoplankton biomass may result in changes to energy flow up the food web, potentially resulting in an increase in secondary production in the zooplankton and benthic invertebrate communities. Studies have shown that nutrient enrichment can result in an increase in biomass of zooplankton and benthic invertebrates (LeBrasseur et al. 1978; Rasmussen and Kalff 1987; Welch et al. 1988; Hershey 1992; Jorgenson et al. 1992; Clarke et al. 1997). Conversely, other studies have reported no effects on biomass (Dinsmore 1999; Bergström et al. 2021). Proportional increases in zooplankton and benthic invertebrate biomass would be expected to be lower than that of phytoplankton because the energy transfer between trophic levels is inefficient (McCauley and Kalff 1981; Kalff 2002). Only about 10% of available energy is transferred between trophic levels (i.e., up the food chain) due to factors such as incomplete ingestion of food, energy used for respiration, and energy lost as waste (Krebs 2009). Given the low predicted magnitude of effect for TP concentrations in the receiving environment and that energy transfer between trophic levels is inefficient, increases in zooplankton and benthic invertebrate biomass would likely be within range of baseline values. If increases do occur, the responses would be negligible and spatially and temporally limited to the area and timeframe associated with peak effects (i.e., Patterson Lake North Arm – West Basin during late Operations from approximately 2040 to 2055). Similarly, measurable changes to zooplankton and benthic invertebrate community composition are unlikely at the anticipated level of effect. Overall, conditions are predicted to remain within the bounds of a healthy oligotrophic ecosystem.

Effects on Fish Populations

Studies have shown that nutrients, and in particular TP, can affect the rate of fish production in waterbodies (Morgan 1966; Colby et al. 1972; McQueen et al 1986; Plante and Downing 1993; Johnston et al. 1999). Potential effects of phosphorus loading on the productivity of fish populations can include changes in growth and reproduction rates, body size (i.e., length, weight, or condition factor that is a measure of the “fatness” of a fish), or abundance (Hyatt and Stockner 1985; Johnston et al. 1990).

Because Patterson Lake and downstream waterbodies are predicted to remain oligotrophic during the 43-year Project lifespan, and because oligotrophic waterbodies are characterized by low nutrient concentrations, low primary productivity, and depressed secondary production (Wetzel 2001), it is unlikely that there would be meaningful changes to the food base for fish, particularly for upper trophic level consumers such as lake trout, walleye, and northern pike. Predicted TP concentrations during the Project lifespan are expected to result in at most, negligible and non-measurable increases in the productivity of fish prey items, including zooplankton and benthic invertebrates. However, an increase in the productivity of forage fish species (e.g., lake whitefish) or life stages that feed primarily on lower trophic organisms (e.g., juvenile lake trout, walleye, and northern pike) is not expected as the energy transfer between trophic levels is inefficient. Similarly, no change in the productivity of upper trophic level consumers that are primarily piscivorous (e.g., adult lake trout, walleye, northern pike) is expected. Additionally, based on the surface water quality modelling results for TP, any increase in the food base that may occur would be largely restricted to Patterson Lake North Arm – West Basin, where peak TP concentrations are predicted to occur. While fish VCs may take advantage of the increased food base in that portion of the waterbody, Patterson Lake is a large waterbody and it is unlikely that the fish population would be meaningfully altered by the predicted small magnitude increases in primary productivity in a single basin of the lake.

Summary

Through the described mitigation, the loading of phosphorus from Project activities and discharge to Patterson Lake is predicted to result in a minimal increase in TP concentration in the aquatic receiving environment with no changes to lake trophic status expected for any of the waterbodies assessed. An increase in TP concentrations may result in minor changes to primary productivity and in potentially negligible and non-measurable effects on the productivity of lower trophic level consumers (e.g., zooplankton and benthic invertebrates). Effects on the productivity of fish, particularly piscivorous, upper trophic level consumers, are not expected. Therefore, this pathway is expected to have negligible effects on fish habitat quality and, survival and reproduction of fish VCs, and was not carried forward for further assessment.

F-07: Air and dust emissions affecting water quality:

- Air and dust emissions, including emissions of criteria air contaminants and fugitive dust, and subsequent deposition (e.g., particulate matter, metals, and radionuclides) may cause changes to surface water quality, which may adversely affect fish habitat availability, survival, and reproduction in local waterbodies and watercourses.

Air and dust emissions from the proposed Project, and the subsequent deposition of constituents (i.e., total suspended particulate [TSP], metals, and radionuclides) can change surface water quality, thereby affecting fish habitat quality and the health of fish and lower trophic organisms. Air and dust emissions that may affect surface water quality include criteria air contaminant emissions and fugitive dust emissions. Criteria air contaminants emissions include particulate matter in two categories (2.5 µm or less in diameter [PM_{2.5}] and 10 µm or less in

diameter [PM_{10}]), TSP, sulphuric acid, sulphur dioxide, and nitrogen dioxides (Section 7), and would be released from the combustion of fossil fuels in large equipment, aircraft, trucks, vehicles, and power generation, as well as through the burning of non-hazardous waste materials. A detailed summary of Project emissions by source category is provided in Appendix 7A (Air Dispersion Modelling Report). Sources of fugitive dust include activities such as land clearing, site preparation, facility construction, site traffic, waste rock handling during Construction and Operations, and infrastructure removal during the Active Closure Stage (Appendix 7A). Particulate matter and dust from Project-related emissions may be deposited onto waterbodies and watercourses, which could change in-water pH and concentrations of TSS, metals, and radionuclides and adversely affect fish habitat availability, and the survival and reproduction of fish VCs.

Indigenous Groups are concerned about the potential effects of Project related air and dust emissions on the quality of water (TSD II: BNDN; TSD IV: MN-S). For example, MN-S members noted concerns of environmental health risks from windblown dust dispersal and airborne contamination of water (TSD IV: MN-S). Specific concerns were expressed by Indigenous Groups related to the adverse effects of uranium dust on the environment, which is believed to travel hundreds of kilometres with the wind and affect the air, water, and vegetation (TSD II: BNDN; TSD IV: MN-S; MN-S-JWG 2019b).

The surface water quality assessment utilized a sensitivity scenario within the RSWQM to evaluate the effects of Project atmospheric deposition on waterbodies in the LSA during Construction, Operations, and Closure (Section 10). Results from the air quality dispersion model were used as inputs for the sensitivity scenario in the RSWQM and included estimates of aerial deposition of particulate matter (i.e., particulate matter less than $2.5\ \mu m$ in diameter, particulate matter less than $10\ \mu m$ in diameter, and TSP), dust, metals, and radionuclides to surface waters. In-water concentrations of metals and radionuclides were estimated from the aerial deposition modelling results.

The effects of atmospheric deposition were assessed for four waterbodies located in the LSA that are not directly connected to the Clearwater River: Lake C; Lake E; Unnamed Lake 1; and Unnamed Lake 2 (Figure 11.2-2). As these waterbodies are not located along the Clearwater River flow path, their water chemistry would not be affected by other Project-related mass inputs or contributions (e.g., treated effluent discharge). Therefore, these waterbodies can be used to evaluate potential air deposition effects in isolation of effects from other Project-related sources.

Results from the atmospheric deposition assessment indicated that effects from aerial deposition would result in minor, localized changes to COPC concentrations in Lake C, Lake E, Unnamed Lake 1, and Unnamed Lake 2. The magnitude of effects was greatest in Unnamed Lake 2, which is attributed to the predominant downwind location of this lake relative to the proposed Project site. The COPCs with the greatest concentration increase relative to the Base Case were mercury, certain radionuclides (i.e., polonium-210, radium-226, thorium-230), and uranium. However, none of the COPCs evaluated were predicted to exceed water quality threshold values (Section 10). Therefore, toxicological effects on fish and lower trophic organisms are not expected to occur as a result of Project-related air emissions and dust deposition. Consequently, no change to the survival and reproduction of fish VCs is expected from Project-related air emissions and dust deposition.

The surface water quality assessment (Section 10) also quantitatively evaluated the potential Project-related changes in TSS resulting from fugitive dust deposition from the Project. A desktop analysis was performed to estimate the average annual increase in TSS in waterbodies due to the aerial deposition of TSP emitted from the Project (Appendix 10A). The air quality dispersion model results for Construction and Operations were used to estimate the total annual air deposition of TSP into each waterbody based on surface area. The predictions for Construction and Operation were used as these Project phases represented peak effects. The predicted

increase in TSS concentration in Lake C, Lake E, Unnamed Lake 1, and Unnamed Lake 2 was less than 0.1 mg/L. This increase is well within the natural variability of TSS concentrations in LSA waterbodies (Section 10) and would not be measurable. Consequently, effects from dust deposition on fish habitat availability are predicted to be negligible.

Effects on water pH are not expected to occur in LSA waterbodies and watercourses as the potential for contribution by Project air emissions to acid deposition was determined by the air quality assessment to be below screening values used by ENV to determine if a facility's emissions would result in acid deposition levels that would warrant additional assessment (Appendix 7A, Section 7A2.1). Therefore, no measurable effects on surface water quality and fish habitat availability, survival, and reproduction are anticipated due to this potential effect mechanism.

Environmental protection and monitoring plans developed for the Project, which include adaptive management, are expected to limit the emissions of criteria air contaminants and fugitive dust and associated effects on surface water and fish habitat quality. Additionally, Project design features and mitigation have been incorporated into the Project to reduce potential effects from air emissions and dust deposition; these include the primary use of liquid natural gas for power generation, procurement criteria that require certain stationary and mobile equipment to meet applicable performance standards, use of emission control devices on combustion-based equipment and vehicles, and regular maintenance of equipment. Water and/or dust suppressants would be applied to the airstrip, site roads, and the existing access road as necessary. Speed limits would be enforced and are expected to reduce dust emissions from site roads. These measures would be developed in accordance with applicable provincial and federal environmental legal requirements and guidelines.

With implementation of best management practices and mitigation, effects on fish VC habitat quality from Project-related air emissions and dust deposition are expected to be localized and negligible in magnitude. No effects on the survival and reproduction of fish VCs are anticipated as a result of air emissions and dust deposition from the Project. Therefore, this pathway was classified as a secondary pathway and not carried forward for further assessment.

F-08: Loss or alteration of fish habitat:

- Physical loss or alteration of fish habitat in Patterson Lake from the Project footprint, including the fresh water intake, treated effluent diffuser, treated sewage outfall, may affect fish habitat availability.

The Project would require construction of water management infrastructure that would include components installed below the high water mark of Patterson Lake. Water management facilities that would have a physical footprint in Patterson Lake include a fresh water intake, treated effluent diffuser, treated sewage outfall, and associated pipelines. These structures would be located in Patterson Lake North Arm at the conceptual locations shown in Figure 11.4-1. The installation of these structures and their associated maintenance activities and removal (i.e., Construction, Operations, and Active Closure Stage) has the potential to adversely affect fish VC habitat availability in the LSA. These effects include the potential for loss or disturbance to riparian vegetation due to development of new site roads, shoreline infrastructure, and the physical footprints of the conveyance pipes for the fresh water intake, treated effluent diffuser, and treated sewage outfall.

Predicted effects on fish VCs were estimated for each component of the water management infrastructure with an in-water footprint based on available conceptual design information and review of baseline fish and fish habitat survey data for the shoreline of Patterson Lake in the vicinity of the proposed Project. Changes in available habitat area, including riparian zone habitat, were estimated in terms of the absolute (m²) and relative

(%) values of lost or altered habitat. Absolute values were estimated based on the conceptual footprints of the developments (i.e., the fresh water intake, treated effluent diffuser, treated sewage outfall). Relative values were estimated based on the proportion of habitat lost relative to the surface area of Patterson Lake and its riparian zone. The surface area of Patterson Lake (38 km²) was defined from the shoreline delineation using georeferenced satellite imagery. The evaluation of direct habitat loss also included consideration of fish habitats that are also wetlands, as assessed by the wetland ecosystems VC (refer to Figure 13.3-4 in Section 13.3.2.2 [Ecosystem Distribution]). Other wetland areas identified in Section 13.5.2 (Wetland Ecosystems) that may potentially be affected by the Project through direct loss or disturbance are not fish habitat (i.e., do not have open-water areas or surface connectivity with downstream fish habitats).

The riparian area for Patterson Lake was defined as all naturally vegetated areas within a 30 m buffer of the lake shoreline. The 30 m buffer zone criterion was assumed to represent a conservative approach for delineating a riparian zone width in terms of fish habitat and is consistent with scientific literature and recommendations outlined by Environment Canada (2013), as well as the approach taken for the vegetation component effects assessment (Section 13). Environment Canada guidelines recommend that water features be buffered by 30 m of naturally vegetated riparian areas on both sides (Environment Canada 2013). Within these buffers, vegetation communities function to maintain aquatic ecosystems by moderating temperature through shading, filtering sediments and nutrients, providing food through leaf litter / organic matter, and influencing the structure of watercourses and waterbodies through fallen woody material (Environment Canada 2013).

As part of the aquatic baseline program, CanNorth characterized the fish habitat conditions present along the Patterson Lake shoreline within the areas that would be affected by the proposed in-water developments (Annex V.1; Figure 11.4-1). This information was reviewed to understand potential changes to habitat quality and to identify potentially sensitive or unique habitats that may be affected by the in-water developments. Sensitive or unique habitats are areas that would be considered limiting or rare within Patterson Lake and therefore would be especially valuable to the sustainability of fish VC populations. Habitat sections were delineated based on physical characteristics, as described in Annex V.1 and summarized in Figure 11.4-1. The focus of the surveys was the shoreline area and littoral zone. Spawning habitat suitability ratings were defined for each habitat section based on known spawning habitat characteristics that have been described in literature, and where available, habitat suitability models that have been developed for the species. Annex V.1 provides detailed information regarding assumptions used to develop the habitat suitability ratings, along with a list of the references considered.

An evaluation of potential effects on fish VCs resulting from development of the fresh water intake, treated effluent diffuser, treated sewage outfall, and associated infrastructure in and immediately adjacent to Patterson Lake is provided below.

Fresh Water Intake

The Project would require a fresh water intake to meet process and potable water requirements. The fresh water intake would draw water from a single location in Patterson Lake at the conceptual location shown in Figure 11.4-1. Components of the conceptual system design that could affect fish habitat in Patterson Lake would include a fresh water intake pumphouse, intake pipe, and fresh water intake structure. Fresh water for the Project is water sourced directly from Patterson Lake that has been screened for sediment and organic materials at the intake location. A new site road would also be required to provide access to the lake shoreline. The fresh water intake pumphouse would be constructed adjacent to Patterson Lake and is estimated to consist of a 10 m by 20 m building (Figure 11.1-3). The intake pipe is assumed to consist of a 750 mm high density polyethylene

(HDPE) pipe, which would extend northeast from the fresh water intake pumphouse into Patterson Lake. The length of pipe installed in the lake would be approximately 740 m, with the remaining length (approximately 80 m) extending over land and intersecting the lake shoreline and riparian zone. The fresh water intake structure would consist of a stainless steel combined passive intake and fish screen affixed over an approximately 1.5 m by 12 m concrete pad installed on the lake bottom. The fresh water intake structure would be installed at a depth more than 3 m and less than 10 m. The intake components would be anchored to the lake bottom by the concrete pad and weights affixed along the pipe length.

Effort was made to site the in-water developments away from potentially sensitive fish habitats and to reduce associated riparian habitat loss. Three candidate locations for the fresh water intake were initially identified and evaluated in Patterson Lake North Arm – East Basin (Section 4.16.15, Fresh Water Supply – Location). The selected location (Figure 11.4-1) was chosen as the other candidate locations were too shallow when accounting for the estimated ice thickness (i.e., of 1.5 m) and intake structure clearance (i.e., 0.5 m) requirements. The fresh water intake pumphouse and the alignments for the intake pipe and new site road were routed through an existing disturbance area adjacent to Patterson Lake. Based on field surveys of the Patterson Lake shoreline area in the vicinity of the proposed fresh water intake site, the intake pipe would intersect a section of shoreline habitat that consists of approximately 50% boulder and 50% cobble substrates (Annex V.1). The habitat section intersected by the intake pipe was assessed as moderately suitable spawning habitat for lake whitefish and walleye, marginally suitable spawning habitat for lake trout, and not suitable for northern pike spawning (Annex V.1). The affected area may also provide nursery, rearing, and adult feeding habitat for VCs.

Based on the conceptual design criteria outlined above, the in-water footprint associated with the fresh water intake structure (i.e., pre-cast concrete pad of 1.5 m by 12 m) and HDPE conveyance pipe (i.e., 740 m by 750 mm diameter) is estimated to be 573 m², consisting of 18 m² for the concrete pad and 555 m² for the intake pipe. This proposed footprint area represents less than 0.002% of the total habitat area of Patterson Lake (i.e., 573 m² of the total Patterson Lake surface area of 38 km²). Although the intake pipe would pass through an area identified as suitable spawning habitat for selected VCs, the fresh water intake structure and a portion of the conveyance pipe would be situated in deeper water (i.e., between 3 m and 10 m), which would be unsuitable as spawning habitat for the selected VCs based on the suitability ratings developed by CanNorth (Annex V.1). Lake whitefish and lake trout typically spawn in water less than 3 m deep (Annex V.1); therefore, the potential for interaction between the fresh water intake structure and spawning habitat and incubating eggs of these VCs is nil to low. Walleye typically spawn in water less than 1.5 m deep (Annex V.1); therefore, walleye spawning is unlikely to interact with the physical footprint of the fresh water intake infrastructure. Additionally, the habitat disturbed by the intake pipe and fresh water intake structure is not unique within Patterson Lake. Based on field surveys of Patterson Lake, 20 km of shoreline, representing 37% of the total Patterson Lake shoreline length of 54 km was assessed as being moderately to highly suitable spawning habitat for lake whitefish and lake trout; 21 km of shoreline, representing 37% of the total Patterson Lake shoreline length, was assessed as being moderately to highly suitable habitat for walleye spawning (Annex V.1). These results indicate that although some limited disturbance to habitats used for spawning and rearing may occur due to the physical footprint of the fresh water intake, when considered in the context of available habitat within Patterson Lake for fish VCs, meaningful effects on fish VCs are not expected to occur.

Based on review of georeferenced satellite imagery for the Patterson Lake shoreline area and 30 m riparian buffer overlaid with the footprint data, the new site road, intake pipe, and fresh water intake pumphouse can be constructed within an existing disturbance area. Therefore, no new disturbance within the 30 m riparian buffer would be required to construct and operate the fresh water intake system and new site road. Overall, the in-water

and riparian habitat losses associated with the fresh water intake are small and would be expected to result in negligible and non-measurable effects on fish VCs.

Treated Effluent Diffuser

The Project would require treated effluent discharge infrastructure to be installed in Patterson Lake at the conceptual location shown in Figure 11.4-1. Infrastructure components that could affect fish habitat in Patterson Lake would include a pipeline and diffuser. A new site road would also be required to provide access to the lake shoreline. The discharge pipe would consist of a 400 mm HDPE pipe, which would extend from the outlet of the effluent monitoring ponds into Patterson Lake North Arm – West Basin (Figure 11.4-1). The pipeline would extend northwest approximately 750 m into the lake and discharge through a diffuser at a water depth of approximately 10 m. The discharge pipeline would intersect the lake shoreline and riparian zone along its alignment from the effluent monitoring ponds. The diffuser would consist of one vertical nozzle connected to the pipe, which would extend approximately 1 m above the lake bed and 0.65 m above the pipe. The diffuser would be affixed to a support structure (e.g., sled or pre-cast concrete pad; expected to be less than 5 m by 5 m in size) to provide stability for the submerged structure. The treated effluent diffuser components would be anchored to the lake bottom by weights affixed along the pipe length.

Six candidate locations for the diffuser were initially identified and evaluated in Patterson Lake – North Arm, including five options in the West Basin and one in the East Basin (Section 4.5-13, Treated Effluent Discharge Location). The selected location (Figure 11.4-1) was chosen because it was estimated to have favourable ambient currents for effluent mixing and because it avoided interaction with higher quality fish habitats that are present along the shoreline of Patterson Lake adjacent to the proposed Project (i.e., suitable spawning habitats for VCs; Figure 11.4-1). Based on field surveys of the Patterson Lake shoreline area in the vicinity of the proposed treated effluent diffuser site, the diffuser pipe would intersect a habitat section consisting of 95% sand and 5% organics (Annex V.1). The shoreline and nearshore area intersected by the diffuser pipe was assessed as not suitable spawning habitat for all four fish VCs. Based on the substrate and physical habitat conditions, the area would not provide high quality habitat for rearing, nursery, or adult feeding life stages. The physical habitat characteristics represented in the affected area are common in Patterson Lake, where the dominant substrate in the littoral zone consisted of sand in approximately half of the area surveyed (Annex V.1). The riparian zone at the selected location for the diffuser was forested to the bank with vegetation consisting of trees and shrubs.

Based on the conceptual design criteria outlined above, the in-water footprint associated with the diffuser structure (i.e., sled or concrete pad) and HDPE pipe (i.e., 750 m length of 400 mm diameter) is estimated to be 325 m², consisting of 25 m² for the support structure and 300 m² for the pipe. This proposed footprint area represents less than 0.009% of the total habitat area of Patterson Lake (i.e., 325 m² of the total Patterson Lake surface area of 38 km²). Additionally, the discharge infrastructure would avoid high quality fish habitats identified during the aquatic environment baseline study (Figure 11.4-1). The riparian habitat loss associated with the treated effluent discharge system is conservatively estimated to be 192 m² and includes the alignment of the new site road and the on-land portion of discharge pipe alignment, which intersect with the 30 m riparian buffer. This area represents 0.01% of the total riparian habitat area associated with Patterson Lake (i.e., 16 km²). Overall, the in-water and riparian habitat losses associated with the treated effluent discharge pipe and diffuser are very small and would be expected to result in no effects, or at most, negligible and non-measurable effects on fish VCs.

Treated Sewage Outfall

The Project would require a treated sewage outfall installed in Patterson Lake at the conceptual location shown in Figure 11.4-1. Components of the treated sewage system that could affect fish habitat in Patterson Lake would include an HDPE pipe and an outfall. At the current stage of the Project, design details for the treated sewage outfall are conceptual; however, the volume of treated sewage discharge expected to be generated for the site is small (i.e., 165 m³/d) relative to the release water volume treated through the ETP and generated from the mine and process plant (i.e., 833 m³/h). Therefore, it is anticipated that the pipe and outfall associated with treated sewage discharge would be smaller in size than the treated effluent discharge pipe and diffuser. Based on conceptual drawings, the pipe would extend from the STP into the Patterson Lake North Arm – West Basin (Figure 11.4-1) and would intersect the lake shoreline and riparian zone along its alignment. The pipe would extend approximately 200 m northwest into the lake before angling west-southwest and extending an additional 700 m into the lake (Figure 11.4-1) to a depth of approximately 10 m. Based on treated sewage discharge flow projections, it is anticipated that this water would discharge directly from the pipe outlet; however, the final outfall design may include an engineered structure at end-of-pipe to promote mixing, if required.

Two candidate locations for the treated sewage outfall were initially identified and evaluated in Patterson Lake – North Arm West Basin. The selected location was chosen to avoid interaction with the fresh water intake and the RMZ associated with the treated effluent discharge pipe and diffuser. Based on field surveys of the Patterson Lake shoreline area in the vicinity of the proposed treated effluent diffuser site, the treated sewage outfall pipe would intersect a habitat section consisting of 80% cobble and 20% boulder (Annex V.1). The habitat section intersected by the pipe was assessed as moderately suitable spawning habitat for lake whitefish, walleye, and lake trout and not suitable for northern pike spawning (Annex V.1). The affected area may also provide nursery, rearing, and adult feeding habitat for fish VCs. However, as described above for the fresh water intake pipe, the treated sewage outfall and a portion of the associated pipeline would be situated in deeper water, which would be unsuitable as spawning habitat for the selected VCs based on the suitability ratings developed by CanNorth (Annex V.1). Additionally, the habitat disturbed by the discharge pipe is not unique due to the same considerations as noted above for the fresh water intake.

Based on the conceptual design details for the treated sewage outfall, it is anticipated that the in-water footprint associated with the treated sewage discharge would be limited to the conveyance pipe (i.e., 900 m of pipe, expected to be 400 mm or less in diameter). Based on these estimates, the in-water footprint associated with the treated sewage discharge is expected to be approximately 360 m², representing less than 0.001% of the total habitat area of Patterson Lake (i.e., 360 m² of the total Patterson Lake surface area of 38 km²). The riparian habitat loss within the 30 m buffer zone is conservatively estimated to be 127 m², which includes the conveyance pipe buffered by 2 m on either side. This area represents 0.008% of the total riparian habitat area associated with Patterson Lake (i.e., 127 m² of the total 1.6 km² riparian area of Patterson Lake). Overall, the in-water and riparian habitat losses associated with the treated sewage discharge are very small and would be expected to result in no effects, or at most, negligible and non-measurable effects on fish VCs.

Summary

Development of water management infrastructure in Patterson Lake would result in a limited amount of physical habitat loss for fish VCs. The total estimated in-water footprint associated with these developments is approximately 1,258 m², which represents 0.003% of the surface area of Patterson Lake (i.e., 1,258 m² of the total Patterson Lake surface area of 38 km²). Approximately 1,215 m² or 97% of the total estimated in-water footprint for these developments is associated with the conveyance pipes for the structures. The estimated loss of riparian habitat associated with these developments is 319 m², representing 0.02% of available riparian

habitat for Patterson Lake (i.e., 319 m² of the total 1.6 km² riparian area of Patterson Lake). Overall, the amount of change to in-water and riparian habitat would be small and localized. Additionally, the developments have been sited to avoid high quality fish habitats, as much as possible. The pipeline associated with the treated effluent discharge pipe and diffuser would pass through an area considered to have relatively low habitat quality for spawning and for use by other life stages of fish as rearing, nursery, or feeding habitat. The fresh water intake and treated sewage outfall pipes would pass through areas assessed as suitable spawning habitat for selected VCs. However, none of the habitats affected by these developments are unique within Patterson Lake, meaning that the infrastructure would not disturb sensitive areas that are vital to the sustainability of fish populations in the LSA or RSA.

Although some limited changes in habitat availability may occur due to these developments, the proposed works are not expected to meaningfully affect VC fish populations (i.e., through effects on growth, survival, or reproduction) or associated fisheries productivity. Changes in habitat distribution are likewise not expected, as these developments would not affect the movements of fish or connectivity of habitats in Patterson Lake. Overall, effects on fish VC populations are predicted to be negligible.

To the extent possible, the proposed in-water developments have been designed such that the structures and related activities minimize adverse effects on fish and fish habitat and avoid a harmful alteration, disruption, or destruction of fish habitat, as defined by the federal *Fisheries Act*. However, the developments would require work below the high water mark in Patterson Lake and would result in limited physical habitat loss or alteration. A Request for Review would be submitted to DFO for the Project to determine if an authorization under the *Fisheries Act* would be required to permit the proposed developments. If DFO determines that residual harmful effects to fish and fish habitat cannot be avoided or mitigated, NexGen would submit an application for a *Fisheries Act* Authorization for the relevant component(s) of the water management infrastructure. NexGen would develop an offsetting plan and implement offsetting measures, if required, to counterbalance the harmful alteration, disruption, or destruction of fish habitat with the goal of protecting and conserving fish and fish habitat. The offsetting plan would be developed in consultation with DFO and with engagement of the Indigenous and local communities, and ultimately, authorized by DFO. The offsetting plan, if required, would be developed during the permitting phase of the Project and would be submitted as part of an Application for Authorization under the *Fisheries Act*.

Through the use of appropriate design, mitigation, and management practices, effects from installation of in-water developments are expected to have negligible effects on fish VCs. Overall, the physical habitat loss associated with these structures is predicted to result in a small change to habitat availability for fish VCs in Patterson Lake and no change to distribution relative to existing conditions. If required by DFO, fish habitat lost or altered because of the developments would be offset with habitat created, restored, or enhanced. Therefore, this pathway was classified as a secondary pathway and not carried forward for further assessment.

F-09: Disturbance during in-water construction:

- In-water construction and related activities for the fresh water intake, treated effluent diffuser, treated sewage outfall can cause injury or mortality to fish, including fish eggs, and disturb fish habitats in Patterson Lake, which may adversely affect fish habitat availability, survival, and reproduction.

In-water construction activities related to the Project's proposed fresh water intake, treated effluent diffuser, and treated sewage outfall, as well as the associated pipelines, have the potential to cause damage or disturbance to fish habitats in Patterson Lake, including spawning substrates, incubating eggs, and the early life stages of fish (e.g., fry, alevin). In-water construction activities could also disturb spawning activity and spawning fish,

which could affect fish VC reproduction success. The installation of these structures and the associated maintenance and removal activities would require work below the high water mark of Patterson Lake, a known fish-bearing waterbody. During in-water construction activities, there is potential for physical injury or mortality of fish to occur, which could affect the survival of fish VCs, including fish eggs, in Patterson Lake.

A summary of the conceptual locations (Figure 11.4-1) and design details for the proposed water management infrastructure developments in Patterson Lake is provided in the assessment of the pathway, F-08: Loss or alteration of fish habitat. In-water components of the water management infrastructure have been designed to minimize the potential for adverse effects on the aquatic environment. The construction methods that would be employed to install the fresh water intake, treated effluent diffuser, treated sewage outfall and associated pipelines would be relatively unobtrusive in terms of the potential to cause injury or mortality of fish or to disturb fish habitats. The structures would be assembled on shore, where practical, and floated into position in Patterson Lake and then submerged and anchored on the lake bottom. The installation activities would not require excavation or operation of heavy equipment in Patterson Lake. Additionally, activities that are associated with a greater risk of potential effects on fish and fish habitat (DFO 2019b), such as dewatering of in-water work areas, fish rescue activities, and the use of intake pumps that can cause impingement or entrainment of fish and eggs, are not required.

The sections of HDPE pipe that would be used for the in-water developments would be fused together on shore and incrementally moved out into Patterson Lake, with the pipelines filled with air and ballast collars attached. The assembled pipes would be floated out to the preferred location and then submerged in place and anchored to the lake bottom using weights affixed along the pipe length. The fresh water intake structure would consist of a stainless steel intake affixed to a concrete pad, which would be floated out into the lake and submerged at the preferred location. The stainless steel intake would either be attached to the concrete pad on shore or by a dive team once the pipe and concrete pad were installed in the lake. Similarly, the vertical nozzle for the diffuser and discharge structure for the treated sewage outfall would be attached to the respective pipes on shore or by a dive team once the pipes were submerged in the lake. Divers may also be used to adjust alignment of in-water developments during installation or maintenance activities.

The locations of in-water developments were selected to avoid high quality fish habitats, where possible. A description of the fish habitat conditions documented in the vicinity of the proposed locations for the fresh water intake, treated effluent diffuser, and treated sewage outfall is provided in the assessment of the pathway, F-08. The treated effluent discharge pipe and diffuser would intersect in an area assessed as having low habitat quality for spawning (Annex V.1). The fresh water intake and treated sewage outfall locations would intersect areas assessed by CanNorth (Annex V.1) as suitable spawning habitat for selected VCs and where spawning activity has been documented (Section 11.4.2; Figure 11.4-1). However, as outlined for the pathway F-08, the affected habitats are common in Patterson Lake. Therefore, although some disturbance to fish habitats may occur due to in-water construction, the activities would not affect sensitive or unique habitats that are vital to the sustainability of VC populations.

All construction activities would occur in accordance with the Environmental Protection Program, which would outline management practices for in-water construction. Where possible, in-water work would be scheduled outside of the DFO restricted activity timing windows, which are: 1 September to 15 July for fall/winter spawning fish in northern Saskatchewan with lake trout present; and 1 May to 15 July for spring spawning fish in northern Saskatchewan without lake sturgeon (DFO 2013a). Construction practices and mitigation measures would follow DFO's *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2019b) to minimize adverse effects on aquatic resources.

Despite the described mitigation and lower level of risk associated with the construction methods that would be employed to install the fresh water intake, treated effluent diffuser, treated sewage outfall, and associated pipelines, limited disturbance to fish habitats and fish VCs may occur during in-water construction related to these developments. In-water construction activities are expected to occur over a period of one to two days for each development. Consequently, the duration of potential effects would be short and limited to the immediate vicinity of the work area. Similar types of effects could occur during maintenance activities for the developments and during removal.

With implementation of best management practices and mitigation, effects on fish VC survival and reproduction from in-water construction and related activities in Patterson Lake are expected to be of short duration and negligible in magnitude. Therefore, this pathway was classified as a secondary pathway and not carried forward for further assessment.

F-10: Impingement and entrainment of fish in the fresh water intake:

- Impingement and entrainment of fish in the fresh water intake may cause injury or mortality to fish and affect the survival of fish.

Water withdrawals from a fish-bearing waterbody have the potential to cause impingement and entrainment of fish that could potentially result in injury or mortality to fish VCs. Impingement occurs when a fish becomes trapped against the intake screen that prevents debris from entering the intake and the fish is unable to free itself. Entrainment occurs when a fish is drawn into a water intake, where mechanical stress can cause injury or mortality.

Water withdrawals from Patterson Lake would be required during Project Construction, Operations, and the Active Closure Stage to meet Project fresh water requirements. The fresh water intake for the Project would be located north of the proposed Project footprint in the Patterson Lake North Arm – East Basin (Figure 11.4-1). The intake system would consist of the fresh water intake pumphouse, intake pipe, and fresh water intake structure. The fresh water intake pumphouse would be fitted with turbine pumps that would supply water to the Project site on demand. As Patterson Lake is a fish-bearing waterbody, fish would be at risk of impingement or entrainment in the intake. Based on the biology and life history requirements of VC fish species (Section 11.3.6) and information regarding fish species distribution in the LSA (Section 11.3.4), there is potential for adults and juveniles of all four fish species considered as VCs to be present in the vicinity of the fresh water intake.

To minimize potential harm to fish, the fresh water intake structure would be fitted with a fish screen designed in accordance with DFO's *Fresh Water Intake End-of-Pipe Fish Screen Guideline* (DFO 1995). The DFO (1995) guidelines for fish screens on fresh water intake pipes would be followed in design, installation, and maintenance of fish screens on the Project fresh water intake. Several studies demonstrate the effectiveness of fish screens in preventing impingement and entrainment of fish at intake pipes with maximum approach velocities suitable to the species present in Patterson Lake (Katopodis 1994; Savitz et al. 1998; Peake 2004; Boys et al. 2013).

Including a properly designed fish screen in the fresh water intake design would limit the screen mesh pore size such that fish greater than a certain size would be physically unable to pass through. Additionally, the screened-in area would be designed to be large enough that the approach velocity of water into the intake would be sufficiently low to enable fish to swim away and avoid the screen. The appropriate screen mesh pore size and screen opening size for the planned pumping rates would be determined to prevent or minimize the potential for fish to enter the intake during pumping. The intake screen would be designed to accommodate nearly uniform and low-flow velocity across the entire screen surface, reducing the intake velocity to a maximum of 0.15 m/s to

allow for juvenile fish to swim away. The intake screen mesh size and dimensions would be influenced by the species found in Patterson Lake, as well as the swimming abilities of species likely to be present at the fresh water intake location.

To further limit the occurrence of impingement and entrainment of fish in the intake pipe, the fresh water intake structure would be located away from identified spawning habitats and locations where incubating eggs have been documented. The fish habitat conditions present along the Patterson Lake shoreline in the vicinity of the fresh water intake were characterized in Annex V.1. The fresh water intake structure and fish screen would be situated in deeper water (i.e., between 3 m and 10 m; Figure 11.4-1) that would be considered unsuitable as spawning habitat for the selected VCs, based on the suitability ratings developed by CanNorth.

Designing and screening the fresh water intake structure in accordance with applicable DFO (1995) guidelines and locating the structure away from high quality fish habitats, including identified spawning habitats along the Patterson Lake shoreline adjacent to the proposed Project site (Figure 11.4-1), would reduce the potential for fish injury or mortality resulting from impingement or entrainment such that effects on VCs fish populations would be negligible. Any impingement or entrainment of small or juvenile fish would be limited to localized areas around the intake pump.

With proper design, installation, and maintenance, injury and mortality of fish due to impingement on the intake screen or entrainment into the fresh water intake is anticipated to result in negligible residual effects on fish VCs. Therefore, this pathway was classified as a secondary pathway and not carried forward for further assessment.

F-11: Habitat disturbance from treated effluent diffuser:

- The area of water turbulence around the treated effluent diffuser may affect local fish habitat availability in Patterson Lake.

Turbulence from a discharge can adversely affect fish habitat in terms of quantity where the turbulence in the water column causes fish to avoid the area, or quality due to the mobilization of lake bed material and sediments into the water column and redistribution of sediments on the lake bottom in the vicinity of the discharge. The velocity of pumped treated effluent discharge entering Patterson Lake during Operations would be reduced by the use of an engineered, submerged diffuser (TSD XXI). The discharge pipe would extend 750 m from the shoreline into Patterson Lake and discharge treated effluent through a diffuser at a water depth of approximately 10 m; the conceptual location is shown in Figure 11.4-1. The treated effluent would be discharged into Patterson Lake in batches released during Construction, Operations, and the Active Closure Stage.

To avoid adverse effects on fish habitat, the diffuser would be located in an area of Patterson Lake that avoids high quality fish habitats (e.g., documented spawning and nursery areas, or unique habitats; WSA 2015). Based on field surveys of the Patterson Lake shoreline area in the vicinity of the proposed treated effluent diffuser site, the diffuser would intersect a section of shoreline assessed as consisting of 95% sand and 5% organics (Annex V.1). A lake bed substrate sample collected at the discharge location indicated that the substrate consisted of medium- to fine-grained sand (TSD XXI). The sand substrate present in the affected area is common throughout Patterson Lake (Annex V.1) and generally would be considered low quality habitat for fish VCs. The area was noted to not be suitable spawning habitat for large-bodied fish, including lake trout, walleye, lake whitefish, and northern pike. Additionally, no eggs of any fish species, including VCs, were found in the area during the baseline surveys (Annex V.1; Figure 11.4-1).

To control the flow velocities and reduce stress on the surrounding lake bed, the diffuser would be placed at a depth of 10 m and the nozzle would be elevated 1 m above the lake bed (TSD XXI). This design would maximize dispersion and attenuation of the discharge from the diffuser. The design is also expected to avoid any potential disturbance or entrainment of the lake bed substrate and associated fish habitat. The diffuser would be inspected upon completion of the installation activities and on a regular basis during Operations to confirm that it is functioning as designed and that disturbance to the lake bottom does not occur. Therefore, effects on fish habitat due to sediment entrainment are not expected (TSD XXI).

Operation of the diffuser in Patterson Lake would create an area of increased turbulence and noticeable velocity in the water column. It is expected that fish would avoid this area upon sensing the increased water turbulence. The area of increased turbulence would extend vertically from the discharge pipe to the water surface, with a limited amount of lateral disturbance also expected. The velocity and turbulence of the water would be greatest at the centreline, closest to the diffuser pipe. Overall, the area of disturbance would be small and limited to the immediate area of the discharge location.

As a result of the design and location of the diffuser and the described mitigation measures, effects on fish habitat availability due to water turbulence from the treated effluent diffuser during Construction, Operations, and the Active Closure Stage are expected to be negligible. Therefore, this pathway was classified as a secondary pathway and not carried forward for further assessment.

F-12: Public access affecting survival:

- Changes in public access to fishing areas on the Clearwater River and in Patterson Lake, and increased density of people (e.g., Project staff and contractors) in the area, may affect the survival of fish.

Project-related changes to roads and associated access conditions can alter public access to fishing areas on the Clearwater River and in Patterson Lake and affect the survival of fish VCs.

Patterson Lake and the Clearwater River provide attractive opportunities for recreational fishing in the region. Fish species that are targeted by fishers (i.e., anglers) in the area include all four VC species (i.e., lake trout, walleye, northern pike, lake whitefish) and other large-bodied species (i.e., Arctic grayling, burbot, yellow perch) (Government of Saskatchewan 2021). Sport fishing in Saskatchewan is regulated by The Fisheries Regulations under *The Fisheries (Saskatchewan) Act, 2020*. All recreational anglers are required to have an angling licence from ENV and follow the regulations outlined in the Anglers Guide (Government of Saskatchewan 2021). Waterbodies and watercourses in the LSA and RSA fall within the Northern Zone management area for angling regulation in Saskatchewan. Season and catch limits and catch-and-release rules are in force in the province and restrict individual angler harvest or activity. The “general” limits defined in the regulations are applied to Patterson Lake, the Clearwater River, and other waterbodies and watercourses in the LSA and RSA. These limits include harvest restrictions for the four fish VCs. Potential changes in angler pressure and fish harvest in the province would continue to be managed by ENV, which is the government agency responsible for managing fisheries resources in the province.

During engagement for the Project, Indigenous Groups expressed concerns about potential effects of the Project on access and fishing opportunities. The potential for disruption to, or diminution of, resource use opportunities, including fishing, is a serious concern for communities (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). Indigenous Groups expressed concerns about Project-related changes in access, including an increase in traffic and non-Indigenous resource users in the area of the Project, which could affect the availability of fish and fishing opportunities.

I think even without the mine being there it's, you know, there's still some – a lot of exploration around that area at [Highway] 955. I think it's going to affect that area. And it's not only that area, but it's even in around closer to – closer to our community because of, because of traffic . . . More trucks. More, you know, more activity, more people. More people coming into our immediate area – our immediate hunting area, our immediate fishing area, our immediate, you know, traditional territory around our community. It's quiet now, but there's always people who look for places to fish, to set up camp, to lease out land to build cabins and – there's always that potential for a lot of other things. (TSD II: BNDN)

The Project would not include the development of new public roads. Access to the Project site would be provided by an existing access road from Highway 955 (Figure 11.2-3). Upgrades to this access road, including widening of the road surface, are planned to support increased traffic volume and heavy vehicle/equipment use associated with the Project. Existing fishing opportunities along the highway and road are limited, with the only road access to a fish-bearing waterbody or watercourse being at the existing bridge crossing of the Clearwater River downstream of the Patterson Lake outlet. Upgrades to the existing access road are not expected to result in measurable changes to existing fishing pressure at this location. However, the increase in use of the road due to an influx of people and traffic accessing the Project site, particularly during Construction and Operations, may result in greater use of the bridge crossing and associated river access for recreational fishing purposes.

Development of the Project would result in an increase in the density of people in the area due to employees and contractors during Construction, Operations, and the Active Closure Stage. New roads would also be developed on the Project site, which would improve access to Patterson Lake for employees and contractors who may wish to fish recreationally during their time off shift while on site. The increase in density of people around the area of the Project, combined with the development of new site roads that improve access to Patterson Lake, could increase recreational angling in the area and, therefore, increase rates of fish injury or mortality. The survival of fish VCs may be adversely affected due to an increase in harvesting of fish, or as a result of incidental injuries or mortality related to catch-and-release fishing.

NexGen is exploring the possibility of implementing a policy that would prohibit or restrict fishing by employees and contractors on the Project site and along the existing access road while on rotation or residing in the camp. As NexGen plans to prioritize employment from local communities where possible, engagement with these communities would be undertaken to gather feedback on whether a no fishing policy is a desired mitigation to reduce effects on harvested fish populations from increased fishing pressure. However, for the purpose of the effects assessment, and to provide a conservative evaluation of potential effects on fish VCs, it was assumed that employees and contractors would be permitted to fish recreationally during their time off while on site, as well as along the existing access road.

New and existing roads on the Project site that would provide access to Patterson Lake include the main road from the gatehouse that runs adjacent to the east shoreline of Patterson Lake and roads accessing the Patterson Lake shoreline at the fresh water intake and treated effluent diffuser locations (Figure 11.4-1). These roads would not be accessible to the public during Construction, Operations, and the Active Closure Stage, but potentially may be used by employees and contractors to access Patterson Lake to fish recreationally. As a result, Patterson Lake could experience an increase in fishing pressure as a result of recreational angling by employees and contractors.

The Preliminary Decommissioning and Reclamation Plan assumes that site roads would be decommissioned (e.g., regraded, scarified) and reclaimed (e.g., revegetated) during the Active Closure Stage, which would discourage long-term use of site roads by the public during post-closure. However, the Preliminary Decommissioning and Reclamation Plan is subject to change and further refinement through the lifespan of the Project and would consider the results of additional public and community engagement on closure planning for site roads. If site roads were to remain in place after Closure, these roads could improve public access to Patterson Lake at the described locations and potentially allow increased fishing pressure.

Mitigation would be implemented to reduce the potential for effects on fish VCs from an increase in recreational fishing pressure. The Project site entrance would be gated at the gatehouse to discourage public access. During Construction, contractors and employees would be transported by bus to site from La Loche until the on-site airstrip is completed, after which employees would be transported to and from site by aircraft. These transportation practices would reduce the amount of personal vehicles and traffic in the area of the Project and limit the opportunity for employees to fish along the access road. Although not a Project mitigation measure, it is expected that ENV would continue to manage sport fishing in Patterson Lake and the Clearwater River through the use of harvest restrictions, as well as the implementation of other regulations as required (e.g., catch-and-release).

With effective implementation of mitigation and continued management by ENV, changes to harvest of fish in the Clearwater River and Patterson Lake and effects on fish habitat quality are anticipated to be minor, with a negligible residual effect on the survival of fish VCs (i.e., lake trout, lake whitefish, northern pike, walleye). Therefore, this pathway was classified as a secondary pathway and not carried forward for further assessment.

11.4.3 Primary Pathways

The following Project interaction was predicted to be a primary pathway to fish and fish habitat VCs and was advanced for further assessment of residual effects (Section 11.5).

F-01: Changes in surface water quality from WRSAs and UGTMF after Closure:

- Runoff and seepage from the WRSAs and groundwater flow from the UGTMF may alter surface water quality in Patterson Lake after Closure and adversely affect fish habitat availability, survival, and reproduction.

11.5 Residual Effects Analysis

Section 11.5 assesses the predicted changes to fish VCs in the receiving environment due to changes in surface water quality and sediment quality from the primary pathway identified in Section 11.4.3, Primary Pathways. This primary pathway addresses the potential effects from altered surface water quality after Closure and in the far future projection. Effects from changes to surface water quality during the Project lifespan are evaluated in Section 11.4.1 and Section 11.4.2.

Potential effects on fish and lower trophic organisms, including phytoplankton, zooplankton, and benthic invertebrates, may occur due to changes in water and sediment quality after Closure and in the far future. The primary source of loading for metals in the far future would be the seepage load through the groundwater flow path from stored mine waste on the Project footprint. Changes to water and sediment quality in the far future could alter the health of fish and lower trophic organisms and the subsequent suitability of fish habitat in affected waterbodies and watercourses; these changes could adversely affect the survival and reproduction of fish VC populations in the RSA or LSA.

During engagement for the Project, Indigenous Groups expressed concern that Project activities could pollute Patterson Lake, and by extension, the Clearwater River watershed (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). Indigenous Groups raised concerns about potential toxins entering the food chain through water and affecting fish (TSD II: BNDN; TSD III: BRDN; TSD IV: MN-S; TSD V.1: CRDN; TSD V.2: CRDN). Specific concerns were expressed by the BNDN regarding the potential for contamination of groundwater and the release of mine-affected water to the environment (TSD II: BNDN). The BNDN and CRDN stated concern of potential for increased incidences of diseased or unhealthy fish and decreased health of fish populations due to water contamination from Project activities (TSD II: BNDN; TSD V.2: CRDN). The BNDN also commented about the potential for changes in sediment quality and effects on bottom-feeding fish species such as lake whitefish (TSD II: BNDN).

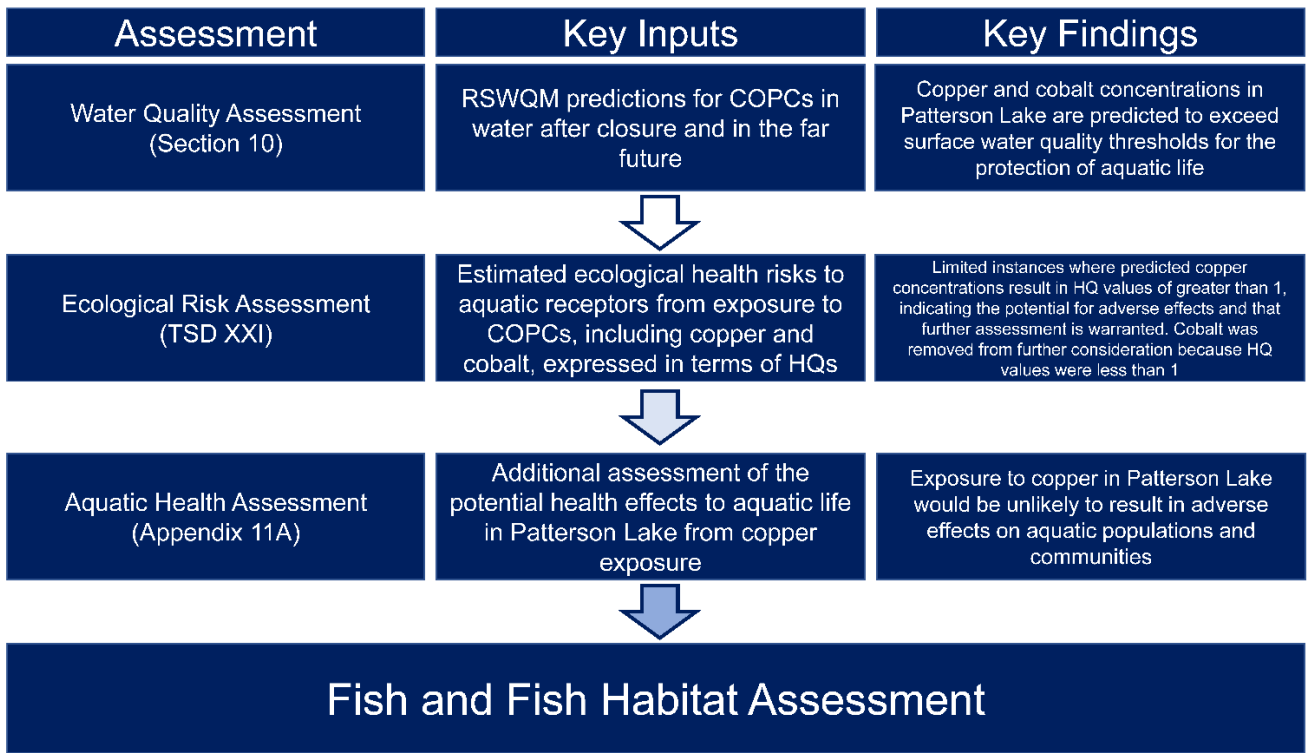
Infiltration and seepage from the Project footprint to the groundwater regime in the far future were predicted through groundwater flow and solute transport modelling to invoke a long-term period of extremely slow migration of COPC metals from the underground mine workings, UGTMF, and WRSAs to the Patterson Lake receiving environment. This migration was predicted to result in incremental mass loadings to Patterson Lake North Arm – West Basin in the far future for a subset of COPC metals. Additional description of the potential mine sources and hydrogeological processes that would be expected to contribute to changes to the groundwater regime, and ultimately surface water quality in the receiving environment after Closure, is provided in the groundwater and surface water quality assessments (Section 8 and Section 10).

The mechanisms by which fish VCs and lower trophic organisms could be affected by exposure to COPCs in the water column or in sediment could either be direct or indirect. Direct mechanisms involve a direct influence on a receptor; for example, direct toxicity to fish and aquatic life could occur as a result of an elevated concentration of potential toxicant (e.g., metal or radionuclide) acting directly at the sites of toxic action, resulting in adverse biological effects (Rand 1995). Indirect mechanisms involve adverse effects or toxicity that results from the agent acting on and producing changes in the physical or biological environment external to the VC (Rand 1995). In aquatic ecosystems, indirect mechanisms often include several levels of the food web. For example, mine-related sources of constituents to the surface water environment may result in a toxicological effect on lower trophic level organisms, which may cause changes in the food base for fish and affect the productivity of higher trophic level organisms such as fish.

11.5.1 Approach

Information from the surface water quality and aquatic health assessments as well as the EcoRA completed for the Project formed the basis of the residual effects analysis for fish and fish habitat. A summary of the methods used by these assessments to predict potential changes in water chemistry and estimate the resulting health effects on aquatic biota for the far future is provided in Sections 11.5.1.1 to 11.5.1.3. Additional details can be found in Section 10, TSD XXI, and Appendix 11A, Aquatic Health Assessment of the Potential for Adverse Effects of Predicted Far-Future Copper Concentrations in Patterson Lake. Information from these assessments was then used to predict potential changes to habitat availability, survival, and reproduction of fish VC populations in the LSA and RSA (Section 11.5.1.5, Assessing Effects on Lake Trout, Lake Whitefish, Walleye, and Northern Pike). A simplified schematic summarizing the key information sources considered in the fish and fish habitat residual effects assessment is provided in Figure 11.5-1.

Figure 11.5-1: Summary of Key Information Sources Considered in the Fish and Fish Habitat Residual Effects Assessment



COPC = constituent of potential concern; HQ = hazard quotient; RSWQM = regional surface water quality model; TSD = technical support document.

11.5.1.1 Summary of Surface Water Quality Assessment Methods

Potential changes to surface water quality in the receiving environment were predicted through the development of an RSWQM (Section 10.2.8.1.2). The purpose of the RSWQM was to assess the expected magnitude, extent, and duration of Project effects in the downstream receiving environment, on a lake-wide scale, or for individually defined basins within a waterbody. To predict effects in the far future, the RSWQM considered an Application Case and an RFD Case. Source term inputs considered in the RSWQM Application Case included inputs from

the Project site-wide water balance model and the groundwater solute transport model. A sensitivity scenario was considered within the Application Case that was representative of reasonable upper bound conditions (Section 10.2.8.1.2). This reasonable upper bound scenario was completed to provide a precautionary, more conservative bound in the surface water quality assessment.

The RFD Case considered inputs from the Fission Patterson Lake South Property, in addition to the Project inputs in the Application Case and included mass loading associated with site runoff from an above-ground tailings management facility and covered waste rock storage facility as outlined in the Fission (2019) prefeasibility study. The potential for inputs related to long-term solute transport associated with Fission Patterson Lake South Property were not considered, as it is not currently known whether there is any potential for mass transport via groundwater to Patterson Lake from this potential development.

Additionally, a sensitivity scenario was considered within the RFD Case that evaluated the effects of future climate change based on hydrological processes (e.g., increased precipitation and evaporation; Sections 9.2.7 and 10.2.8.1.2). Site-specific future climate projections were developed for the Project through analysis of available projections from a multi-model ensemble (Section 9.8.2, Model Predictions). 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 period from 2041 to 2070 presents a conservative estimate in terms of climate change during the Project timeline. 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. 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 (Appendix 9A, Appendix 10A, and Appendix 22A, Climate Change Dataset Summary Report).

The modelling of the tailings-affected groundwater migration by the groundwater solute transport model demonstrated that the time for groundwater to reach surface water spans a very large temporal scale extending hundreds of thousands of years into the future (Section 8, Hydrogeology). However, computational limits with the RSWQM precluded the use of such a large temporal scale as demonstrated in the solute transport model. To address this limitation, loadings from the groundwater solute transport model were effectively fast-tracked to allow for a shorter modelling timeframe that considered maximum effects on surface water quality. The far-future modelling period considered in the RSWQM extends 357 years after Closure and includes two time periods: an initial 157-year period that includes the natural hydrological and hydrogeological processes from the site following Closure; and a subsequent 200-year period that includes the natural hydrological and hydrogeological processes that account for maximum mass loadings associated with solute transport by groundwater, as predicted by the groundwater model. As the RSWQM modelled conditions for the far future were effectively fast-tracked, these “years” do not correspond to actual future years. Thus, any mention of a specific year in this residual effects analysis refers only to a point in the far future that represents reasonable worst-case conditions.

Surface water quality predictions generated for the far future were developed using a conservative approach and assumptions. Conservative assumptions were applied when calculating the loading rates of COPCs associated with the groundwater solute transfer inputs (Section 8 and Section 9); these assumptions include limited control of the source material from the WRSAs and UGTMF and maximum potential for contamination and infiltration.

Surface water quality predictions were compared to water quality thresholds (Section 10.2.8.3.1), which are Project-specific water quality guidelines applied to the aquatic receiving environment. These guidelines are

primarily based on the CCME (CCME 2021) and Saskatchewan provincial water quality objectives (WSA 2015) and are intended to provide protection to fresh water life from anthropogenic stressors such as chemical inputs.

11.5.1.2 Summary of Ecological Risk Assessment Methods

The EcoRA component of the ERA completed for the Project provides an evaluation of the estimated ecological health risks to aquatic receptors potentially affected by the Project. Ecological health risks resulting from changes in surface water quality were examined in the EcoRA for aquatic species or receptors, including phytoplankton, zooplankton, benthic invertebrates, and predator fish and forage fish, which were represented in the EcoRA by northern pike and lake whitefish, respectively.

Potential chemical stressors in the environment were selected as COPCs for further evaluation in the EcoRA. For the far future, constituents were included as COPCs if predicted maximum water quality concentrations exceeded water quality objectives after the addition of groundwater solute loadings. The environmental pathways model, IMPACT, was used to predict concentrations of COPCs in environmental media and the resulting risks to ecological receptors. The conservative assumptions applied in the development of these models (Section 10; Appendix 10A; Section 8; TSD XIV, Groundwater Flow and Solute Transport Modelling Report) were carried forward into the IMPACT model assumptions.

For fish and lower trophic organisms, contact with water and contaminant uptake from water via bioaccumulation (i.e., feeding on other aquatic organisms) represents the main pathway of exposure to COPCs. Direct contact or uptake from sediment was also considered for benthic invertebrates and bottom-feeding fish (i.e., lake whitefish). Bioaccumulation factors based on surface water concentrations were used in the EcoRA to estimate COPC concentrations in invertebrate and fish tissue based on ambient media concentrations. The radiological dose and non-radiological risk were characterized for each receptor at downstream waterbodies in the LSA. A radiation dose benchmark of 9.6 mGy/d (UNSCEAR 2008) was selected for the assessment of effects on aquatic biota (CSA Group 2022). For non-radiological COPCs, chronic dose-based TRVs were used. The TRVs were derived based on chronic effects levels that represent measurable and statistically meaningful exposure or dose levels affecting only 20% of the organisms tested (i.e., 20% effect concentrations values). This level of effect was preferred because 20% is near the level at which effects become statistically discernible or measurable in both laboratory and field studies.

For radiological COPCs, the ecological risk was assessed through comparison with the dose benchmark identified above. For non-radiological COPCs, the ecological risk to aquatic organisms was estimated by calculating an HQ that provides a quantitative estimate of overall risk to a receptor. Hazard quotients were calculated by dividing the exposure value by the TRV for a given COPC, and the resulting HQ value is compared to a benchmark HQ value of 1. An HQ value greater than 1 would indicate the potential for adverse effects and further assessment would be warranted. An HQ that is less than or equal to 1 suggests that adverse effects on an ecological receptor are unlikely because exposure estimates do not exceed levels known to cause adverse effects.

11.5.1.3 Summary of Aquatic Health Assessment Methods

The EcoRA identified limited instances where predicted copper concentrations in the far future resulted in HQ values of greater than 1, indicating the potential for adverse effects (Section 11.5.2). Therefore, an aquatic health assessment was undertaken to further evaluate the potential effects of exposure of aquatic biota in Patterson Lake to elevated copper concentrations (Appendix 11A). Other COPCs considered in the EcoRA

(Section 11.5.1.2) were not carried forward into the aquatic health assessment because their estimated HQ values were less than 1.

The aquatic health assessment specifically focused on characterizing the potential health effects from copper exposure for the limited instances where concentrations in Patterson Lake were predicted to exceed the minimum fresh water copper TRV used in the EcoRA (i.e., instances where HQs were greater than 1). In the EcoRA, the minimum receptor-specific TRV used for copper was 0.002 mg/L, which corresponds to the CCME's and Province of Saskatchewan's default water quality guideline for the protection of aquatic life (CCME 2021; WSA 2015).

Effects from copper exposure were described in the aquatic health assessment using Environment and Climate Change Canada's recently developed copper biotic ligand model (BLM; ECCC 2021) combined with a multiple linear regression (MLR)-based approach developed by Brix et al. (2017, 2021). These tools predict the bioavailability of copper, and hence the toxicity, based on ambient water chemistry conditions. These tools allow the assessment of the potential for toxicity on aquatic biota by evaluating the predicted copper concentrations in consideration of predicted exposure and toxicity modifying factors. Exposure and toxicity-modifying factors are ambient surface water quality conditions that can affect copper bioavailability and toxicity, such as water hardness and the concentrations of certain ions. Additional explanation and rationale for the approach is provided in the aquatic health assessment (Appendix 11A).

The BLM and MLR approaches were used to evaluate how predicted copper concentrations might adversely affect all forms of aquatic life in Patterson Lake, including phytoplankton, zooplankton, benthic invertebrates, and fish. Effects were evaluated in relation to predicted "no effect" and "low effect" thresholds for copper toxicity in Patterson Lake. No effect thresholds were derived based on the results of the copper BLM, and low effect thresholds were derived based on the results of the MLR model. Detailed information regarding the derivation of these thresholds is provided in the aquatic health assessment (Appendix 11A).

As the BLM and MLR models estimate toxicity based on predicted ambient water chemistry conditions, the resulting no effect and low effect thresholds vary depending on the predicted far future conditions (i.e., assessment case [i.e., Application Case, RFD Case], modelled time step, and Patterson Lake basin [i.e., North Arm – West Basin, South Arm]). Figures illustrating the no effect and low effect thresholds derived by the BLM and MLR for the far future water quality predictions are presented in Appendix 11A and in Sections 11.5.2.3 and 11.5.3.3.

11.5.1.4 *Summary of Threshold Values Applied for Copper*

A summary of the threshold values applied for copper in the surface water quality assessment, EcoRA, and aquatic health assessment is provided in Table 11.5-1. This information is provided for reference purposes and to summarize the water quality benchmarks and exposure threshold values considered for copper in the fish and fish habitat assessment. Details regarding the derivation of these threshold values are provided in the respective technical sections (Section 10; TSD XXI; and Appendix 11A).

Table 11.5-1: Summary of Water Quality and Exposure Threshold Values Applied for Copper in the Surface Water Quality Assessment, Ecological Risk Assessment, and Aquatic Health Assessment of the Potential for Adverse Effects of Predicted Far-Future Copper Concentrations in Patterson Lake

Assessment	Threshold/Guideline	Source/Derivation	Value
Surface Water Quality Assessment (Section 10.2.8.3, Development of Thresholds)	Project-Specific Water Quality Threshold	Canadian Council of Ministers of the Environment (CCME) Guidelines - Long-term Chronic (CCME 2021) guideline	Copper in water = 0.002 mg/L
Ecological Risk Assessment (TSD XXI Section 6.0)	Lowest Receptor Specific Toxicity Reference Value (TRV)	Estimated 20% effect concentrations (i.e., EC ₂₀ values; concentrations at which only 20% of the test organisms respond). This level of effect was used because 20% is near the level at which effects become statistically discernible or measurable in both laboratory and field studies. EC ₂₀ values were obtained from the United States Environmental Protection Agency ECOTOXicology database (lake whitefish) or from CCME (zooplankton and benthic invertebrates)	Zooplankton TRV = 0.002 mg/L Benthic invertebrates TRV = 0.002 mg/L Lake whitefish TRV = 0.002 mg/L
	Hazard Quotients (HQs)	HQs provide a quantitative estimate of overall risk to a receptor. HQs were calculated by dividing the exposure value by the TRV, and the resulting HQ value is compared to a benchmark HQ value of 1. An HQ value greater than 1 would indicate the potential for adverse effects and further assessment would be warranted	Benchmark = 1
Aquatic Health Assessment of the Potential for Adverse Effects of Predicted Far-Future Copper Concentrations in Patterson Lake (Appendix 11A)	No Effect Threshold Values	Environment and Climate Change Canada (ECCC) copper biotic ligand model (BLM; ECCC 2021). No effect thresholds are concentrations of copper at which health effects on aquatic life would not be expected to occur (ECCC 2021)	Variable based on predicted ambient water quality conditions (Figure 11.5-2 and Figure 11.5-5)
	Low Effect Threshold Values	Multiple linear regression-based approach developed by Brix et al. (2017, 2021). Low effect thresholds are concentrations at which only 20% to 25% of organisms may be affected. This level of effect is consistent with relevant guidance for a permissible level of effect (Suter et al. 1995) and for providing protection against unacceptable adverse effects (Mebane 2010). A difference of less than or equal to 20% in response to a test is widely considered to be within the range of natural variability often observed in the field among normal, unexposed populations	Variable based on predicted ambient water quality conditions (Figure 11.5-2 and Figure 11.5-5)

CCME = Canadian Council of Ministers of the Environment; TRV = toxicity reference value; HQ = hazard quotient.

11.5.1.5 *Assessing Effects on Lake Trout, Lake Whitefish, Walleye, and Northern Pike*

Predicted effects on fish VCs from changes to surface water quality are described for the far-future projection that considers the long-term, slow migration of hydrogeological mass load inputs from certain areas of the Project site following Closure. The approach used to characterize potential effects on fish VCs and associated measurement indicators was quantitative where possible; however, the approach was primarily qualitative. Changes in measurement indicators for fish VCs were estimated relative to the Base Case to describe the following residual effects:

- **Habitat availability:** Changes in the habitat availability measurement indicator were estimated by examining potential changes to habitat quantity or quality, as well as the use of potentially affected habitat(s) by fish VCs.

The primary mechanism that could alter fish habitat availability after Closure and in the far future is the potential for effects on the food base for fish. This mechanism could occur as a result of exposure of lower trophic organisms and forage fish, which are important prey items for fish VCs, to COPCs in water or sediment. Effects on the available food supply for fish were assessed qualitatively based on the results of the EcoRA and aquatic health assessment completed for the Project, which provided quantitative predictions regarding the potential for effects on the health of lower trophic organisms, including phytoplankton, zooplankton, benthic invertebrates, and forage fish (represented by lake whitefish in the EcoRA). Also considered in the evaluation of the habitat availability measurement indicator was the potential for effects on the viability and suitability of the affected habitat for use by fish VCs. For example, if changes to the available food supply for fish occurred, the evaluation considered how these changes might affect fish use of the affected habitat.

- **Habitat distribution:** Changes in habitat distribution were estimated by qualitatively examining potential changes in the arrangement and spatial distribution of habitats in the LSA and RSA. Predictions for habitat distribution considered the potential for changes in habitat availability and whether changes to habitat quality could result in corresponding effects on the ability of fish to move between habitats to carry out their life processes.
- **Survival and reproduction:** Changes in survival and reproduction were estimated by considering the potential for direct effects from exposure to COPCs in water or sediment (e.g., direct toxicity as a result of exposure to an elevated concentration of potential toxicant) and the potential for indirect effects from changes in habitat (e.g., effects from a change in available food supply). Predicted changes in survival and reproduction were then summarized qualitatively in consideration of both potential effect mechanisms.

Potential direct effects on the survival and reproduction of fish VCs were assessed based on the results of the EcoRA component of the ERA and aquatic health assessment completed for the Project, which provided quantitative predictions regarding the potential health risks to fish. The EcoRA provided an assessment of the potential health risks for a defined list of aquatic receptors, of which two (i.e., lake whitefish, northern pike) are VCs in the fish and fish habitat assessment. The results of the EcoRA can also be used to interpret potential direct effects on lake trout and walleye, which are the other two fish VCs considered in the fish and fish habitat assessment. Toxicity reference values used in the EcoRA for fish receptors were derived for two broad functional categories: forage fish and predator fish. These TRVs are not specific to individual VCs. Therefore, the estimated health risks identified for northern pike, a predator species, can be used as a surrogate to predict effects on lake trout and walleye, which are also primarily piscivorous. Potential direct effects on all forms of aquatic life, including the four fish VCs, were considered in the aquatic health assessment (Appendix 11A).

Potential indirect effects on the survival and reproduction of fish VCs were assessed qualitatively based on the results for habitat availability. Therefore, the assessment considered the potential for effects on the lower trophic food base for fish to propagate up the food web and affect the survival and reproduction of fish VCs.

The effects of future climate change on fish and fish habitat were considered in the RFD Case through the inclusion of a climate change scenario in the hydrological data inputs to the RSWQM (Section 11.5.1.1). These inputs were considered in the EcoRA, the aquatic health assessment, and ultimately in the residual effects analysis for fish VCs.

11.5.2 Application Case

This subsection presents the results of the residual effects analysis for fish and fish habitat for the Application Case. A summary of the results of the predicted changes to surface water quality and resulting health effects on aquatic biota in the Application Case for the far-future projection is provided in Sections 11.5.2.1 to 11.5.2.3. Additional details and results can be found in Section 10, TSD XXI, and Appendix 11A. Predicted effects on fish VC populations in the LSA and RSA resulting from changes to habitat availability, survival, and reproduction in the Application Case are described in Section 11.5.2.4, Effects on Lake Trout, Lake Whitefish, Walleye, and Northern Pike.

Mitigation measures have been incorporated into the Project (Table 11.4-1), where feasible, to limit potential effects on fish VCs from Project components or activities that could alter surface water quality after Closure and in the far future. As part of the Project design, source control would be applied to the WRSAs and UGTMF to reduce and control infiltration, runoff, and seepage to limit the potential mass loading from these facilities to groundwater and surface water. Source control with respect to the PAG WRSA includes incorporating a physical liner under the storage area and providing a form of cover that enhances runoff, limits infiltration, and reduces oxygen ingress to the waste rock. Water quality of runoff from the PAG and NPAG would be managed by the final design and closure plans of the two storage areas, in accordance with the Mine Waste Management Plan. Source control with respect to the UGTMF would include the design, maintenance, and monitoring of a mine dewatering system to control the flow of groundwater inflow, applying a binder to reduce permeability in backfill and tailings, and engineering tailings geochemistry such that the release of mass is controlled. Further details about how the water quality from these areas would be managed can be found in Section 5, Project Description and Section 10.

11.5.2.1 Summary of Predicted Changes to Surface Water Quality

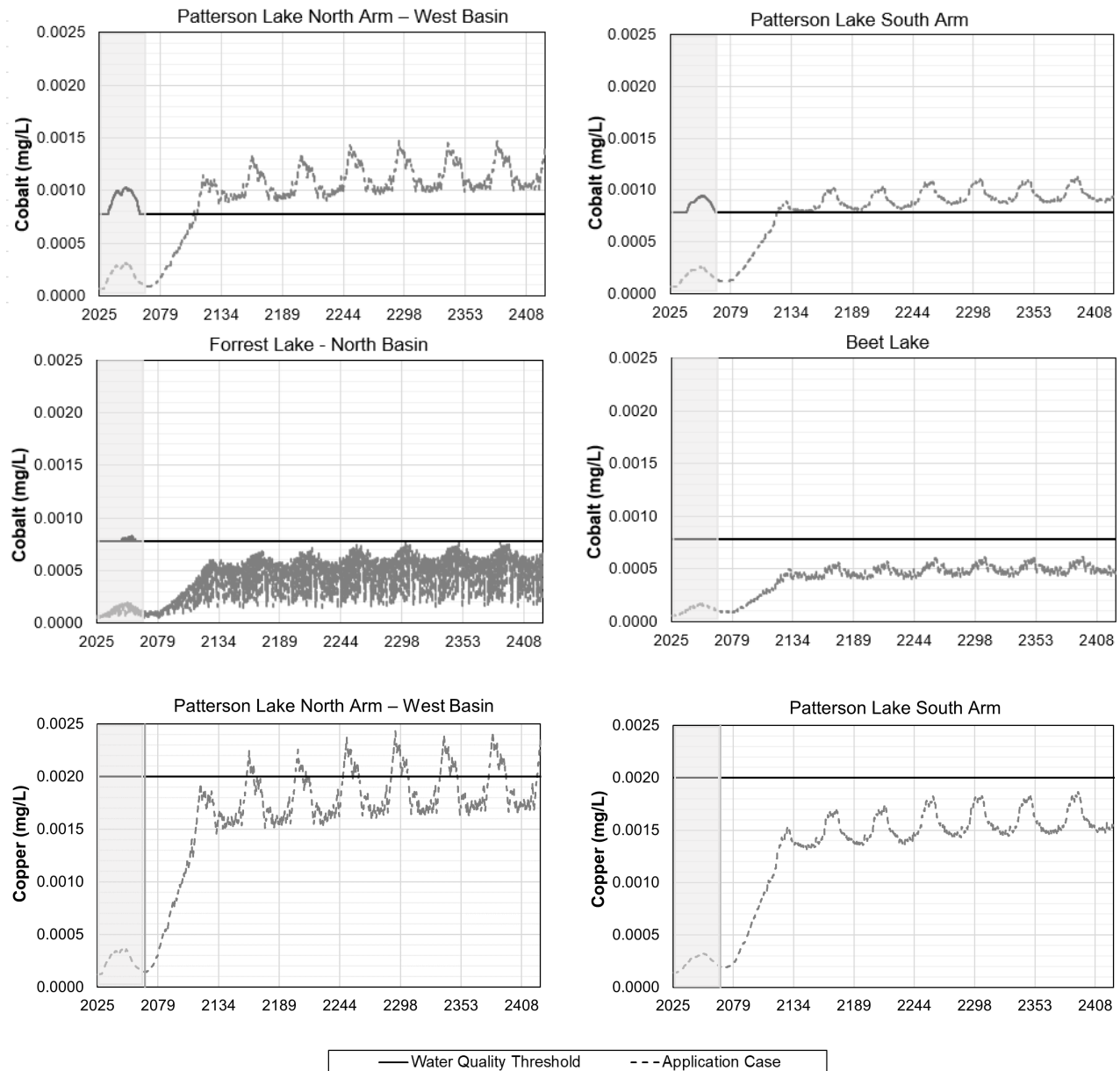
A summary of predicted changes to surface water quality is presented to provide an understanding of water chemistry conditions in the receiving environment in the far future. The results summary is focused on predicted changes in potential toxicants (i.e., metals and radionuclides) that could affect the health of fish and lower trophic organisms after Closure and in the far future.

In the far future, COPC metals (i.e., aluminum, cobalt, copper, iron, manganese, molybdenum, nickel, selenium, uranium, and zinc) were predicted to increase in the receiving environment due to slow migration from the UGTMF and PAG WRSA. The concentrations of these COPCs were predicted to increase during the far future compared to during the Project lifespan and the Base Case. The concentrations of these metals were predicted to increase after Closure because of an influx of mass loading from groundwater and peak after the maximum groundwater loadings are applied to the RSWQM. Note that the peaks represent a fast-tracked timeline as described in Section 11.5.1.1. As outlined in Section 10.5.1.2.3, predicted metal COPC concentrations are influenced by climate, where concentrations are generally higher during dry years and lower during wet years. Overall, the magnitude of metal COPC concentration increases were predicted to be greater in the reasonable upper bound scenario compared to the Application Case.

Although increases were noted for these COPCs in the Application Case and reasonable upper bound scenario, only cobalt and copper were predicted to exceed surface water quality thresholds. Cobalt exceedances were predicted in Patterson Lake North Arm – West Basin and Patterson Lake South Arm in the Application Case (Figure 11.5-2) and Patterson Lake North Arm – West Basin, Patterson Lake South Arm, Forrest Lake – North Basin, and Beet Lake in the reasonable upper bound scenario. Copper exceedances were limited to Patterson Lake North Arm – West Basin for both the Application Case (Figure 11.5-2) and reasonable upper bound scenario. The extent and magnitude of the cobalt and copper exceedances were predicted to be greater in the reasonable upper bound scenario compared to the Application Case (Figure 10.5-13 and Figure 10.5-14). These results for cobalt and copper were carried forward to the EcoRA, which evaluated risks to aquatic receptors and is summarized in Section 11.5.3.2, Summary of Ecological Risk Assessment Results.

In the Application Case, concentrations of radionuclides in the receiving environment are predicted to decline after Closure, eventually reaching steady-state conditions. Concentrations of radionuclides defined as COPCs (i.e., lead-210, polonium-210, radium-226, and thorium-230) are predicted to remain below water quality threshold values in all waterbodies in the far future.

Figure 11.5-2: Cobalt and Copper Concentrations Predicted by the Regional Surface Water Quality Model, Application Case



Note: The shaded area of the plot is representative of the lifespan of the Project, and the unshaded area is representative of the far-future projection.

11.5.2.2 *Summary of Ecological Risk Assessment Results*

The EcoRA evaluated and presented the estimated risks to aquatic receptors due to releases from the Project to Patterson Lake in the far future once groundwater solute would reach the Patterson Lake North Arm – West Basin. Based on the COPC screening process undertaken for the EcoRA, chloride, sulphate, arsenic, cobalt, copper, uranium, and the radionuclides, uranium-238, uranium-234, thorium-230, radium-226, lead-210, polonium-210 were selected as COPCs for surface water. Based on the EcoRA screening process, no COPCs in sediment were identified for further evaluation of potential risks for ecological health, and thus toxicity via direct contact with sediment was not considered further.

Estimated HQs for the far future were predicted to be below the benchmark of 1 for all COPCs, except for copper in the Application Case and reasonable upper bound scenario. Although cobalt concentrations were predicted to exceed surface water quality guidelines (Section 11.5.2.1), estimated HQs for cobalt were less than 1 in all assessment cases and for all aquatic receptors; therefore, cobalt was not considered further. The maximum HQ for copper was predicted to exceed 1 in Patterson Lake North Arm – West Basin for benthic invertebrates, zooplankton, and forage fish (represented by lake whitefish in the EcoRA) in the far future for the Application Case and the reasonable upper bound scenario. Additionally, the estimated HQ for copper was predicted to exceed 1 in Patterson Lake South Arm for the same three receptors in the far future in the reasonable upper bound scenario. All other modelled waterbodies in the receiving environment had predicted HQs below 1 for the Application Case and reasonable upper bound scenario. There were no predicted exceedances of the 9.6 mGy/d radiation dose benchmark for aquatic biota (UNSCEAR 2008; CSA Group 2022) for the far future.

The results of the EcoRA indicated that direct toxicity from exposure to elevated copper concentrations cannot be ruled out for a subset of aquatic receptors. However, an HQ that is slightly above 1 is not indicative of impending risk to aquatic biota, but rather, that the potential for adverse effects may be increased and that additional investigation is warranted. In the Application Case, the maximum estimated HQs for copper were predicted to slightly exceed the benchmark of 1 and remained below 1.4 in all instances where exceedances occur. A slight exceedance of the benchmark value of 1 indicated that the exposure concentration (i.e., maximum copper concentration in Patterson Lake North Arm – West Basin) only slightly exceeded the reference concentration (i.e., TRV). While the HQ cannot be translated to a probability that adverse health effects would occur and is not directly proportional to risk, a lower HQ would generally have a lower magnitude of effect than a high HQ (e.g., HQ value greater than 10).

The fresh water copper TRV used in the EcoRA for lake whitefish, zooplankton, and benthic invertebrates was based on the CCME's default water quality guideline of 0.002 mg/L (CCME 2021). The CCME water quality guideline is a conservative benchmark below which adverse effects for most aquatic biota are not expected to occur. The EcoRA concluded that effects from copper exposure, if evident, would be limited to exposed individuals of the most sensitive taxa, which included fresh water snails and clams, and water fleas. The most sensitive endpoints for chronic exposure to copper include growth for benthic invertebrates, reproduction for zooplankton, and growth and reproduction for fish (ECCC 2021).

Exceedances of the HQ benchmark value of 1 were predicted to be spatially limited to Patterson Lake North Arm – West Basin in the Application Case and were predicted to extend as far downstream as Patterson Lake South Arm in the reasonable upper bound scenario. Population-level effects on forage fish (e.g., lake whitefish), zooplankton, and benthic invertebrates were not predicted to occur due to the limited magnitude of effect and spatial extent of predicted effects in the LSA.

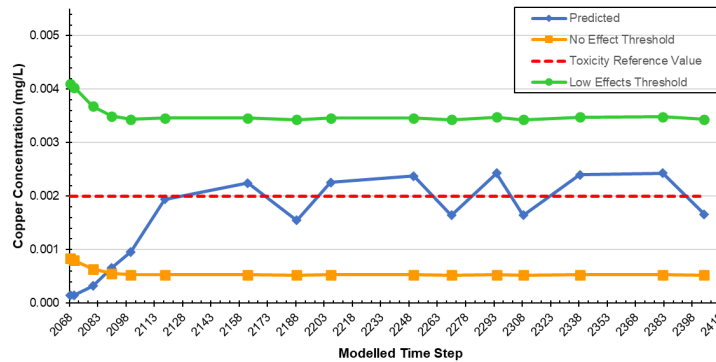
11.5.2.3 *Summary of Aquatic Health Assessment Results*

An aquatic health assessment was undertaken to further evaluate the potential effects of exposure of aquatic biota in Patterson Lake to elevated copper concentrations (Appendix 11A), focusing on the limited instances where concentrations exceed the minimum receptor-specific TRV of 0.002 mg/L. In the Application Case, copper concentrations in Patterson Lake North Arm – West Basin were predicted to consistently exceed the no effect threshold predicted by the BLM beginning after Closure but would remain below the low effect threshold predicted by the MLR over the modelling timeframe (Figure 11.5-3). Although effects on aquatic life cannot be ruled out for this period, the aquatic health assessment concluded that at the predicted magnitude of effect, exposure to copper in Patterson Lake would be unlikely to result in adverse effects on aquatic populations and communities. If effects occurred, the predicted magnitude would be within the range of background variability and thus unlikely to be measurable (Appendix 11A).

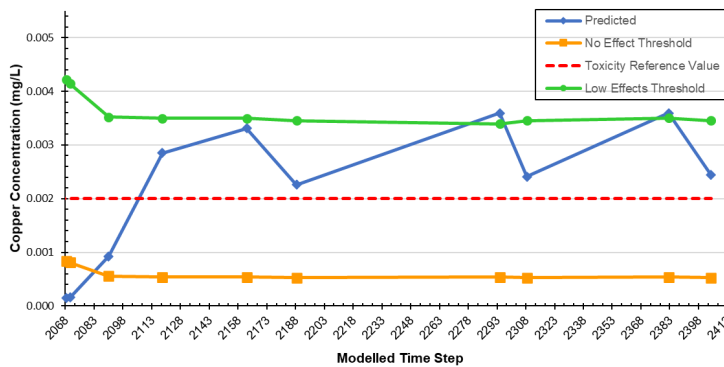
Under the more conservative assumptions considered in the reasonable upper bound scenario, predicted copper concentrations in Patterson Lake North Arm – West Basin would exceed the no effect threshold beginning after Closure but would largely remain below the low effect threshold over the modelling timeframe (Figure 11.5-2). However, concentrations were predicted to occasionally fluctuate above the low effect threshold during periods of dry climate conditions (Appendix 11A). Predicted concentrations above the low effect threshold may result in potential adverse effects on sensitive aquatic receptors. Therefore, a review of the potential magnitude of effects on sensitive species was undertaken. The results of this analysis indicated that adverse effects on aquatic biota are unlikely to occur because predicted copper concentrations are lower than the lowest low effect concentration for the most sensitive species.

Figure 11.5-3: Predicted Copper Concentrations relative to No Effect and Low Effect Thresholds derived by the Biotic Ligand Model and Multiple Linear Regression Model, Patterson Lake North Arm – West Basin and South Arm, Application Case and Reasonable Upper Bound Scenario

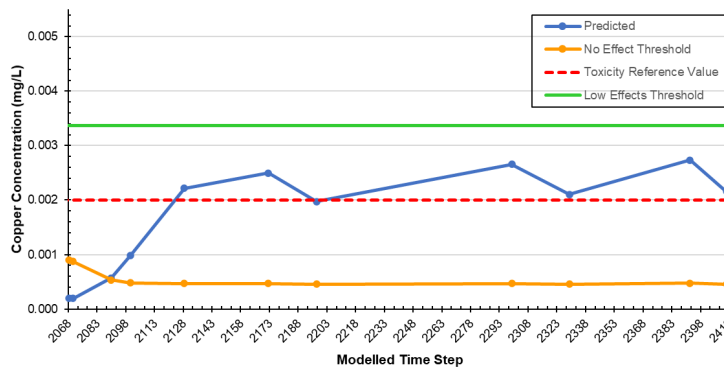
Patterson Lake North Arm – West Basin: Application Case



Patterson Lake North Arm – West Basin: Application Case, Reasonable Upper Bound Scenario



Patterson Lake South Arm: Application Case, Reasonable Upper Bound Scenario



Source: Appendix 11A.

11.5.2.4 Effects on Lake Trout, Lake Whitefish, Walleye, and Northern Pike

The evaluation of effects on fish VCs follows directly from the predictions generated from the surface water quality assessment, aquatic health assessment, and the EcoRA, and therefore incorporates a similar level of conservatism to these assessments. Residual effects on fish VCs were assessed in terms of the measurement indicators defined in Section 11.2.2.2 (i.e., habitat availability, habitat distribution, and survival and reproduction). Changes in measurement indicators for fish VCs relative to the Base Case were assessed according to the approach described in Section 11.5.1.4.

11.5.2.4.1 Effects on Habitat Availability

The residual effects assessment for fish VCs indicated limited potential for changes in habitat availability due to exposure to predicted copper concentrations in Patterson Lake North Arm – West Basin after Closure and in the far future. Changes to health of lower trophic level communities (e.g., plankton, benthic invertebrates) and forage fish (e.g., lake whitefish) due to exposure to copper could alter the available food supply for fish, and consequently the quality of available habitat for fish VCs in Patterson Lake. Zooplankton are an important food source for pelagic fish; therefore, direct toxicological effects on zooplankton could alter habitat quality for pelagic fish (e.g., lake trout and walleye). Similarly, benthic invertebrates exposed directly to potential toxicants in water or sediment are a key food supply for fish feeding on the lake bottom; therefore, direct toxicological effects on benthic invertebrates could alter habitat quality for bottom-feeding fish (e.g., lake whitefish). Forage fish, including lake whitefish, are an important food source for piscivorous fish; therefore, direct toxicological effects on forage fish could adversely affect habitat quality for upper trophic level consumers such as lake trout, walleye, and northern pike.

The results of the EcoRA component of the ERA and the aquatic health assessment completed for the proposed Project indicated that exposure to predicted copper concentrations in the Application Case and reasonable upper bound scenario would be unlikely to result in adverse effects on lower trophic level organisms and forage fish species that form the food base for fish. In the EcoRA, estimated HQs for copper for zooplankton, benthic invertebrates, and forage fish (represented by lake whitefish) were slightly greater than 1, indicating that toxicological effects could not be ruled out for these receptors. Each of these receptors may be targeted as prey by fish VCs in Patterson Lake. However, at the predicted level of exposure, effects would be limited to individual taxa or species that may be sensitive to elevated copper concentrations. The aquatic health assessment results supported these findings and indicated that any potential changes to the lower trophic food base for fish would be minimal and within the range of variability observed in unexposed populations. This assessment is based on the prediction that copper concentrations in the Application Case would remain below the low effect threshold, which as outlined in Section 11.5.1.3 and Appendix 11A, is considered to be a level of effect below which changes in aquatic populations would not be measurable.

Based on the results of the EcoRA and aquatic health assessment, there is some limited potential that a decrease in the abundance and/or biomass of certain prey items for fish VCs could occur. However, both the EcoRA and aquatic health assessment concluded that population and/or community level effects on lower trophic organisms and forage fish are not predicted to occur; therefore, broadscale changes to the food base for fish VCs are not expected at the predicted magnitude of effect. If small changes to the availability of selected prey items occurred, these effects would not be expected to measurably alter fish habitat use of affected areas in Patterson Lake, as overall prey availability would not be expected to be affected. Therefore, no adverse effects on the viability and suitability of habitats for use by fish VCs are predicted to occur.

Based on the results of the EcoRA and aquatic health assessment, and given the conservatism applied to the surface water quality modelling assumptions for copper in the far future, predicted effects on fish VC habitat availability in the Application Case are considered to be negative in direction and negligible in magnitude (i.e., within the range of background variability and unlikely to be measurable); however, it is conservatively considered possible that low magnitude effects may occur. Therefore, the predicted magnitude of effects on fish VCs due to changes in habitat availability in the Application Case was assessed as being negligible to low.

Exposure of lower trophic level prey and forage fish species to maximum copper concentrations would be limited spatially to Patterson Lake North Arm – West Basin for the Application Case. In the reasonable upper bound scenario, effects may extend into Patterson Lake South Arm. However, the likelihood that reasonable upper bound conditions would be realized is low given the high level of conservatism considered in the modelling for this scenario. The frequency of potential effects on fish VC habitat availability is also limited. As shown in Figure 11.5-2, copper concentrations in the Application Case in the far future are influenced by climate where concentrations are generally higher during dry years and lower during wet years. Thus, exposure to maximum copper concentrations would occur only during dry climate years when there is a lower natural runoff to the lake. However, effects on fish habitat availability could potentially occur continuously during periods when predicted concentrations exceed reference values (i.e., TRVs, no effects or low effects thresholds).

The summary of potential residual effects on fish VC habitat availability considered the implementation of mitigation outlined in Section 11.4 and 11.5.2, Application Case, which is expected to reduce the magnitude and duration of residual effects on surface water quality, aquatic health, and ultimately fish habitat availability. However, notably, the assumptions of the groundwater solute transport modelling, which provided information for development of the RSWQM, and subsequently the fish and fish habitat effects analysis, assumed only limited mitigation associated with the WRSAs and the UGTMF (Section 10.6.1.4); as a result, predicted effects on fish VCs from changes in habitat availability may be overestimated. Additional discussion related to uncertainty associated with the groundwater and surface water quality modelling is provided in Section 11.6.

In consideration of all assessment factors, the predicted effects to habitat availability are considered to be possible, meaning that the changes may occur but are not likely.

11.5.2.4.2 Effects on Habitat Distribution

No adverse effects on habitat distribution in the LSA and RSA are predicted to occur as a result of predicted changes to surface water quality in the aquatic receiving environment after Closure and in the far future. While there is some potential that exposure to copper could result in negligible to low magnitude effects on the available food supply for fish, no change in the viability of habitats for use by fish in Patterson Lake is expected at the predicted magnitude of effect. Therefore, fish would be able to continue using the habitats present, and move between habitats, to carry out their life processes (e.g., spawning, rearing, overwintering), and no effects on habitat arrangement or the spatial distribution and movement of fish in Patterson Lake are expected to occur.

11.5.2.4.3 Effects on Survival and Reproduction

Effects on the survival and reproduction of fish VCs could directly occur as a result of exposure to copper in the water column or indirectly due to changes in habitat availability resulting from potential effects on the lower trophic food base for fish, as described in Section 11.5.2.4.1, Effects on Habitat Availability. Potential effects on fish VCs that may occur due to these mechanisms are discussed below. The effects associated with both mechanisms (i.e., direct exposure and changes in habitat availability) were then considered when describing the resulting residual effects on the survival and reproduction of fish VCs.

The results of the EcoRA component of the ERA and the aquatic health assessment completed for the Project indicate that effects on the health, and therefore survival and reproduction, of fish are unlikely to occur in the Application Case and reasonable upper bound scenario. Based on the results of the EcoRA, direct toxicological effects on predator fish (represented by northern pike) are not expected to occur, as the estimated HQ for copper for predator fish was below 1 for both the Application Case and reasonable upper bound scenario. Therefore, no changes to the survival and reproduction of predator VCs, including lake trout, walleye, and northern pike, are expected due to exposure to copper in the water column.

The EcoRA concluded that direct toxicological effects on forage fish (represented by lake whitefish in the EcoRA) could not be ruled out based on an estimated HQ of slightly greater than 1. However, if effects were to occur, the predicted magnitude would be limited by the minimal exceedance of the copper TRV. Overall, the results of the aquatic health assessment supported these conclusions and indicated that any potential health effects on aquatic biota, including fish VCs, would be minimal and would be within the range of variability observed in unexposed populations. Both the EcoRA and aquatic health assessment results indicated that population-level effects are not expected to occur. Large-bodied fish such as lake whitefish are mobile and can move around among basins within Patterson Lake, or to nearby waterbodies; therefore, it is unlikely that individuals would be exposed to the maximum copper concentration for extended periods.

The growth and productivity of fish is strongly influenced by the available food supply. As described in Section 11.5.2.4.1, changes to the health of lower trophic level organisms and forage fish due to exposure to copper in the water column could result in limited effects on the food base for fish in Patterson Lake North Arm – West Basin. These potential changes could propagate up the food web and adversely affect the survival and reproduction of fish VCs. The potential effects of a reduction or change in the quality or quantity of available prey for fish can include changes in growth, body size, reproductive output, or population size. The type and magnitude of effect is dependent of several factors including the complexity of feeding interactions, the preferred diet of the affected fish species, and the existing density of affected fish populations.

Because effects on habitat availability resulting from changes to the food base for fish are predicted to be negligible, or at most low in magnitude, and because any realized changes would be limited by the limited spatial extent of elevated copper concentrations, it is unlikely that there would be meaningful changes to the survival and reproduction of fish VC populations due to changes in available food supply. Some limited effects on the food base for fish are possible due to the potential for a slight reduction in the availability or biomass of individual prey items (e.g., taxa or species that may be sensitive to elevated copper concentrations); however, corresponding effects on the productivity of forage fish species such as lake whitefish, and piscivorous species such as lake trout, walleye, and northern pike, are unlikely to occur as the transfer of energy between trophic levels is inefficient. Only about 10% of available energy typically is transferred between trophic levels due to factors such as incomplete ingestion of food, energy used for respiration, and energy lost as waste (excreted) (Krebs 2009). Therefore, only limited effects on fish VC survival and reproduction are possible due to changes to food supply, and it is unlikely that these changes would be measurable at the predicted copper concentrations for both the Application Case and the reasonable upper bound scenario.

Based on the results of the EcoRA and aquatic health assessment, and given the conservatism applied to the surface water quality modelling assumptions for copper in the far future, predicted effects on fish VCs due to changes in survival and reproduction in the Application Case are considered to be negative in direction and negligible in magnitude (i.e., within the range of background variability and unlikely to be measurable); however, it is conservatively considered possible that low magnitude effects may occur. Therefore, the predicted magnitude of effects on fish VC survival and reproduction due to potential direct effects resulting from exposure to copper in the water column, and indirect effects related to changes in habitat availability, was assessed as negligible to low.

Exposure of fish VCs to maximum copper concentrations and predicted changes in habitat availability would be limited spatially to Patterson Lake North Arm – West Basin for the Application Case and may extend into Patterson Lake South Arm in the reasonable upper bound scenario. However, as fish VCs can move around, the geographic extent of effects on survival and reproduction was assessed as local. The frequency of potential effects on fish VC survival and reproduction would be limited to dry climate years when there is a lower natural runoff to the lake. However, effects could potentially occur continuously during periods when predicted concentrations exceed reference values (i.e., TRVs, no effects or low effects thresholds).

In consideration of all assessment factors, the predicted effects to survival and reproduction are considered to be possible, meaning that the predicted changes may occur but are not likely.

11.5.3 Reasonably Foreseeable Development Case

This subsection presents the results of the residual effects analysis for fish and fish habitat for the RFD Case. A summary of the results of the predicted changes to surface water quality and resulting health effects on aquatic biota in the RFD Case for the far future is provided in Section 11.5.3.1 to Section 11.5.3.3. Details can be found in Section 10, TSD XXI, and Appendix 11A. Predicted effects on fish VC populations in the RSA resulting from changes to habitat availability, survival, and reproduction in the RFD Case are described in Section 11.5.3.4, Effects on Lake Trout, Lake Whitefish, Walleye, and Northern Pike.

Mitigation measures incorporated into the Project, as described for the Application Case (Table 11.4-1 and Section 11.5.2.1, Summary of Predicted Changes to Surface Water Quality), are expected to also limit the potential for effects on fish VCs due to the cumulative effects of the Project and Fission Patterson Lake South Property. Information on specific mitigation measures that would be implemented for the Fission Patterson Lake South Property to avoid or reduce effects on surface water quality was unavailable; however, it was assumed that similar types of measures that are being employed for the Project would be implemented for the Fission Patterson Lake South Property.

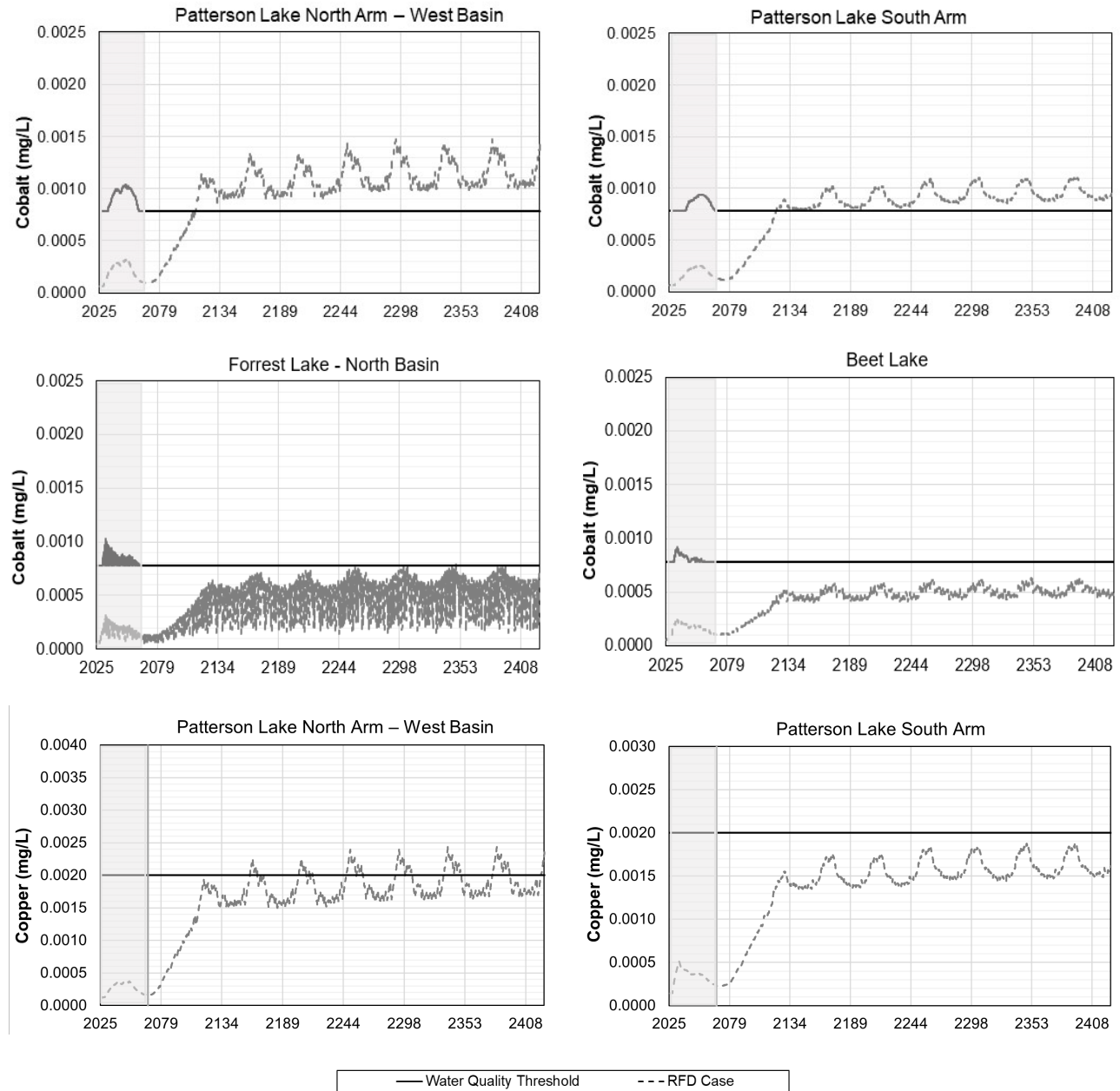
11.5.3.1 *Summary of Predicted Changes to Surface Water Quality*

The general influence of the RFD Case on surface water quality in the far future projection would represent a very slight increase in the concentrations of metal COPCs in Patterson Lake compared to the Application Case. Similar to the Application Case, concentrations of metal COPCs were predicted to increase in the far future compared to during the Project lifespan and Base Case. The primary loading source for metals in the far future is from groundwater influenced by loadings generated by seepage from the WRSAs and the UGTMF. However, despite the primary contribution of COPC metals being from loading to groundwater from the Project, COPC metals concentrations are slightly elevated compared to the Application Case because of the additional metal mass loadings to Patterson Lake contributed by the Fission Patterson Lake South Property site runoff from the above-ground tailings management facility and covered waste rock storage facility. Overall, concentration trends in the far future remain very similar to the concentrations and trends predicted for the Application Case. Similar to the Application Case, all metal COPC concentrations in the RFD Case were predicted to remain below thresholds in all waterbodies in the LSA during the far future, with exception of cobalt and copper. Cobalt was predicted to exceed water quality thresholds during the modelled far future period in Patterson Lake North Arm – West Basin and Patterson Lake South Arm (Figure 11.5-4). Cobalt exceedances are limited to Patterson Lake with the maximum monthly concentrations in Forrest Lake – North Basin (i.e., 0.00077 mg/L) predicted to be below the Project threshold. Copper exceedances are predicted periodically in Patterson Lake North Arm – West Basin only (Figure 11.5-4).

In the RFD Case, radionuclide concentrations were predicted to be slightly greater compared to the Application Case due to the loading of these constituents from the Fission Patterson Lake South Property. Radionuclides defined as COPCs were predicted to remain below water quality thresholds in all waterbodies in the LSA in the far future.

The results of the climate change sensitivity scenario completed for the RFD Case indicate that the effects of climate change on COPC concentrations were minor overall. Climate change is generally expected to result in wetter and warmer conditions in the RSA in the far future projection (Section 9.4). In general, the influence of these changes is an increase in water levels and flows in the RSA. However, variability of water levels and flows would also increase, which results in some COPCs having slightly higher concentrations and others having slightly lower concentrations (Section 10.5.2.1.6). For copper and cobalt, which were predicted to exceed water quality threshold values in the RFD Case, there is some minor variability between trends for the RFD Case and RFD plus climate change sensitivity scenario (Section 10, Figure 10.5-17); however, climate change is not predicted to result in a meaningful increase in the concentrations of these COPCs over the modelling timeframe, nor is it expected to alter the frequency or magnitude of the threshold exceedances.

Figure 11.5-4: Cobalt and Copper Concentrations Predicted by the Regional Surface Water Quality Model, Reasonably Foreseeable Development Case



Note: The shaded area of the plot is representative of the lifespan of the Project, and the unshaded area is representative of the far-future projection.

RFD = reasonably foreseeable development.

11.5.3.2 Summary of Ecological Risk Assessment Results

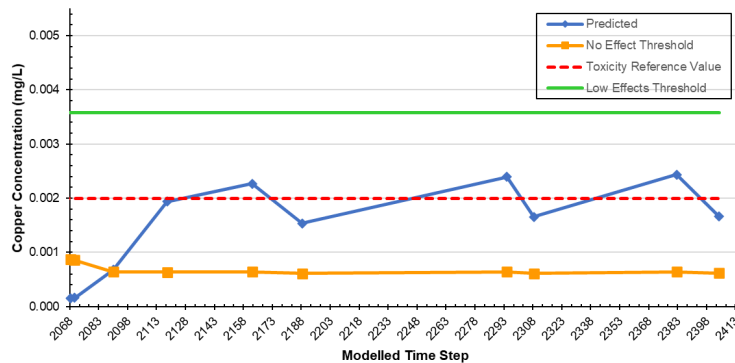
The EcoRA component of the ERA presents the estimated risks to aquatic receptors due to releases from the Project and the Fission Patterson Lake South Property to Patterson Lake in the far future. The list of COPCs considered in the RFD Case was the same as that evaluated in the Application Case. Similar to the Application Case, the estimated HQs in the RFD Case were predicted to be below 1 for all COPCs, except for copper. The results for the RFD Case are very similar to the far future in the Application Case, where the maximum HQ for copper was predicted to exceed 1 in Patterson Lake North Arm – West Basin for benthic invertebrates, zooplankton, and forage fish (represented by lake whitefish). There were no predicted exceedances of the 9.6 mGy/d radiation dose benchmark (UNSCEAR 2008; CSA Group 2022) for aquatic biota in the RFD Case.

11.5.3.3 Summary of Aquatic Health Assessment Results

The BLM and MLR model results for the RFD Case produced similar results to the Application Case. Copper concentrations in Patterson Lake North Arm – West Basin were predicted to consistently exceed the no effect threshold beginning after Closure but would remain below the low effect threshold for duration of the far future modelling timeframe (Figure 11.5-5). Predicted effects on the health of aquatic biota were the same as those described for the Application Case. Exposure of aquatic biota to predicted copper concentrations in Patterson Lake was assessed as unlikely to result in adverse effects on aquatic populations and communities. If effects occurred, the predicted magnitude would be within the range of background variability and thus unlikely to be measurable.

Figure 11.5-5: Predicted Copper Concentrations relative to No Effect and Low Effect Thresholds derived by the Biotic Ligand Model and Multiple Linear Regression Model, Patterson Lake North Arm – West Basin, Reasonably Forseeable Development Case

Patterson Lake North Arm – West Basin: Reasonably Foreseeable Development Case



Source: Appendix 11A.

11.5.3.4 Effects on Lake Trout, Lake Whitefish, Walleye, and Northern Pike

As described for the Application Case (Section 11.5.2.2, Summary of Ecological Risk Assessment Results), the evaluation of effects on fish VCs follows directly from the predictions generated from the surface water quality assessment, aquatic health assessment, and the EcoRA. Therefore, the RFD Case assessment for fish and fish habitat incorporates a similar level of conservatism to that considered by these assessments. Uncertainty associated with the effects predictions related to the surface water quality assessment was carried forward into the RFD Case assessment for fish and fish habitat.

Overall, predicted effects on surface water quality, aquatic health, and ultimately the four fish VCs in the RFD Case were similar to the Application Case predictions. The main reason is that the additional metal mass loadings to Patterson Lake contributed by the Fission Patterson Lake South Property are minor overall compared to the inputs associated with the Project, which for the far future were largely associated with long-term solute transport from the WRSAs and UGTMF. The main influence of the Fission Patterson Lake South Property in the RFD Case is a slight increase in COPC concentrations, including copper concentrations, in the receiving environment. However, the inclusion of the Fission Patterson Lake South Property in the RFD Case does not result in meaningful changes to the effects predictions for fish VCs as outlined for the Application Case because mass loading from long-term solute transport from the Project is the main driver of the predicted effects on surface water quality and fish VCs.

The effects of future climate change were considered in the RFD Case through the inclusion of a climate change sensitivity scenario in the hydrological data inputs to the RSWQM. These inputs were thus carried through the EcoRA, the aquatic health assessment, and finally to the residual effects analysis for fish VCs. Results from the RFD plus climate change sensitivity scenario indicated that climate change effects on surface water quality within the LSA based on hydrological projections would be minor (Section 11.5.3.1). These minor changes in hydrologic conditions did not result in changes to COPC concentrations that ultimately changed the predicted effects for fish VCs from exposure to elevated copper concentrations in Patterson Lake after Closure of the Project and in the far future.

11.5.3.4.1 Effects on Habitat Availability

The results of the RFD Case assessment for effects on fish VC habitat availability are the same as those presented for the Application Case. Overall, negligible, or at most low magnitude effects on habitat availability are predicted to occur, resulting from the potential for effects on the health of lower trophic level communities and forage fish (e.g., lake whitefish) that form the food base for fish. The predicted geographic extent, duration, reversibility, frequency, and probability of occurrence of residual effects are the same as described for the Application Case.

11.5.3.4.2 Effects on Habitat Distribution

The results of the RFD Case assessment for effects on habitat distribution are the same as those presented for the Application Case. Overall, no adverse effects on habitat distribution in the RSA are predicted to occur as a result of changes to surface water quality in the aquatic receiving environment after Closure and in the far future. The predicted geographic extent, duration, reversibility, frequency, and probability of occurrence of residual effects are the same as described for the Application Case.

11.5.3.4.3 Effects on Survival and Reproduction

The results of the RFD Case assessment for effects on fish VC survival and reproduction are the same as those presented for the Application Case. Overall, negligible, or at most low magnitude effects on survival and reproduction are predicted to occur due to potential direct effects resulting from exposure of fish VCs to copper in the water column and changes in habitat availability. The predicted geographic extent, duration, reversibility, frequency, and probability of occurrence of residual effects is the same as described for the Application Case.

11.5.4 Residual Effects Classification and Determination of Significance

11.5.4.1 Classification Summary

Residual effects were classified for the Application Case and the RFD Case (Table 11.5-2). The residual effects classification for fish and fish habitat is focused on the far future projection that considers the long-term, slow migration of hydrogeological mass load inputs from certain areas of the site following Closure (i.e., WRSAs and the UGTMF).

Residual effects on fish VCs due to exposure to elevated copper concentrations in Patterson Lake in the far future are predicted to occur as a result of potential changes in habitat availability and survival and reproduction. No residual adverse effects on habitat distribution are expected; therefore, residual effects were classified for the habitat availability and survival and reproduction measurement indicators only.

For the Application Case, which considered a reasonable upper bound scenario, the residual effects classification was based on the Application Case predictions and not the predicted reasonable upper bound conditions. The reasonable upper bound scenario incorporated a high level of conservatism that was intended to provide a precautionary, more conservative bound for the assessment. The Application Case presents a more realistic yet reasonably conservative representation of the potential Project-related effects on fish VCs from changes in surface water quality after Closure and in the far future, and was, therefore, the focus of the residual effects classification.

Effects of future climate change were considered in the RFD case. As outlined in Section 10.2.8.1.2 and Section 11.5.1.1, a sensitivity scenario was considered within the RFD Case for the RSWQM, which evaluated the effects of future climate change based on hydrological processes. These inputs were then carried through to the residual effects analysis for fish VCs. The classification of effects for the RFD Case under the climate change scenario is consistent with the classification for the RFD Case. Results from the RFD plus climate change sensitivity scenario indicated that climate change effects on surface water quality within the LSA based on hydrological projections would be minor and did not result in changes to COPC concentrations that ultimately changed the effects classification for fish VCs.

The residual effects classification considered the implementation of mitigation outlined in Section 11.4 to reduce the magnitude of residual effects on surface water quality, aquatic health, and consequently, fish VCs. Effective implementation of mitigation outlined in Section 11.4 would be expected to reduce the magnitude and duration of residual effects on fish VCs.

Residual effects on fish VCs are summarized according to direction, magnitude, geographic extent, duration/reversibility, frequency, and probability of occurrence following the methods described in Section 11.2.8, Residual Effects Analysis.

Table 11.5-2: Classification of Residual Effects on Lake Trout, Lake Whitefish, Walleye, and Northern Pike Measurement Indicators for the Application Case and Reasonably Foreseeable Development Case in the Far Future

Measurement Indicator	Criterion	Rating / Effect Size	
		Application Case	RFD Case
Habitat availability	Direction	Negative	Negative
	Magnitude	Negligible to low: due to the potential for limited changes to the food base for fish resulting from exposure to elevated copper concentrations in the far future projection	Negligible to low: due to the potential for limited changes to the food base for fish resulting from exposure to elevated copper concentrations in the far future projection
	Geographic extent	Local: restricted to Patterson Lake North Arm – West Basin where peak copper concentrations are predicted to occur	Local: restricted to Patterson Lake North Arm – West Basin where peak copper concentrations are predicted to occur
	Duration	Permanent	Permanent
	Reversibility	Irreversible: not reversible before end of modelling timeframe	Irreversible: not reversible before end of modelling timeframe
	Frequency	Periodic: fluctuating with climate	Periodic: fluctuating with climate
	Probability of occurrence	Possible	Possible
Survival and reproduction	Direction	Negative	Negative
	Magnitude	Negligible to low: due the potential for direct toxicological effects (lake whitefish) and/or due to predicted changes in habitat availability (i.e., food base; all VCs)	Negligible to low: due the potential for direct toxicological effects (lake whitefish) and/or due to predicted changes in habitat availability (i.e., food base; all VCs)
	Geographic extent	Local: exposure of fish VCs to peak copper concentrations and changes in habitat availability would be restricted to Patterson Lake North Arm – West Basin. However, as fish VCs can move around, the geographic extent of effects on survival and reproduction was assessed as local	Local: exposure of fish VCs to peak copper concentrations and changes in habitat availability would be restricted to Patterson Lake North Arm – West Basin. However, as fish VCs can move around, the geographic extent of effects on survival and reproduction was assessed as local
	Duration	Permanent	Permanent
	Reversibility	Irreversible: not reversible before end of modelling timeframe	Irreversible: not reversible before end of modelling timeframe
	Frequency	Periodic: fluctuating with climate	Periodic: fluctuating with climate
	Probability of occurrence	Possible	Possible

VC = valued component; RFD = reasonably foreseeable development.

11.5.4.2 Significance Determination

Fish VC populations are considered to have ecological resilience and adaptive capacity to changes in habitat availability and survival and reproduction in the Base Case. Each of the fish VCs included in the fish and fish habitat assessment are common in Saskatchewan (SKCDC 2021b) and occur throughout the LSA and RSA (Section 11.3.6; Annex V.1). In particular, lake whitefish, walleye, and northern pike were found to be abundant and widely distributed throughout the LSA and RSA based on the results of the aquatic environment baseline study (Annex V.1). Lake trout were somewhat less common in the LSA and RSA but were present in the larger, deeper lakes in the LSA and RSA. Suitable habitat for spawning, nursery, rearing, feeding, and overwintering was readily available for all four VCs in the LSA and RSA. The results of baseline studies completed in Patterson Lake, the Clearwater River, and downstream waterbodies along the Clearwater River flow path indicate the presence of relatively undisturbed conditions (Annex V.1). This finding is based on the relatively dilute nature of waterbodies and watercourses in the LSA and RSA (i.e., the incidence of low concentrations of metals and major ions) and the occurrence of oligotrophic conditions (Annex V.1). Existing pressures on fish VC populations include effects from recreational and subsistence fishing. However, overall, the evidence indicates that fish VC populations in the RSA are self sustaining and ecologically effective in the Base Case.

Application Case

In the Application Case, changes to habitat availability and the survival and reproduction of fish VCs as a result of the Project are predicted to be negative in direction and negligible to low in magnitude. These effects are predicted to occur due to changes in surface water quality in Patterson Lake in the far future. The primary source of loading for COPCs in the far future would be the seepage load through the groundwater flow path from the Project footprint. In particular, predicted copper concentrations in the far future would have the potential to affect fish VC habitat availability, survival, and reproduction.

Effects on fish habitat availability could occur due to the potential for changes to the food base for fish. However, at the predicted copper concentrations, any changes to the food base that may be realized would be limited to a potential decrease in abundance and/or biomass of selected prey items for fish VCs (i.e., species or taxa that may be sensitive to elevated copper concentrations). This decrease would not be expected to meaningfully change the available food supply for fish or adversely affect the suitability of the affected habitat for use by fish VCs. Any changes in habitat quality would be unlikely to be measurable.

Effects on survival and reproduction could occur directly as a result of exposure to copper in the water column, or indirectly, as a result of changes in habitat. Based on the results of the EcoRA and aquatic health assessment completed for the Project, effects on the health of fish due to direct exposure to copper in the water column are not expected for predator fish (e.g., lake trout, walleye, northern pike) and are unlikely for forage fish (e.g., lake whitefish). Changes in habitat quality are considered unlikely to measurably affect the survival and reproduction of fish VCs. Effects on fish VC habitat availability and survival and reproduction were determined to be local in geographic extent since exposure of aquatic organisms to maximum copper concentrations would be spatially limited to the Patterson Lake North Arm – West Basin. The predicted effects are not reversible before the end of the modelling timeframe and are therefore considered to be permanent. The frequency of effects is anticipated to be periodic, as exposure of aquatic organisms to maximum copper concentrations would occur only during limited periods (i.e., dry climate years when there is a lower natural runoff to the lake). The likelihood for the effects occurring is expected to be possible. This likelihood is based on the conservative assumptions and moderate to high degree of uncertainty associated with the groundwater solute transfer inputs to the RSWQM in the far future.

Reasonably Foreseeable Development Case

The predicted effects in the RFD Case are very similar to the Application Case. The main influence of the Fission Patterson Lake South Property in the RFD Case would be a slight increase in COPC concentrations in the receiving environment, including for copper, compared to the Application Case. However, the inclusion of the Fission Patterson Lake South Property in the RFD Case does not result in any meaningful changes to the effects predictions for fish VCs, as outlined for the Application Case, because mass loading from long-term solute transport from the Project is the main driver of the predicted effects on surface water quality and fish VCs.

The effects of future climate change were considered in the RFD Case through the inclusion of a climate change scenario in the hydrological data inputs to the RSWQM, which was then carried through to the residual effects analysis for fish VCs. Overall, the effects of climate change on surface water quality were minor and did not result in changes to COPC concentrations that ultimately changed the predicted effects on fish VCs for the Application Case due to exposure to elevated copper concentrations after Closure of the Project and in the far future.

Overall Significance

Overall, the results of the residual effects analysis for fish and fish habitat indicate that the incremental effects from the Project would not have a significant adverse effect on the maintenance of self-sustaining and ecologically effective fish populations in the RSA; effects to fish and fish habitat VCs are predicted to be not significant. Although changes to fish VC habitat availability and survival and reproduction are possible, the predicted effects would be within the resilience and adaptability limits for the four fish VCs (i.e., lake trout, lake whitefish, walleye, northern pike). Similarly, the incremental cumulative effects from the Fission Patterson Lake South Property in the RFD Case and with the addition of climate change would be not significant.

11.5.5 Effects on Biodiversity

Aquatic biodiversity encompasses the variety of fish and aquatic species present in an area, as well as the ecosystem complexes to which they contribute. Biodiversity includes all levels of organization, including diversity within species (i.e., genetic diversity), among species (i.e., richness), and of ecosystems (Canadian Biodiversity Strategy 1995, 2020).

The aquatic environment baseline study (Annex V.1) describes the aquatic ecosystems, habitats, and taxa present throughout the LSA and RSA so that they may be adequately managed to prevent a loss of biodiversity. This baseline study included identification of fish and lower trophic level communities, including phytoplankton, zooplankton, and benthic invertebrates. The LSA and RSA defined for the fish and fish habitat assessment contain both riverine (i.e., in river or watercourse) and lacustrine (i.e., waterbody) ecosystems, which provide fish habitat and support a variety of fish and aquatic species. These study areas include several large waterbodies, the Clearwater River, and numerous tributaries and smaller waterbodies. The larger waterbodies provide fish habitat year-round, including spawning, rearing, feeding, and overwintering habitat. Smaller waterbodies and tributary habitats provide suitable habitat for spawning, rearing, and feeding for portions of the year but may not provide overwintering habitat since DO levels in shallow lakes can be limiting and tributary habitats may freeze to bottom. Spring and fall spawning habitats are available for a variety of fish species.

In total, 17 fish species were identified in the LSA and RSA. Each of these species is common in northern Saskatchewan and native to the area. Consistent with the recommendations of Environment Canada (2012), the characterization of lower trophic level diversity occurred at the level of family. In total, 27 phytoplankton families, 13 zooplankton families, and 16 benthic invertebrate families were identified in the LSA and RSA through baseline sampling for the Project. When compared with the biological diversity represented by fish communities, lower trophic level organisms represent high levels of diversity within the local aquatic environment.

The genetic diversity of fish populations in the Project LSA and RSA is expected to be healthy. This finding is based on the relative absence of major existing developments, or disturbances in the LSA and RSA that might threaten the maintenance of diversity within a species. For example, there are no known barriers to fish movement identified in the LSA and RSA that might subdivide fish species into isolated or semi-isolated populations with little genetic differentiation (Parkinson et al. 1999). Existing effects on genetic diversity are likely to include limited effects from the harvesting of fish for recreational and subsistence purposes, which may limit genetic diversity to some degree by removing individuals, and therefore genetic information, from populations.

Potential Project-related effects on aquatic biodiversity were evaluated based on the assessment completed for the fish VCs, which were selected, in part, because they are strong ecological indicators of broader species assemblages and ecosystems (Section 11.2.2.1, Valued Components). For example, effects on lake whitefish

are representative of effects on forage fish assemblages that support a variety of piscivorous fish species. Additionally, the effects assessment for fish VCs considered the potential for changes to lower trophic level organisms, including phytoplankton, zooplankton, and benthic invertebrates, which are an important component of the aquatic food web and provide the food base for fish. The assessment of the selected VCs also considered the potential for effects on the key elements comprising aquatic biodiversity (i.e., genetic, species, and ecosystem diversity) through the evaluation of changes in measurement indicators defined for VCs. For example, changes to species diversity were considered in the assessment of the survival and reproduction measurement indicator.

The primary mechanism by which the Project could affect aquatic biodiversity in the LSA and RSA would be through alteration of surface water quality in Patterson Lake after Closure and in the far future and the potential for corresponding effects on aquatic health and fish habitat quality (Section 11.5.2). The primary source of loading for COPCs in the far future is predicted to be from the seepage load through the groundwater flow path from selected areas of the Project footprint (i.e., WRSAs, UGTMF). In particular, exposure to elevated copper concentrations in Patterson Lake North Arm – West Basin has the potential to affect the health of fish and aquatic organisms. Aquatic species diversity could therefore be affected as a result of direct exposure of fish and aquatic organisms to elevated concentrations of copper in water or sediments.

The results of the EcoRA and aquatic health assessment completed for the proposed Project indicated that exposure to predicted copper concentrations in the far future would be unlikely to result in residual adverse effects on aquatic species diversity in the LSA and RSA for both the Application Case and the RFD Case (TSD XXI; Appendix 11A; Section 11.5.2 and Section 11.5.3). The results of these assessments indicate that any potential effects from copper exposure would be limited to individual taxa or species that may be sensitive to elevated copper concentrations. Population-level effects are not expected to occur based on the predicted level of exposure and limited spatial extent of elevated copper concentrations (i.e., Patterson Lake North Arm – West Basin). Overall, there would be limited potential for effects on aquatic species diversity locally in Patterson Lake South Arm – West Basin; however, changes to species diversity at the lake-wide scale, or the scale of the LSA and RSA are not anticipated. Additionally, at most, negligible effects on genetic diversity would be expected at the predicted magnitude of effect due to the limited potential for losses of individuals and, therefore genetic material, from aquatic populations.

Effects on ecosystem diversity are considered unlikely to occur as a result of the Project, for both the Application Case and the RFD Case. Limited and localized effects on fish habitat quality would be possible in Patterson Lake North Arm – West Basin due to the limited potential for health effects on lower trophic level organisms and on forage fish species that form the food base for fish (Section 11.5.2.4). However, no adverse effects on the viability of habitats for use by fish VCs or on the functionality of affected habitats are predicted to occur. Therefore, there would be no resulting loss of habitat that could contribute to an overall loss of ecosystem diversity. Additionally, based on the results of the EcoRA and aquatic health assessment, exposure to copper in Patterson Lake would be unlikely to result in adverse effects on aquatic communities, which in combination with abiotic factors (e.g., water quality) form an important component of the overall aquatic ecosystem.

Water pollution is only one of many potential threats to aquatic biodiversity in Canada (Canadian Biodiversity Strategy 1995, 2020). Other factors that could adversely affect aquatic biodiversity, and that were considered in the analysis of potential Project-related effects on fish and fish habitat, include the potential for direct habitat loss, including changes in riparian vegetation, habitat fragmentation, sediment release, and effects from increased fishing pressure. Each of these factors was considered in the evaluation of the potential pathways of effects on fish and fish habitat in Section 11.4. However, with implementation of best management practices

and mitigation, the effects of these potential factors on fish VCs and aquatic biodiversity are expected to be negligible in magnitude.

Overall, the predicted effects of the Project and RFDs on aquatic biodiversity were considered to be negligible. As exposure of aquatic biota to elevated copper concentrations would be restricted to Patterson Lake North Arm – West Basin, the geographic extent of effects was considered local. The duration and reversibility of the predicted effects would be permanent and not reversible. The probability of occurrence was characterized as possible, meaning that effects are unlikely, but may occur.

11.6 Prediction Confidence and Uncertainty

Scientific inference is associated with uncertainty, and prediction confidence (i.e., the level of confidence in assessment results) depends on the level of uncertainty and the way this uncertainty is addressed. Primary factors affecting confidence in the predictions made in the fish and fish habitat assessment include:

- availability and accuracy of baseline data;
- level of understanding of baseline fish and fish habitat conditions, range of natural variation, and the resilience of fish VCs to disturbance;
- accuracy and certainty of water balance modelling inputs and results;
- accuracy and certainty of environmental modelling inputs and results for intermediate components and technical support documents (i.e., air quality, hydrogeology, hydrology, surface water quality, EcoRA, aquatic health), which provided the basis for assessing effects on fish and fish habitat;
- understanding of Project-related effects on complex ecosystems that contain interactions across different scales of time and space (e.g., exactly how the Project would influence fish VCs);
- level of understanding of the cumulative drivers of change in measurement indicators and associated effects on fish VCs, including uncertainty related to climate change projections with respect to future hydrologic and surface water quality conditions, and the associated responses of fish VCs; and
- level of certainty associated with the effectiveness of proposed mitigations, where applicable.

Uncertainty was managed by:

- reviewing baseline studies and other relevant information related to existing fish and fish habitat conditions in the LSA and RSA;
- completing quality assurance and quality control of baseline data;
- applying conservative assumptions regarding the footprint area and related Project activities that may cause disturbance or direct fish habitat loss to increase confidence that the effects were not underestimated;
- applying conservative assumptions regarding the potential for effects from changes to surface water quantity and quality to increase confidence that the effects were not underestimated; and
- comparing assessment results to relevant published scientific literature.

Prediction confidence and uncertainty with respect to predictions related to hydrogeology, surface water quality, and the EcoRA, and aquatic health are described in Sections 8.6, 9.6, 10.6, TSD XXI, and Appendix 11A.

Overall, there is a moderate to high degree of confidence in the predictions related to the changes to fish VCs during the Project lifespan (i.e., effects occurring during Construction, Operations, and Closure). Mitigation measures and best management practices would be implemented to reduce effects on the aquatic ecosystem and fish VCs. There is a high degree of confidence associated with the predicted changes in fish habitat availability associated with the development of water management infrastructure (i.e., fresh water intake, treated effluent diffuser, treated sewage outfall) in Patterson Lake. The estimated physical footprint of these structures is generally well understood and is based on conceptual design information and previous experience with similar types of developments for mining developments in northern Canada. There is also a good understanding of the existing fish habitat conditions in the immediate vicinity of the affected areas in Patterson Lake, where intensive surveys were completed during the aquatic environment baseline study (Annex V.1). Additionally, conservative assumptions were used when estimating the potential loss or disturbance to riparian vegetation (e.g., use of a conservative 30 m buffer). Overall, it is unlikely that effects associated with this Project interaction are underestimated.

There is a moderate to high degree of confidence in the predicted changes in fish VC habitat availability and distribution resulting from changes to surface water hydrology. As with any predictions of future conditions, the hydrologic predictions made in Section 9.6 (Residual Effects Analysis) embody some degree of uncertainty, which was carried forward into the fish and fish habitat assessment. Sources of uncertainty associated with the hydrologic modelling included assumptions related to initial conditions and variability in current climate data, particularly rainfall, wind speed, and humidity (Section 9.6). Uncertainty in model input data was mitigated using various methods, including calibrating the regional hydrology model using baseline hydrometric data and validating the model against long-term regional data. These approaches demonstrated that the model generated realistic predictions. Conservative approaches were used when describing effects; for example, the summary of potential effects on hydrometric measurement indicators focused on the Project phases and locations where peak effects were expected to occur. Consequently, uncertainty was addressed in a manner that increased the level of confidence that residual effects on hydrometric conditions and, therefore fish habitat, were conservatively predicted (Section 9.6).

The level of certainty associated with the predicted effects on fish VC habitat availability, survival, and reproduction due to changes in surface water quality during the Project lifespan, was moderate to high. Sources of uncertainty for the surface water quality modelling used to support the assessment of effects on fish and fish habitat included adequacy of baseline data and uncertainties related to the air quality dispersion model, the groundwater solute transport model, and the site-wide water balance model, which were used as inputs to the RSWQM (Section 10.6). Baseline water quality data were considered adequate but were subject to limitations related to the list of constituents and detection limits. For example, the elevated detection limit used for TP during the baseline monitoring period limited the sensitivity of the effects analysis for fish and fish habitat to predict the potential changes to biological productivity in Patterson Lake with a high level of accuracy; however, given that no changes to lake trophic status were predicted to occur due to Project discharges and activities, it is likely that residual effects on fish VCs related to nutrient inputs were conservatively predicted. Inputs to the RSWQM were developed based on conservative assumptions, as described in Section 10.6. Consequently, uncertainty was addressed in a manner that increased the level of confidence that the assessed residual effects on surface water quality in the receiving environment, and therefore fish VCs, did not underestimate potential effects from Project interactions.

Uncertainty associated with the results of the EcoRA component of the ERA completed for the Project also influenced the level of confidence in the effects predictions for fish VCs due to changes in surface water quality during the Project lifespan. Sources of uncertainty associated with the EcoRA included uncertainties related to the exposure of ecological receptors to maximum COPC concentrations and limitations associated with the estimation of ecotoxicological effect levels for COPCs (i.e., TRVs). The measures taken to address uncertainties in the EcoRA are described in TSD XXI and are anticipated to produce conservative exposure estimates, TRVs, and resulting risk estimates for ecological receptors. In general, measures used to address uncertainties are expected to cause an overestimation, and not an underestimation, of risk due to the conservative approaches employed in the EcoRA. Therefore, the resulting predictions for fish VCs due to exposure to COPC in surface waters are also considered conservative.

Monitoring of water and sediment quality, fish, and benthic invertebrates in the receiving environment would be used throughout the Project lifespan to address residual uncertainty by evaluating the responses of aquatic organisms to Project discharges against the predicted effects in the EIS (Section 11.7). Adaptive management would be incorporated into the design of monitoring programs and would identify management actions that could be used to reverse or reduce unacceptable adverse effects on aquatic ecosystem components.

Overall, the degree of confidence in the predictions related to the changes to fish VCs from changes to water quality after Closure and in the far future was lower than for the Project lifespan; however, conservatism considered in the assessments completed for intermediate components and TSDs that provided the basis for the assessment of effects on fish and fish habitat improved the overall level of confidence that effects are not underestimated. Inputs from the groundwater solute transport model are the primary source of uncertainty associated with the predicted effects on surface water quality, aquatic health, and consequently fish VCs. The inputs from the groundwater solute transport model were considered to be conservative as the source terms used in the model were derived in a conservative manner.

The assumptions in the groundwater solute transfer model include limited source control associated with the WRSAs and the UGTMF, which means that all infiltration and seepages through and from these facilities generate mass via contact with waste rock and ore tailings and carry them to the groundwater. Of these sources, the PAG WRSA was identified as being the main source that could lead to copper guideline exceedances in Patterson Lake in the far future. Despite this process being slow, the incremental mass eventually reaches Patterson Lake and propagates downstream through the waterbodies in the LSA. Further, the geochemical source terms associated with the waste rock that are assigned to the seepage and infiltration as they migrate to the groundwater in the far future period are conservative, assuming that all contact material is consistent with PAG material sources, which are assumed to be the prominent waste rock condition in the far future, conservatively assuming no source depletion over time.

As part of the Project design, source control would be applied to the WRSAs and UGTMF to reduce and control infiltration and seepage to reduce the potential mass loading from these facilities to the groundwater. Source control with respect to the PAG WRSA includes incorporating a physical liner under the storage area, reducing oxygen ingress to the waste rock, and providing a form of cover that enhances runoff and limits infiltration. Additionally, monitoring seepages and runoff quality at the PAG and NPAG WRSAs during and after Operations, and incorporating adaptive management would be expected to result in notable reductions in the mass loading carried into the far future surface water quality assessment. Adaptive management would be used to refine source terms, reduce uncertainty, and adapt the level of mitigation in response to operational datasets. Source control with respect to the UGTMF includes the design, maintenance, and monitoring of a mine dewatering system to control the flow of groundwater inflow, applying a binder to reduce permeability in backfill and tailings,

and engineering tailings geochemistry such that the release of mass is controlled. Additionally, monitoring the UGTMF during and after Operations, and incorporating adaptive management would be expected to result in notable reductions in the mass loading carried into the far future surface water quality assessment.

The groundwater solute transport applied a number of sensitivity analyses to address uncertainty. Please refer to Section 8.6 for a full explanation.

The conservatism and sources of uncertainty previously described for the EcoRA and those associated with the aquatic health assessment (Appendix 11A) also influence the level of confidence in the predictions for fish VCs due to changes in surface water quality in the far future. As with all models, the BLM and MLR models used in the aquatic health assessment have limitations based on their assumptions and data inputs. Model limitations were mainly related to uncertainty associated with measured and predicted water quality used as inputs. Overall, uncertainties in the aquatic health assessment were considered to have low influence on the interpretation or use of the results for the purpose of evaluating the potential for adverse effects on aquatic health due to predicted copper concentrations. Overall, it is unlikely that potential health effects on aquatic biota have been underpredicted.

Overall, the level of confidence associated with the predictions related to the changes to fish VCs during the Project lifespan (i.e., effects occurring during Construction, Operations, and Closure) is moderate to high, whereas the level of confidence in the predicted effects on fish VCs after closure and in the far future are lower overall. 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, the predicted effects incorporate a high degree of conservatism and are unlikely to be underestimated.

11.7 Monitoring, Follow-Up, and Adaptive Management

Monitoring programs are proposed to address the uncertainties associated with the effect predictions and the performance of environmental design features and mitigation related to the proposed Project. In general, monitoring is used to verify the effects predictions, to identify any unanticipated effects, and implement adaptive management to limit these effects. This subsection presents a summary of the identified monitoring and follow-up activities proposed to monitor for potential Project effects in the receiving environment. Specifically, monitoring programs would be used to:

- Monitor for changes to fish and fish habitat, including lower trophic level community conditions (e.g., benthic invertebrates), in the receiving environment as a result of Project activities.
- Verify the predictions of the EIS and confirm that the aquatic ecosystem in the receiving environment is protected.
- Evaluate the effectiveness of mitigation measures and modify or enhance as necessary through monitoring and developing updated mitigation, if needed.
- Identify unanticipated negative effects, estimate spatial extent of effects, and support the implementation of adaptive management measures to address previously unanticipated adverse environmental effects.
- If applicable, monitor and evaluate the success of any fish habitat offsetting measures constructed for the Project.
- Contribute to the overall continual improvement of the Project.

The Environmental Monitoring Plan would be implemented to mitigate effects on fish and fish habitat and apply adaptive management where necessary. Monitoring results would be used to adjust or adapt mitigation measures or reclamation approaches used to limit Project effects on fish. In the context of REGDOC-2.9.2 (CNSC 2021b), adaptive management is a planned and systematic process for continuously improving environmental management practices by learning more about the outcomes where such information could improve site-specific understandings and possibly reduce the level of conservatism initially used to compensate for the lack of complete understanding of the interaction. Adaptive management provides flexibility to identify and implement new mitigation measures or to modify existing ones during the life of a project. It may include increased monitoring, changes in monitoring plans, or additional mitigation. In addition, special studies, which are studies proposed with the intent to supplement the primary monitoring programs, address potential data gaps, and support future monitoring, may be considered.

With regards to the specific issue of copper loading from the PAG WRSA to Patterson Lake in the far future, NexGen is developing an adaptive management plan to reduce uncertainty and manage risks related to this pathway.

The Environmental Monitoring Plan would be developed in accordance with the Metal and Diamond Mining Effluent Regulations (MDMER) for metal and diamond mining environmental effects monitoring (EEM), the federal *Fisheries Act*, the CNSC operating licence, and the ENV operating licence requirements.

The key components of the aquatic ecology environmental monitoring program are expected to include water and sediment quality, benthic invertebrates, and fish. Monitoring for water and sediment quality is addressed in detail in Section 10.7. Monitoring would be carried out in accordance with the MDMER and requirements of EEM (Environment Canada 2012) and with conditions identified through the licencing processes. The MDMER prescribes that EEM studies be performed to evaluate the potential effects of treated effluent release in the aquatic receiving environment. Environmental effects monitoring studies are designed to detect and measure changes in aquatic ecosystems and may include biological monitoring studies to determine if mine effluent is affecting fish, fish habitat, or the use of fisheries resources (Environment Canada 2012). Effects are assessed using regular cyclical monitoring and interpretation phases designed to evaluate changes in the receiving environment using standardized methods.

The monitoring program for water and sediment quality, benthic invertebrates, and fish would be designed to integrate the requirements of an EEM biological monitoring study (Environment Canada 2012). The MDMER identify triggers for biological monitoring based on effluent concentration in the receiving environment. Based on predictions for effluent dilution in the receiving environment, monitoring for benthic invertebrates and fish under EEM is expected to be initiated during Construction and continue on a cyclical basis during Operations.

Monitoring stations for benthic invertebrates and fish would be strategically located within the LSA, and specifically in Patterson Lake, to capture any potential effects in receiving waters as well as in reference waters. These stations would be identified under guidance of MDMER, ENV, and CNSC within the licensing process, and would be co-located with water and sediment quality sampling stations. The final study design for the Environmental Monitoring Plan and EEM would be determined through the permitting process and detailed planning, which would include consultation and engagement with regulatory agencies and local Indigenous communities.

Monitoring and sampling techniques and analysis procedures would be consistent with methods used during the baseline survey period to the extent possible. The field and laboratory processes would include the implementation of quality assurance / quality control measures for data acquisition, water and biota sampling, and analysis and reporting.

Along with the regular cyclical monitoring identified in the Environmental Monitoring Plan, additional monitoring may be required in accordance with the MDMER as part of an EEM program. The metal mining EEM program is an iterative system of monitoring and interpretation phases that is used to assess the effectiveness of environmental management measures by evaluating the effects of effluents on aquatic ecosystems. The EEM protocol has been designed to provide confirmation that a change or effect on the environment has or may occur prior to expending additional resources on additional monitoring and assessment and would be an overlay to the proposed protocol in the Environmental Monitoring Plan. If effects are confirmed in the receiving environment, a study investigating the potential cause of the observed effects may be required as part of the EEM protocol (Environment Canada 2012).

It is possible that a *Fisheries Act* Authorization may be required to permit component(s) of the site water management infrastructure proposed to be installed in Patterson Lake and that fish habitat offsetting may be required to counterbalance any residual adverse effects of these developments on fish habitat. If required, NexGen would develop an offsetting plan that would include a description of the monitoring measures that would be implemented to assess the effectiveness of the selected offsetting measures. The purpose of monitoring would be to determine if the selected measures are successful in meeting their objectives (DFO 2020). Details of the monitoring program, if required, would be developed in consultation with DFO and local Indigenous communities as a component of the *Fisheries Act* Authorization Application, which would be prepared during the permitting phase of the Project.

In compliance with MDMER, the federal *Fisheries Act*, the CNSC operating licence, and the ENV operating licence requirements, results of biological monitoring in the receiving environment would be reported in EEM reports on a schedule determined based on the monitoring phase for the Project.

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 proposed Project (TSD IV: MN-S; TSD V.2: CRDN; TSD VI: YNLR). NexGen has committed to provide funding for the life 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 report openly and without restriction to the Environment Committee and Indigenous Group members on the performance of the Project. The Indigenous Monitor would also provide regular reports to the Environmental Committee.

11.8 Key Findings

The objectives of Section 11 were to provide a detailed and comprehensive assessment of all potential Project-specific effects and cumulative effects with RFDs on fish and fish habitat. Fish form an important role in the function of the aquatic food web and are an important resource culturally, economically, and traditionally to local Indigenous communities. During engagement for the Project, Indigenous community members spoke of the importance of fishing for subsistence, survival, and livelihood, and highlighted fishing as an important aspect of community and cultural life. Patterson Lake is highly valued by community members, in terms of both its historical and its current value and is considered of paramount importance to community members. Effects on fish and fish habitat were assessed for four VCs, lake trout, lake whitefish, walleye, and northern pike, which were informed by engagement with Indigenous communities.

This section meets the Terms of Reference for the Project submitted to the ENV and the Canadian Nuclear CNSC Generic Guidelines for the Preparation of an EIS Pursuant to CEAA 2012 (Appendix 1A) by providing a detailed and comprehensive assessment of potential Project-specific effects, and cumulative effects from the Project and other developments on fish and fish habitat.

A summary of key findings for fish and fish habitat section is provided as follows:

- Development of the physical Project footprint and activities related to the management of surface water on site were predicted in the hydrology assessment (Section 9) to result in limited changes to surface hydrology during Construction, Operations, and Closure. Small but undetectable increases in natural lake levels and watercourse flow rates were predicted to occur, with the largest increases expected in Patterson Lake and the Clearwater River downstream of Patterson Lake. Given the predicted magnitude of effects on hydrometric conditions, the predicted increases in natural lake levels and watercourse flow rates are expected to result in negligible and non-measurable residual effects on fish habitat availability and distribution in the LSA.
- Sediment release during in-water construction and from runoff due to ground disturbance may result in increased TSS and turbidity in Patterson Lake. These activities could result in short-term, localized, and minor changes to surface water quality in Patterson Lake. Implementation of sediment and erosion control best practices for both Construction and any other Project lifespan activities requiring ground disturbance are expected to effectively minimize the potential erosion of soils and associated transfer of sediment into nearby waterbodies. Overall, sediment release is expected to have negligible effects on fish habitat availability and the survival and reproduction of fish VCs.
- Project activities and discharges are predicted in the surface water quality assessment (Section 10) to result in an increase in the concentrations of metals and radionuclides in the downstream receiving environment during Construction, Operations, and Closure. However, concentrations were predicted to remain below Project-specific water quality threshold values. Exposures of aquatic organisms to COPCs in surface waters were predicted and assessed based on the results of the EcoRA (TSD XXI). Hazard quotients derived for aquatic receptors considered in the EcoRA were estimated to be less than the benchmark (i.e., HQ) of one, indicating that toxicological effects on aquatic populations or communities are not expected to occur during the Project lifespan, as exposure estimates to COPCs in water and sediment are below levels known to cause adverse effects. Therefore, negligible residual effects on the survival and reproduction of fish VCs were predicted as a result of the anticipated changes to water quality during the Project lifespan.

- The release of treated effluent and treated sewage from the ETP and STP, respectively, is anticipated to result in a minimal increase in nutrient concentrations in the receiving environment during Construction, Operations, and Closure. However, no changes to the trophic status of affected waterbodies are expected; Patterson Lake and downstream waterbodies are predicted to remain oligotrophic based on modelled concentrations of TP. The minimal increase in TP concentrations may result in limited changes to the productivity of phytoplankton, and potentially negligible and non-measurable effects on the productivity of zooplankton and benthic invertebrates. Effects on the productivity of fish, particularly piscivorous, upper trophic level consumers, are not expected. Overall, negligible residual effects on fish habitat quality and potentially, survival and reproduction of fish VCs, were predicted from changes in nutrient concentrations.
- Development of water management infrastructure components in Patterson Lake, including a fresh water intake, treated effluent diffuser, treated sewage outfall, and associated pipelines would result in a limited loss of fish habitat along the shoreline of the lake, adjacent to the proposed Project site. These developments have been designed to limit the in-water footprint in Patterson Lake and have been sited to avoid high quality fish habitats as much as possible. The total estimated in-water footprint associated with these developments is approximately 1,258 m², which represents 0.003% of the surface area of Patterson Lake (i.e., 38 km²). The large majority (i.e., greater than 97%) of this footprint is associated with the conveyance pipes for the three structures. Overall, the physical habitat loss associated with these structures is predicted to result in a negligible change to habitat availability for fish VCs in Patterson Lake and no change to habitat distribution relative to existing conditions. If required, NexGen would submit a *Fisheries Act* Authorization application and an offsetting plan for the relevant component(s) of the water management infrastructure during the permitting phase of the Project.
- Effects on fish VCs could occur directly as a result of exposure to copper in the water column from runoff and seepage from the WRSFs and UGTMF in the far future. This could indirectly cause changes in habitat resulting from potential effects on the lower trophic food base for fish. The results of the EcoRA and aquatic health assessment (TSD XXI; Appendix 11A) completed for the Project indicated that effects on the health of fish due to direct exposure to copper in the water column, and therefore survival and reproduction, are not expected for predator fish (e.g., lake trout, walleye, northern pike) and are unlikely for forage fish (e.g., lake whitefish). Limited effects on the available food supply for fish are possible due to exposure of lower trophic level organisms (e.g., zooplankton and benthic invertebrates) and forage fish species to predicted copper concentrations; however, broadscale changes to the fish food base are not expected to occur. Any changes in habitat quality are considered unlikely to measurably affect the survival and reproduction of fish VCs.
- Overall, the predicted effects on fish habitat availability and survival and reproduction are expected to be negligible to low in magnitude and likely not distinguishable from natural background variability. Exposure of aquatic biota to maximum copper concentrations would be limited spatially to the North Arm – West Basin of Patterson Lake and temporally limited to dry climate years when there is a lower natural runoff to the lake. The predicted effects are considered possible, meaning that the changes may occur but are not likely permanent in duration and are irreversible. The effects of the Fission Patterson South Property on surface water quality during the far future are not expected to result in any changes to these effects predictions for fish VCs.

- The effects of future climate change on fish VCs were considered through the inclusion of a climate change scenario in the hydrological data inputs to the RSWQM, which was then carried through to the residual effects analysis for fish VCs. The effects of future climate change on the concentrations of COPCs defined in the surface water quality assessment, far future projection, were minor. Overall, based on the results of environmental modelling, climate change is not expected to meaningfully change the predicted effects defined for fish VCs in the RFD Case.

11.9 References

Acts and Regulations

Fisheries Act. RSC 1985, c F-14. Last amended 28 August 2019. Available at <https://laws-lois.justice.gc.ca/eng/acts/f-14>.

Metal and Diamond Mining Effluent Regulations. SOR/2002-222 under the *Fisheries Act*. Last amended 10 June 2024. Available at <https://laws-lois.justice.gc.ca/eng/Regulations/SOR-2002-222/index.html>.

Species at Risk Act. SC. 2002, c 29. Last amended 17 June 2024. Available at <https://laws-lois.justice.gc.ca/eng/acts/s-15.3/>.

The Fisheries (Saskatchewan) Act, 2020. SS 2020, c 23. Effective 3 July 2020. Available at <https://www.canlii.org/en/sk/laws/stat/ss-2020-c-23/latest/ss-2020-c-23.html>.

The Fisheries Regulations. RRS c F-16.1 Reg 1 under *The Fisheries (Saskatchewan) Act, 1994*. Effective 9 May 1995. Available at <https://www.canlii.org/en/sk/laws/regu/rrs-c-f-16.1-reg-1/latest/rrs-c-f-16.1-reg-1.html>.

Literature Cited

ACFN (Athabasca Chipewyan First Nation). 2019. NexGen Energy Ltd. Rook 1 Project. July 2019.

Allan CJ, Roulet BT, Hill AR. 1993. The Biogeochemistry of Pristine, Headwater Precambrian Shield Watersheds: An Analysis of Material Transport within a Heterogeneous Landscape. *Biogeochemistry*. 22: 37-79. Cited in Steedman RJ, Allan CJ, France RL, Kushneriuk RS. 2004. Land, Water, and Human Activity on Boreal watersheds. In *Boreal Shield Watersheds: Lake Trout Ecosystems in a Changing Environment*. Gunn JM, Steedman RJ, Ryder RA, (Eds). Lewis Publishers. CRC Press. 2004. pp. 59-85.

Anderson DM, Gilbert PM, Burkholder JM. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. *Estuaries* 25: 704-726.

Arthington AH, Bunn SE, Poff NL, Naiman RJ. 2006. The challenge of providing environmental flow rules to sustain river ecosystems. *Ecological Applications*. 16: 1311–1318.

Bash J, Berman C, Bolton S. 2001. Effects of turbidity and suspended solids on salmonids. Washington State Transportation Center (TRAC) Report No. WA-RD 526.1, November 2001, Olympia, WA, 92 pp.

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.

Berg L, Northcote TG. 1985. Changes in territorial, gill-flaring, and feeding behaviour in juvenile coho salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. *Canadian Journal of Fisheries and Aquatic Sciences*. 42:1410–1417.

- Bergström AK, Deininger A, Jonsson A, Karlsson J, Vrede T. 2021. Effects of nitrogen enrichment on zooplankton biomass and N: P recycling ratios across a DOC gradient in northern-latitude lakes *Hydrobiologia*, 848 (2021), pp. 4991-5010. Available at <https://link.springer.com/article/10.1007/s10750-021-04689-5>.
- Berli BI, Gilbert MJ, Ralph AL, Tierney KB, Burkhardt-Holm P. 2014. Acute exposure to a common suspended sediment affects the swimming performance and physiology of juvenile salmonids. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 176:1–10. DOI:[10.1016/j.cbpa.2014.03.013](https://doi.org/10.1016/j.cbpa.2014.03.013).
- Billard R. 1996. Reproduction of pike: gametogenesis, gamete biology and early development. In: *Pike Biology and Exploitation*, Ed. J.F. Craig. Pp 13-43. Chapman and Hall, London.
- 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 #9. 25 March 2021.
- BNDN-JWG. 2021b. Meeting Minutes. Meeting #10. 22 April 2021.
- Boys CA, Robinson W, Baumgartner LJ, Rampano B, Lowry M. 2013. Influence of approach velocity and mesh size on the entrainment and contact of a lowland river fish assemblage at a screened irrigation pump. *PloS one*, 8(6), e67026.
- Bradford MJ, Randall RG, Smokorowski KS, Keatley BE, Clarke KD. 2014. A framework for assessing fisheries productivity for the Fisheries Protection Program. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/067. v + 25 p.
- 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. 2020. Meeting Minutes. Meeting #4. 21 February 2020.
- BRDN-JWG. 2021a. Meeting Minutes. Meeting #9. 31 March 2021.
- BRDN-JWG. 2021b. Meeting Minutes. Meeting #11. 23 June 2021.
- Brix KV, DeForest DK, Tear L, Grosell M, Adams WJ. 2017. Use of multiple linear regression models for setting water quality criteria for copper: A complementary approach to the biotic ligand model. *Environmental Science and Technology*. 51:5182-5192.
- Brix KV, Tear L, Santore RC, Croteau K, DeForest DK. 2021. Comparative performance of multiple linear regression and biotic ligand models for estimating the bioavailability of copper in freshwater. *Environmental Toxicology and Chemistry* 40(6):1649-1661.
- Broadmeadow S, Nisbet TR. 2004. The effects of riparian forest management on the freshwater environment: a literature review of best management practice. *Hydrology and Earth System Sciences*. 8: 286–305.
- Brönmark C, Hansson LA. 1998. *The Biology of Lakes and Ponds*. Oxford University Press, New York NY, USA.

- Caissie D. 2006. The thermal regime of rivers: a review. *Freshwater Biology* 51: 1389–1406.
- Canadian Biodiversity Strategy. 1995. Canada's Response to the Convention on Biological Diversity. Minister of Supply and Services Canada 1995. ISBN 0-662-23221-6. Available at <https://www.cbd.int/doc/world/ca/ca-nbsap-01-en.pdf>.
- Canadian Biodiversity Strategy. 2020. Biodiversity Goals and Targets for Canada. Available at <https://www.biodivcanada.ca/national-biodiversity-strategy-and-action-plan/2020-biodiversity-goals-and-targets-for-canada>.
- Carpenter SR, Kitchell JF, Hodgson JR. 1985. Cascading Trophic Interactions and Lake Productivity. *BioScience*. 35:634-639.
- Caux P-Y, Moore DRJ, MacDonald D. 1997. Ambient water quality guidelines (criteria) for turbidity, suspended and benthic sediments. Technical Appendix. Prepared for BC Ministry of Environment, Land and Parks, pp 146.
- CCME (Canadian Council of Ministers of the Environment). 1999. Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (freshwater). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, MB.
- CCME. 2004. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. Canadian Environmental Quality Guidelines, 2004. Winnipeg, MB.
- CCME. 2021. Canadian Environmental Quality Guidelines Summary Table. Accessed August 2021. Available at <https://ccme.ca/en/summary-table/>.
- 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.
- Clarke KD, Knoechel R, Ryan PM. 1997. Influence of trophic role and life-cycle duration on timing and magnitude of benthic macroinvertebrate response to whole-lake enrichment. *Canadian Journal of Fisheries and Aquatic Sciences*. 54(1), 89-95.
- Clifford HF. 1991. Aquatic invertebrates of Alberta. The University of Alberta. Press, Edmonton, Alberta. 538 pp.
- 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. 2021a. Generic Guidelines for the Preparation of an Environmental Impact Statement – Pursuant to the *Canadian Environmental Assessment Act, 2012*. Available at <https://www.cnsccsn.gc.ca/eng/resources/environmental-protection/ceaa-2012-generic-eis-guidelines/>.
- CNSC. 2021b. REGDOC-2.9.2, Environmental Protection: Controlling Releases to the Environment. DRAFT. March 2021. Available at <https://www.cnsccsn.gc.ca/eng/acts-and-regulations/regulatory-documents/published/html/regdoc2-9-2/>.

- Coen LD. 1995. A review of the potential impacts of mechanical harvesting on subtidal and intertidal shellfish resources. South Carolina Division of Natural Resources, Marine Resources Research Institute, James Island, South Carolina, pp 46.
- Colby PJ, McNicol RE, Ryder RA. 1979. FAO Fish. Synop., (119):139 p. Synopsis of biological data on the walleye, *Stizostedion v. vitreum*. 148 pages.
- Colby PJ, Spangler GR, Hurley DA, McCombie AM. 1972. Effects of Eutrophication on Salmonid Communities in Oligotrophic Lakes. Journal of the Fisheries Board of Canada. 29:975-983.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2021. COSEWIC wildlife species assessment. Accessed November 2021. Available at <https://www.cosewic.ca/index.php/en/assessment-process.html>.
- Cott P, Hanna B. 2005. Monitoring Explosive-based Winter Seismic Exploration in Waterbodies, NWT 2000–2002. In Offshore Oil and Gas Environmental Effects Monitoring: Approaches and Technologies. Armsworthy S.L., Cranford P.J., and Lee K (eds). pp. 473-490. Columbus: Batelle Press.
- 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 of License Renewal for Orano Canada Inc. Cluff Lake Project. Canadian.
- CRDN-JWG (Clearwater River Dene Nation-Joint Working Group). 2020. Meeting Minutes. Meeting #2. 19 February 2020.
- CRDN-JWG. 2021. Meeting Minutes. Meeting #4. 24 March 2021.
- CSA Group (Canadian Standards Association Group). 2022. CSA N288.6-22: Environmental risk assessments at Class I nuclear facilities and uranium mines and mills.
- Cunjak RA. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity.
- De Beers (De Beers Group). 2019. Snap Lake Mine 2018 Aquatic Effects Monitoring Program Report. Submitted to the Mackenzie Valley Land and Water Board, May 2019. Yellowknife, NT, Canada.
- De Beers. 2021a. Gahcho Kué Mine 2020 Aquatic Effects Monitoring Program Report. Submitted to the Mackenzie Valley Land and Water Board, May 2021. Yellowknife, NT, Canada.
- De Beers. 2021b. Snap Lake Mine 2020 Aquatic Effects Monitoring Program Report. Submitted to the Mackenzie Valley Land and Water Board, May 2021. Yellowknife, NT, Canada.
- de Bernardi R, Giussani G, Manca M. 1987. Cladocerans: predators and prey. *Hydrobiologia* 145: 225-243.
- Devito KJ, Dillon PJ, Lazerte BD. 1989. Phosphorus and Nitrogen Retention in Five Precambrian Shield Wetlands. *Biogeochemistry* 8:185-204. Cited in: Steedman, R.J., C.J. Allan, R.L. France and R.S. Kushneriuk. 2004. Land, Water, and Human Activity on Boreal Watersheds. In *Boreal Shield Watersheds: Lake Trout Ecosystems in a Changing Environment*. Gunn, J.M., R.J. Steedman and R.A. Ryder, (eds). Lewis Publishers. CRC Press. 2004.
- DeWalle DR. 2010. Modeling stream shade: riparian buffer height and density as important as buffer width. *Journal of the American Water Resources Association*. 46: 323–333.

- DFO (Fisheries and Oceans Canada). 1995. Freshwater intake end-of-pipe fish screen guideline. DFO, Ottawa, ON, Canada.
- DFO. 2013a. Saskatchewan Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat. Available at <https://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/sk-eng.html>.
- DFO. 2013b. Framework for Assessing the Ecological Flow Requirements to Support Fisheries In Canada. Canadian Science Advisory Secretariat. May 2013.
- DFO. 2019a. Aquatic species at risk map. Accessed November 2021. Available at <https://www.dfo-mpo.gc.ca/species-especes/sara-lep/map-carte/index-eng.html>.
- DFO. 2019b. Measures to avoid causing harm to fish and fish habitat. DFO, Winnipeg, Ontario. Website: Measures to protect fish and fish habitat. Accessed August 2021. Available at <https://www.dfo-mpo.gc.ca/pnw-ppe/measures-mesures-eng.html>.
- DFO. 2020. Policy for applying measures to offset adverse effects on fish and fish habitat under the *Fisheries Act*. Accessed November 2020. Available at <https://www.dfo-mpo.gc.ca/pnw-ppe/reviews-revues/policies-politiques-eng.html>.
- DFO (Fisheries and Oceans Canada) and Saskatchewan Environment and Resource Management. 1995. Fish Habitat Protection Guidelines: Road Construction and Stream Crossings. Available at <https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/254099.pdf>.
- Dillon PJ, Clark BJ, Evans HE. 2004. The Effects of Phosphorus and Nitrogen on Lake Trout (*Salvelinus namaycush*) Production and Habitat. In Boreal Shield Watersheds: Lake Trout Ecosystems in a Changing Environment. Gunn, J.M., R.J. Steedman and R.A. Ryder, (eds). Lewis Publishers. CRC Press. 2004. pp. 119-131.
- Dinsmore WP, Scrimgeour GJ, Prepas EE. 1999. Empirical relationships between profundal macroinvertebrate biomass and environmental variables in boreal lakes of Alberta, Canada. *Freshwater Biology*, 41(1), 91-100.
- ECCC (Environment and Climate Change Canada). 2021. Federal Water Quality Guideline for Copper: Biotic Ligand Model Tool and User Manual. National Guidelines and Standards Office Gatineau, QC.
- Elser JJ, Marzolf E, Goldman CR. 1990. The Roles of Phosphorus and Nitrogen in Limiting Phytoplankton Growth in Freshwaters: A Review of Experimental Enrichments. *Canadian Journal of Fisheries and Aquatic Sciences*. 47:1468-1477.
- Environment Canada. 2012. Metal mining technical guidance for Environmental Effects Monitoring. Government of Canada, Environment Canada, National EEM Office, Science Policy and Environmental Quality Branch, Ottawa, ON.
- Environment Canada. 2013. How Much Habitat is Enough. Third Edition. Canadian Wildlife Service. Toronto, ON.
- Evans CL, Reist JD, Minns CK. 2002. Life history characteristics of freshwater fishes occurring in the Northwest Territories and Nunavut, with major emphasis on riverine habitat requirements. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2614: xiii + 169 p.
- Fahrig L. 2001. How much habitat is enough? *Biological Conservation* 100:65-74.

- Faulkner SG, Tonn WM, Welz M, Schmitt DR. 2006. Effects of explosives on incubating lake trout eggs in the Canadian Arctic. *North American Journal of Fisheries Management*. 26(4): 833-842.
- Faulkner SG, Welz M, Tonn WM, Schmitt DR. 2008. Effects of simulated blasting on mortality of rainbow trout eggs. *Transactions of the American Fisheries Society*. 137:1-12.
- 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.
- Fleming SW, Quilty EJ, Farahmand T, Hudson P. 2005. Magnitude-duration based ecological risk assessment for turbidity and chronic temperature impacts: method development and application to millionaire creek. Prepared for the environmental quality section, environmental protection branch, British Columbia Ministry of Environment, Surrey. Prepared by Aquatic Informatics Inc., Vancouver, pp 56.
- Ford BS, Higgins PS, Lewis AF, Cooper KL, Watson TA, Gee CM, Ennis GL, Sweeting RL. 1995. Literature reviews of the life history, habitat requirements and mitigation/compensation strategies for thirteen sport fish species in the Peace, Liard and Columbia river drainages of British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences. 2321: 342 pp.
- Goddard DR, Peters L, Evans R, Wautier K, Cott PA, Hanna B, Palace V. 2008. Histopathological assessment of the sub-lethal effects of instantaneous pressure changes (IPCs) on rainbow trout (*Onchorhynchus mykiss*) early life stages following exposure to detonations under ice cover. Environmental Studies Research Funds, Report No. 164, Winnipeg, MB.
- Golder (Golder Associates Ltd.). 2020. Aquatic Effects Monitoring Program 2019 Annual Report. Prepared for Diavik Diamond Mines (2012) Inc. Yellowknife, NT. April 2020.
- Government of Canada. 2021. Species at risk public registry. Accessed October 2021. Available at <https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html>.
- Government of Saskatchewan. 2021. Saskatchewan Angler's Guide 2021-2022. Accessed November 2021. Available at <https://www.saskatchewan.ca/residents/parks-culture-heritage-and-sport/hunting-trapping-and-angling/angling>.
- Harvey B. 2009. Canadian Manuscript Report Of. Fisheries and Aquatic Sciences 2885. A Biological Synopsis of Norther Pike (*Esox lucius*). 39 pp.
- Hassan MA, Ferrer-Boix C, Cienciala P, Chartrand SM. 2018. Sediment Transport and Channel Morphology Implications for Fish Habitat. In book: Open Channel Hydraulics, River Hydraulic Structures and Fluvial Geomorphology (pp.322-348) Chapter: 17. Publisher: CRC Press - Taylor & Francis Group. Editors: Artur Radecki-Pawlik, Stefano Pagliara, Jan Hradecky, Erik Hendrickson. DOI:[10.1201/9781315120584-17](https://doi.org/10.1201/9781315120584-17).
- 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.

- Hershey AE. 1992. Effects of experimental fertilization on the benthic macroinvertebrate community of an Arctic lake. *Journal of the North American Benthological Society*. 204-217.
- Hyatt KD, Stockner JG. 1985. Responses of sockeye salmon (*Oncorhynchus nerka*) to fertilization of British Columbia coastal lakes. *Canadian Journal of Fisheries and Aquatic Sciences*. 42:320-331.
- Inskip PD. 1982. Habitat suitability index model: northern pike. Western Energy and Land Use Team, Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C. Biological Report FWS/OBS-82/10.17.
- Johnston NT, Perrin CJ, Slaney PA, Ward BR. 1990. Increased Salmonid Growth by Whole-river Fertilization. *Canadian Journal of Fisheries and Aquatic Sciences*. 47:862-872.
- Johnston NT, Stamford MD, Ashley KI, Tsumura K. 1999. Responses of Rainbow Trout (*Oncorhynchus mykiss*) and Their Prey to Inorganic Fertilization of an Oligotrophic Montane Lake. *Canadian Journal of Fisheries and Aquatic Sciences*. 56:1011-1025.
- Jorgenson JK, Welch HE, Curtis MF. 1992. Response of Amphipoda and Trichoptera to Lake Fertilization in the Canadian Arctic. *Canadian Journal of Fisheries and Aquatic Sciences*. 49: 2354-2362.
- Kalff J. 2002. Phytoplankton Production in Char Lake, a Natural Polar Lake, and in Meretta Lake, a Polluted Lake, Cornwallis Island, Northwest Territories. *J Fish Res Board Can.* 31:621-636.
- Katopodis C. 1994. Analysis of ichthyomechanical data for fish passage or exclusion system design. In *Proceeding of an International Fish Physiology Symposium*, Vancouver, BC, Canada, p. 318.
- Keddy PA, Reznicek AA. 1986. Great Lakes vegetation dynamics—the role of fluctuating water levels and buried seeds. *Journal of Great Lakes Research* 12: 25–36.
- Krebs CJ. 2009. *Ecology* 6th ed. San Francisco CA: Pearson Benjamin Cummings, 2009.
- Lake RG, Hinch SG. 1999. Acute effects of suspended sediment angularity on juvenile coho salmon (*Oncorhynchus kisutch*). *Canadian Journal of Fisheries and Aquatic Sciences* 56:862–867.
- Lane JA, Portt CB, Minns CK. 1996. Nursery habitat characteristics of Great Lakes fishes. *Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2338*. Burlington, ON.
- Langhorne AL, Neufeld M, Hoar G, Bourhis V, Fernet DA, Minns CK. 2001. Life history characteristics of freshwater fishes occurring in Manitoba, Saskatchewan and Alberta, with major emphasis on lake habitat requirements. *Canadian Manuscript Report of Fisheries and Aquatic Sciences*. 2579: xii+170pp.
- LeBrasseur RJ, McAllister CD, Barraclough WE, Kennady OD, Manzer J, Robinson D, Stevens K. 1978. Enhancement of Sockeye Salmon (*Oncorhynchus nerka*) by Lake Fertilization in Great Central Lake: Summary Report. *Journal of the Fisheries Board of Canada*. 35: 1580-1596.
- Levine SN, Schindler DW. 1999. Influence of nitrogen and phosphorus supply ratios and physicochemical conditions on cyanobacteria and phytoplankton species composition in the Experimental Lakes Area, Canada. *Canadian Journal of Fisheries and Aquatic Sciences*. 56: 451-466.
- Martin NV. 1956. Reproduction of lake trout in Algonquin Park, Ontario. *Trans. Am. Fish. Soc.* 95: 415-422.
- McCauley E, Kalff J. 1981. Empirical relationships between phytoplankton and zooplankton biomass in lakes. *Canadian Journal of Fisheries and Aquatic Sciences*. 38(4), 458-463.

- McPhail JD, Lindsey CC. 1970. Freshwater fishes of northwestern Canada and Alaska. Fisheries Research Board of Canada Bulletin: 173, 381 pp.
- McPhail JD. 2007. The Freshwater Fishes of British Columbia (Vol. 6), University of Alberta, Edmonton, AB, Canada.
- McQueen DJ, Johannes MRS, Lafontaine NR, Young AS, Longbottom E, Lean DRS. 1990. Effects of planktivore abundance on chlorophyll-a and Secchi depth. *Hydrobiologia* 200/201: 337-341.
- McQueen DJ, Post JR, Mills EL. 1986. Trophic Relations in Freshwater Pelagic Ecosystems. *Canadian Journal of Fisheries and Aquatic Sciences* 43:1571-1581.
- Mebane CA. 2010. Cadmium risks to freshwater life: Derivation and validation of low-effect criteria values using laboratory and field studies (version 1.2): U.S. Geological Survey Scientific Investigations Report 2006-5245. p. 130.
- Miner JG, Stein RA. 1996. Detection of predators and habitat choice by small bluegills: effects of turbidity and alternative prey. *Transactions of the American Fisheries Society*. 125:97–103.
- 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 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.
- Morgan NC. 1966. Fertilization Experiments in Scottish Freshwater Lochs. II. Sutherland, 1954. 2. Effects on the Bottom Fauna. *Freshwater Salmon Fisheries Research*. 36:1-19. Department of Agriculture and Fisheries for Scotland, Edinburgh.
- Muck J. 2010. Biological effects of sediment on bull trout and their habitat—guidance for evaluating effects. Fish and Wildlife Service, Lacey, p 57.
- Murdoch WW. 1970. Population Regulation and Population Inertia. *Ecology*. Volume 51, Issue 3. Pages 497-502.
- Newcombe CP, Jensen JOT. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. *North American Journal of Fisheries Management* 16:693–727.
- Newcombe CP. 2003. Impact assessment model for clear water fishes exposed to excessively cloudy water. *Journal of the North American Water Resources Association*. 39:529–544.
- 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).
- Nicholson E, Westphal MI, Frank K, Rochester WA, Pressey RL, Lindenmayer DB, Possingham HP. 2006. A new method for conservation planning for the persistence of multiple species. *Ecology Letters* 9:1049-1060.

- NRCan (Natural Resources Canada). 2021. Topographic Data of Canada GeoGratis CanVec Series. Available at <https://open.canada.ca/data/en/dataset/8ba2aa2a-7bb9-4448-b4d7-f164409fe056>.
- Paragamian VL. 1989. Seasonal habitat use by walleye in a warmwater river system, as determined by radiotelemetry. *North American Journal of Fisheries Management*. 9: 392-401.
- Parkinson E, Taylor E, Keeley E. 1999. Conserving genetic diversity in rainbow trout. *Proc. Biology and Management of Species and Habitats at Risk*, Kamloops, B.C. 15-19 Feb.1999.
- Peake SJ. 2004. Effect of approach velocity on impingement of juvenile northern pike at water intake screens. *North American Journal of Fisheries Management*. 24(2): 390-396.
- Plante C, Downing JA. 1993. Relationship of Salmonine Production to Lake Trophic Status and Temperature. *Canadian Journal of Fisheries and Aquatic Sciences*. 50:1324-1328.
- Poff NL, Richter B, Arthington A, Bunn SE, Naiman RJ, Kendy E, Acreman M, Apse C, Bledsoe BP, Freeman M, et al. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. *Freshwater Biology* 55: 147–170.
- Power ME. 1992. Top-down and Bottom-up Forces in Food Webs: Do Plants Have Primacy? *Ecology*. 73:733-746.
- Rand GM. 1995. *Fundamentals of Aquatic Toxicology. Effects, Environmental Fate and Risk Assessment*. Second Edition. Taylor Francis. 1148 pp. <https://doi.org/10.1201/9781003075363>.
- Randall RG, Bradford MJ, Clarke KD, Rice JC. 2013. A science-based interpretation of ongoing productivity of commercial, recreational or Aboriginal fisheries. DFO Canadian Science Advisory Secretariat. Doc. 2012/112 iv + 26 p.
- Rasmussen JB, Kalff J. 1987. Empirical models for zoobenthic biomass in lakes. *Canadian Journal of Fisheries and Aquatic Sciences*. 44(5), 990-1001.
- Reed DH, O'Grady JJ, Brook BW, Ballou JD, Frankham R. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. *Biological Conservation*, 113(1), 23-34.
- Renkonen O. 1938. Statistisch-okologische Untersuchungen uber die terrestrische Kafferwelt der finnischen Bruchmoore. *Annales Botanici Societatis Zoologicae-Botanicae Fennicae*. Vanamo 6: 1-231. (Cited in Hruby 1987).
- Reynolds CS. 2006. *Ecology of Phytoplankton*. 1st Edition. Cambridge University Press, Cambridge, UK.
- Richardson ES, Reist JD, Minns CK. 2001. Life history characteristics of freshwater fishes occurring in the Northwest Territories and Nunavut, with major emphasis on lake habitat requirements. *Canadian Manuscript Reports of Fisheries and Aquatic Sciences*. 2569: vii + 146 p.
- Richter BD, Davis MM, Apse C, Konrad C. 2012. A presumptive standard for environmental flow protection. *River Research and Applications*, 28(8), 1312-1321.
- Ruggiero LF, Hayward GD, Squires JR. 1994. Viability analysis in biological evaluations: concepts of population viability analysis, biological population, and ecological scale. *Conservation Biology* 8:364-372.
- Saskatchewan Parks and Renewable Resources. 1991. Fisheries Branch, Fish Species Distribution in Saskatchewan. Volume 91, Issue 7 of Fisheries technical report. 102 pp.

- Savitz J, Bardygula-Nonn LG, Nonn RA, Wojtowicz G. 1998. Impingement and entrainment of fishes within a high volume-low velocity deep water intake system on Lake Michigan. *Journal of Freshwater Ecology*, 13(2), 165-169.
- Schindler DW. 1974. Eutrophication and Recovery in Experimental Lakes: Implications for Lake Management. *Science*. 184:897-899.
- Schreck CB, Olla BL, Davis MW. 1997. Behavioural responses to stress. In: Iwama OK, Pickering AD, Sumpter JP, Schreck CB (eds) *Fish stress and health in aquaculture*. Society for Experimental Biology, Cambridge, pp 145–170.
- Scott WB, Crossman EJ. 1973. *Freshwater Fishes of Canada*. Fish Res Board Can, Bulletin 184.
- SKCDC (Saskatchewan Conservation Data Centre). 2021a. Saskatchewan Vertebrate Taxa List - Current as of 17-May 2021. Regina, Saskatchewan. Accessed October 2021. Available at <http://biodiversity.sk.ca/SppList.htm>.
- SKCDC. 2021b. Hunting, Angling, and Biodiversity Information of Saskatchewan online mapping database. Accessed October 2021. Available at <http://biodiversity.sk.ca/>.
- Smith TM, Smith RL. 2009. *Elements of Ecology* 7th ed. San Francisco CA: Pearson Benjamin Cummings, 2009.
- Snodgrass JW, Bryan AL, Lide RF, Smith GM. 1996. Factors affecting the occurrence and structure of fish assemblages in isolated wetlands of the upper coastal plain, USA. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 443–454.
- Steedman RJ, Allan CJ, France RL, Kushneriuk RS. 2004. Land, Water, and Human Activity on Boreal watersheds. In *Boreal Shield Watersheds: Lake Trout Ecosystems in a Changing Environment*. Gunn JM, Steedman RJ, Ryder RA, (Eds). Lewis Publishers. CRC Press. 2004. pp. 59-85.
- Stewart KW, Watkinson DA. 2004. *The Freshwater Fishes of Manitoba*. University of Manitoba Press, Winnipeg. 276 pp.
- Suter GW II, Sample BE, Jones DS, Ashwood TL, Loar JM. 1995. Approach and strategy for performing ecological risk assessments for the U.S. Department of Energy's Oak Ridge Reservation: 1995 Revision. ES/ER/TM-33/R2. Environmental Restoration Risk Assessment Program, Lockheed Martin Energy Systems, Inc., Oak Ridge, Tennessee, USA.
- UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). 2008. Sources and Effects of Ionizing Radiation. Annex E. Effects of Ionizing Radiation on Non-human Biota, Report to the General Assembly with Scientific Annexes. United Nations Scientific Committee on Effects of Ionizing Radiation.
- USEPA (United States Environmental Protection Agency). 2002. National Recommended Water Quality Criteria: 2002. Office of Water 4304T. United States Environmental Protection Agency. EPA 822-R-02-047.
- Vasconcelos RP, Batista MI, Henriques S. 2017. Current limitations of global conservation to protect higher vulnerability and lower resilience fish species. *Scientific Reports* 7, 7702. Available at <https://doi.org/10.1038/s41598-017-06633-x>.
- Wehr JD, Sheath RG. 2003. *Freshwater Algae of North America*. Academic Press, San Diego CA, USA.

- Welch HE, Jorgenson JK, Curtis MF. 1988. Emergence of Chironomidae (Diptera) in Fertilized and Natural Lakes at Saqvaquac, N.W.T. Canadian Journal of Fisheries and Aquatic Sciences. 45:731-737.
- Wetzel RG. 2001. Limnology 3rd Edition. Elsevier Science Academic Press, New York. 1,006 pp.
- With KA, Crist TO. 1995. Critical thresholds in species responses to landscape structure. Ecology 76:2446-2459.
- Wright DG, Hopky GE. 1998. Guidelines for the use of explosives in or near Canadian fisheries waters. Canadian technical report of fisheries and aquatic sciences 2107. DFO, Winnipeg, MB, Canada.
- Wright DG. 1982. A Discussion Paper on the Effects of Explosives on Fish and Marine Mammals in the Water of the Northwest Territories. Canadian Technical Report on Fisheries and Aquatic Sciences. No. 1052.
- WSA (Water Security Agency). 2015. Surface Water Quality Objectives, Interim Edition, EPB 356. Saskatchewan Environmental and Municipal Management Services Division, Water Security Agency. June 2015.
- Yan ND. 1986. Empirical prediction of crustacean zooplankton biomass in nutrient-poor Canadian Shield lakes. Canadian Journal of Fisheries and Aquatic Sciences. 43: 788-796.
- 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 11A Aquatic Health Assessment of the Potential for Adverse Effects of Predicted Far-Future Copper Concentrations in Patterson Lake

Abbreviations and Units of Measure

Abbreviation	Definition
BLM	biotic ligand model
CCME	Canadian Council of Ministers of the Environment
COPC	constituent of potential concern
DOC	dissolved organic carbon
EC ₂₀	20% effect concentration
EC ₂₅	25% effect concentration
ECCC	Environment and Climate Change Canada
ETMF	exposure and toxicity modifying factor
FEQG	federal environmental quality guideline
HC ₅	hazard concentration at 5%
HQ	hazard quotient
IC	inhibition concentration
LOEC	lowest observed effect concentration
MATC	maximum acceptable toxicant concentration
MLR	multiple linear regression
NexGen	NexGen Energy Ltd.
pH	potential of hydrogen; measure of the acidity or alkalinity of a solution on a scale of 0 to 14
Project	Rook I Project
RFD	reasonably foreseeable development
RSWQM	regional surface water quality model
SSD	species sensitivity distribution
TRV	toxicity reference value
USEPA	United States Environmental Protection Agency

Unit	Definition
%	percent
°C	degrees Celsius
µg/L	micrograms per litre
km	kilometre
mg/L	milligrams per litre

Table of Contents

11A1 INTRODUCTION	1
11A1.1 Background	3
11A1.1.1 Predicted Effects on Surface Water Quality	3
11A1.1.2 Overview of the Results of the Ecological Risk Assessment	4
11A1.2 Scope of the Aquatic Health Assessment	4
11A2 METHODS	5
11A2.1 Assessing Copper Toxicity	5
11A2.1.1 Chemical Form and Bioavailability	5
11A2.1.2 Current Water Quality Guidelines	5
11A2.1.3 Biotic Ligand Model Overview	6
11A2.1.4 Multiple Linear Regression Model Overview	7
11A2.2 Model Input Requirements	8
11A2.2.1 Biotic Ligand Model	8
11A2.2.2 Multiple Linear Regression Model	9
11A2.3 Receiving Environment Chemistry Inputs	9
11A2.4 Modelling Scenarios	10
11A3 RESULTS	11
11A4 UNCERTAINTY	18
11A5 REFERENCES	20

List of Figures

Figure 11A-1: Location of Patterson Lake	2
Figure 11A-2: Predicted Copper Concentrations in Patterson Lake North Arm – West Basin: Application Case	12
Figure 11A-3: Predicted Copper Concentrations in Patterson Lake North Arm – West Basin: Application Case, Reasonable Upper Bound Scenario	13
Figure 11A-4: Species Sensitivity Distribution Curve for Chronic Copper Toxicity Based on the Log-Normal Distribution in Patterson Lake North Arm – West Basin: Application Case, Reasonable Upper Bound Scenario, Maximum Predicted Copper Concentration	14
Figure 11A-5: Predicted Copper Concentrations in Patterson Lake North Arm – West Basin: Reasonably Foreseeable Development Case	17
Figure 11A-6: Predicted Copper Concentrations in Patterson Lake South Arm: Application Case, Reasonable Upper Bound Scenario	18

List of Tables

Table 11A-1:	Selection of Scenarios Retained for Further Evaluation in the Aquatic Health Assessment	4
Table 11A-2:	Patterson Lake Water Quality Data Used in Biotic Ligand Model and Multiple Linear Regression Models	10
Table 11A-3:	Chronic Aquatic Toxicity Data for Copper Used in the Species Sensitivity Distribution for Patterson Lake North Arm – West Basin: Application Case, Reasonable Upper Bound Scenario, Maximum Predicted Copper Concentration	15
Table 11A-4:	Uncertainties Associated with the Biotic Ligand Model and Multiple Linear Regression Model Approaches to Derive No Effect and Low Effects Thresholds	19

List of Attachments

Attachment 11A-1 Patterson Lake Water Quality Data Used in the Biotic Ligand Model and Multiple Linear Regression Analyses	
Attachment 11A-2 Chronic Toxicity Data Used in Species Sensitivity Distribution for Modelled Maximum Copper Concentration	

11A1 INTRODUCTION

The Rook I Project (Project) is a proposed new uranium mining and milling operation that is 100% owned by NexGen Energy Ltd. (NexGen). The Project would be located in northwestern Saskatchewan, 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. The Project would reside within Treaty 8 territory and within the Métis Homeland. At a regional scale, the Project would be situated within the southern Athabasca Basin adjacent to Patterson Lake and along the upper Clearwater River system (Figure 11A-1). The Project would include underground and surface facilities to support the extraction and processing of uranium ore from the Arrow deposit, a land-based, basement-hosted, high-grade uranium deposit.

This appendix presents the results of an aquatic health assessment completed in support of the Project's Environmental Impact Statement (EIS). An aquatic health assessment was undertaken to evaluate the potential effects of exposure of fish and other aquatic organisms to elevated copper concentrations, which are predicted in the aquatic receiving environment after Decommissioning and Reclamation (i.e., Closure) of the Project and in the far future. The primary source of loading for copper in the far future is the slow migration of hydrogeological mass load inputs from the waste rock storage areas and to a lesser extent, the underground tailings management facility.

The results of the surface water quality assessment (EIS Section 10, Surface Water Quality and Sediment Quality) and ecological risk assessment (TSD XXI, Environmental Risk Assessment) completed for the Project indicated that copper concentrations in Patterson Lake in the far future were predicted to be above thresholds representing concentrations below which no effects on aquatic life would be expected. The results of the surface water quality assessment indicated that copper concentrations in the water column were predicted to exceed generic water quality guidelines for the protection of aquatic life (0.002 mg/L; CCME 2021; WSA 2015). Concentrations of copper were also predicted to exceed the minimum fresh water copper toxicity reference value (TRV) used in the ecological risk assessment (0.002 mg/L; CCME 2021). The guidelines used in these assessments represent threshold concentrations below which no effects are likely, and above which effects are possible. More specific thresholds based on site-specific conditions and ecology were derived herein. This additional assessment was undertaken to further describe the potential effects from copper exposure on the health of fish and aquatic life.

11A1.1 Background

11A1.1.1 Predicted Effects on Surface Water Quality

Potential effects on surface water quality were predicted through the development of a regional surface water quality model (RSWQM) used to assess the expected magnitude, extent, and duration of Project effects in the downstream receiving environment. The RSWQM considered an Application Case and a Reasonably Foreseeable Development (RFD) Case. Source term inputs considered in the RSWQM Application Case included inputs from the Project site-wide water balance model and the groundwater solute transport model. Model simulations were completed for all Project phases, although this aquatic health assessment focuses only on far-future results because concentrations were predicted to remain below generic thresholds in the receiving environment during the Project lifespan (i.e., Construction, Operations, Closure). A sensitivity scenario was also considered, which was representative of reasonable upper bound conditions (EIS Section 10.2.8.1.2, Near-Field Water Quality Model). This reasonable upper bound scenario was completed for the Application Case to provide a precautionary, more conservative upper bound in the surface water quality assessment, and addressed uncertainty associated with the model outputs.

Infiltration and seepages from the Project footprint to groundwater in the far future were predicted through groundwater flow and solute transport modelling to predict migration of metals from the underground mine workings, underground tailings management facility, and waste rock storage areas to Patterson Lake. The modelling of the tailings-affected groundwater migration by the groundwater solute transport model demonstrated that the time for groundwater to reach surface water spans a very large temporal scale extending hundreds of thousands of years into the future (EIS Section 8, Hydrogeology). However, computational limits with the RSWQM precluded the use of such a large temporal scale as demonstrated in the solute transport model. To address this limitation, loadings from the groundwater solute transport model were effectively fast-tracked to allow for a shorter modelling timeframe that considered maximum effects on surface water quality. The far-future modelling period considered in the RSWQM extends 357 years after Closure and includes two time periods: an initial 157-year period that includes the natural hydrological and hydrogeological processes from the site following Closure; and a subsequent 200-year period that includes the natural hydrological and hydrogeological processes that account for maximum mass loadings associated with solute transport by groundwater, as predicted by the groundwater model. As the RSWQM modelled conditions for the far future were effectively fast-tracked, these “years” do not correspond to actual future years. Thus, any mention of a specific year in this appendix refers only to a point in the far future that represents reasonable worst-case conditions.

The RSWQM predicted incremental mass loadings to Patterson Lake North Arm – West Basin in the far future for a group of metals that were predicted to increase in the receiving environment. Overall, the magnitude of constituent of potential concern (COPC) concentration increases is greater in the reasonable upper bound scenario of the Application Case and in the RFD Case compared to the Application Case. In particular, the concentration of copper was predicted to exceed water quality thresholds for the protection of aquatic life (EIS Section 10, Surface Water Quality and Sediment Quality). As indicated above, increases in concentrations of other COPCs were not predicted to result in potential effects on aquatic biota.

11A1.1.2 Overview of the Results of the Ecological Risk Assessment

Ecological health risks resulting from changes in surface water quality were examined in the ecological risk assessment (TSD XXI) for aquatic species or receptors, including phytoplankton, zooplankton, benthic invertebrates, predator fish species (represented by northern pike), and forage fish species (represented by lake whitefish). The IMPACT environmental pathways model was used to predict transport of COPCs through the environment, their concentrations in environmental media, and potential risks to ecological receptors. Exposures of aquatic organisms to COPCs in surface waters were predicted and assessed. Toxicity reference values were used to assess the potential for effects. The ecological risk to aquatic organisms was then estimated by calculating hazard quotients (HQs) that provide a quantitative estimate of overall risk to a receptor.

The HQ was calculated as the ratio between the exposure estimate and the TRV. An HQ of less than or equal to one suggests low risk to the ecological receptor because exposure estimates do not exceed levels known to cause adverse effects. If the HQ is greater than one, toxicological effects may be possible.

For the far-future projection (i.e., after mine Closure, more than 100 years into the future), copper concentrations in Patterson Lake are predicted to intermittently exceed the minimum receptor-specific TRV of 0.002 mg/L, resulting in HQ values greater than one (TSD XXI). Copper concentrations were predicted to exceed the TRV in Patterson Lake North Arm – West Basin in the Application Case and the RFD Case, as well as in the reasonable upper bound scenario for the Application Case. In Patterson Lake South Arm, copper was predicted to exceed the TRV only in the reasonable upper bound scenario.

11A1.2 Scope of the Aquatic Health Assessment

The aquatic health assessment evaluated the scenarios that had predicted copper concentrations greater than TRVs in the environmental risk assessment (TSD XXI). Thus, out of the six scenarios evaluated by the environmental risk assessment, four scenarios were carried forward for further evaluation in the aquatic health assessment (Table 11A-1).

Table 11A-1: Selection of Scenarios Retained for Further Evaluation in the Aquatic Health Assessment

Patterson Lake Area	Assessment Case	HQ ^(a)	Retained in Aquatic Health Assessment ^(b)
North Arm – West Basin	Application Case	>1	Yes
North Arm – West Basin	Application Case, reasonable upper bound scenario	>1	Yes
North Arm – West Basin	RFD Case	>1	Yes
South Arm	Application Case	<1	No
South Arm	Application Case, reasonable upper bound scenario	>1	Yes
South Arm	RFD	<1	No

a) HQ is the predicted concentration divided by the TRV of 0.002 mg/L. A HQ of less than or equal to one indicates low risk to aquatic health because predicted concentrations are below levels known to cause adverse effects.

b) Model scenarios that resulted in HQs greater than 1 were retained for further evaluation.

RFD = reasonably foreseeable development; HQ = hazard quotient; < = less than; > = greater than; TRV = toxicity reference value.

Predicted effects on aquatic health due to copper exposure were described for the far future using an approach based on the biotic ligand model (BLM) and a multiple linear regression (MLR) model. The BLM is a tool that predicts the bioavailability of copper based on water chemistry and relates it to copper toxicity. The MLR model is an alternative to the BLM, based on the same principles of using water chemistry to predict copper toxicity. The use of these approaches allows for the assessment of the potential for toxicity on fish, invertebrates, and

aquatic plants by evaluating the predicted copper concentrations in consideration of predicted exposure and toxicity modifying factors (ETMFs). The ETMFs are ambient water quality conditions that can affect copper bioavailability and toxicity, such as hardness and concentrations of certain ions. This information was used to support the assessment of effects on fish and fish habitat (EIS Section 11, Fish and Fish Habitat), including the potential for direct toxicological effects on the survival and reproduction of fish, as well as indirect effects that can result through reduction of, or changes to, the food base for fish.

Toxicological effects on aquatic biota were not predicted to occur due to exposure to other COPCs or during Project phases (i.e., Construction, Operations, Closure), and thus, these other COPCs and Project phases were not considered in the aquatic health assessment.

11A2 METHODS

11A2.1 Assessing Copper Toxicity

11A2.1.1 Chemical Form and Bioavailability

Copper can be toxic to aquatic life, but at low concentrations, it is an essential nutrient for both aquatic plants and animals (Grosell 2012). In natural waters, the divalent cupric ion is highly reactive, forming complexes and precipitates with organic and inorganic constituents and suspended solids in the water column (USEPA 1985). As a result, water quality characteristics can substantially affect the toxicity and bioavailability of copper to aquatic life. Bioavailability is a measure of the rate and extent to which a toxicant, like a metal, reaches the site of toxic action (Adams et al. 2019). Generally, a decrease in copper toxicity is observed as water hardness increases because hardness in natural waters is controlled by the presence of divalent calcium and magnesium ions that compete with metal cations for binding sites on the gills of aquatic organisms (ICME 1995).

11A2.1.2 Current Water Quality Guidelines

In developing their water quality criteria for copper, the United States Environmental Protection Agency (USEPA) recognized the relationship between copper toxicity and hardness, and developed a regression equation to incorporate hardness into the calculation of acute and chronic copper criteria (USEPA 1985). The Canadian Council of Ministers of the Environment (CCME) adopted the USEPA's revised hardness-based chronic copper criteria as a federal water quality guideline for the protection of aquatic life (CCREM 1987). However, hardness typically co-varies with pH and alkalinity, which means that the influence of hardness cannot easily be separated from the toxicity-modifying effects of pH and alkalinity. The hardness-based equation works best when the water of interest has similar combinations of pH, alkalinity, and hardness to those represented in the dataset used to develop the hardness-based criteria. Outside of this range of conditions, the hardness-based equation may not be as effective at predicting the toxicity of copper. Another issue with the hardness-based equation is that hardness is a surrogate for calcium and magnesium ion concentrations, which can exert different influences on copper bioavailability; therefore, toxicity may be more effectively modelled by considering calcium and magnesium as separate toxicity-modifying factors (Paquin et al. 2002).

Since the development of hardness-based criteria, an improved understanding of ETMFs and copper toxicity has led to the development of copper BLMs. The BLM explicitly considers the influence of multiple water chemistry parameters on copper bioavailability and toxicity. The USEPA considers the BLM to represent the best available method to predict copper toxicity and recommends it as the basis for developing site-specific fresh

water, water quality criteria for copper in the United States (USEPA 2007). However, the USEPA copper BLM uses a toxicity database of acute lethality (i.e., 50% lethal concentration¹) data and derives a chronic criterion by applying an acute-to-chronic ratio. In Canada, chronic water quality guidelines are preferentially derived using chronic toxicity data. Thus, Environment and Climate Change Canada (ECCC) recently published a federal environmental quality guideline (FEQG) for dissolved copper based on a BLM using chronic toxicity data that were selected according to the CCME (2007) guidance for the derivation of water quality guidelines (ECCC 2021a).

11A2.1.3 Biotic Ligand Model Overview

The BLM is based on the understanding that copper accumulation at the physiologically active site in the biological organism, referred to as the biotic ligand, elicits a toxic action within that organism. It is assumed that the dissolved copper concentration that elicits this toxic response is always associated with a fixed, critical level of metal accumulation at the biotic ligand; thus, copper toxicity can be predicted based on the water chemistry that produces that dissolved copper concentration (ECCC 2021a). This fixed level of metal-biotic ligand accumulation is constant and species-specific, regardless of the chemical characteristics of the water. The critical accumulation values can be based on any measure of biological impairment including survival, growth, or reproduction. The BLM uses binding constants (e.g., copper-pH, copper-calcium, copper-magnesium, copper-dissolved organic carbon [DOC]) to predict the concentration of dissolved copper based on the water chemistry. Any changes in water chemistry that would affect the dissolved copper concentration would also change the bioavailability and hence the toxicity of copper. Dissolved copper is generally considered to be the most bioavailable form of copper (ECCC 2021a).

The approach and development of the ECCC BLM is similar to that of the USEPA BLM, which was issued in 2007. For example, the ECCC BLM also uses a single set of parameters for all aquatic organisms; that is, the binding constants do not change for different organisms. This allows the BLM to apply a consistent mechanistic framework to metal bioavailability for organisms (ECCC 2021a). Like the USEPA BLM, the ECCC BLM is also used to normalize the available toxicity data to a consistent set of exposure conditions. These normalized data are then used to develop a species sensitivity distribution (SSD), which relates copper concentrations to toxicity endpoints observed in multiple species. The fifth percentile of the normalized SSD is determined and is used to set the criteria referred to as the hazard concentration at 5% (HC₅). The HC₅ represents the concentration of copper predicted to cause effects in the most sensitive 5% of species on the SSD.

The ECCC (2021a) followed the CCME (2007) protocol in the selection of chronic toxicity data for use in the toxicity database. The ECCC (2021a) selected EC₁₀² (i.e., effect concentration that results in 10% adverse effect), IC₁₀ (i.e., inhibition concentration that results in 10% adverse effect) maximum acceptable toxicant concentration (MATC³), and no observed effect concentration from studies with fish, invertebrates, and plants.

¹ The 50% lethal concentration is the concentration of a test material at which 50% of exposed test organisms die in a laboratory toxicity test.

² The EC_x is the concentration of a test material that is estimated to cause an effect of x% magnitude to test organisms. The EC_x describes quantal effects (i.e., effect can be one thing or the other, such as dead/alive or normal/abnormal). IC_x is the concentration of a test material that is estimated to cause a x% impairment in a quantitative biological function (e.g., size) in exposed test organisms compared to a control group. For example, an IC₁₀ for weight would be the concentration at which weight is 10% less than that observed in control test organisms. Both the EC_x and IC_x are estimated by linear regression or interpolation from the concentration-response curve.

³ MATC is the geometric mean of the no observed effect concentration and LOEC. The no observed effect concentration is the concentration of a test material identified by hypothesis testing to have no significant difference from control in terms of an effect on exposed test organisms. The LOEC is the lowest concentration that is statistically different from control.

The ECCC BLM involves three steps, the details of which can be found in ECCC (2021a). A brief summary is provided below:

1. The critical copper accumulation levels are calculated, based on the exposure conditions in the original laboratory toxicity test that generated the chronic toxicity value. These exposure conditions include values for temperature, pH, DOC, alkalinity, calcium, magnesium, sodium, potassium, sulphate, and chloride. Two model parameters are used: one for fish and invertebrates and one for plants.
2. Toxicity data are normalized to the site conditions or water chemistry of interest.
3. Normalized data are used to develop an SSD. The species mean values (i.e., geometric mean of compiled chronic endpoints) are ranked and a distribution is fit to the data (i.e., log-normal, log-logistic, log-gumbel, log-extreme); the fifth percentile is calculated from this distribution (i.e., the HC₅). This HC₅ is selected as the FEQG.

The output of the ECCC BLM includes SSDs for each set of exposure conditions, the distribution used to fit the data, and the resulting HC₅ with 95% confidence intervals. From this information, the most sensitive species and the relative ranking of all species can be identified.

As with all federal water quality guidelines derived using CCME (2007), the FEQG is intended to be protective of all forms of aquatic life (i.e., all species and life stages) for indefinite exposure periods. Thus, there is high confidence that predicted copper concentrations below the FEQG would not adversely affect aquatic life. However, exceedances of the FEQG do not necessarily mean that there would be adverse effects. Given that the toxicity database is based on no effect concentrations, the FEQG could be considered as a no effect threshold and was applied as such in this aquatic health assessment.

For the aquatic health assessment, it was necessary to evaluate the extent and magnitude of adverse effects on aquatic receptors when predicted copper concentrations occur above this no effect threshold. To do this, a low effects threshold was derived using the MLR model of Brix et al. (2021).

11A2.1.4 Multiple Linear Regression Model Overview

The MLR model is based on the same principles of the BLM of predicting copper toxicity under various water chemistry conditions. It can be simpler to use than the BLM because it requires fewer water chemistry inputs and can be calculated in an Excel spreadsheet. A key difference between the MLR model and the ECCC BLM is that of the underlying toxicity dataset; the MLR model developed by Brix et al. (2021) uses low level effects concentrations whereas the ECCC BLM uses no effect concentrations. This difference is useful for this aquatic health assessment because both no effect and low effects thresholds can be derived using the same set of exposure conditions. In addition, both models produce SSDs, which allow for an evaluation of what species are most sensitive and the magnitude of the potential adverse effects at a particular predicted copper concentration.

To develop the MLR model, Brix et al. (2017) first identified the ETMFs that influence copper bioavailability the most, starting with the list of ETMFs that are considered as part of the BLM. Based on their evaluation, pH, DOC, and hardness were selected for use in deriving a MLR model. Using the same methodology that USEPA used to derive the hardness-based copper regression equation, Brix et al. (2021) developed a regression equation that incorporated all three ETMFs. Relationships between toxicity and hardness or DOC tend to be linear, whereas a linear relationship between toxicity and pH is observed when toxicity is transformed (Brix et al. 2017). Thus, toxicity, hardness, and DOC were log transformed, but pH was not transformed in the final model. The statistical methods to develop and select the best-fitting model are provided by Brix et al. (2017, 2021).

Similar to the BLM, the MLR model normalizes toxicity data to a consistent set of exposure conditions, specifically those for pH, DOC, and hardness. The MLR model uses a database of toxicological data compiled by the USEPA (2007) and subsequently updated by Brix et al. (2017) to include more recent studies that meet USEPA (1985) test acceptability guidelines. The data compilation also considered the chronic toxicity dataset compiled by ECCC (2021a). The MLR model database includes chronic toxicity data for 26 fish, amphibian, and invertebrate species. The chronic endpoints include EC₂₀ (20% effect concentration), EC₂₅ (25% effect concentration), MATC, and lowest observed effect concentration (LOEC). The CCME (2007) considers these endpoints to represent low effects thresholds. Low level adverse effects may occur to sensitive species in long-term exposures if predicted copper concentrations are at or above low effects thresholds.

Table S5 in the supplemental information provided by Brix et al. (2021) provides the chronic copper SSDs based on moderately hard water (i.e., pH 7.5, DOC of 0.5 mg/L, hardness of 85 mg/L). Specifically, the individual normalized toxicity values and the species mean values based on this set of exposure conditions were calculated based on the MLR equation provided in the spreadsheet. By changing the water chemistry values used to normalize the data, the spreadsheet can provide a revised list of species mean values based on a new set of exposure conditions. For the aquatic health assessment, a log-normal distribution was fitted to the species means values because this distribution was consistently selected in the ECCC BLM for the same modelling scenario. The fifth percentile of the fitted log-normal distribution was selected as the low effects threshold.

11A2.2 Model Input Requirements

11A2.2.1 Biotic Ligand Model

The BLM Windows Interface, Environment and Climate Change Canada FEQG Chronic Cu BLM Version 1.2, (ECCC 2021b) was used to derive the no effect thresholds. The water quality parameters necessary to run the BLM are:

- physical parameters (i.e., water temperature, and pH);
- DOC and proportion of humic acid⁴;
- major cations (i.e., calcium, magnesium, sodium, and potassium);
- major anions (i.e., sulphate, and chloride); and
- total alkalinity.

In general, the proportion of humic acid is not measured in water quality assessments; this is recognized by ECCC (2021c) and is not considered a deterrent to running the BLM. As recommended by the BLM User Guide (ECCC 2021c), the humic acid proportion of DOC was assumed to be 10%.

⁴ Humic acid is the organic acid obtained from humic material and can complex with metals differently from other organic acids like fulvic acid. The ECCC (2021c) notes that characterizing dissolved organic matter content beyond measuring DOC concentrations is not a critical factor in the predictability of the BLM.

The copper BLM was developed and calibrated under a range of water quality parameters that reflect typical conditions in the toxicity tests selected to support BLM development. If any input value is outside the prescribed range, then the BLM substituted the lower or upper bound for that input parameter before normalizing the data. This substitution was applied for temperature because average baseline temperature in Patterson Lake was less than the lower bound prescribed value of 8.5°C. However, ECCC (2021c) notes that temperature effects on copper toxicity are relatively minor and the application of temperature input values outside the range is not a concern.

11A2.2.2 Multiple Linear Regression Model

The MLR model requires three parameters: pH, DOC, and hardness. No calibration ranges were noted by Brix et al. (2021) but it is assumed that these ranges would be similar to those of the ECCC BLM, as the underlying toxicity dataset is similar.

11A2.3 Receiving Environment Chemistry Inputs

To run the BLM and MLR models, it was necessary to use a combination of measured laboratory and field data, as well as modelled data. Modelled data were available for calcium, magnesium, sodium, and sulphate (Attachment 10A-2, Regional Surface Water Quality Model Results). Hardness for the MLR model was calculated from predicted calcium and magnesium concentrations. Measured data for pH, DOC, alkalinity, and potassium were obtained from the baseline dataset (i.e., measured in Patterson Lake between 2015 and 2020). Average values for these parameters were used in the models. Average values were selected as representative of typical future conditions. As noted in Section 11A2.2.1, Biotic Ligand Model, the lower bound of the prescribed range for temperature was used in the BLM.

Table 11A-2 summarizes the input values used in the BLM and the MLR models. Multiple BLM runs were performed, each reflecting different water quality scenarios predicted by the three water quality models at different time steps in the far future. Values used in BLM runs for water quality parameters with model predictions (i.e., calcium, magnesium, sodium, sulphate) varied depending on model data for each timepoint. Water quality parameters for which average baseline values were used (i.e., pH, DOC, alkalinity, potassium) in the BLM remained the same across all BLM runs on a given area of Patterson Lake. For the MLR model, only hardness varied among model runs as average baseline pH and DOC were used for all modelling scenarios.

Table 11A-2: Patterson Lake Water Quality Data Used in Biotic Ligand Model and Multiple Linear Regression Models

Parameter	Source	Values Used for North Arm – West Basin	Values Used for South Arm	Model Parameters Used in
Temperature (°C)	Baseline ^(a)	6.9 ^(b)	7.5 ^(b)	BLM
pH	Baseline ^(a)	6.95	6.89	BLM and MLR
DOC (mg/L)	Baseline ^(a)	2.3	2.2	BLM and MLR
Alkalinity (mg/L as CaCO ₃)	Baseline ^(a)	29	31	BLM
Potassium (mg/L)	Baseline ^(c)	0.55	0.57	BLM
Humic acids (%)	ECCC 2021c ^(d)	10	10	BLM
Calcium (mg/L)	Predicted ^(e)	3.37-10.3	3.89-16.6	BLM
Magnesium (mg/L)	Predicted ^(e)	1.14-1.97	1.35-2.78	BLM
Sodium (mg/L)	Predicted ^(e)	1.44-10.6	1.61-18.9	BLM
Sulphate (mg/L)	Predicted ^(e)	2.37-29.5	2.88-52.1	BLM
Chloride (mg/L)	Predicted ^(e)	0.747-22.4	0.943-40.5	BLM
Hardness (mg/L)	Predicted ^(f)	13.2-33.6	15.3-53.0	MLR

Note: Minimum and maximum values are provided for parameters with a range of values produced by model predictions.

a) Average baseline water quality as measured between 2015 and 2020.

b) Temperature was below lower bound of prescribed range of 8.5°C; therefore, lower bound was substituted in the BLM run.

c) Average baseline water quality as measured between 2018 and 2020 (not available for earlier years).

d) Recommended value from ECCC in absence of chemical characterization (ECCC 2021c).

e) Model predicted value from the Application Case, RFD Case, or reasonable upper bound scenario (sensitivity scenario for the Application Case).

f) Hardness was calculated from predicted calcium and magnesium concentrations.

CaCO₃ = calcium carbonate; BLM = biotic ligand model; DOC = dissolved organic carbon; MLR = multiple linear regression;

RFD = reasonably foreseeable development; ECCC = Environment and Climate Change Canada.

11A2.4 Modelling Scenarios

The water quality model yielded monthly time steps for each assessment case during the far-future modelling period. Time steps were chosen to capture representative scenarios within each assessment case with regards to predicted copper concentrations. This included time steps at the modelled start of the period immediately following Closure (i.e., 2068), during the modelled period when copper concentrations are predicted to increase in Patterson Lake (i.e., 2068 to 2100), and during the period when predicted copper concentrations appear to stabilize and only fluctuate with climatic conditions (i.e., peaks occurring during dry periods, troughs during wet periods; 2100 to 2425). It should be noted that the years listed do not correspond to actual future years as stated in Section 11A1.1.1, Predicted Effects on Surface Water Quality, as the far-future modelling timeframe condensed thousands of years into 357 years. Thus, any mention of a specific year in this assessment only refers to some point in the far future, which is relatively closer or farther away from another point in the far future (e.g., 2068 immediately follows Closure, so 2100 is relatively closer to the start of the post-closure timeframe than 2400).

For the BLM, a total of 47 modelling scenarios were run through the BLM: 16 time steps from the Patterson Lake North Arm – West Basin Application Case, 10 time steps from the Patterson Lake North Arm – West Basin reasonable upper bound scenario, 10 time steps from the Patterson Lake North Arm – West Basin RFD Case, and 11 time steps from the Patterson Lake South Arm reasonable upper bound scenario (Attachment 11A-1, Patterson Lake Water Quality Data Used in the Biotic Ligand Model and Multiple Linear Regression Analyses).

For the MLR model, fewer modelling scenarios were run because of the similarity in predicted hardness, which was the only parameter that varied among scenarios (i.e., average baseline pH and DOC were used for all runs). A total of 31 modelling scenarios were run through the MLR model: 16 time steps from the Patterson Lake North Arm – West Basin Application Case, 10 time steps from the Patterson Lake North Arm – West Basin reasonable upper bound scenario, 2 time steps from the Patterson Lake North Arm – West Basin RFD Case, and 3 time steps from the Patterson Lake South Arm reasonable upper bound scenario (Attachment 11A-1).

11A3 RESULTS

Copper toxicity in Patterson Lake was modelled using both BLM and MLR approaches to evaluate how predicted copper concentrations above the TRV might adversely affect aquatic life. The results were interpreted as follows:

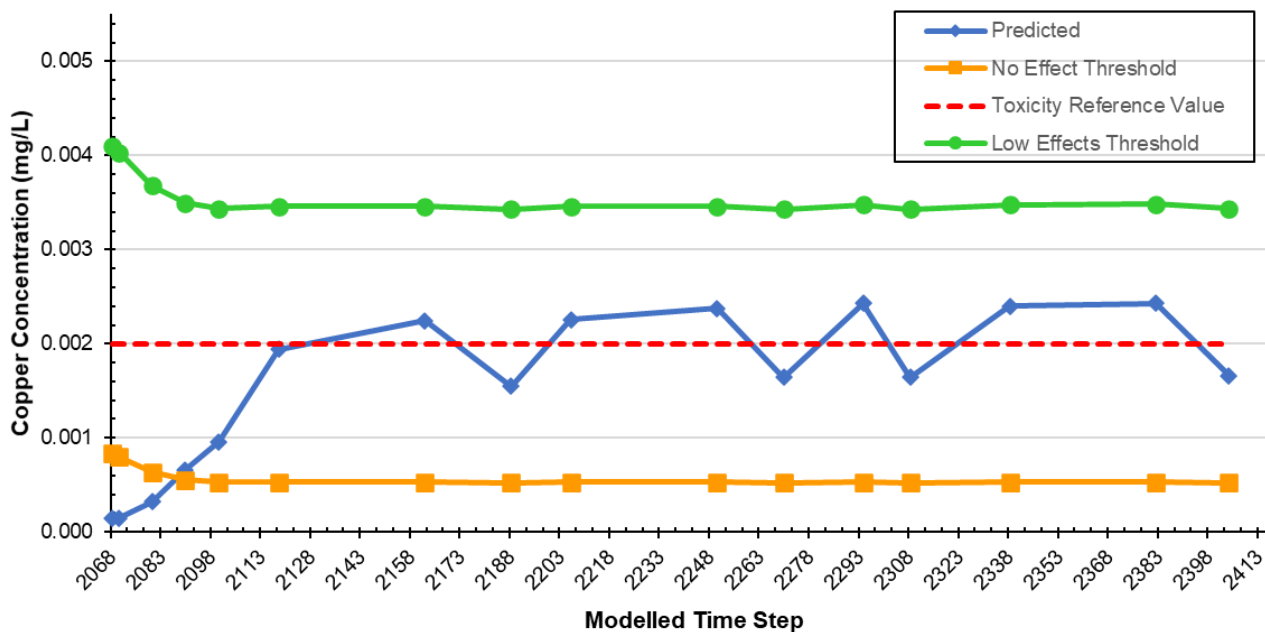
- Predicted copper concentrations that are at or below the no effect threshold are not expected to result in adverse effects on aquatic health.
- Predicted concentrations that are between the no effect and low effects thresholds are unlikely to result in adverse effects because the magnitude of effects, if any, are likely to be within the range of background variability and unlikely to be measurable. This interpretation is consistent with ecological risk assessment guidance. The low effect thresholds were developed using 20% to 25% level of effect, which is consistent with guidance for a permissible level of effect (Suter et al. 1995). Mebane (2010) also supports the use of an effects level of 20% for protection against unacceptable adverse effects on invertebrate and fish populations. A 20% difference in response to a test is widely considered to be within the range of natural variability often observed in the field among normal, unexposed populations. Environment and Climate Change Canada recommends the use of 25% for reporting the results of sublethal toxicity testing and IC_{25s} and/or EC_{25s} are commonly reported in the literature. Population or community level effects would not be expected to occur at or below the low effects thresholds.
- Predicted concentrations above the low effects threshold may result in potential adverse effects on sensitive aquatic receptors. In this case, further evaluation of the SSD is required to describe what species may be affected and the level of effect, including whether community level effects may be observed.

Summaries of the results for each retained assessment cases are provided below.

Patterson Lake North Arm – West Basin: Application Case

Based on predicted water quality in the Application Case, predicted copper concentrations in Patterson Lake North Arm – West Basin would exceed the no effect threshold from around modelled year 2090 onward. However, copper concentrations are not predicted to exceed the low effects threshold in the far future (Figure 11A-2). Predicted copper concentrations below the low effects thresholds are unlikely to result in adverse effects on fish, invertebrates, or plants.

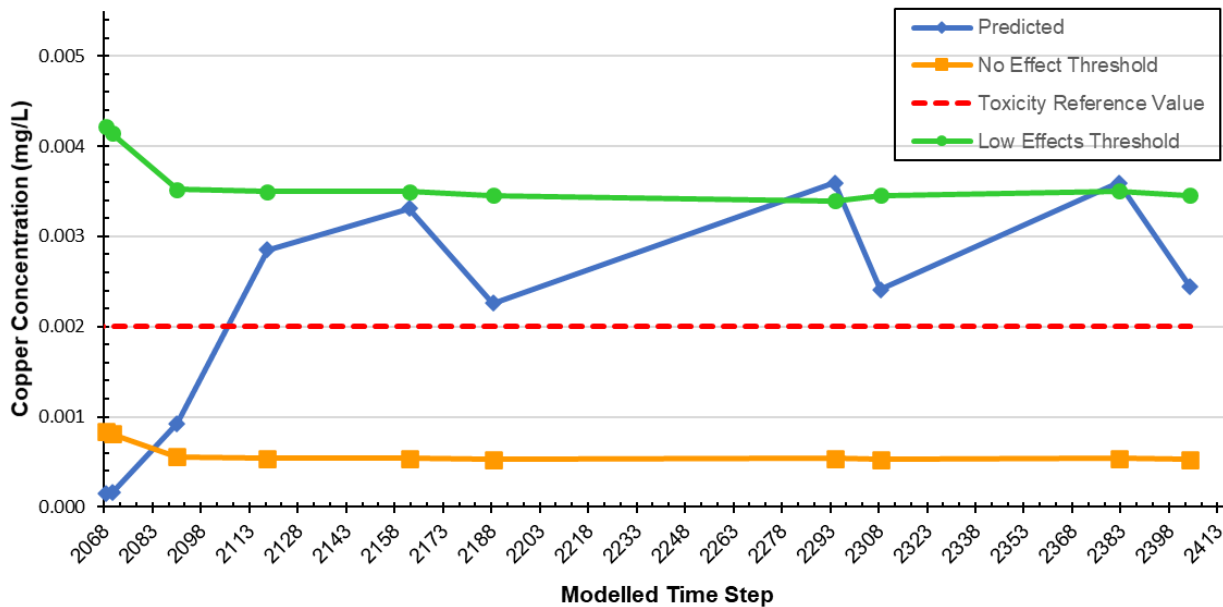
Figure 11A-2: Predicted Copper Concentrations in Patterson Lake North Arm – West Basin: Application Case



Patterson Lake North Arm – West Basin: Application Case, Reasonable Upper Bound Scenario

The use of more conservative assumptions in water quality modelling resulted in higher predicted copper concentrations for the reasonable upper bound scenario. Predicted copper concentrations were above the no effect threshold from around year 2080 onward (Figure 11A-3). Predicted copper concentrations remained below the low effects threshold, with the exception of periods of dry climatic conditions with HQs of 1.06 and 1.03 in modelled years 2294 and 2382, respectively (Figure 11A-3). Note that these peaks represent a fast-tracked timeline as described in Section 11A1.1.1, and do not represent actual future years. The maximum predicted copper concentration is 0.0036 mg/L.

Figure 11A-3: Predicted Copper Concentrations in Patterson Lake North Arm – West Basin: Application Case, Reasonable Upper Bound Scenario



The SSD for the low effects threshold (Figure 11A-4 and Table 11A-3) was reviewed to evaluate the potential magnitude of effects on sensitive species:

- The most sensitive fish species in the SSD is the white sturgeon (*Acipenser transmontanus*) with a normalized EC_{20} for biomass of 0.0039 mg/L (Wang et al. 2014). The next most sensitive fish species in the SSD is chinook salmon (*Oncorhynchus tshawytscha*) with a normalized EC_{20} for biomass of 0.0062 mg/L (Chapman 1975, 1982).
- The most sensitive invertebrate species is the pond snail (*Lymnaea stagnalis*) with a normalized geometric mean EC_{20} of 0.0057 mg/L (Brix et al. 2021).

Brix et al. (2021) did not include plant species in their SSDs. However, based on the SSD for the no effect threshold (from the ECCC BLM), plants were less sensitive to copper toxicity than fish and invertebrates. The two fish species (white sturgeon and chinook salmon) and several invertebrate species (including pond snail) were located lower on the SSD (i.e., toxicity tests with these species yielded lower no effect concentrations).

Based on the evaluation of the SSD, adverse effects on fish, invertebrates, and plants are unlikely because predicted copper concentrations are lower than the lowest low effect concentration for the most sensitive species.

Figure 11A-4: Species Sensitivity Distribution Curve for Chronic Copper Toxicity Based on the Log-Normal Distribution in Patterson Lake North Arm – West Basin: Application Case, Reasonable Upper Bound Scenario, Maximum Predicted Copper Concentration

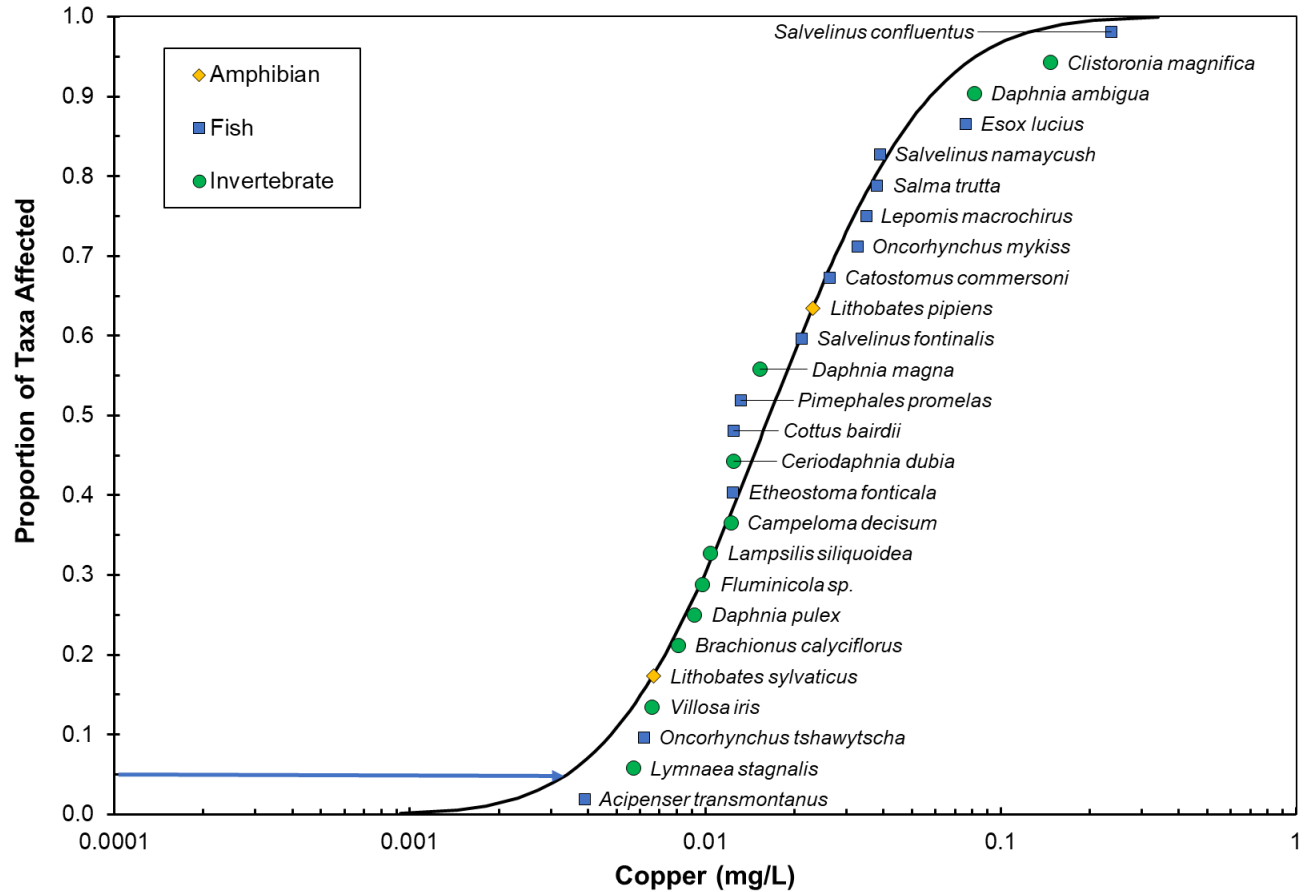


Table 11A-3: Chronic Aquatic Toxicity Data for Copper Used in the Species Sensitivity Distribution for Patterson Lake North Arm – West Basin: Application Case, Reasonable Upper Bound Scenario, Maximum Predicted Copper Concentration

Receptor Group	Species	Common Name	Endpoint	Species Mean Copper Concentration ^(a) (mg/L)
Fish	<i>Acipenser transmontanus</i>	White sturgeon	EC ₂₀	0.0039
Invertebrate	<i>Lymnaea stagnalis</i>	Pond snail	EC ₂₀	0.0057*
Fish	<i>Oncorhynchus tshawytscha</i>	Chinook salmon	EC ₂₀	0.0062
Invertebrate	<i>Villosa iris</i>	Rainbow mussel	EC ₂₀	0.0066*
Amphibian	<i>Lithobates sylvaticus</i>	Wood frog	MATC	0.0067
Invertebrate	<i>Brachionus calyciflorus</i>	Rotifer	EC ₂₀	0.0081*
Invertebrate	<i>Daphnia pulex</i>	Water flea	EC ₂₀ , MATC	0.0092*
Invertebrate	<i>Fluminicola</i> sp.	Snail	EC ₂₀	0.00975
Invertebrate	<i>Lampsilis siliquidea</i>	Fatmucket clam	LOEC, EC ₂₀	0.0104*
Invertebrate	<i>Campeloma decisum</i>	Pointed campeloma (snail)	EC ₂₀	0.0122*
Fish	<i>Etheostoma fontinala</i>	Fountain darter	MATC	0.0124*
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₀	0.0125*
Fish	<i>Pimephales promelas</i>	Fathead minnow	MATC, EC ₂₀	0.0132*
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0153*
Fish	<i>Salvelinus fontinalis</i>	Brook trout	MATC, LOEC	0.0212*
Amphibian	<i>Lithobates pipiens</i>	Northern leopard frog	MATC	0.0231*
Fish	<i>Catostomus commersonii</i>	White sucker	MATC, EC ₂₀ , EC ₂₅	0.0264*
Fish	<i>Cottus bairdii</i>	Mottled sculpin	EC ₂₀	0.0320*
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀ , MATC	0.0328*
Fish	<i>Lepomis macrochirus</i>	Bluegill	EC ₂₀	0.0350

Table 11A-3: Chronic Aquatic Toxicity Data for Copper Used in the Species Sensitivity Distribution for Patterson Lake North Arm – West Basin: Application Case, Reasonable Upper Bound Scenario, Maximum Predicted Copper Concentration

Receptor Group	Species	Common Name	Endpoint	Species Mean Copper Concentration ^(a) (mg/L)
Fish	<i>Salma trutta</i>	Brown trout	MATC	0.0381
Fish	<i>Salvelinus namaycush</i>	Lake trout	MATC	0.0390
Fish	<i>Esox lucius</i>	Northern pike	MATC	0.0762
Invertebrate	<i>Daphnia ambigua</i>	Water flea	EC ₂₀	0.0814
Invertebrate	<i>Clistoronia magnifica</i>	Caddisfly	EC ₂₀	0.147
Fish	<i>Salvelinus confluentus</i>	Bull trout	MATC	0.237

Source: Chronic toxicity values are from Brix et al. (2017, 2021), citing various sources.

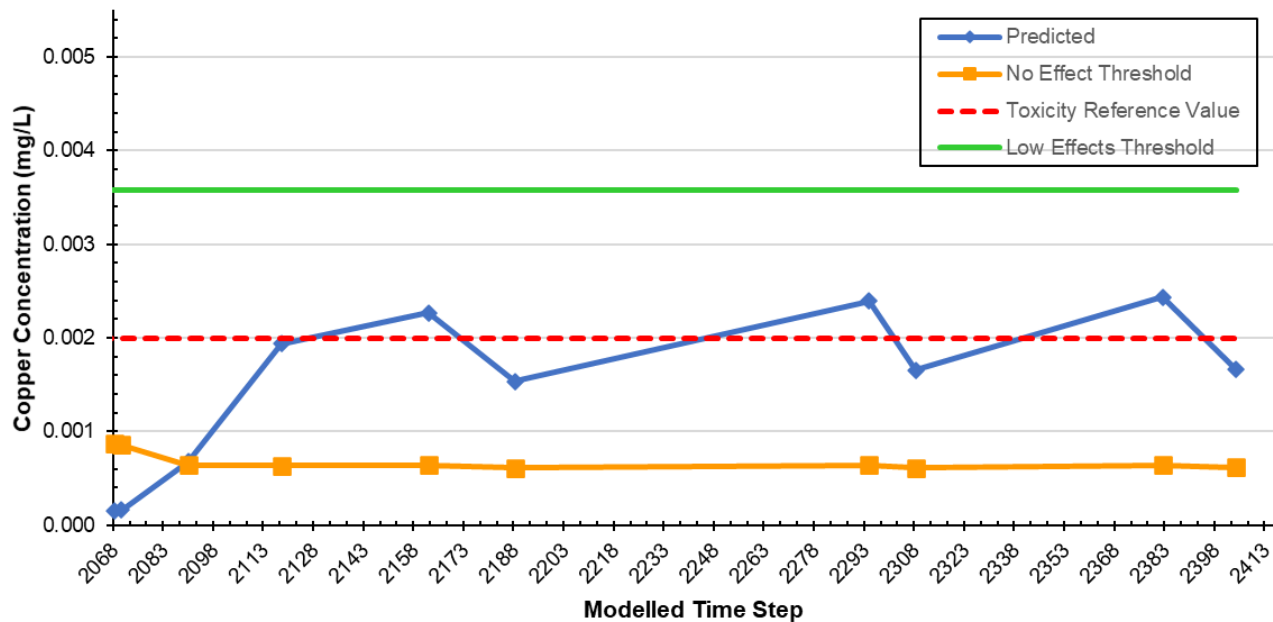
a) Effect concentrations normalized to pH 6.95, DOC of 2.3 mg/L, and hardness of 14.4 mg/L as CaCO₃ using the MLR provided in Table S5 of Brix et al. (2021). When multiple effect concentrations were available for the same species, geometric means were calculated and are marked with an asterisk (*). The full dataset is provided in Attachment 11A-2.

EC₂₀ = 20% effect concentration; MATC = maximum acceptable toxicant concentration; LOEC = lowest observed effect concentration; EC₂₅ = 25% effect concentration; CaCO₃ = calcium carbonate; DOC = dissolved organic carbon; MLR = multiple linear regression.

Patterson Lake North Arm – West Basin: Reasonably Foreseeable Development Case

The BLM and MLR model results for the RFD Case produced similar results to the Application Case. Concentrations of copper are predicted to exceed the no effect threshold beginning around modelled year 2090 but are not expected to exceed the low effects threshold during the far future (Figure 11A-5). Predicted copper concentrations below the low effects thresholds are unlikely to result in adverse effects on fish, invertebrates, or plants.

Figure 11A-5: Predicted Copper Concentrations in Patterson Lake North Arm – West Basin: Reasonably Foreseeable Development Case

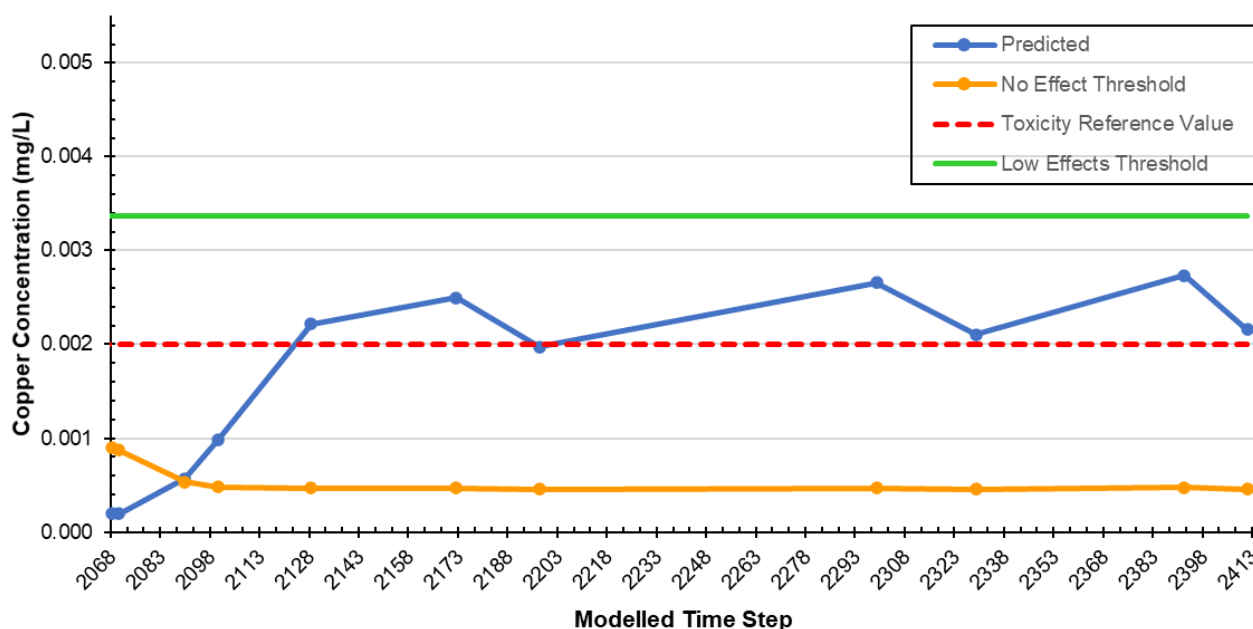


Note: The low effects threshold shown on the plot is based on the HC_5 derived with the lowest predicted hardness. HC_5 = hazard concentration at 5%.

Patterson Lake South Arm: Application Case, Reasonable Upper Bound Scenario

The use of more conservative assumptions in water quality modelling resulted in higher predicted copper concentrations for the reasonable upper bound scenario for the Patterson Lake South Arm, which exceed the no effect threshold from around year 2090 onward (Figure 11A-6). However, predicted copper concentrations remain below the low effects threshold. Predicted copper concentrations below the low effects thresholds are unlikely to result in adverse effects on fish, invertebrates, or plants.

Figure 11A-6: Predicted Copper Concentrations in Patterson Lake South Arm: Application Case, Reasonable Upper Bound Scenario



Note: The low effects threshold shown on the plot is based on the HC_5 derived with the lowest predicted hardness.
 HC_5 = hazard concentration at 5%.

11A4 UNCERTAINTY

As with all models, the BLM and MLR models have limitations based on their assumptions and data inputs. Model limitations mainly related to uncertainty associated with measured and predicted water quality used as inputs. Specific uncertainties associated with the use of the BLM and the MLR model to support the aquatic health assessment are summarized in Table 11A-4. The assessment concluded that the identified uncertainties had low influence on the interpretation or use of the results for the purpose of evaluating the potential for adverse effects on aquatic health due to predicted copper concentrations. The predictive abilities of the BLM and MLR models are expected to offset the uncertainties in parameterization, such that these models as implemented are anticipated to be more accurate than through the use of hardness alone.

Predicted copper concentrations in all scenarios, including the reasonable upper bound scenario, indicated no effects or unlikely effects. Therefore, there is high degree of certainty that the potential effects on aquatic biota have not been under-predicted.

Table 11A-4: Uncertainties Associated with the Biotic Ligand Model and Multiple Linear Regression Model Approaches to Derive No Effect and Low Effects Thresholds

Uncertainty Source / Assumption	Influence on the Interpretation or Use of the BLM and MLR Model Results
Use of the baseline average values to define future conditions	Low: using baseline average values for pH and DOC could lead to lower or higher copper thresholds if future concentrations vary substantially from this condition. - Increased DOC concentrations would mitigate copper toxicity (Grosell 2012) and result in a higher effects thresholds for copper. - Increased pH would also mitigate copper toxicity but a decrease in pH would exacerbate copper toxicity. - Long-term changes in pH or DOC in Patterson Lake due to groundwater seepage is not expected. The reasonableness of the input parameters used in this assessment can be assessed over time through ongoing water quality monitoring in Patterson Lake and waste rock chemistry during Operations and re-evaluating predictions of water quality following Closure using measured data.
Average baseline temperature was outside the prescribed range for the BLM	Low: ECCC (2021c) notes that temperature effects on copper toxicity are relatively minor, and the application of temperature input values outside the range is not a concern. Brix et al. (2017, 2021) did not identify temperature as a key parameter for copper bioavailability.
Use of water quality predictions for the far-future projection	Low: uncertainty associated with the water quality predictions is discussed in EIS Section 10. Water quality predictions for the far-future projection incorporated conservative assumptions, particularly in the reasonable upper bound scenario for the Application Case.
Use of the MLR model to derive low effects thresholds	Low: the MLR model was derived using the same principles of the BLM, which incorporates the latest scientific understanding of copper bioavailability and toxicity. The toxicity database of low effects concentrations was recently compiled according to federal and international standards and provides sufficient information to evaluate predicted copper concentrations.

BLM = biotic ligand model; MLR = multiple linear regression; DOC = dissolved organic carbon; ECCC = Environment and Climate Change Canada.

11A5 REFERENCES

Literature Cited

- Adams W, Blust R, Dwyer R, Mount D, Nordeim, Rodriguez PH, Spry D. 2019. Bioavailability assessment of metals in freshwater environments: A historical review. *Environmental Toxicology and Chemistry*. 39(1):48-59.
- Brix KV, DeForest DK, Tear L, Grosell M, Adams WJ. 2017. Use of multiple linear regression models for setting water quality criteria for copper: A complementary approach to the biotic ligand model. *Environmental Science and Technology*. 51:5182-5192.
- Brix KV, Tear L, Santore RC, Croteau K, DeForest DK. 2021. Comparative performance of multiple linear regression and biotic ligand models for estimating the bioavailability of copper in freshwater. *Environmental Toxicology and Chemistry* 40(6):1649-1661.
- CCME (Canadian Council of Ministers of the Environment). 2007. A Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life 2007. Winnipeg, MB, Canada.
- CCME. 2021. Federal Environmental Quality Guidelines – Copper. April 2021.
- CCREM (Canadian Council of Resource and Environment Ministers). 1987. Canadian water quality guidelines. Canadian Council of Resource and Environment Ministers, Ontario.
- Chapman GA. 1975. Toxicity of Copper, Cadmium and Zinc to Pacific Northwest Salmonids; U.S. Environmental Protection Agency, Corvallis, OR. As cited in Brix et al. (2017).
- Chapman GA. 1982. Letter to Charles E. Stephan, US EPA, Duluth, MN, December 6; U.S. Environmental Protection Agency: Corvallis, OR. As cited in Brix et al. (2017).
- ECCC (Environment and Climate Change Canada). 2021a. *Canadian Environmental Protection Act, 1999 Federal Environmental Quality Guidelines Copper*.
- ECCC. 2021b. BLM Windows Interface, Environment and Climate Change Canada FWQG Chronic Cu BLM Version 1.2.
- ECCC. 2021c. Federal Water Quality Guideline for Copper: Biotic Ligand Model Tool and User Manual. National Guidelines and Standards Office Gatineau, QC.
- Grosell M. 2012. Copper. In Wood CM, Farrell AP, Brauner CJ, editors, Homeostasis and toxicology of essential metals. *Fish Physiology Volume 31A*. New York NY: Academic Press / Elsevier. pp. 53–133.
- ICME (International Council on Metals and the Environment). 1995. Persistence, bio accumulation and toxicity of metals and metal compounds. Ottawa, ON, Canada.
- Mebane CA. 2010. Cadmium risks to freshwater life: Derivation and validation of low-effect criteria values using laboratory and field studies (version 1.2): U.S. Geological Survey Scientific Investigations Report 2006 to 5245. p. 130.
- Paquin PR, Gorsuch JW, Apte S, Batley GE, Bowles KC, Campbell PGC, Delos CG, Di Toro DM, Dwyer RL, Galvez F, et al. 2002. The biotic ligand model: A historical review. *Comparative Biochemistry and Physiology Part C*. 133: 3-35.

- Suter GW II, Sample BE, Jones DS, Ashwood TL, Loar JM. 1995. Approach and strategy for performing ecological risk assessments for the U.S. Department of Energy's Oak Ridge Reservation: 1995 Revision. ES/ER/TM-33/R2. Environmental Restoration Risk Assessment Program, Lockheed Martin Energy Systems, Inc., Oak Ridge, Tennessee, USA.
- USEPA (United States Environmental Protection Agency). 1985. Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and their Uses. Duluth, MN.
- USEPA. 2007. Aquatic Life Ambient Freshwater Quality Criteria - Copper. 2007 Revision. EPA-822-R-07-001. US EPA Office of Water. Washington, DC, USA. 204 pp.
- Wang N, Ingersoll CG, Dorman RA, Brumbaugh WG, Mebane CA, Kunz JL, Hardesty DK. 2014. Chronic sensitivity of white sturgeon (*Acipenser transmontanus*) and rainbow trout (*Oncorhynchus mykiss*) to cadmium, copper, lead, or zinc in laboratory water-only exposures. Environmental Toxicology and Chemistry. 33(10):2246 to 2258.
- WSA (Water Security Agency). 2015. Surface Water Quality Objectives – Interim Edition. Regina, Saskatchewan.

Attachment 11A-1 Patterson Lake Water Quality Data Used in the Biotic Ligand Model and Multiple Linear Regression Analyses

Table 11A-1-1: Model Input Parameters Used in the Aquatic Health Assessment

Patterson Lake Area	Assessment Case or Modelling Scenario	Modelling Time Step	Temperature (°C)	pH	Predicted Copper (mg/L)	DOC (mg/L)	Humic Acids (%)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Sulphate (mg/L)	Chloride (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	BLM HC ₅ (mg/L)	MLR HC ₅ (mg/L)
North Arm – West Basin	Application Case	2068-01-01	6.9	6.95	0.000147	2.3	10	8.732	1.882	8.959	0.55	24.130	1.315	29.0	29.545	0.000832	0.004102
North Arm – West Basin	Application Case	2070-01-01	6.9	6.95	0.000151	2.3	10	8.031	1.786	7.951	0.55	21.194	1.237	29.0	27.401	0.0008	0.004032
North Arm – West Basin	Application Case	2080-01-01	6.9	6.95	0.000321	2.3	10	5.042	1.366	3.730	0.55	8.784	0.875	29.0	18.205	0.000639	0.00368
North Arm – West Basin	Application Case	2090-01-01	6.9	6.95	0.00066	2.3	10	3.795	1.184	2.009	0.55	3.776	0.764	29.0	14.343	0.000555	0.003496
North Arm – West Basin	Application Case	2100-01-01	6.9	6.95	0.000959	2.3	10	3.473	1.143	1.569	0.55	2.556	0.750	29.0	13.367	0.000531	0.003438
North Arm – West Basin	Application Case	2118-04-01	6.9	6.95	0.001943	2.3	10	3.543	1.200	1.523	0.55	2.807	0.936	29.0	13.776	0.000531	0.00346
North Arm – West Basin	Application Case	2162-04-01	6.9	6.95	0.002245	2.3	10	3.530	1.212	1.506	0.55	2.867	0.939	29.0	13.792	0.00053	0.00346
North Arm – West Basin	Application Case	2188-11-01	6.9	6.95	0.001546	2.3	10	3.373	1.153	1.439	0.55	2.374	0.747	29.0	13.162	0.000524	0.003431
North Arm – West Basin	Application Case	2206-04-01	6.9	6.95	0.002259	2.3	10	3.533	1.213	1.508	0.55	2.877	0.942	29.0	13.806	0.00053	0.003459
North Arm – West Basin	Application Case	2250-04-01	6.9	6.95	0.002376	2.3	10	3.543	1.220	1.510	0.55	2.927	0.958	29.0	13.862	0.000531	0.003458
North Arm – West Basin	Application Case	2270-07-01	6.9	6.95	0.001642	2.3	10	3.380	1.158	1.440	0.55	2.416	0.762	29.0	13.198	0.000524	0.003431
North Arm – West Basin	Application Case	2294-04-01	6.9	6.95	0.002431	2.3	10	3.554	1.225	1.514	0.55	2.962	0.971	29.0	13.907	0.000531	0.003479
North Arm – West Basin	Application Case	2308-07-01	6.9	6.95	0.001644	2.3	10	3.372	1.156	1.437	0.55	2.413	0.761	29.0	13.170	0.000524	0.003431
North Arm – West Basin	Application Case	2338-04-01	6.9	6.95	0.002402	2.3	10	3.552	1.224	1.513	0.55	2.944	0.964	29.0	13.897	0.000531	0.003477
North Arm – West Basin	Application Case	2382-04-01	6.9	6.95	0.002431	2.3	10	3.560	1.227	1.517	0.55	2.964	0.972	29.0	13.928	0.000532	0.003486
North Arm – West Basin	Application Case	2404-08-01	6.9	6.95	0.001661	2.3	10	3.391	1.163	1.445	0.55	2.433	0.767	29.0	13.244	0.000525	0.003433
North Arm – West Basin	Application Case, reasonable upper bound scenario	2068-01-01	6.9	6.95	0.000149	2.3	10	10.3	1.9	9.7	0.55	24.54	22.41	29.0	33.571	0.000839	0.004219
North Arm – West Basin	Application Case, reasonable upper bound scenario	2070-01-01	6.9	6.95	0.000157	2.3	10	9.378	1.819	8.611	0.55	21.579	19.481	29.0	30.902	0.000807	0.004143
North Arm – West Basin	Application Case, reasonable upper bound scenario	2090-01-01	6.9	6.95	0.000927	2.3	10	3.979	1.196	2.113	0.55	4.096	2.484	29.0	14.850	0.000559	0.003523
North Arm – West Basin	Application Case, reasonable upper bound scenario	2118-04-01	6.9	6.95	0.002852	2.3	10	3.681	1.236	1.612	0.55	3.538	1.261	29.0	14.273	0.000536	0.003497
North Arm – West Basin	Application Case, reasonable upper bound scenario	2162-04-01	6.9	6.95	0.003307	2.3	10	3.668	1.257	1.595	0.55	3.681	1.223	29.0	14.324	0.000536	0.003496
North Arm – West Basin	Application Case, reasonable upper bound scenario	2188-11-01	6.9	6.95	0.002261	2.3	10	3.467	1.184	1.499	0.55	2.922	0.938	29.0	13.520	0.000528	0.003453
North Arm – West Basin	Application Case, reasonable upper bound scenario	2294-04-01	6.9	6.95	0.003593	2.3	10	3.689	1.274	1.606	0.55	3.829	1.249	29.0	14.447	0.000537	0.003391
North Arm – West Basin	Application Case, reasonable upper bound scenario	2308-07-01	6.9	6.95	0.002412	2.3	10	3.461	1.189	1.498	0.55	2.987	0.944	29.0	13.527	0.000528	0.003453
North Arm – West Basin	Application Case, reasonable upper bound scenario	2382-04-01	6.9	6.95	0.003594	2.3	10	3.695	1.276	1.608	0.55	3.831	1.249	29.0	14.468	0.000537	0.003505
North Arm – West Basin	Application Case, reasonable upper bound scenario	2404-08-01	6.9	6.95	0.002439	2.3	10	3.481	1.196	1.506	0.55	3.012	0.952	29.0	13.606	0.000529	0.003453
North Arm – West Basin	RFD Case	2068-01-01	6.9	6.95	0.000156	2.3	10	9.551	1.969	10.59	0.55	29.49	1.404	29.0	31.951	0.000878	0.004173
North Arm – West Basin	RFD Case	2070-01-01	6.9	6.95	0.000161	2.3	10	9.025	1.895	9.879	0.55	27.514	1.351	29.0	30.332	0.000857	n/m
North Arm – West Basin	RFD Case	2090-01-01	6.9	6.95	0.000677	2.3	10	4.788	1.293	3.925	0.55	10.060	0.884	29.0	17.272	0.000642	n/m
North Arm – West Basin	RFD Case	2118-04-01	6.9	6.95	0.001939	2.3	10	4.741	1.329	3.861	0.55	10.465	1.068	29.0	17.299	0.000639	n/m
North Arm – West Basin	RFD Case	2162-04-01	6.9	6.95	0.002266	2.3	10	4.747	1.344	3.878	0.55	10.652	1.080	29.0	17.376	0.00064	n/m

Table 11A-1-1: Model Input Parameters Used in the Aquatic Health Assessment

Patterson Lake Area	Assessment Case or Modelling Scenario	Modelling Time Step	Temperature (°C)	pH	Predicted Copper (mg/L)	DOC (mg/L)	Humic Acids (%)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Sulphate (mg/L)	Chloride (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	BLM HC ₅ (mg/L)	MLR HC ₅ (mg/L)
North Arm – West Basin	RFD Case	2188-11-01	6.9	6.95	0.001538	2.3	10	4.335	1.256	3.321	0.55	8.542	0.852	29.0	15.990	0.000614	n/m
North Arm – West Basin	RFD Case	2294-04-01	6.9	6.95	0.002397	2.3	10	4.773	1.354	3.902	0.55	10.776	1.099	29.0	17.484	0.000641	n/m
North Arm – West Basin	RFD Case	2308-07-01	6.9	6.95	0.001653	2.3	10	4.328	1.259	3.301	0.55	8.528	0.870	29.0	15.982	0.000613	0.003581
North Arm – West Basin	RFD Case	2382-04-01	6.9	6.95	0.002435	2.3	10	4.806	1.361	3.950	0.55	10.943	1.112	29.0	17.594	0.000643	n/m
North Arm – West Basin	RFD Case	2404-08-01	6.9	6.95	0.001665	2.3	10	4.388	1.270	3.392	0.55	8.816	0.879	29.0	16.177	0.000617	n/m
South Arm	Application Case, reasonable upper bound scenario	2068-01-01	7.5	6.89	0.000198	2.2	10	16.65	2.775	18.87	0.57	52.05	40.53	31.0	53.002	0.000897	0.004435
South Arm	Application Case, reasonable upper bound scenario	2070-01-01	7.5	6.89	0.000196	2.2	10	15.64	2.680	17.288	0.57	47.260	37.182	31.0	50.094	0.00087	n/m
South Arm	Application Case, reasonable upper bound scenario	2090-01-01	7.5	6.89	0.000571	2.2	10	5.432	1.480	3.558	0.57	7.804	5.733	31.0	19.648	0.000534	n/m
South Arm	Application Case, reasonable upper bound scenario	2100-01-01	7.5	6.89	0.000987	2.2	10	4.340	1.370	2.132	0.57	3.913	2.198	31.0	16.468	0.00048	n/m
South Arm	Application Case, reasonable upper bound scenario	2128-12-01	7.5	6.89	0.002216	2.2	10	4.237	1.451	1.768	0.57	3.288	1.158	31.0	16.542	0.00047	n/m
South Arm	Application Case, reasonable upper bound scenario	2172-12-01	7.5	6.89	0.002498	2.2	10	4.251	1.473	1.761	0.57	3.366	1.117	31.0	16.668	0.00047	n/m
South Arm	Application Case, reasonable upper bound scenario	2197-06-01	7.5	6.89	0.001971	2.2	10	3.907	1.352	1.614	0.57	2.885	0.944	31.0	15.312	0.000458	0.003366
South Arm	Application Case, reasonable upper bound scenario	2299-08-01	7.5	6.89	0.002658	2.2	10	4.204	1.464	1.742	0.57	3.416	1.116	31.0	16.512	0.000468	n/m
South Arm	Application Case, reasonable upper bound scenario	2329-06-01	7.5	6.89	0.002102	2.2	10	3.927	1.365	1.623	0.57	2.952	0.952	31.0	15.416	0.000458	n/m
South Arm	Application Case, reasonable upper bound scenario	2392-09-01	7.5	6.89	0.002731	2.2	10	4.267	1.487	1.768	0.57	3.487	1.141	31.0	16.762	0.000471	n/m
South Arm	Application Case, reasonable upper bound scenario	2411-06-01	7.5	6.89	0.002155	2.2	10	3.887	1.352	1.608	0.57	2.969	0.960	31.0	15.260	0.000457	0.003364

BLM = biotic ligand model; DOC = dissolved organic carbon; MLR = multiple linear regression; RFD = reasonably foreseeable development; n/m = not modelled; HC₅ = 5% hazard concentration.

Attachment 11A-2 Chronic Toxicity Data Used in Species Sensitivity Distribution for Modelled Maximum Copper Concentration

Table 11A-2-1: Chronic Toxicity Data Normalized Using the Multiple Linear Regression Model, Adapted from Table S5 in Brix et al. (2021)

Receptor Group	Species	Common Name	Endpoint	Normalized Effects Concentration in Brix et al. (2021) ^(a) (mg/L)	Normalized Effect Concentration ^(b) (mg/L)	Species Mean Chronic Value (mg/L)
Fish	<i>Acipenser transmontanus</i>	White sturgeon	EC ₂₀	0.0018	0.00388	0.00388
Invertebrate	<i>Brachionus calyciflorus</i>	Rotifer	EC ₂₀	0.0018	0.00402	0.0081
Invertebrate	<i>Brachionus calyciflorus</i>	Rotifer	EC ₂₀	0.0029	0.00642	
Invertebrate	<i>Brachionus calyciflorus</i>	Rotifer	EC ₂₀	0.0062	0.01375	
Invertebrate	<i>Brachionus calyciflorus</i>	Rotifer	EC ₂₀	0.0055	0.01223	
Invertebrate	<i>Cameloma decisum</i>	Pointed cameloma (snail)	EC ₂₀	0.0049	0.01086	0.0122
Invertebrate	<i>Cameloma decisum</i>	Pointed cameloma (snail)	EC ₂₀	0.0061	0.01361	
Fish	<i>Catostomus commersonii</i>	White sucker	MATC	0.0119	0.02635	0.02635
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₀	0.0052	0.01152	0.0125
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₀	0.0019	0.00414	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₀	0.0454	0.10052	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	MATC	0.0343	0.07595	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	MATC	0.0485	0.10726	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₅	0.0164	0.03621	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₅	0.0035	0.00768	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₅	0.0023	0.00498	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₅	0.0030	0.00655	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₅	0.0027	0.00593	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₅	0.0065	0.01430	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₅	0.0029	0.00647	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₀	0.0005	0.00114	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₀	0.0115	0.02553	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₀	0.0074	0.01643	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₀	0.0040	0.00884	
Invertebrate	<i>Ceriodaphnia dubia</i>	Water flea	EC ₂₀	0.0026	0.00568	
Invertebrate	<i>Clistoronia magnifica</i>	Caddisfly	EC ₂₀	0.0666	0.14744	0.14744
Fish	<i>Cottus bairdii</i>	Mottled sculpin	EC ₂₀	0.0134	0.02959	0.032
Fish	<i>Cottus bairdii</i>	Mottled sculpin	EC ₂₀	0.0156	0.03461	
Invertebrate	<i>Daphnia ambigua</i>	Water flea	EC ₂₀	0.0368	0.08142	0.08142
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0068	0.01514	0.0153
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0070	0.01545	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0053	0.01180	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0059	0.01314	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0061	0.01359	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0117	0.02590	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0019	0.00413	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0069	0.01528	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0055	0.01211	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0084	0.01856	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0122	0.02692	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0043	0.00941	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0090	0.02000	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0086	0.01909	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0065	0.01442	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0088	0.01936	

Table 11A-2-1: Chronic Toxicity Data Normalized Using the Multiple Linear Regression Model, Adapted from Table S5 in Brix et al. (2021)

Receptor Group	Species	Common Name	Endpoint	Normalized Effects Concentration in Brix et al. (2021) ^(a) (mg/L)	Normalized Effect Concentration ^(b) (mg/L)	Species Mean Chronic Value (mg/L)
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0059	0.01309	0.0153
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0062	0.01380	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0090	0.01991	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0086	0.01912	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0050	0.01105	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0068	0.01511	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0072	0.01585	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0081	0.01791	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0068	0.01495	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0086	0.01896	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0079	0.01741	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0130	0.02876	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0068	0.01495	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0066	0.01452	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0063	0.01386	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0105	0.02330	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0073	0.01612	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0067	0.01491	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0119	0.02640	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0068	0.01500	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0146	0.03233	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0083	0.01829	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0072	0.01602	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0100	0.02208	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0077	0.01714	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0118	0.02619	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0106	0.02338	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0096	0.02120	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0081	0.01783	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0074	0.01638	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0076	0.01687	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0082	0.01807	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0057	0.01269	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0058	0.01283	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0069	0.01518	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0046	0.01011	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0074	0.01634	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0030	0.00658	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0035	0.00767	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0041	0.00905	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0049	0.01091	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0046	0.01021	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0034	0.00750	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0060	0.01336	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0062	0.01383	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0069	0.01521	

Table 11A-2-1: Chronic Toxicity Data Normalized Using the Multiple Linear Regression Model, Adapted from Table S5 in Brix et al. (2021)

Receptor Group	Species	Common Name	Endpoint	Normalized Effects Concentration in Brix et al. (2021) ^(a) (mg/L)	Normalized Effect Concentration ^(b) (mg/L)	Species Mean Chronic Value (mg/L)
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0071	0.01571	0.0153
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0059	0.01304	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0059	0.01298	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0092	0.02035	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0036	0.00795	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0033	0.00738	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0080	0.01769	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0129	0.02847	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0068	0.01512	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0061	0.01346	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0053	0.01167	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0055	0.01209	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0097	0.02147	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0082	0.01822	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0200	0.04418	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0129	0.02853	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0063	0.01393	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0065	0.01445	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0146	0.03235	
Invertebrate	<i>Daphnia magna</i>	Water flea	EC ₂₀	0.0017	0.00378	
Invertebrate	<i>Daphnia pulex</i>	Water flea	EC ₂₀	0.0024	0.00536	0.0092
Invertebrate	<i>Daphnia pulex</i>	Water flea	MATC	0.0051	0.01124	
Invertebrate	<i>Daphnia pulex</i>	Water flea	EC ₂₀	0.0059	0.01305	
Fish	<i>Esox lucius</i>	Northern pike	MATC	0.0344	0.07618	0.07618
Fish	<i>Etheostoma fontinala</i>	Fountain darter	MATC	0.0051	0.01135	0.0124
Fish	<i>Etheostoma fontinala</i>	Fountain darter	MATC	0.0061	0.01359	
Invertebrate	<i>Fluminicola</i> sp.	Snail	EC ₂₀	0.0044	0.00975	0.00975
Invertebrate	<i>Lampsilis siliquoidea</i>	Fatmucket clam	LOEC	0.0024	0.00523	0.0104
Invertebrate	<i>Lampsilis siliquoidea</i>	Fatmucket clam	EC ₂₀	0.0093	0.02063	
Fish	<i>Lepomis macrochirus</i>	Bluegill	EC ₂₀	0.0158	0.03501	0.03501
Amphibian	<i>Lithobates pipiens</i>	Northern leopard frog	MATC	0.0051	0.01124	0.0232
Amphibian	<i>Lithobates pipiens</i>	Northern leopard frog	MATC	0.0215	0.04766	
Amphibian	<i>Lithobates sylvaticus</i>	Wood frog	MATC	0.0030	0.00665	0.00665
Invertebrate	<i>Lymnaea stagnalis</i>	Pond snail	EC ₂₀	0.0019	0.00410	0.0057
Invertebrate	<i>Lymnaea stagnalis</i>	Pond snail	EC ₂₀	0.0088	0.01950	
Invertebrate	<i>Lymnaea stagnalis</i>	Pond snail	EC ₂₀	0.0030	0.00666	
Invertebrate	<i>Lymnaea stagnalis</i>	Pond snail	EC ₂₀	0.0009	0.00193	
Invertebrate	<i>Lymnaea stagnalis</i>	Pond snail	EC ₂₀	0.0027	0.00606	
Invertebrate	<i>Lymnaea stagnalis</i>	Pond snail	EC ₂₀	0.0027	0.00606	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0153	0.03392	0.0328
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	MATC	0.0116	0.02558	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	MATC	0.0062	0.01375	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	MATC	0.0335	0.07419	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0089	0.01979	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0083	0.01836	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0304	0.06729	

Table 11A-2-1: Chronic Toxicity Data Normalized Using the Multiple Linear Regression Model, Adapted from Table S5 in Brix et al. (2021)

Receptor Group	Species	Common Name	Endpoint	Normalized Effects Concentration in Brix et al. (2021) ^(a) (mg/L)	Normalized Effect Concentration ^(b) (mg/L)	Species Mean Chronic Value (mg/L)
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0100	0.02220	0.0328
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0117	0.02597	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0130	0.02870	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0111	0.02459	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0118	0.02615	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0224	0.04953	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0139	0.03078	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0187	0.04140	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0178	0.03938	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0337	0.07455	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0091	0.02016	
Fish	<i>Oncorhynchus mykiss</i>	Rainbow trout	EC ₂₀	0.0330	0.07311	
Fish	<i>Oncorhynchus tshawytscha</i>	Chinook salmon	EC ₂₀	0.0028	0.00620	0.0062
Fish	<i>Pimephales promelas</i>	Fathead minnow	MATC	0.0079	0.01759	0.0132
Fish	<i>Pimephales promelas</i>	Fathead minnow	MATC	0.0021	0.00464	
Fish	<i>Pimephales promelas</i>	Fathead minnow	MATC	0.0116	0.02558	
Fish	<i>Pimephales promelas</i>	Fathead minnow	EC ₂₀	0.0213	0.04724	
Fish	<i>Pimephales promelas</i>	Fathead minnow	EC ₂₀	0.0019	0.00410	
Fish	<i>Salma trutta</i>	Brown trout	MATC	0.0172	0.03810	0.0381
Fish	<i>Salvelinus confluentus</i>	Bull trout	MATC	0.1072	0.23721	0.23721
Fish	<i>Salvelinus fontinalis</i>	Brook trout	MATC	0.0178	0.03931	0.0212
Fish	<i>Salvelinus fontinalis</i>	Brook trout	LOEC	0.0052	0.01144	
Fish	<i>Salvelinus namaycush</i>	Lake trout	MATC	0.0176	0.03904	0.03904
Invertebrate	<i>Villosa iris</i>	Rainbow mussel	EC ₂₀	0.0069	0.01534	0.0066
Invertebrate	<i>Villosa iris</i>	Rainbow mussel	EC ₂₀	0.0016	0.00344	
Invertebrate	<i>Villosa iris</i>	Rainbow mussel	EC ₂₀	0.0024	0.00538	

a) As presented in Table S5 of Brix et al. (2021); these are chronic toxicity data normalized to pH 7.5, DOC of 0.5 mg/L, and hardness of 85 mg/L using the multiple regression equation in Table S5 in Brix et al. (2021).

b) Chronic toxicity data normalized to site characteristics of pH 6.95, DOC of 2.3 mg/L, and hardness of 14.447 mg/L using the MLR equation in Table S5 in Brix et al. (2021).

MATC = maximum acceptable toxicant concentration; DOC = dissolved organic carbon; EC₂₀ = 20% effect concentration; EC₂₅ = 25% effect concentration; LOEC = lowest observed effect concentration; MLR = multiple linear regression.