VOLUME 1:

MILESTONE 3 - FINAL SEA REPORT

Strategic Environmental Assessment of Wood Buffalo National Park World Heritage Site

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May 2018

COVERING LETTER

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30 May 2018

Parks Canada
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Attention: Katherine Cumming
National Manager of Impact Assessment, Natural Resource Conservation Branch

RE: **Final Strategic Environmental Assessment of Potential Cumulative Impacts of all Developments on the Outstanding Universal Value of Wood Buffalo National Park World Heritage Site**

Independent Environmental Consultants (IEC) is pleased to submit this final Strategic Environmental Assessment (SEA) report. This two-volume report is being submitted in accordance with completion of Milestone 3 of the above noted Contract.

Yours very truly,
Independent Environmental Consultants

Donald M. Gorber, PhD, P. Eng.
President

ACKNOWLEDGEMENT

The journey to complete this Strategic Environmental Assessment has involved the gathering of a significant volume of available information, including both western science and Indigenous Traditional Knowledge. All of this has been accomplished through phone discussions with government staff, researchers, industrial associations and Non-Government Environmental Organizations, and face-to-face meetings with the local Cree, Dene and Métis representatives. This valuable and graciously provided information has made this report a more complete and holistic document.

In particular we valued the participation, cooperation, direct input, and review from the Indigenous groups in and around the Wood Buffalo National Park, including Mikisew Cree First Nation, Athabasca Chipewyan First Nation, Fort Chipewyan Métis Local 125, Little Red River Cree Nation, Salt River First Nation, Smith's Landing First Nation, K'atlodeeche First Nation, Deninu K'ue First Nation, and Northwest Territories Métis Nation (Hay River Métis Government Council and Fort Smith Métis, and Fort Resolution Métis Council). These groups have a generational commitment to the land, water and animals of the park and its surrounding area. They have lived there since long before the park was formed and, in remembering what it was like in the past, hope to restore it for future generations. They are proud and eloquent peoples with the ability to cut to the heart of the issue to develop powerful sayings such as "Water is Boss", which directly communicate their thoughts in a very meaningful way. The various meetings with Elders, councillors, land users and other community members were extremely valuable to this report. In spite of sharing their stories many times for similar studies, the land users were very generous with their time and participated in the SEA process in good faith. Each of the Indigenous groups were given an opportunity to review, edit and provide input to the report before it went out to others for review. For these generous and open contributions, we are extremely grateful.

There are many researchers working on environmental, social, cultural, Indigenous and engineering issues related to the park. Where there were alternative views on topics, we have tried to present both sides. We thank those researchers for their valuable input. To all members of the IEC team and all your valuable contributions, a heartfelt thanks. In particular, the endless hours put in by Lisa White and Cole Atlin in researching, writing, editing and meeting with the Indigenous peoples has to be recognized.

Lastly, this was a Parks Canada project. Their help in directing, coordinating, writing and editing the report, facilitating meetings with researchers, government partners, and Indigenous groups and providing guidance throughout the project was an extremely valuable contribution. Specifically, the extensive input and involvement by Katherine Cumming, Steve Oates, Patrick Yarnell, Stuart Macmillan, Cam Zimmer and Don Aubrey is greatly appreciated.

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SYMBOLS, ABBREVIATIONS AND ACRONYMS

~	approximately
<	less than
>	greater than
AB	Province of Alberta
ABF	Aboriginal Base Flow
ACFN	Athabasca Chipewyan First Nation
AERCB	Alberta Energy Resources Conservation Board
AFN	Assembly of First Nations
Al	aluminum
ANI	Aboriginal Navigation Index
ARB	Athabasca River Basin
As	arsenic
Avg	Average
AWBP	Aransas-Wood Buffalo Population of Whooping Cranes
AXF	Aboriginal Extreme Flow
BC	Province of British Columbia
BCA	Bison Control Area
C	Celsius
CAPMon	Canadian Air and Precipitation Monitoring Network
CAPP	Canadian Association of Petroleum Producers
CAAQS	Canadian Ambient Air Quality Standards
CCME	Canadian Council of Ministers of the Environment
CEA	Cumulative Effects Assessment

CEAA 2012	*Canadian Environmental Assessment Act*, 2012
CEAA	Canadian Environmental Assessment Agency
CEMA	Cumulative Environmental Management Association
CH_4	Methane
Cl	chloride
cm	centimetre
CMC	Cooperative Management Committee
CNPA	*Canada National Parks Act*
CBM	Community Based Monitoring
CFIA	Canadian Food Inspection Agency
CL-RAs	chlorinated resin acids
cm	centimetre
CO	carbon monoxide
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
Cr	chromium
CSS	Cyclic Steam Stimulation
CTMP	Chemical Thermo-Mechanical Pulping
Cu	copper
CWS	Canadian Wildlife Service
dam^3	cubic decametres
DBT	Dibenzothiopene
DFO	Fisheries and Oceans Canada
DKFN	Deninu K'ue First Nation
EA	Environmental Assessment
EARMP	Eastern Athabasca Regional Monitoring Program

ECCC	Environment and Climate Change Canada
EI	Ecological Integrity
EIS	Environmental Impact Statement
EMSD	Environmental Monitoring and Science Division
ENGOs	Environmental Non-Government Organisations
EROD	Ethoxyresorufin-O-deethylase
ETA	external tailings area
FA	Federal Authority
Fe	iron
FFT	fine fluid tailings
FPT	Federal, Provincial, Territorial
ft	feet
GHG	Greenhouse Gas
GIR	Government Industry Relations
GoA	Government of Alberta
GOWN	Groundwater Observation Well Network
GWh/year	Gigawatt hours per year
Ha	hectare
Hg	mercury
IAS	Invasive Alien Species
IEC	Independent Environmental Consultants
ITK	Indigenous Traditional Knowledge
IUCN	International Union for the Conservation of Nature
JOSM	Joint Oil Sands Monitoring
JPM	Jackpine Oil Sands Mine

JRP	Joint Review Panel
KFN	K'atl'odeeche First Nation
km	kilometer
km^2	square kilometre
L/s	litres per second
LAR	Lower Athabasca River
LARP	Lower Athabasca Regional Plan
LRRCN	Little Red River Cree Nation
m	metre
mm	millimetre
m^3	cubic metre
m^3/year	cubic metres per year
m^3/s	cubic metres per second
MAF	mean annual flood
Mb	molybdenum
MCBA	*Migratory Birds Convention Act*
MCFN	Mikisew Cree First Nation
MeHg	Methylmercury
Mg	magnesium
Mn	manganese
MOSR/A	Mineable Oil Sands Region/Area
MSES	Management and Solutions in Environmental Sciences
MW	Megawatt
N	nitrogen
Na	sodium

NAOS	Northern Athabasca Oil Sands area
n.d.	no date
ng/L	nanograms per litre
NH_3	ammonia
Ni	nickel
NO	nitric oxide
NO_2	nitrogen dioxide
NOx	Nitrogen oxides
NMHCs	non-methane hydrocarbons
NRBS	Northern River Basins Study
NRCAN	Natural Resources Canada
NWT	Northwest Territories
O_3	ozone
OSPW	Oil Sands Process-affected Water
OUV	Outstanding Universal Value
P	phosphorus
PAC	Polycyclic Aromatic Compounds
PAD	Peace-Athabasca Delta
PAH	Polycyclic Aromatic Hydrocarbon
PADEMP	Peace-Athabasca Delta Ecological Monitoring Program
Pb	lead
PBPAHs	products of biotransformation of PAHs
PBDEs	Polybrominated diphenyl ethers
PCA	Parks Canada Agency
PCBs	Polychlorinated Biphenyls

$PM_{2.5}$	particulate matter
PPPs	Policies, Plans, and Proposals
RAMP	Regional Aquatics Monitoring Program
RSEA	Regional Strategic Environmental Assessment
RFD	Reasonably Foreseeable Developments
RFP	Request for Proposals
RMM	Reactive Monitoring Mission
ROR	Run-of-River
SAGD	Steam-Assisted Gravity Drainage
SAOS	Southern Athabasca Oil Sands area
SARA	*Species at Risk Act*
Se	selenium
SEA	Strategic Environmental Assessment
SLFN	Smith's Landing First Nation
SO_2	sulfur dioxide
SO_3	sulfate
SRFN	Salt River First Nation
SWQMF	Surface Water Quantity Management Framework
TDS	Total Dissolved Solids
THC	Total Hydrocarbons
THg	Total Mercury
ToR	Terms of Reference
TP	Total Phosphorus
TRS	Total Reduced Sulfur
TSS	Total Suspended Solids

µg/L	Micrograms per Litre
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
US EPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
V	vanadium
VC	Valued Component
VOC	Volatile Organic Compounds
WBEA	Wood Buffalo Environmental Association
WBNP	Wood Buffalo National Park of Canada
WHC	World Heritage Committee
WHS	World Heritage Site
WQI	Water Quality Index
Zn	zinc

DEFINITIONS

Aboriginal Base Flow (ABF)

A flow rate that "reflects a level on the Athabasca River and adjacent streams where MCFN members are able to practice their rights, and access their territories fully" (Candler et al., 2010).

Aboriginal Extreme Flow (AXF)

A flow rate that "reflects a level at which widespread and extreme disruption of Treaty and aboriginal rights occurs along the Athabasca river, delta, and tributaries due to a loss of access related to low waters" (Candler et al., 2010).

Bison Control Area (BCA)

An area created in 1987 to reduce the risk of tuberculosis or brucellosis spreading to uninfected bison in the Mackenzie, Nahanni and Hay-Zama (Alberta) populations. The BCA is managed as a bison-free zone designed to prevent bison from moving out of the Slave River Lowlands or WBNP area from coming into contact with uninfected populations.

Canadian Council of Ministers of the Environment (CCME)

Primary minister-led intergovernmental forum for collective action on environmental issues of national and international concern. It is comprised of the environment ministers from the Canadian federal, provincial, and territorial governments. The Council seeks to achieve positive environmental results, focusing on issues that are Canada-wide in scope and that require collective attention by a number of governments (Canadian Council of Ministers of the Environment, 2014a).

Critical Factors

Those characteristics of the environment essential to the integrity of important ecological, cultural or visitor experience resources that are likely to be affected by the proposal or activity. See also Valued Components.

Cumulative Effect

A change in the environment caused by multiple interactions among human activities and natural processes that accumulate across space and time (Canadian Council of Ministers of the Environment, 2014b).

Cumulative Effects Assessment (CEA)

A systematic process of identifying, analyzing, and evaluating cumulative effects (Canadian Council of Ministers of the Environment, 2014b).

Cumulative Effects Management

Identification and implementation of measures to control, minimize or prevent the adverse consequences of cumulative effects (Canadian Council of Ministers of the Environment, 2014b).

Cumulative Environmental Management Association (CEMA)

Multi-stakeholder group operating in the Regional Municipality of Wood Buffalo, Alberta that provides advice and recommendations to provincial and federal governments on management of cumulative impact of oil sands development in North-Eastern Alberta. The group has delivered management frameworks for Acid Deposition, Trace Metals, Nitrogen, Ecosystems and Water, and others parameters (Cumulative Environmental Management Association, 2012).

Cyclic Steam Stimulation (CSS)

Method applied to heavy-oil reservoirs to boost recovery during the primary production phase by injecting steam to thin the oil so it will more easily move through the formation to the injection/production wells (US Department of Energy, n.d.).

Ecological Integrity (EI)

A condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes. (s. 2(1) *Canada National Parks Act)*

Environment

Consistent with the Bellagio Principles of sustainable development, environment in this document adopts a holistic perspective and includes the biophysical and the human environment and their component interactions (Canadian Council of Ministers of the Environment, 2009).

Environmental Assessment (EA)

A generic term that is often used interchangeably as a qualifier for specific types of impact assessment, such as ‘project-based’ environmental assessment or ‘strategic-based’ environmental assessment (Canadian Council of Ministers of the Environment, 2009).

Indigenous Traditional Knowledge (ITK)

Commonly understood to refer to collective knowledge of traditions used by Indigenous groups to sustain and adapt themselves to their environment over time. This information is passed on from one generation to the next within the Indigenous group. Such Traditional Knowledge is unique to Indigenous communities and is rooted in the rich culture of its peoples.

Joint Oil Sands Monitoring (JOSM)

The Governments of Canada and Alberta have committed to implementing scientifically rigorous, comprehensive, integrated and transparent environmental monitoring of the oil sands region to ensure this important national resource is developed in a responsible way. Working together, the implementation of monitoring enhancements will ensure installation of necessary infrastructure and appropriate integration with existing monitoring activities in the region. Our efforts contribute to an improved understanding of the long-term cumulative effects of oil sands development (Government of Canada, 2017).

List of World Heritage in Danger

Properties which the World Heritage Committee has decided to include on the List of World Heritage in danger in accordance with Article 11 (4) of the World Heritage Convention (UNESCO- List of World Heritage in Danger, 2018).

Methodological Framework

A methodology is a higher-order activity—a framework or structure for organizing a process, a way by which SEA is performed, a system of conduct, a series of systematic steps (CCME, 2009).

Mineable Oil Sands Region (MOSR)

A 4,800 km^2 area north of Fort McMurray, AB where the top of the oil sands deposit lies less than 75 metres below the ground. This is the only area where surface mining has been deemed an appropriate extraction method (Alberta Environment and Parks, n.d.).

Outstanding Universal Value (OUV) (Also known as World Heritage Values)

The basis for a site's inscription on the World Heritage List, it is defined in paragraph 49 of the Operational Guidelines for the Implementation of the World Heritage Convention (WHC.15/01 8 July 2015) as "...natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole. The Committee defines the criteria for the inscription of properties on the World Heritage List" (WHC.15/01. July 2015).

Peace-Athabasca Delta Ecological Monitoring Program (PADEMP)

Initiated by Parks Canada in 2008, PADEMP is a multi-stakeholder group established to develop an integrated ecological monitoring program that can measure, evaluate and communicate the state of the Peace Athabasca Delta ecosystem including any changes to this ecosystem that result from cumulative regional development. PADEMP includes 11 Indigenous governments, 6 provincial, federal and territorial governments, and 2 non-governmental organizations.

Polycyclic Aromatic Compounds (PAC)

A group of more than 100 different chemicals that are released from burning coal, oil, gasoline, trash, tobacco, wood, or other organic substances such as charcoal-broiled meat. They can occur naturally when they are released from forest fires and volcanoes. Other activities that release PAHs include driving, agricultural burning, roofing or working with coal tar products, sound- and water-proofing, coating pipes, steelmaking, and paving with asphalt. PAHs are persistent organic pollutants. Polycyclic Aromatic Hydrocarbons (PAHs) are a type of PACs. (U.S. National Library of Medicine, 2018).

Project

For the purpose of this document, 'project' refers to physical actions, development activities, or physical works on the landscape as per the definition of 'project' under the *Canadian Environmental Assessment Act* (CCME, 2009).

Ramsar Convention

The Convention on Wetlands, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources (Ramsar website).

Regional Strategic Environmental Assessment (RSEA)

A process designed to systematically assess the potential environmental effects, including cumulative effects, of alternative strategic initiatives, plans, or programs for a region (CCME, 2009).

Reactive Monitoring Mission (RMM)

A component of statutory reporting on the state of conservation of specific properties that are under threat, as undertaken by the Secretariat and the Advisory Bodies to the World Heritage Committee. They are requested by the World Heritage Committee to ascertain, in consultation with the State Party concerned, the condition of the property, the dangers to the property and the feasibility of adequately restoring the property or to assess progress made in implementing such corrective measures, and include a reporting back to the Committee on the findings of the mission. The terms of reference of Reactive Monitoring Missions are proposed by the World Heritage Centre, in line with the decision adopted by the World Heritage Committee, and consolidated in consultation with the State Party and the relevant Advisory Body(ies) (WHC.15/01. July 2015).

State Party

States Parties are countries that adhere to the World Heritage Convention. In this context, Canada is the State Party, and as such, works with the provinces and territories in its implementation of the Convention. In the context of Decision 39 COM 7B.18, Canada as State Party, is working with Provincial and Territorial Governments with a role in approving or managing projects that may potentially generate impacts upon the OUV of WBNP. This includes the governments of Canada, British Columbia, Alberta, and the Northwest Territories. Parks Canada, as the federal agency responsible for implementation of the World Heritage Convention in Canada, is taking a lead role to plan and host a Reactive Monitoring Mission whereby World Heritage Centre and IUCN representatives visit Canada at the request of the Committee to investigate the state of conservation of WBNP and the threats to its conservation status.

Strategic Environmental Assessment (SEA)

The systematic process of evaluating the potential environmental effects of proposed or existing policies, plans, and programs and their alternatives (CCME, 2009).

Steam-Assisted Gravity Drainage (SAGD)

High-temperature steam is injected underground through a horizontal well to melt the bitumen, allowing it to flow to an adjacent horizontal well. From there, it is pumped to the surface for further processing. Steam injection and oil production happen continuously and simultaneously. The resulting mixture of bitumen and water (which is condensed from the steam) is then piped from the producing well to a nearby upgrading plant, where the bitumen is separated from the water and treated. The produced water is then recycled to steam generators to generate new steam, which then travels through above-ground pipelines back to the wells for injection (ConocoPhillips Canada, 2018)

Valued Components (VCs)

Components of the environment (biophysical and human) that are identified as important ecologically, socially, or economically and are the focus of attention in environmental assessment (CCME, 2009).

World Heritage Convention

The World Heritage Convention, (Full title: "The Convention Concerning the Protection of the World Cultural and Natural Heritage"), was adopted by UNESCO in 1972 and signed by Canada in 1976. As of August 15, 2014 there are 191 countries (“State Parties”) that are party to The Convention. Through this instrument nations of the world agree to inventory, recognize, and protect unique and irreplaceable properties of universal value.

World Heritage Site

Exceptional places around the world that are considered to have Outstanding Universal Value. As such, they are part of the common heritage of humankind. “State Parties,” such as Canada, which have ratified UNESCO’s 1972 Convention Concerning the Protection of the World Cultural and Natural Heritage, have pledged to ensure the identification, protection, conservation, presentation and transmission to future generations of World Heritage sites in their territory and to avoid deliberate measures that could damage World Heritage in other countries (Parks Canada, 2017).

World Heritage Values (Also known Outstanding Universal Value (OUV))

The basis for a site’s inscription on the World Heritage List, it is defined in paragraph 49 of the Operational Guidelines for the Implementation of the World Heritage Convention (WHC.15/01 8 July 2015) as “...natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole. The Committee defines the criteria for the inscription of properties on the World Heritage List" (WHC.15/01. July 2015).

EXECUTIVE SUMMARY


Peace-Athabasca Delta, August 2017. Photo: Parks Canada

Wood Buffalo National Park (WBNP) was established in the 1920s to protect the last remaining herds of bison in northern Canada. Straddling the boundary of northern Alberta and southern Northwest Territories, WBNP is the largest national park in Canada with an area of 44,807 square kilometres. In 1983, the global significance of WBNP was recognized with its designation as a world heritage site. The addition of WBNP to the World Heritage List recognizes the international importance of the landscapes and species that the park protects. The world heritage values include: salt plains, gypsum karst, Great Plains boreal grasslands, wolf-bison predator prey relationship, migratory waterfowl, and the Peace-Athabasca Delta (PAD).

In 2014, Mikisew Cree First Nation (MCFN) petitioned the World Heritage Committee to have WBNP added to the List of World Heritage in Danger. For Indigenous groups that rely on the Peace-Athabasca Delta (PAD), their way of life, who they are, is interconnected with the world heritage values, specifically with maintaining healthy relationships between water, vegetation, birds, animals and people. Following their obligations as stewards of their territory, MCFN's petition described observations by MCFN Elders and land-users, and other evidence that existing upstream developments have driven the waters, lands and resources in the PAD – and MCFN's way of life – to a point of crisis. In 2015, the World Heritage Committee responded to the petition by asking Canada to undertake a Strategic Environmental Assessment (SEA) of the cumulative impacts of all developments (including hydroelectric dams, oil sands development, and mining) on the world heritage values of WBNP World Heritage Site. The results of the SEA are reported in this document.

Considering the pace, scale and complexity of potential threats to WBNP, the overall objective of the SEA is to assess the cumulative impacts of all developments on the world heritage values of WBNP in a way that is inclusive of Indigenous Traditional Knowledge and science. Specific objectives are:

- To improve the identification, recognition, and management of cumulative effects impacting WBNP;
- To inform the scope and support the effectiveness of project-level environmental assessments; and,
- To influence the development and implementation of the Action Plan for the protection of the world heritage values of WBNP.

These objectives are for the interconnected purposes of protecting the world heritage values of the site, maintaining or restoring ecological integrity of WBNP, and maintaining or restoring Indigenous ways of life.

SEA Methods

As a 15-month strategic assessment that will inform ongoing action, the SEA did not initiate any new studies, either science or Indigenous Traditional Knowledge. The SEA relied on an extensive review of information and materials provided by experts, including representatives of Indigenous groups (leadership, knowledge holders, land-users, and advisors), researchers, industry, stakeholders, and federal and provincial governments. The assessment was challenged by the complexity of the ecosystem it evaluated, the volume of information, as well as by the relatively short timeline for completion of the project. The assessment was further limited because no data was collected or analysed (ITK or science). All findings are subject to the limitations of available information, much of which was originally collected in order to meet other goals.

The SEA begins by identifying desired outcomes for WBNP's world heritage values. Achievement of these outcomes is central to protecting the world heritage values, the ecological integrity (EI) of WBNP, and Indigenous ways of life. The SEA then uses existing scientific information and Indigenous Traditional Knowledge to describe the current status of the world heritage values, the pathways of effects likely to influence those values, and the current trends that have been observed. It then examines the potential impacts of reasonably foreseeable developments, and climate change, on the pathways of effects. The SEA concludes with 44 recommendations to restore objectives that are not being met and address gaps in information.

Current status, trends and pathways of effects

Wood Bison, WBNP. Photo: Parks Canada

Migratory waterfowl from four continental flyways converge in great numbers on WBNP, especially in the PAD which provides critical wetland habitat for migrating, breeding, molting and staging birds. The spring and fall migratory waterfowl are very important to the Indigenous groups, peoples and communities social, economic, cultural, and spiritual needs. Indigenous Traditional Knowledge indicates populations of waterfowl that have typically stopped in WBNP during migration have shifted their migration route to other areas. Changes in hydrological regime have also decreased the quantity and quality of habitat for waterfowl. As a result, the ability of Indigenous groups, peoples and communities to practice their traditional way of life is being negatively impacted, and desired outcomes for the world heritage values are not being met.

Evidence suggests that the desired outcomes for the karst, salt plains and Great Plains boreal grasslands are being achieved. Stable, neutral trends have been observed for these world heritage values. One observed exception to this trend is the grasslands which support bison. These grasslands are declining in extent or quality as a result of changes to the amount of water recharge occurring in the PAD. Whooping cranes are not yet at the desired population goals, but their populations are increasing so the


Peace-Athabasca Delta. Photo: Parks Canada

trend is positive. More analysis is needed to understand the current status of the wolf-bison population dynamics, but bison at their current population and distribution do not adequately support Indigenous ways of life.

The PAD is one of the world's largest inland deltas and arguably the largest boreal delta in the world. It is formed by a unique system of waterways created by the convergence of the Peace and Athabasca Rivers, along with many smaller rivers and creeks, on the west side of Lake Athabasca. The Indigenous peoples of Fort Chipewyan introduce the PAD, or *Ayapaskaw* in Cree, in a much different way. Their stories about the PAD make it clear that the PAD is their home, their grocery store, their classroom, their medicine cabinet, their church, their highway, their photo album, and the place where their happiest memories live. For many Elders and land-users, how they think and how they see the world comes from the PAD.

> *We were all born in different areas out on the land…[in] the delta, that's why I love the delta so much…this is where you're born and it's such a beautiful feeling when you go out there. It's like going home.*

In the PAD, with the exception of one unknown trend and one mixed trend, all pathways of effects and valued components are showing negative trends. In particular, flow rates in the Peace River have become less variable due to flow regulation on the river and (past) climate change, resulting in decreased summer flows and increased winter flows. Seasonal flows in the Athabasca River have declined over the past fifty years due to a combination of increased water withdrawals and (past) climate change. Flow rate changes on the Peace and reduced seasonal flows on the Athabasca, in conjunction with climate change, have decreased water levels and the extent of open water in the PAD.

While science monitoring of water quality over 6 years has shown a stable trend, Indigenous land-users in the PAD report noticeable changes in the qualities of surface water in the rivers and lakes of the PAD over the last five or six decades. Many land users who used to dip a cup into the water and drink it, now refuse to. Without the springtime flush of water through the PAD, water bodies can become stagnant. In addition, land-users are concerned about the contamination that may be coming down the rivers from municipal, agricultural and industrial development. They are also seeing deformed fish, which the people will not eat when they catch them, and mercury has also been found in high levels in fish and bird eggs, so consumption limits were set by the government, further limiting access to food sources and further eroding confidence in local food sources.

Future development, climate change and management of cumulative effects


Peace-Athabasca Delta, August 2017. Photo: Parks Canada

In order to assess the effects stemming from future development on the world heritage values of WBNP, future developments with the potential to affect the park were identified. These included existing, and reasonably foreseeable developments such as: hydroelectric development, oil sands development, pulp and paper facilities, industrial mines, forestry activities, and municipal development.

With respect to climate change, the majority of relevant literature reviewed indicated future climate changes in the PAD over the next thirty-plus years will likely cause less surface water to be available, and what will be available will reach PAD water bodies earlier in the spring than at present. Increased temperatures will potentially produce thinner snowpack in the headwater and tributary areas of the PAD, which in turn will result in reduced average annual peak, spring peak, and summer flows. Anticipated increases in air temperature may also produce mid-winter thaws, which could cause winter flows to increase from current levels and have a negative impact on ice quality both in terms of safe travel across and in the structural quality of the ice and its ability to contribute to ice jam flooding events.

Predictions for trends combining the past trends, predicted developments and climate changes were only possible for migratory waterfowl, the PAD and Whooping Crane. With the PAD and migratory waterfowl desired outcomes already not being met and predicted negative trends, the predicted trends of these desired outcomes is negative. The trend of Whooping Crane population related desired outcomes were expected to continue to be positive.

The analysis was conducted within the context of the cumulative effects tools currently being used to manage the pathways of effects. The existence of such a broad suite of cumulative effects and other environmental effects management tools is evidence of the evolving sophistication of management of cumulative effects. Only a decade ago, this breadth of tools was not available. The SEA found that though these tools were mitigating impacts to the WBNP world heritage values, many tools had either not been completed or fully implemented, or were developed without analysis to ensure they were protective of the WBNP World Heritage Values.

Conclusions

The PAD, in particular, is a very complex ecosystem and as a result, there will always be unanswered questions. However, by applying the precautionary principle, a lack of information should not prevent action. Adaptive management solutions must be advanced with the involvement of Indigenous peoples and Indigenous Traditional Knowledge. Furthermore, collaborative approaches involving all parties will be necessary to develop the best possible mitigations and increase the likelihood of success. In particular, collaboration with Indigenous peoples will be important because it is Indigenous peoples who experience the impacts most directly given their intrinsic connection to the land.

The call for immediate action was repeated throughout the course of developing this SEA, in particular from Indigenous communities who rely on the PAD. While ecological monitoring and ITK have shown that with shifts in flooding, for example, ecosystems can rebound, permanent changes to the delta environment are possible and undesirable. Permanent changes could put at risk the world heritage values of the PAD and its ecological integrity, and would be particularly undesirable for Indigenous people who transfer cultural knowledge and skills to the next generation on the land in the context of carrying out traditional activities. When this knowledge is not passed down, communities risk losing their culture and connections to the land. The more time with lack of access, or changes to the quantity and quality of resources, the higher the risk that this transfer of knowledge is interrupted or prevented.

The recommendations in this report are put forward as considerations for the responsible jurisdictions in the multi-jurisdictional Action Plan that is presently being developed for WBNP.

1.0 CHAPTER 1: ASSESSMENT SCOPE AND FOCUS

The opening chapter of this report provides background about world heritage, defines strategic environmental assessment (SEA) and explains why and how a SEA is being applied to Wood Buffalo National Park (WBNP) World Heritage Site (WHS). The concepts described in this chapter include the purpose of the SEA and its guiding principles, as well as the impact of feedback from partners and stakeholders which influenced the structure and analysis of the report.

1.1 THE WORLD HERITAGE CONVENTION

Canada is party to the International Convention Concerning the Protection of World Cultural and Natural Heritage (the World Heritage Convention). The convention falls under United Nations Educational Scientific Cultural Organization (UNESCO) and is implemented by the World Heritage Committee, which meets annually, with the World Heritage Centre providing a secretariat function. By ratifying the convention, Canada has pledged to care for its world heritage sites. On behalf of Canada as a State Party to the convention, Parks Canada is the lead agency for responding to matters related to world heritage.

Based on the global significance of its landscape and the species it supports, WBNP is designated as a world heritage site (further detail on the criteria related to the inclusion of WBNP on the World Heritage List is presented in s. 2.2).

1.1.1 Initiating Petition

The SEA is part of a larger World Heritage process that was initiated through a December 2014 petition by Mikisew Cree First Nation (MCFN) to have the World Heritage Committee include WBNP on the List of World Heritage Sites in Danger. MCFN's way of life is interconnected with the Peace Athabasca Delta (PAD) in WBNP and MCFN Elders are traditional stewards of that area. According to MCFN, its petition is rooted in the Cree term, *kitaskina owicita*, which describes MCFN's obligation to see that the PAD is managed in a way that supports MCFN's way of life. MCFN's petition described observations by MCFN's Elders, community members and other evidence that existing upstream developments have driven the lands, waters and resources in the PAD – and MCFN's way of life – to a point of crisis. It also described MCFN's concerns that governments are not doing enough to respond to the existing and future threats to WBNP and MCFN's way of life (Candler et al., 2015b; Candler et al., 2010; Carver, 2013; MCFN, 2016a). In the words of MCFN's chief at the time when describing MCFN's petition:

> *We are simply asking for certainty for the Delta. Certainty that it will no longer be forgotten and certainty that Canada will stop ignoring its promises to MCFN and to the United Nations to protect this Delta (MCFN testimony to Reactive Monitoring Mission, Day 1)*

In workshops related to development of the SEA, MCFN Elders and leadership have continued to stress how the concerns of MCFN have "fallen on deaf ears" and how inaction continues to put the PAD and MCFN's way of life in peril (MCFN, 2018b). Other Indigenous communities reliant on the Peace-Athabasca Delta in the southern part of WBNP supported MCFN's petition and have expressed similar concerns. This includes Athabasca Chipewyan First Nation (ACFN), and Fort Chipewyan Métis Local 125, both also located in Fort Chipewyan, as well as Smith's Landing First Nation (SLFN), all of which provided letters of support for the petition. Little Red River Cree Nation (LRRCN) has raised similar concerns ("provided filing cabinets worth of information over the years") about the impacts of flow regulation on the Peace River (LRRCN, 2018). Communities located north of WBNP on Great Slave Lake share similar concerns about the Slave River and its delta. MCFN's petition was also supported by numerous environmental groups and researchers, including former Parks Canada officials.

Not all of the eleven Indigenous communities that work with WBNP on a regular basis were involved with the petition, nor support MCFN's approach, or share MCFN's concerns about the health of WBNP (CMC, 2017; SRFN, 2018). However, all groups have met with Parks Canada and the contractor about the SEA, and 10 of the 11 communities have contracts with Parks Canada to support their involvement with the SEA. Several Indigenous communities located south of WBNP have also expressed support for MCFN's concerns and expressed interest in the SEA and Action Plan. Additional information on Indigenous perspectives and involvement with the SEA are provided in Section 2.3.

Following its annual meeting in July 2015, the World Heritage Committee posted Decision 39 COM 7B.18 which outlines several initiatives that Canada is requested to undertake as a result of the Committee's review of MCFN's petition. Included within that request, Canada must "undertake a Strategic Environmental Assessment (SEA) to assess the potential cumulative impacts of all developments on the OUV of the property, including hydroelectric dams, oil sands development, and mining, in line with IUCN's [International Union for the Conservation of Nature] World Heritage Advice Note on Environmental Assessment."

1.1.2 Request for an SEA

In its decision requesting that Canada undertake this SEA (Decision 39 COM 7B.18), the World Heritage Committee noted that there were concerns about the ecological integrity of the PAD. The request to conduct a SEA indicates that, from the viewpoint of protecting the global significance of WBNP's landscapes for future generations, the possibility exists that increased development around WBNP has resulted in negative environmental impacts on the world heritage values and warrants attention.

As Canada's representative for the World Heritage Convention, Parks Canada issued a Request for Proposals, and in December 2016, Independent Environmental Consultants (IEC) was retained to carry out the SEA.

1.1.3 Reactive Monitoring Mission

Also within its 2015 decision, the World Heritage Committee requested a field investigation. Parks Canada had the lead role for planning and hosting a Reactive Monitoring Mission (RMM) whereby representatives of the World Heritage Committee and the International Union for the Conservation of Nature (IUCN) would jointly visit Canada to investigate the state of conservation of WBNP and the potential threats to its world heritage values. After a postponement due to wildfires in the region, the RMM took place from September 25 to October 4, 2016. Its public report was issued March 10, 2017. The RMM report is separate from this independent SEA, but provides insight into the international concerns about how the changing nature and scale of development around WBNP may be impacting the site's world heritage values.

The RMM noted that many of the values justifying WBNP's World Heritage status are concentrated in the PAD. The mission highlighted that the PAD is both disproportionately important and disproportionately vulnerable from the perspective of both conservation values and values to Indigenous peoples. The RMM concluded that cumulative impacts on WBNP directly impact Indigenous peoples.

The RMM determined that the concerns about the PAD described by MCFN and others were not overstated and that documented changes can be linked to decades of industrial development along the Peace and Athabasca river corridors. Ultimately, the RMM concluded that the threats to WBNP's OUV have reached a point that major and timely actions are urgently needed to ensure the park's ecological integrity.

1.1.4 Request for Action Plan

The state of conservation of WBNP was again discussed at the World Heritage Committee's July 2017 meeting. At that meeting the World Heritage Committee rendered Decision 41 COM 7B.2, wherein it requested Canada respond to the recommendations of the 2017 RMM report by developing an Action Plan. This decision noted the pace, scale and complexity of development around WBNP. The Action Plan is due December 1, 2018 and will outline a coordinated, multi-jurisdictional approach for addressing concerns about the world heritage values of WBNP. The SEA results will inform the development of this Action Plan and this report includes recommendations regarding research, monitoring, and management. Figure 1-1 illustrates the connections between the petition and the subsequent requests from the World Heritage Committee.

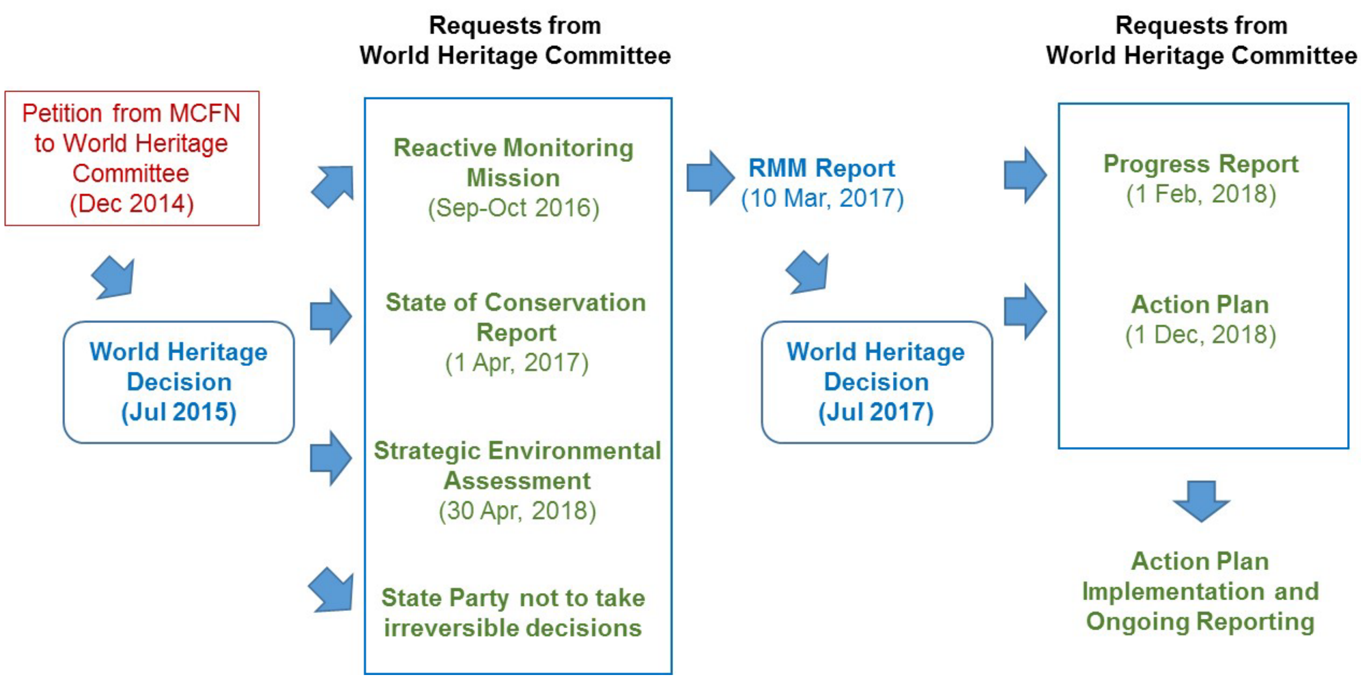


Figure 1-1: Connections Between the Petition and the Requests from the World Heritage Committee.

The request from the World Heritage Committee indicates that attention to the world heritage values of WBNP needs to involve decision makers from multiple jurisdictions and sectors, and needs to include Indigenous rights-holders and stakeholders. The Action Plan will build on the shared understanding of the values, impacts and indicators developed through the SEA. The use of SEA for this project, as requested by the World Heritage Committee, aligns well with concerns brought forward in the petition and in subsequent meetings and workshops. Elders from the delta are not questioning whether environmental changes are happening, but they are seeking answers and urgent action (MCFN, 2018a). In separate meetings with representatives of each of the Indigenous groups based in Fort Chipewyan, individuals wondered if SEA and Action Plan "may be 40 years too late" (Métis Local 125, 2018a; ACFN, 2018a).

1.2 INTRODUCTION TO STRATEGIC ENVIRONMENTAL ASSESSMENT

SEA is a separate type of environmental assessment, different from the environmental impact assessments that examine the effects of a single proposed project. Project-level assessments are more common and have an established methodology, while SEA practice has been more flexible (Noble & Storey, 2001; Noble, 2009). The focus of a project assessment is outward from the proposed activities that may impact the environment (i.e., looking "downstream" to the environment), but the focus of this SEA is outward from the environment, based on observed changes in environmental conditions (including looking "upstream" and to broader influencers of change). Project-level assessments tend to consider a much smaller scale or scope, such as the project footprint and its vicinity, and tend to be focused on the decision about the proposed project, while SEAs are applied to larger areas and can inform a range of decisions by multiple decision makers at the policy and regional, as well as project levels.

An SEA process can address broad goals and objectives, and lead to a proactive strategy for action by providing information to help answer the question "what is the preferred future?" (Noble & Storey, 2001). As a higher-level approach, advantages include that SEA facilitates proper attention to cumulative effects, increases transparency, and improves the information base for decision making (Caratti, Dalkmann, & Jiliberto, 2004). In the case of this SEA, the preferred future is the protection of WBNP world heritage values.

The specific focus of this SEA is the potential threats to the "world heritage values" of WBNP. The site's world heritage values (technically referred to as the Outstanding Universal Value or OUV) relate to the reasons why WBNP was designated a world heritage site. In general, these globally significant values are the landscape-level features that represent unique and important conservation opportunities at the world scale. In the current case these include the salt plains, karst landscape, relatively undisturbed boreal forest, and the Peace-Athabasca Delta (PAD) ecosystem, and some specific threatened and important wildlife they support, including migratory waterfowl, Whooping Crane, bison and wolves. Further detail on the criteria related to WBNP's designation as a world heritage site is provided in Section 2.2.

1.2.1 Cumulative Effects and SEA

SEAs are particularly relevant in regions with extensive potential, planned or existing industrial and resource development (Harriman & Noble, 2008). Complex development pressures have the potential to result in cumulative effects, meaning "changes to the environment that are caused by an action in combination with other past, present and future human actions" (Hegmann et al., 1999), for which existing policy frameworks may be unprepared. Combined actions may not only be additive, but may combine to create new effects or effects that are unexpectedly severe.

SEA recognizes that effects can combine in a number of different ways, and that "ideally, cumulative effects should be assessed relative to a goal in which the effects are managed on a regional basis." (Hegmann et al., 1999, p. 7). SEA is designed to consider cumulative effects, and overlapping jurisdictions. The benefit of a SEA process is to "systematically evaluate cumulative effects of multi-sector land uses and surface disturbances in a region – evaluating past, present and alternative future scenarios and conditions of development, (and) asking 'what if' questions about cumulative change to inform regional sustainable development" (Noble, 2009).

WBNP as a national park allows only limited infrastructure and activities. However, it is located downstream from hydroelectric dams, oil sands mines, forest land tenures, and expanding municipal and agricultural activities, among other developments. Within WBNP, the PAD is a place where waters combine from the Peace River from the west and the Athabasca River from the south, and Lake Athabasca and its tributaries from the east, into one vast, complex, interconnected system of delta environments. The large scale of the basins that feed the PAD, and the varied types of land use through which these waters flow on their way to the PAD make this an obvious case for the possibility of cumulative effects (Figure 1-2).

Typical project-level assessments define cumulative effects in a limited way, following the identification of "residual effects" based on a proponent's analysis of the impacts of specific activities on the environment, and the ability to avoid or manage those impacts. The residual effects are those impacts that remain after mitigation measures have been employed, and the potential cumulative effects of these residual impacts are then considered. In the case of this SEA however, the potential cumulative effects include the changes that have been observed in the receiving environment over a period of time. These observations of changes to the environment started with Indigenous Traditional Knowledge (ITK) and the SEA seeks to collect and compare all available ITK, government monitoring results, academic research and other sources of information to present a full, balanced, independent assessment of changes, including what activities or trends may be combining to cause the changes, and what management alternatives could be considered in the future to avoid or reduce cumulative effects.

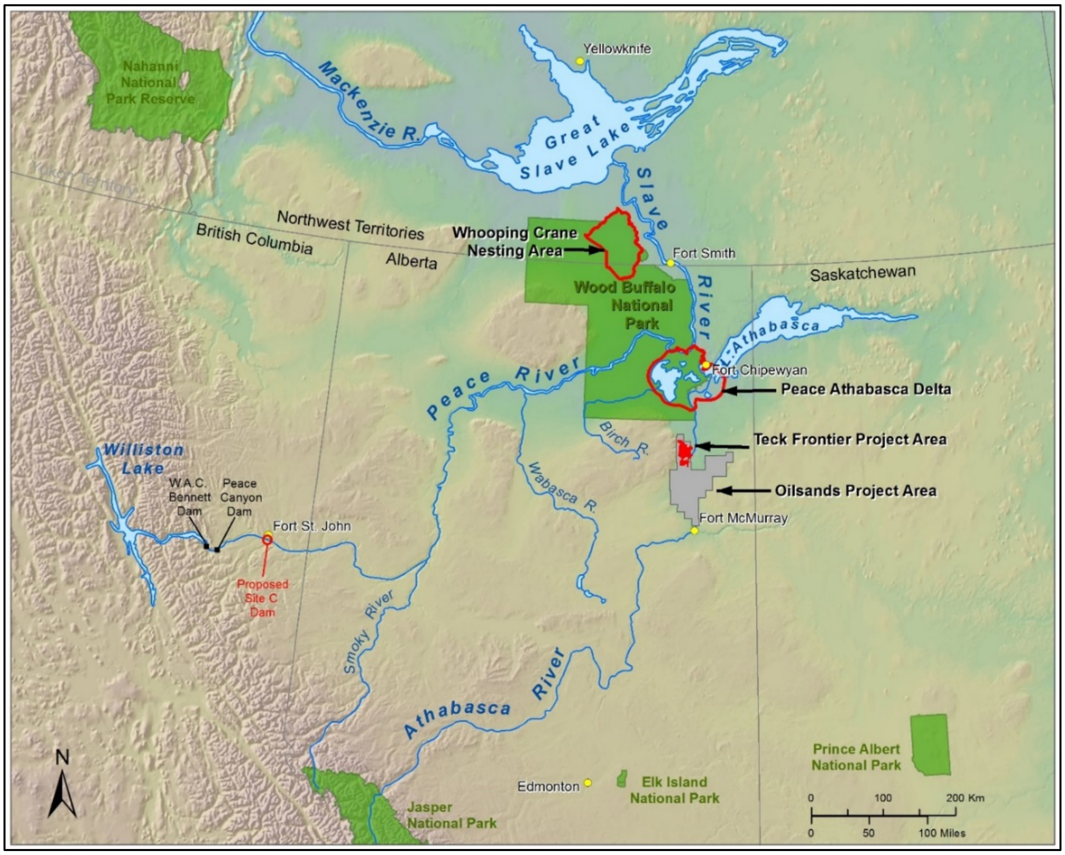


Figure 1-2: Location of WBNP at the Confluence of the Peace and Athabasca Rivers

1.2.2 Cumulative Impacts to Indigenous Ways of Life

In recent years, the global conservation community has acknowledged the injustices to Indigenous ways of life caused by traditional approaches to conserved areas. These approaches separated conservation values and Indigenous peoples cultural, spiritual and other values. The World Heritage Committee has encouraged State Parties to involve Indigenous communities in the monitoring and evaluation of the state of conservation of World Heritage Properties. These acknowledgements and recommendations have clear implications for evaluations like this SEA.

At every stage of this SEA, Indigenous peoples clearly articulated that the interconnected relationship between their ways of life and WBNP meant that this SEA must both incorporate their ITK and consider cumulative effects on their ways of life. This SEA acknowledges the inseparable links between the Indigenous communities of WBNP and WBNP's conservation values. Indigenous knowledge systems provide another source of information, and an alternative framework of hypothesis, understanding, social rules, and relationships that produce critical insight into ecological and cultural relationships. As traditional stewards of WBNP's lands and waters, Indigenous land-users in WBNP, and especially the PAD, are able to provide specific examples of changes have experienced in their lives that are understood to have resulted from cumulative effects, and such examples will be expanded upon throughout the SEA report. For example:

- combined effect on changes to water levels in the delta related to changes to flow patterns from both rivers, including volume and timing;
- combined impacts on water quality related to lower water levels and concerns about increasing contaminants;
- combined effects on the break-up of Peace River ice related to higher flows in the winter and reduced peak flows in the spring;
- combined impacts of industrial light and noise south of the park (deflecting birds away from the park) with vegetation changes in the PAD and outside the park (the PAD becoming relatively less attractive to the birds); and,
- environmental and access limitations (because birds and animals don't use as many places and/or because land-users can no longer get to certain places) can cause a higher level of travel and harvesting in more concentrated areas, which can cause further changes in the behaviours of animals and people.

Also, Elders and land-users explain that everything is connected: every environmental change can "break a chain" in the ecosystem and have additional effects, making natural cycles less predictable, and traditional activities more uncertain or impossible to undertake. This is acutely the case in the PAD, where Indigenous communities say "water is boss" and "water is everything", *nipî tapîtum* in Cree, meaning that changes to water quantity and quality reverberate and amplify through the entire PAD ecosystem and the Indigenous communities that rely on the PAD. For example:

- lower water and longer periods without flooding cause vegetation to change (lakes, wetlands and grasslands change into dry areas with thistle and old willow);
- wetland vegetation provides the habitat and food for geese, ducks, muskrat, moose and bison, etc. so the birds and animals no longer come to dry areas; and,
- predator-prey relationships can change because wolves have an easier time hunting in dry areas than in water, and if bison no longer come to an area, wolves may hunt more moose.

Indigenous peoples of WBNP are also able to provide evidence of how these environmental changes combine to impact the ability of Indigenous peoples to exercise their rights and remain connected to their lands and culture. For example:

- low water on rivers and lakes makes travel difficult, limiting access to camps and wildlife;
- the need to carry drinking water (extra weight) due to concerns about pollution adds to the difficulty of travel;
- access challenges increase the efforts, time, costs and risks associated with traditional activities, causing stress for land-users;
- due to access challenges, costs and risks, cabins become difficult to maintain;

- access challenges combined with a less reliable supply of birds, eggs, moose, muskrats, etc. make traditional activities less inviting/rewarding (effort is increasing, success is decreasing);
- people consume less country foods, increasing costs and diminishing connections to the land;
- families can be separated from areas of spiritual significance, where they have rights, stories, and access to country foods, creating loss of confidence and pride, and social challenges as access/territories shift;
- cultural norms such as sharing within the community before filling your own freezer can be altered; and,
- Elders lose the opportunity to teach future generations, while youth lose the opportunity to learn cultural stories and skills.

This connection between impacts to place and people is illustrated by the words of one former councillor and Elder:

> *I may be alive, but if I can't practice my culture, if I can't enjoy being a Cree, what am I? If I can't enjoy being a Cree out on the land, what am I? And like I said, when we were born, when we were raised out there [in the Delta], it was the most happiest times. Those times, those feelings…never leave you. So how could I be somebody else different when that's who I am? That's my connection there. I never, ever knew I'd be talking like this. Seriously, never. To fight for who you are in this day and age. Never thought that…We're not asking them to change the whole Wood Buffalo National Park. We're not asking them to change the whole Alberta. We're asking them to make sure that you keep our Delta clean the way it used to be…It's not like we're asking for the end of the world…It's just maintaining our way of life, that's all.*

Connections between a healthy environment and Indigenous ways of life in the PAD are described in s. 1.4.3, and further examples will be shared throughout the SEA.

1.2.3 Benefits of SEA

By working with a diverse range of representatives from Indigenous communities, federal and provincial governments, industry, and environmental non-governmental organizations (ENGOs), this SEA endeavors to provide a balanced and independent assessment of changes to the environment in and around WBNP based on the best available information. The first step in better management of cumulative effects in the region is to gain a better understanding of the activities and impact pathways that are affecting the world heritage values of WBNP. This SEA is focused on improving that understanding, and to the extent possible, creating a shared understanding, through a balanced assessment of past and present environmental conditions at the site. In addition, the SEA offers a first look at what possible future conditions and cumulative effects may manifest themselves, given continued expansion of industrial activities in the region and the influences of climate change.

The potential for cumulative effects in and around WBNP are of concern when considered in conjunction with projected industrial and municipal development in the region and the additive effects possible from climate change (addressed in Chapter 6). Other considerations include: not all development pressures undergo project-level environmental assessments (e.g. municipal and agricultural expansion); some older projects may not have undergone rigorous assessment (e.g. the W.A.C. Bennett Dam in the 1960s); and, the pace, scale and complexity of development in areas surrounding WBNP have increased dramatically since the park was added to the World Heritage List in 1983. Additional detail on increased development pressures around WBNP are provided in Section 2.4 and throughout the analysis.

In summary, while previous project-level assessments outside WBNP have found that individual projects may have significant effects on particular local areas, or on particular limited aspects of the regional environment, the focus of this SEA is on the accumulation of large and small impacts coming from different places and different activities that may combine to impact the world heritage values of WBNP.

1.3 Purpose of the SEA

The original purpose of this SEA was to determine the cumulative impacts of all developments (including hydroelectric dams, oil sands development, and mining) on the world heritage values of WBNP. The objective of the project, as stated in Parks Canada's Request for Proposals (October 2016) was:

> *…to assess the cumulative impacts of present and proposed industrial development projects located outside WBNP upon the Outstanding Universal Value of Wood Buffalo National Park. The SEA requirements outlined in the UNESCO [United Nations Educational, Scientific and Cultural Organization] WHC decision document (Decision 39 COM 7B.18) are the primary requirement that must be fulfilled in this contract. Methods employed in undertaking this work will be based on scientific analysis using the best existing information available, not on primary investigations, or field work.*

A number of comments received on the Draft Scoping Report (during September 2017), indicated that this purpose was limited in its breadth and considerations. As a result of the consultation, the purpose of the SEA was expanded as follows:

> *Considering the pace, scale and complexity of potential threats to WBNP, the overall objective of the SEA is to assess the cumulative impacts of all developments (including but not limited to hydroelectric dams, oil sands development, and mining) on the world heritage values of WBNP in a way that is inclusive of Indigenous knowledge and science.*

Specific objectives are:

- To improve the identification, recognition, and management of cumulative effects impacting WBNP;
- To inform the scope and support the effectiveness of project-level environmental assessments; and,
- To influence the development and implementation of the Action Plan for the protection of the world heritage values of WBNP.

These objectives are for the interconnected purposes of protecting the world heritage values of WBNP, maintaining or restoring ecological integrity, and maintaining or restoring Indigenous ways of life.

The goal of the SEA is to inform the Action Plan for WBNP and regional land-use policies and decisions. As described in the *IUCN World Heritage Advice Note on Environmental Assessment*, "ultimately, the aim of environmental assessment is to equip decision-makers with the information necessary to preserve these exceptional sites for future generations" (IUCN, 2013). This SEA provides an independent assessment of the activities and trends that may threaten the park's world heritage values and the Indigenous ways of life that depend on many of those values. It endeavors to present a collective view of the cumulative impacts, and the findings of the SEA can be used by decision makers and affected parties to focus their individual and collective responses to the protection of WBNP's world heritage values.

1.4 Guiding Principles

The updated purpose statement provided guidance on how to move forward with the SEA. In addition, feedback on the Draft Scoping Report broadened the scope of assessment and improved the process of the assessment to consider more information and to make more transparent the way various sources were used. Further details on the changes made as a result of comments on the Draft Scoping Report are provided in Section 1.5.2.

The SEA's purpose statement provides three guiding principles as focal points for the analysis:

- world heritage values,
- ecological integrity, and
- Aboriginal rights and Indigenous ways of life.

In the analysis, effects were considered in terms of how they related to those concepts, and recommendations needed to determine how the adherence to these principles could be achieved. In the following sections, the guiding principles are defined.

1.4.1 World Heritage Values

The world heritage values, or outstanding universal values (OUVs), are the basis for a site's inscription on the World Heritage List and is defined by UNESCO as "natural significance, which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole" (UNESCO, 2006). Ensuring the maintenance and continuance of this international standing is a foundational component of this assessment.

1.4.2 Ecological Integrity

Another primary focus underpinning this SEA is the ecological integrity of WBNP.

The *Canada National Parks Act* (CNPA) defines ecological Integrity as a "first priority" which is notable both as a conceptual framework and as a legal obligation. The CNPA defines ecological integrity as:

> *A condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes.*

This concept of ecological integrity and its relation to Parks Canada's mandate are central to each stage in this assessment and provides guiding direction for the SEA.

1.4.3 Indigenous Rights and Ways of Life

The presence and health of natural features and wildlife (i.e., the world heritage values), are inseparable from Indigenous ways of life and the constitutional rights of Indigenous peoples. Many Elders who contributed to the SEA by sharing their stories of environmental change were born on the land in WBNP. They have shared their knowledge of how environment and culture are intertwined. Given the connections between healthy landscapes supporting strong populations of plants and animals (world heritage values) and the ability of land-users to continue their culture and exercise their treaty and Aboriginal rights, the SEA cannot assess one without considering the other. What scientists who work in environmental assessment call "pathways of impacts", Indigenous land-users - with intimate connections to the sights, sounds, smells and tastes of the environment and knowledge of a pre-development baseline – have called their "stories of change" (MCFN, 2017b).

WBNP is a national park and a world heritage site, but to the Dene, Cree and Métis communities in and around the park, it is also home. Land-users in the PAD describe the park as their grocery store, their kitchen, their school, and their photo album, and the place where they have their happiest memories of family and nature (MCFN, 2018a; MCFN, 2018b). The PAD has also been referred to as the heart of the park and the region. The idea that "everything is connected" also applies downstream from the PAD, and management of the Peace and Athabasca Rivers and the PAD is also of interest to communities on the Slave River and Great Slave Lake (NWT Métis, 2018).

Based on meetings with representatives of Indigenous groups during the development of the SEA, Parks Canada prepared the diagram in Figure 1-3. The figure is an attempt to capture how ITK informs resource management, and how resource quantity and quality, including the importance of access to resources, affect Indigenous ways of life. This is consistent with Parks Canada's resource guide *Promising Pathways* which expresses how access and continued traditional use create stronger ITK, and how ITK and strong relationships create healthier communities and better management decisions (Parks Canada, 2014, p. 18).

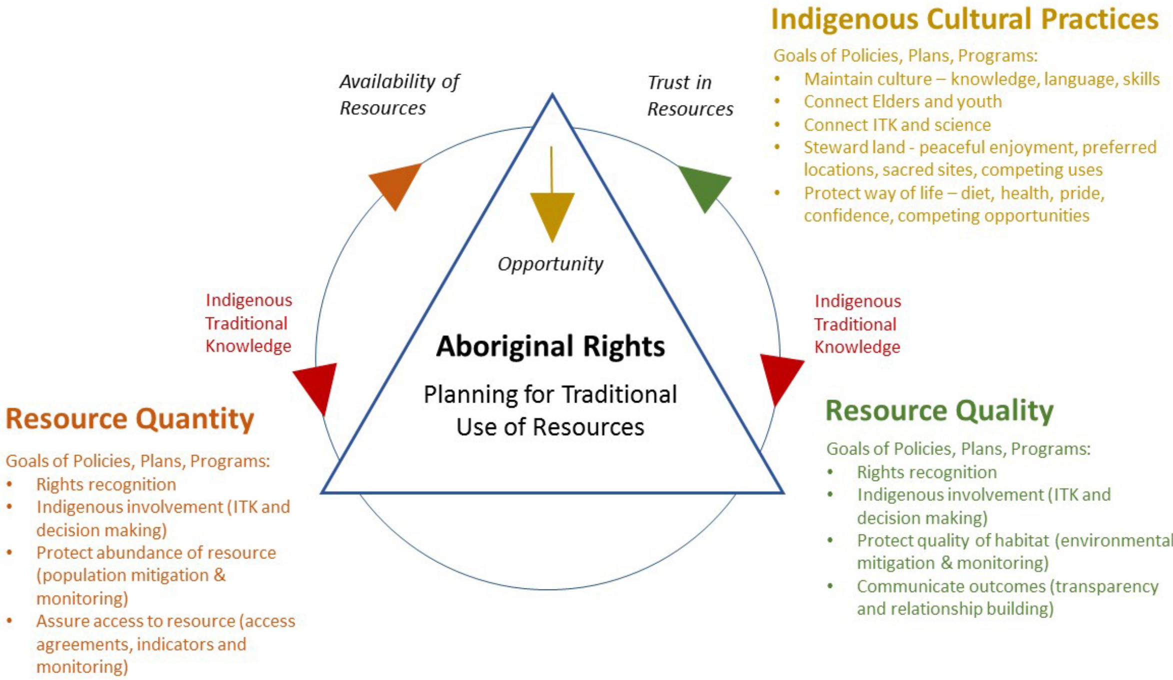


Figure 1-3: Connections Between Indigenous Ways of Life and Access to Resources (Parks Canada, 2018)

Further detail on Indigenous perspectives is provided in Chapter 2 and throughout the SEA analysis. The concept of inter-dependence ("everything is connected") and the importance of ITK and Indigenous access to resources are central to the SEA.

1.5 Approach to the SEA

The SEA begins with consideration of all of WBNP's world heritage values (the features for which the park is globally significant). An early focus of the assessment was to identify which elements warranted greater attention. The starting point of the SEA was the observed changes in environmental conditions reported by MCFN land-users in the PAD. The RMM report and requests from the World Heritage Committee supported this focus on the PAD. This SEA continues the focus on the PAD, and after careful and independent review of available data, including the consideration of sources and comments provided by a broad range of interested parties (from different Indigenous communities, government, industry and ENGOs), the SEA reaches its own conclusions.

A SEA is ideally undertaken prior to major physical development as a means to anticipate development trajectories, adverse effects, and to determine mitigation strategies and identify alternatives. This SEA differs in that it is taking place mid-stream, with major developments already in place and operating upstream of WBNP, with some large scale developments approved and in construction or about to begin operations and other projects in the application stage. It is anticipated that further large scale developments will be proposed in the near and long term. For the region in which WBNP is situated, economic development and land management objectives have been determined by various levels of government and these objectives largely focus on oil sands, hydropower, agriculture and other types of developments persisting and expanding. This SEA cannot alter history and does not have a legal basis to require change to any government objective, policy, plan or approval. The results it generates however can be used for collaborative planning processes and other discussions going forward.

A challenge for the SEA is to determine how cumulative effects of pre-existing development combine to influence the current state of the ecosystem, and how they are likely to do so in the future. Factors that contribute to this challenge include: gaps in availability of monitoring data, a range of views on appropriate baselines, a wide range of activities contributing to numerous types of human-induced changes in the environment, and a very dynamic and complex ecosystem that is challenging to conclusively understand. This SEA, however, assesses the extent of overall change that has been observed in the environment through ITK and western science information regarding changes to among other aspects, flow regime, water levels, water quality, lake and vegetation cover, and wildlife health and abundance. This SEA therefore assesses what cumulative effects may have resulted in observed changes in the world heritage values, based on the above information (current and historic data provided through ITK and scientific papers), determines whether world heritage value objectives are currently being met, and assesses the direction of change for WBNP from existing cumulative effects. The SEA then anticipates what direction of change is likely for WBNP's world heritage values, given foreseeable development and climate change and trends without further action.

The SEA recognizes that observed changes in WBNP and the PAD are multi-faceted, and all parties, including federal, provincial and territorial governments, different Indigenous governments and communities, industry in different sectors, ENGOs, and academic researchers have crucial roles to play in ensuring the protection of WBNP's world heritage values. As noted by representatives of MCFN, "solutions must be cumulative as well" (MCFN, 2017a).

1.5.1 Study Limitations

The assessment was challenged by the complexity of the ecosystem it evaluated, the volume of information, as well as by the relatively short timeline for completion of the project (December 2016 – April 2018). The assessment is further limited because no new data collection or analysis (ITK or science) was possible within the scope and timeframe available. All findings are subject to the limitations of available information, much of which was originally collected in order to meet other goals.

The challenge of distilling the vast amount of available information into this report was met by using a systematic method focused of collecting information from credible sources and evaluating the relevance of the information based on the SEA's objectives. Aided by guidance from representatives of Indigenous communities, government scientists, and other experts, this SEA represents best efforts to synthesize the substantial body of existing information.

Numerous industrial sectors are considered within the SEA as potential contributors to cumulative effects in the PAD. Due to the complexity of the ecological systems involved, this report does not delineate specific contributions that any given activity or project has on environmental conditions.

This SEA reflects the information available to date. However, major research and monitoring projects are on-going that may identify many of the knowledge gaps. New information can be carried forward and into the Action Plan process for WBNP.

1.5.2 Changes Based on the Review of the Draft Scoping Report

A Draft Scoping Report (MILESTONE 1: SCOPING REPORT Strategic Environmental Assessment of Wood Buffalo National Park available in Appendix A.1) was made available in August 2017 and input from partners, stakeholders and the public was invited during September 2017. Comments were received from a wide spectrum of reviewers including federal government departments and agencies, provincial and territorial governments, Indigenous communities, industry and industrial associations, and ENGOs. Based on the submissions received, it is apparent there is a keen interest in the SEA and the issues it is addressing, along with other issues concerning the adequacy of scientific information, governance, consultation and engagement.

Comments on the Draft Scoping Report were grouped into 5 categories:

- Data Sources,
- Indigenous Traditional Knowledge,
- Assessment Approach,
- Governance Framework, and
- Consultation.

Some of the comments received were contrary to others (e.g. different perspectives on the influence of human-induced changes compared to natural variation, and different preferences for what sources of information are relied upon); as such, the SEA report endeavors to reflect differing or opposing points of view where possible. The input received was considered for three different forms of response: refining the information and approach used for the SEA; informing the multi-jurisdictional Action Plan being coordinated by Parks Canada; and sharing comments with the relevant decision-makers.

The comments that were integrated to inform the SEA have broadened the scope of the assessment and improved transparency. In response to feedback received during the scoping phase, the broadened scope of this SEA has resulted in an expansion of the assessment approach. Going beyond what was presented in the Draft Scoping Report, "pathways of effects" methods were used to demonstrate the relationships between important ecological components within the PAD, including their connections to world heritage values, ecological integrity, and Indigenous ways of life. The methods initially presented in the Draft Scoping Report have been strengthened through increased engagement and expansion of the scope of the SEA.

Details on the comments that were received and how they have been included in the SEA and/or Action Plan processes are available in an Addendum to the Draft Scoping Report, which is included as Appendix A.2 of this SEA report.

1.5.3 Structure of the SEA

This report is structured to systematically consider the impacts of industrial development on the world heritage values of WBNP, ecological integrity, and traditional land use. The report contains a review of all WBNP's world heritage values, with emphasis on the PAD. Other world heritage values are reviewed to examine their current status with respect to potential threats and long term protection. These evaluations were developed through literature review and discussions with representatives of Indigenous communities, government, industry, ENGOs, and academic researchers. In summary, the report is structured as follows:

- **Chapter 2** provides the context of the site as a national park, world heritage site and a homeland for Indigenous peoples.
- **Chapter 3** describes the methodology used in the analysis and report.
- **Chapters 4 and 5** provide an assessment of the pathways of effects or stories of change for impacts to each element of the world heritage values. These chapters also assess the current status and trend of the elements. Chapter 4 assesses other world heritage values, and Chapter 5 is focused on the PAD.
- **Chapter 6** describes the current and reasonably foreseeable developments that may impact the world heritage values of WBNP. It also describes predicted impacts of climate change and concludes with an assessment of the future trend to the WBNP world heritage values in the future.
- **Chapter 7** concludes with recommendations to address the risks that were identified. The recommendations from the SEA will be considered in the subsequent multi-jurisdictional Action Plan for the protection of WBNP's world heritage values.

An extensive bibliography is included within the appendices, and source documents are available from Parks Canada. Overviews of the information collected and analyzed are provided in the appendices, including issues about WBNP that were raised by affected parties but have been excluded from the main body of the SEA due to the lack of a direct relationship with world heritage values (i.e., issues that are not connected to the reasons for which the park is designated as a world heritage site). These concerns have been noted because they may have value for future research and for consideration in WBNP operations (e.g. development of the next management plan).

2.0 CHAPTER 2: SITE CONTEXT

This chapter provides an introduction to WBNP and the Indigenous peoples who reside in the area, and presents additional detail about its designation as a world heritage site. The world heritage values of the park provide the focus for this SEA.

2.1 WOOD BUFFALO NATIONAL PARK


Wood Bison Herd, WBNP. Photo: Parks Canada

Wood Buffalo National Park spans the Alberta/Northwest Territories boundary and at 44,807 square kilometres, it is the largest national park in North America. The land that WBNP occupies has been inhabited for at least 2500 years, and likely much longer. The park is located within the bounds of Treaty 8 and in Métis homelands. The treaty was signed in 1899 and it guarantees the hunting, fishing and trapping rights of signatory First Nations, to support and maintain traditional livelihoods. Métis communities are not signatories to the treaty, but have Aboriginal rights in WBNP.

For generations, the Cree, Dene and Métis peoples have depended upon the ecosystems that are now part of WBNP as an integral part of their identity, culture and well-being. Within the park, maintaining a functional ecosystem is critical for the cultural, spiritual and physical health of these communities (Candler et al., 2010). This report acknowledges that healthy lands and resources, including access to resources, are critical to supporting and maintaining traditional livelihoods.

WBNP was first created in 1922 to protect the last free roaming herds of wood bison (historically called the 'wood buffalo') in northern Canada, and in 1926 its boundary was extended south of the Peace River to encompass a large portion of the Peace-Athabasca Delta (Parks Canada, 2010). The global significance of WBNP was recognized in 1983 when the park was designated a UNESCO World Heritage Site

The Parks Canada Agency is responsible for managing WBNP, while the Province of Alberta and the Northwest Territories have jurisdiction immediately outside the park boundaries.

Conservation values of particular note include:

- Some of the largest relatively undisturbed and least fragmented boreal forest, grassland and wetland ecosystems in North America, including one of the largest inland freshwater deltas in the world (the PAD);
- Increasingly rare ongoing large-scale ecosystem processes with limited human interference, including the comparatively natural fire regime;

- Significant populations of migrating, nesting, breeding and moulting waterfowl at an intersection of four major bird migration flyways - among many other significant wildlife populations;
- Some of the finest examples of gypsum karst landforms in North America and extensive, unique salt plains, both with associated extraordinary plant communities;
- Two Wetlands of International Importance under the Ramsar Convention – the PAD and the last remaining natural nesting area for the endangered Whooping Crane; and,
- The world's largest Dark Sky Preserve since 2013.

For Indigenous peoples, the history of WBNP is more complicated. Further explanation of this history is set out in Section 2.3.3 below.

2.2 World Heritage Values

World heritage sites are designated based on criteria established by the World Heritage Convention. The criteria are used by the UNESCO World Heritage Committee to define a site's world heritage values, which are expressed in terms of its OUV. OUV or World heritage values are the basis for a site's inscription on the World Heritage List, and OUV is defined by UNESCO as: "natural significance, which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole" (UNESCO, 2006).

WBNP was inscribed as a world heritage site under three world heritage criteria. These criteria are presented below along with the rationale for their selection, as defined by the World Heritage Committee:

> **Criterion (vi): to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;**

The great concentrations of migratory wildlife are of world importance and the rare and superlative natural phenomena include a large inland delta, salt plains and gypsum karst that are equally internationally significant.

> **Criterion (ix): to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals;**

WBNP is the most ecologically complete and largest example of the entire Great Plains- Boreal grassland ecosystem of North America, the only place where the predator-prey relationship between wolves and wood bison has continued, unbroken, over time.

> **Criterion (x): to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.**

WBNP contains the only breeding habitat in the world for the Whooping Crane, an endangered species brought back from the brink of extinction through careful management of the small number of breeding pairs in the park. The park's size, complete ecosystems and protection are essential for conservation of the Whooping Crane.

2.3 Indigenous Perspectives on the SEA

It is important to note there is no single "Indigenous perspective" on WBNP or the SEA. The distance between the park's northwest corner near Buffalo Lake and the community of Hay River, NWT to the community of Fort Chipewyan, AB and the park's southeast corner below the PAD is about 500km (Figure 2-1). Across such a distance, and across different landscapes (salt plains in the northwest, the PAD in the southeast, and boreal forest in between), the observations of different land-users cannot be expected to be consistent. This became clear during meetings with the eleven groups during development of the SEA.

Given that Indigenous use of the park includes different cultures, different communities and different families using different resources in different areas, it is not surprising that not all Indigenous groups share the same concerns. During development of the SEA, it was noted that concerns about the effects of dams and industry were generally highest among Indigenous peoples who are dependent on the PAD for access to their territory within the park. For example, a land-user accessing upland forest environments using roads in the northern half of WBNP may not raise the same concerns as a land-user travelling by boat through the PAD. Leaders and representative land-users from a First Nation based in the central portion of WBNP have stated they do not see the negative impacts from development, and do not feel the park's world heritage values are at risk (CMC, 2017; SRFN, 2018). The perspectives presented by different communities are reflected in the sections of the SEA that address the relevant world heritage values (e.g. the Whooping Crane nesting area in the north, Chapter 4; and the PAD in the south, Chapters 5 and 6).

The long-standing concerns of MCFN were well articulated in their December 2014 petition and associated materials, and supported by the other communities reliant on the PAD. However, not all Indigenous groups with interests in WBNP welcomed the MCFN petition, or the subsequent involvement of UNESCO in WBNP matters (CMC, 2017; SRFN, 2018). All WBNP Indigenous communities had an opportunity to share their knowledge to influence the development of the SEA, including reviewing the Draft Scoping Report and reviewing drafts of the SEA, and all of the communities also have the ongoing opportunity to submit follow-up reports to Parks Canada that will present their perspectives on the completed SEA.

Each of the eleven Indigenous communities that work with WBNP, including communities with Dene/Chipewyan, Cree and Métis backgrounds, have their own unique histories and their own perceptions and priorities. Additional information on the cultural history of WBNP is available on the park's website (http://Www.pc.gc.ca/en/pn-np/nt/woodbuffalo/decouvrir-discover/natcul2), or from the communities directly.

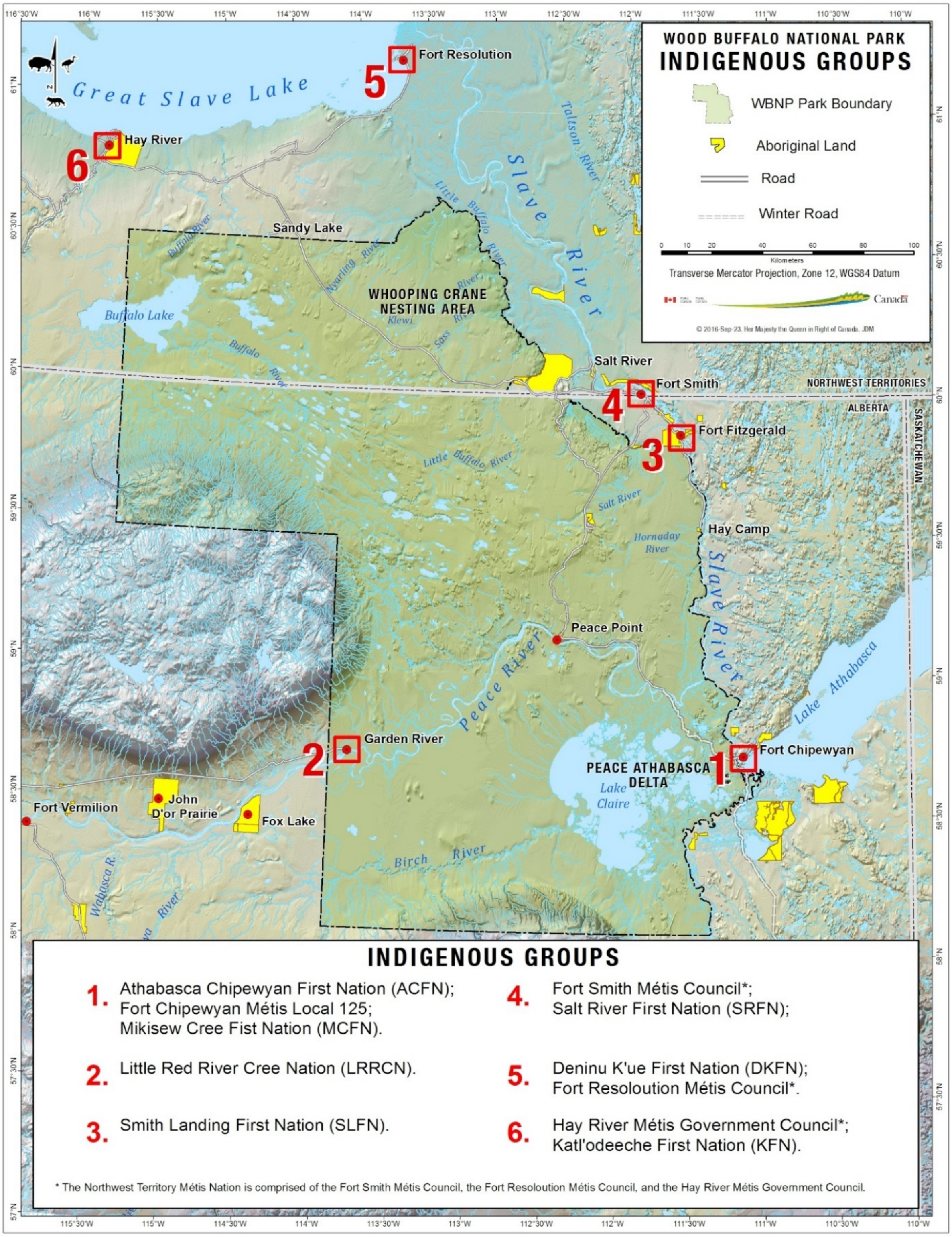


Figure 2-1: The Location of Indigenous Communities Around WBNP

2.3.1 Indigenous Perspectives on World Heritage Values

Representatives of different Indigenous communities highlighted that the designation of WBNP as a world heritage site was carried out without consultation, and that the criteria for world heritage values were developed without Indigenous input. Given the lack of Indigenous involvement in the establishment of the criteria and designation process, it has been pointed out that the nature-based world heritage values for WBNP do not relate very well to the more holistic Indigenous perspective. Specifically, from an Indigenous perspective based on meetings and workshops related to the SEA, the following considerations are important to Indigenous peoples, and are not explicitly included in WBNP's world heritage values:

- Recognition of treaty and Aboriginal rights;
- Access to healthy lands and resources for the peaceful exercise of rights;
- WBNP as a cultural landscape and a homeland to Indigenous peoples;
- The health and welfare of Indigenous peoples;
- The role of Indigenous peoples in ecosystem relationships;
- The role of other species (e.g. vegetation and moose) in relation to bison and wolves;
- The role of other areas of the park in safeguarding the world heritage values; and
- Inter-connections among all species (e.g. vegetation, bugs, frogs, mice, bats, birds, etc., and Indigenous peoples).

2.3.2 Concerns about Water Levels in the PAD

In general, the concerns raised by the three communities based in the PAD (MCFN, Athabasca Chipewyan First Nation, and Fort Chipewyan Métis Local 125) were consistent, which aligns well with the concerns noted by the World Heritage Committee and the SEA's emphasis on the world heritage values associated with the PAD.

For the Indigenous peoples who depend on the PAD, water replenishes life and connects to the vegetation, bugs, frogs, birds, mammals and people of the delta (MCFN, 2018a). In raising their concerns about changes to the annual pattern of water flows in the Peace River following development of the W.A.C. Bennett Dam (hereafter "Bennett Dam"), it was the parents of today's Elders who coined the term "Water is Boss" (nipî tapîtam) (MCFN, 2017a).

At several workshops, participants expressed how often knowledge holders have been asked to share these stories over the years. They emphasized that, on behalf of their ancestors and future generations, Elders and land-users continue to share their knowledge in good faith, with a combination of frustration and hope (ACFN, 2018a; MCFN 2018a). The feelings expressed at workshops on the SEA made it clear that the Indigenous peoples in the PAD see the need for urgent action, and that they need to be part of the solution and want everybody who affects the PAD to work together (MCFN 2018a; MCFN 2018b).

2.3.3 Negative Histories Between Parks Canada and Indigenous Peoples

In materials provided during SEA, and in workshops with Indigenous communities, it was not uncommon for participants to point out that their ancestors were using these lands long before WBNP was established, and that WBNP has a dark history with Indigenous peoples. Indigenous communities explained how the existence and management of the park interfered with Indigenous ways of life through enforcement activities that at times resulted in either the expulsion of Indigenous land-users from the park, or their incarceration for participating in activities central to their ways of life. Indigenous land-users also speak of a culture of fear created due to park management practices and have many stories about how they were not allowed to exercise their Aboriginal or Treaty rights freely, and about the negative relationship with Parks Canada wardens (e.g. Indigenous people hiding their guns, removing feathers from their hats, etc.). The legacy created due to land user's fear of reprisal continues to be felt by a number of individuals that participated in the SEA workshops. Several participants in the SEA workshops explained that they do not feel that the management of WBNP adequately respects their rights and explained that the relationship between Indigenous groups and Parks Canada remains difficult (MCFN, 2017a; 2017b; 2018a).

Representatives of Indigenous communities pointed out that these histories have not been acknowledged by Parks Canada in WBNP; that WBNP's visitor information makes the park ("vast, undisturbed expanses of boreal wilderness") sound healthier and better protected than it is; and that Parks Canada maps show vast areas of blue (water) on their maps of the delta that hide the actual drying conditions within the wetlands. Several participants at different workshops stated that in the interest of reconciliation, Parks Canada needs to acknowledge the negative histories of the park, so that everyone is able to build trust and move forward together. Stories of negative histories with Parks Canada were one thing that communities had in common from the south, west, north and east parts of the WBNP (ACFN, 2018a; LRRCN 2018; Métis Local 125, 2018a; MCFN, 2017a; 2017b; 2018a). While it is beyond the scope of the SEA to recommend solutions to the historical and current challenges between Parks Canada and the Indigenous communities of WBNP, it is clear that work remains to be done.

At various stages of the process for developing the SEA, representatives of a few communities noted that this engagement process has been a continuation of some negative relationships and practices. For example, communities pointed out the following in relation to the SEA:

- they needed more capacity support to enable meaningful participation;
- more lead time needed for planning meetings and reviewing documents;
- more visuals and better use of plain language in writing; and,
- SEA did not include a process for the proper, respectful collection of ITK.

2.3.4 Recommendations on Genuine Partnerships

The park's current management plan (2010) identifies building stronger relationships with Indigenous partners as a key strategy, and since 2014 the park has been convening a Cooperative Management Committee (CMC). However, the concerns raised by MCFN, the subsequent responses from other communities, and the stories shared at workshops, underscore the limitations of WBNP's approach to cooperative management, and that, at times, each Indigenous group will need bi-lateral relations with Parks Canada, and may need to act according to its own vision and principles for its territory, activities and history within WBNP. The RMM recommendations that are to be addressed through the Action Plan include several items related to cooperative management and partnerships with Indigenous communities.

2.4 DEVELOPMENT PRESSURES AROUND WBNP

As referenced in Chapter 1, this SEA was preceded by a petition from MCFN, based on observed changes to environmental conditions in the PAD, and was subsequently requested of by the World Heritage Committee. A key element of the background to the SEA and Action Plan is the pace, scale and complexity of development that has been taking place around WBNP in recent decades (Decision 41 COM 7B.2), as was raised by many reviewers during the comment period on the Draft Scoping Report.

At the time of WBNP's designation as a world heritage site in 1983, the park's world heritage values were relatively well protected because of the park's remoteness and large size. However, given the pace, scale and complexity of development in the region and upstream, the concerns raised by MCFN and others, and the requests of the World Heritage Committee to complete an SEA and develop an Action Plan, decision makers are now being asked to work together to re-assess the protection and management framework for the world heritage values of WBNP.

3.0 CHAPTER 3: METHODOLOGY

This chapter describes the methods that were used to undertake the SEA.

3.1 Methodology Used In The SEA

Due to the complexity of the environment being assessed, and the large volume of information collected, a variety of assessment methods were used. These methods combined to provide a good understanding of the status and trends for all of WBNP's world heritage values. The assessment was carried out using the following steps:

1) Step 1 -- Define SEA Approach, Objectives and Desired Outcomes
   a) Develop Assessment Framework for World Heritage Values
   b) Determine Desired Outcomes and Objectives for Those Values
2) Step 2 – Assess Current Status and Trend of World Heritage Values (Chapter 4 and 5)
   a) Set Geographic and Temporal Boundaries
   b) Define Information Gathering Approach
   c) Identify Pathways of Effects
   d) Identify Valued Components for the PAD
3) Step 3 – Project Future Trends for World Heritage Values (Chapter 6)
   a) Define Cumulative Effects Assessment Approach
   b) Identify Potential Effects from Reasonably Foreseeable Development
   c) Identify Potential Effects from Future Climate Change
   d) Assess Trend Resulting from Reasonably Foreseeable Development and Climate Change in the Context of Cumulative Effects Management
4) Step 4 – Develop Recommendations to Mitigate or Reverse Trends or Address Information Gaps (Chapter 7)

The complete list of world heritage criteria for WBNP provided the initial bounding for the SEA. The assessment methods highlighted components of the site that were deemed particularly vulnerable, or have a well-documented body of information supporting the view that they are vulnerable to outside influences. Although each of the world heritage values are assessed in the SEA, particular focus is given to the PAD. Each step listed here is described in greater detail in the next section of the SEA report.

3.2 STEP 1 -- DEFINE SEA APPROACH, OBJECTIVES AND DESIRED OUTCOMES

3.2.1 Develop Assessment Framework for World Heritage Values

An important first step for the assessment was determining how to convert the world heritage criteria statements which describe the values of WBNP in broad terms (e.g. "great concentrations of migratory wildlife"), into elements or components that are measurable and could be more easily evaluated. This was accomplished using a method developed by Jon Day that was employed for a similar evaluation of the Great Barrier Reef World Heritage Site.

Day refers to the world heritage values statements for properties as "somewhat high level and nebulous, or (managers) do not understand how it might assist or help to prioritize their planning and management efforts" (Day, 2015). In order to make the world heritage statements more assessable, Day developed the following method:

1) To "break the complex Statement of OUV into smaller more understandable components. This involved breaking down the full approved Statement text into smaller 'excerpts' for each of the natural criteria and integrity";

2) Sequentially to:

   a) "identify key examples of values or attributes against each Statement excerpt"

   b) "identify the factors affecting those values"

   c) "prioritize the highest priority threats"

   d) "consider what are the priority management needs to address the highest priority threats" (Day, 2015)

As described by Day, the advantages to this approach are that it "helps them more readily identify the key values or attributes for their property and prioritize their management actions", "helps to directly link the property's values to management operations", "clarifies the research priorities for the property" and "ensures that the committees themselves are focusing on the world heritage values of the property when giving advice" (Day, 2015).

Day's methodology was used to break individual OUV criterion statements for WBNP into constituent elements. The results of the exercise were captured in a summary table (Table 3-2). The process was of great value, as it provided a much higher level of clarity and focus for the SEA by more clearly identifying the individual features or systems that are nested within the broader language of individual world heritage criterion statements. The findings from this exercise were carried forward and helped to focus all the subsequent steps in the SEA process. They also will inform the Action Plan initiative that has recently commenced, and the next park management planning exercise for WBNP, which is likely to begin in the next few years.

3.2.2 Determine Desired Outcomes and Objectives for World Heritage Values

This SEA employed a "desired outcomes" based approach. The world heritage value elements listed in Table 3-2 of this report were the starting point in the process. Once the key elements were identified using the methods developed by Jon Day as described in Section 3.2 of this report, the focus shifted to determining the desired outcome(s) for each element. Desired outcomes provide benchmarks against which impacts can be measured. Although all the world heritage values for WBNP are based on world heritage criteria, the desired outcomes also reflect the importance of these elements to Indigenous ways of life in WBNP.

The overall desired outcome is to protect the world heritage values of WBNP, and maintain or enhance the ecological integrity of the national park. Achievement of those desired outcomes will assist local Indigenous peoples in continuing to practice traditional ways of life. Preliminary valued components and associated indicators were identified during the SEA process. It is anticipated they will be further refined during the development and implementation of the Action Plan as additional collaboration takes place and new information comes to light.

3.3 Step 2 – Assess Current Status and Trend of World Heritage Values (see Chapter 4 and 5)

3.3.1 Set Geographic and Temporal Boundaries

Identification of suitable geographic and temporal boundaries for the SEA posed some challenges given the long time frame since the park was established (1922), the extent of change in land use surrounding the park since its establishment, and the large size of the drainage basins (i.e., Peace River, Athabasca River) which flow into the park and influence ecosystem states at the site. Boundary setting was further complicated by the need to incorporate the effects of climate change into the SEA. Based on a review of information collected from a wide variety of sources, as well as engagement and review process comments, the following geographic and temporal boundaries were identified.

Geographic Boundary: The geographic boundaries of WBNP are well defined and enshrined in legislation within Schedule 1 (National Parks of Canada) of the *Canada National Parks Act*. The PAD is primarily fed by the waters of the Peace and Athabasca rivers whose basins lie largely outside the boundary of the park. For this assessment, the starting point for the geographic boundary is the entire world heritage site, whose boundary is the same as Wood Buffalo National Park. The geographic boundaries of the assessment of individual world heritage values vary with the nature of the specific value being assessed. For the PAD, the entirety of the PAD (the portion of the PAD that lies within WBNP is 80%), and these two rivers systems are included as part of the PAD system. Impacts on the Slave River will be briefly considered to recognize that the state of the environment in the PAD can influence downstream environments in the Slave River basin. The geographic boundary of the SEA was also influenced by the decisions of the world heritage committee. These decisions outlined the types of projects that were to be assessed including flow regulation on the Peace River, and oil sands mining and upgrading in the Athabasca River basin.

Temporal Boundary: ITK recorded in project level environmental assessment documents (e.g. Teck Frontier Oil Sands Mine), and academic literature indicate the important temporal boundary for the

Peace River to be pre-1968, before construction and operation of the W.A.C. Bennett Dam. Relevant hydrological monitoring records for the Athabasca River are from the 1950s onward. Commercial oil sands mining started in the Fort McMurray region in the 1960s. Although the site was designated in 1983, an earlier temporal boundary was appropriate because the cumulative effects from after designation have added to those that began before designation. In order to understand the full extent of cumulative effects, all of the effects needed to be included. In addition, some of the effects of prior development were only just beginning to be felt and understood at the time of designation. Therefore, the implications of those effects on the world heritage values wasn't understood at the time of designation.

Climate change modelling typically reliably predicts up to about 30 years in the future. Therefore, the temporal boundary was initially proposed to start in 1950 and extend to 2050. However, in undertaking the SEA it was found that there is valuable information available in the 100 years prior to 1950 and in the far distant past. Where available and applicable this information was incorporated into the SEA.

3.3.2 Define Information Gathering Approach

After identifying desired outcomes for all world heritage value elements, literature reviews and engagement were used to evaluate the current status, trends and the pathways of effects for each element. The literature review and engagement process that made this possible are described here.

3.3.2.1 Literature Review of Available Information

This report is a desktop study: no new research was initiated, for either the collection of scientific information or ITK. In addition, no data analysis was done. Research supporting the SEA included an extensive literature review supplemented by in-person and teleconference meetings, and email exchanges. The foundation of this report is the extensive review of information and materials provided by experts, including representatives of Indigenous groups, researchers, industry, stakeholders, and government.

During the initial information gathering process, the primary focus was on cumulative effects in the PAD. While engaging with various groups, it quickly became apparent that the scope of the assessment needed to expand to include all elements of the world heritage values. Additional changes were made to the SEA methods to increase the level of engagement and integration of Indigenous perspectives and to develop recommendations in the SEA based on the results of the investigation. Information was gathered and reviewed for all of WBNP's world heritage values. Information sources included climate projection reports and papers; environmental monitoring reports; project-level environmental assessments; regional, provincial, territorial, and federal legislation and policies; and reports from Indigenous groups, industry, researchers and consultants.

The snowball method was used to gather peer reviewed papers and published reports. The approach built on Parks Canada's relationships with Indigenous communities, industry, and government experts. Documents, research and contacts for other individuals to collaborate with were developed during each meeting. From there, the network expanded to include additional researchers and the materials they recommended. All of the information gathered was assessed for relevance to the issues at hand. Some materials were not deemed appropriate or relevant to the issues in the report, and as a result, were not included. A full list of materials reviewed is provided in a bibliography appended to this report.

With a few exceptions, information contained in project-level impact assessment or supporting technical documents or other documents submitted as part of environmental assessment review processes were not included for three reasons.

First, project level assessments tend to inadequately assess cumulative effects. In 2006, Duinker and Greig reported a number of problems with cumulative effects assessment (CEA) in Canada, one of which is the ineffective application of CEA in project-level EA. The main problem stems from the fact that project-level environmental assessment (EA), as practiced currently, is focused on identifying and mitigating specific incremental impacts from the proposed project under review, rather than assessing and managing the full scope of human activities and other stressors on valued components of an ecosystem. The focus is on what the project might do to the valued component, rather than asking what human activities and other stressors could do to the valued component, which "is difficult to adopt when a proponent is focused on getting a project approved, and regulators are focused on making sure that the impacts of the project are acceptably small" (Duinker and Greig, 2006, p. 155).

This problem is exemplified by the environmental baseline chosen for assessing cumulative impacts from the proposed project. In most cases, the current (at the time of the assessment) condition of the biophysical environment (i.e., air, water, land) is used as a baseline against which potential impacts from the proposed project are assessed. Rarely is the pre-industrial baseline presented to describe the state of the system before experiencing impacts from industrial projects. As a result of this approach, most EAs completed to date for relevant projects in the WBNP area have determined they will have a negligible effect on the PAD system. This is due to the fact that the environmental effects from single proposed developments with the potential to affect the WBNP are assessed on individual 'post-development' river systems, rather than as incremental and cumulative pressures on the WBNP system in the context of both past and future development. This approach prevents the accurate projection of cumulative effects on the world heritage values of the WBNP, particularly in the absence of a pre-industrial baseline.

Second, project-level impact assessment documents such as Environmental Impact Statements (EIS), and supporting technical documents submitted as part of environmental assessment review processes are evaluated through environmental assessment reviews; contain a range of views and opinions on the matters under review; and typically do not present final conclusions, but instead represent the materials for the decision-making authorities to consider when reaching conclusions and making project approval decisions. Referring to one document and the counter argument in another document as part of this SEA would lead to a replication of the whole environmental assessment review process.

Third, most project level environmental assessment reviews undertaken to date have not required an assessment of the impacts on world heritage values within WBNP so contain no analysis of the impacts of project activities upon the world heritage site and are therefore of limited value to the SEA.

3.3.2.2 Engagement

The engagement process employed for the SEA was managed by Parks Canada. Parks Canada and representatives from IEC, both collectively and independently, participated in calls, meetings and workshops with representatives of each of the eleven Indigenous communities that regularly work with WBNP, as well as other Indigenous groups south of the park. In many cases, depending on the approach taken by the Indigenous group, engagement included meeting with elected leadership, Elders, land users, knowledge holders, technical staff and external experts/consultants. In addition to calls and in-person meetings/workshops, many Indigenous groups provided written submissions outlining their views on the draft scoping report, as well as the draft final report. Further submissions to Parks Canada are anticipated following these group's review of the final SEA report.

Parks Canada also produced newsletters and posted information on WBNP's web site describing its responses to the World Heritage Committee requests (http://www.pc.gc.ca/en/pn-np/nt/woodbuffalo/info/SEA_EES). This information was circulated to other Indigenous groups south of the WBNP and to representatives of industry and ENGOs, and was available to the public. Parks Canada and IEC also communicated directly by phone and/or in person with several industry and ENGO representatives during the development of the SEA. The draft scoping report, and the draft SEA report were also posted on the Consulting Canadians website in September 2017 and April 2018 respectively.

Representatives of Indigenous groups, researchers, government departments and agencies, industries and industrial associations, and ENGOs provided information but also offered guidance on how to move forward, how to fill information gaps, and where they felt time and energy should be focused in the SEA.

"The Mikisew Cree First Nation (MCFN) Elders and Land Users were brought to the table to participate and tell their stories regarding their Traditional Territory/Homeland within the Wood Buffalo National Park. We were invited to share this information to help with the Strategic Environmental Assessment (SEA) of Wood Buffalo National Park, led by Parks Canada, as directed by UNESCO. As noted, story-telling is the oral tradition and holds a different perspective/method from society's way of documentation, which leads to a final technical report. With the wealth of knowledge within the group of Elders and Land Users, I decided to offer my experience to help facilitate the work in understanding two different perspectives in a way that does not diminish either, and that honours both. Drafts of the SEA were provided to the Elders and the MCFN Technical team to review as the work progressed. We then realized the drafts were not capturing the true reflection of our stories and words. Parks then made the attempt to include the voices by identifying quotes by the Elders. Through the help of the MCFN Technical team, we went to work to ensure the quotes had a name attached, as a way of showing respect along with the context of the quote to tie the quote to the section of the report. The Elder's short profile was included to validate his/her experience as an expert on the subject."

Source: *Alice Martin*
About Alice Martin: *Alice was born on the land within MCFN Traditional Territory, which is within Wood Buffalo National Park. Alice's experience on the land and her passion for her 'Way of Knowing' is the premise of her work today. Alice is still an active land user and goes out on the land for fall hunting trips and moose camps with her boat. Passing on the Cree Way of Knowing through on the land experience with her sons and grandchildren is very important.*

The recommendations of this SEA will carry forward to inform the next park management plan for WBNP (with a focus on the eleven Indigenous communities that partner with WBNP), and the development of the Action Plan for the World Heritage Committee (being prepared in cooperation with other federal, provincial and territorial initiatives and including involvement of a broader group of Indigenous communities).

Representatives of Indigenous Groups: Parks Canada and IEC engaged with Indigenous groups in and around WBNP, by means of in-person meetings in Fort Chipewyan, Fort Smith, High Level, and Edmonton, and through written materials provided by Indigenous groups. In total, eleven Indigenous groups participated in various group or individual meetings with the SEA consultants and Parks Canada staff, and others also provided comment and/or discussed the project with Parks Canada (see Table 3-1). Tours of the PAD to understand changes and impacts (MCFN, 2017a), dialogue at community events, and specific meetings to explain the SEA process and results to leaders, Elders, land users and knowledge holders were important aspects of this assessment.

> ***We are the scientists. We are the specialists. We know what it was and we are the ones who haves seen the changes.***
>
> ***Quote context:*** *The land users and trappers and traditional users on the land, we see the changes. We are out there every day. Growing up as young people, it was our store, fresh drinking water, and our fresh food. We start seeing changes animals, finding dead muskrats, fish kills. That tells us something is wrong. And the western science now is backing up what we are saying. We all agree something is happening and something needs to be done to save it!*
> ***Source:*** *Ron Campbell*
> ***About Ron Campbell:*** *I was born in Fort Chip. I have and still do spend a lot of time in the delta. I've been trapping muskrats since I was a kid. And I do spring hunts and moose hunting etc. Everything I got was once natural and country food. We spent a lot of time in the bush, and learned about life from the traditional users.*

Open dialogue between Indigenous group community members and Parks Canada was a priority, and much useful information was made available for use in the SEA through this process. Draft SEA content was also reviewed by Indigenous groups and their experts to ensure that available ITK and stories of change were accurately and appropriately included in the SEA document. This was a valuable feedback loop and helped ensure that Indigenous perspectives shared through this project were reported respectfully and accurately. Not all concerns identified by Indigenous groups representatives were integrated into the SEA report, as some issues and concerns raised were outside the scope of the project (i.e., not related to WBNP world heritage criteria). These issues were captured and are listed in Volume 2: Appendix A.5. This SEA has attempted to fairly and accurately record and integrate Indigenous knowledge, stories and perspectives throughout the report.

Table 3-1: Summary of Trips for In-person Engagement with Representatives of Indigenous Groups

Dates of Trips	Location	Description of Events	SEA Representatives
May 24 - 25, 2017	Fort Smith	• Meeting of WBNP Cooperative Management Committee	Parks Canada
August 14 - 18, 2017	Fort Chip	• Boat and Aerial Tour of PAD; Elders' retreat and workshop with MCFN • Meetings with representatives of ACFN and Fort Chip Métis	Parks Canada IEC
September 12 - 14, 2017	Fort Smith	• Meetings with representatives of DKFN, SLFN	Parks Canada IEC
October 19, 2017	Edmonton	• Meeting with representatives of MCFN	Parks Canada
November 22, 2017	Edmonton	• Workshop with representatives of MCFN	Parks Canada IEC
January 22, 2018	Fort Smith	• Meeting with representatives of SLFN	Parks Canada
January 28 - February 2, 2018	Fort Chip, Fort Smith, Edmonton	• Workshops/meetings with representatives of Indigenous groups: MCFN, ACFN, Fort Chip Métis, SLFN, SRFN, DKFN, KFN, NWT Métis, and LRRCN	Parks Canada IEC
March 4 - 11, 2018	Fort Chip, High Level	• Workshops/meetings with representatives of MCFN, ACFN, Fort Chip Métis, and LRRCN	Parks Canada IEC
March 12 - 15, 2018	Fort Smith	• Meetings with representatives of NWT Métis, DKFN, and SLFN	Parks Canada
April 17-18, 2018	Fort Chip	• Meetings with representatives of MCFN and ACFN	Parks Canada and IEC

Researchers: Over the course of the project, there was communication with a number of researchers who have present and/or past involvement in studies relevant to the issues being assessed in the WBNP SEA project. Materials provided include peer reviewed papers, published reports, grey literature, initial results of current investigations, and expert opinions in a wide variety of disciplines and subject areas. These include surface hydrology and flooding, ecosystems and habitat, wildlife, migratory waterfowl, contaminants and effluents, governance approaches, and management approaches. The information shared by these researchers was crucial to gaining a more complete understanding of cumulative effects impacting the world heritage values within WBNP, as well as for predicting potential impacts.

Government Departments and Agencies: Many of the issues affecting the state of conservation of WBNP world heritage values are trans-boundary in nature. The Parks Canada Agency manages WBNP within the boundaries. The Province of Alberta manages the land around the southern portion of the boundary and Northwest Territories manages the land around the northern portion of the boundary. This means that decisions made by jurisdictions managing lands adjacent to WBNP and further upstream have the potential to affect the state of conservation of the world heritage site. It is therefore obvious that jurisdictions and government bodies other than Parks Canada can play an important role in maintaining the integrity of the site. Over the course of the SEA, numerous federal and provincial government departments and agencies provided useful information for the assessment. These agencies and departments provided reports and recommendations. They also provided detailed and comprehensive comments on the Draft Scoping Report and other draft SEA documents.

Industry and Industrial Associations: Industry plays an important role in the development and operation of projects in the region. Federal and provincial government mandates include monitoring and measurement of various environmental parameters, such as air and water quality to detect changes in the regional ambient environment related to development activities. Collection of monitoring data is, therefore, part of project approvals for many new development projects. In recognition of this, the Governments of Canada and Alberta launched a comprehensive Joint Oil Sands Monitoring (JOSM) initiative in 2012. JOSM was established to consolidate and integrate a variety of existing monitoring programs into a single integrated program. Monitoring reports from various industries were made available for the SEA.

ENGOs: The feedback and support of ENGOs aided in refining the approach of the SEA. Groups recommended broadening the scope of the assessment by widening the timeframe, assessing additional types of impacts, and made additional suggestions to improve methodology. Given the international and local significance of WBNP, the materials from ENGOs provided additional context and guidance for the consideration of future management approaches in the region.

3.3.3 Identify Pathways of Effects

A pathway of effects model was used in the SEA. This tool is useful when assessing systems where cause and effect relationships are very complex or involve uncertainties. The method is based upon exploring the degree to which one factor in the system impacts another factor or factors. It is a means of overcoming the shortcomings that occur when individual elements in an ecosystem are considered in isolation. This method is particularly useful when trying to gain insights into the myriad interactions that occur in a complex system such as the Peace-Athabasca Delta.

Systems mapping is often undertaken when utilizing “Pathways of Effects” models. Pathways of effects methods are used to visually represent the interactions between individual impact sources and environmental receptors to provide insights into the possible scope and extent of impacts and cumulative effects that may occur. Several Indigenous groups described cumulative effects as “stories of change”, when explaining the differences, they had observed in the natural world in their lifetime. Additionally, systems-based diagrams show the integration of these pathways across time, space and scale by generating a web where all the pathways are connected. These models will be able to identify opportunities and challenges for future management.

The model developed by Fisheries and Oceans Canada (DFO) has the capacity to illustrate cumulative change across a system by demarcating pathways. This approach has been used widely across the federal government. In addition, it allows for differentiation between activity, pressure, stressor and end point. The results of the systems mapping are captured in Section 5.15.2.

3.3.4 Identify Valued Components for the PAD

The need to focus substantial effort on understanding the observed changes and complexities of the PAD became clear through the scoping exercise, literature review and engagement processes. The PAD has been subject to numerous and continual human-induced changes over the last 60 years. The vulnerable and complex nature of the delta means that all forms of change can generate unintended consequences across the ecosystem. As a result, the PAD provides an excellent example of the challenges associated with identifying and managing cumulative effects. Each development, in and of itself, only generates a small effect. However, when many small effects combine, the magnitude of the impact increases.

An extensive review of available literature was conducted to determine the issues of concern and current trends being experienced in the PAD resulting from stressors outside the WBNP, including industrial, commercial, and municipal development, as well as climate change over the past 60 plus years. Issues and challenges specifically facing the PAD were initially identified through interviews with relevant provincial and federal government personnel, as well as local Indigenous groups, who highlighted areas of concern and described the changes observed over time. These groups provided relevant literature, including peer-reviewed scientific literature, non-peer reviewed 'grey' literature, government reports and documents, stakeholder reports and documents, monitoring reports, JOSM monitoring information, Environmental Impact Statements and Joint Review Panel reports for projects in the region, as well as government and stakeholder presentations. Based on the review of literature provided, additional relevant literature was also found through internet and database searches, as well as follow-up meetings and conversations with a variety of experts.

The stressors and trends in the PAD, as identified through interviews and available literature, were grouped by area of concern and the relevant information compiled and presented in a logical format. This resulted in the identification of a series of valued components, including ice jam recharge, Athabasca River water quality, Peace River flow rates, habitat for water birds and wildlife, contaminant levels in fish water, and local Indigenous people's access. The trends observed in the PAD were linked to potential sources (stressors) of change and a determination made as to the direction of change being observed. The complexity of hydrologic and ecological processes in the PAD prevented the definitive linkage of individual stressors to trends being observed. A number of the trends observed in the PAD could be linked to changes in other aspects of the PAD, hence pathways of effects were developed for a number of PAD valued components.

3.4 Step 3 – Predict Future Trends for World Heritage Values (see Chapter 6)

Cumulative effects analysis, as with predictive analysis in all kinds of environmental assessment (EA), is an exercise of applied systems analysis (see Beanlands, et al., 1983; Munn, 1979). The goal is to understand the mechanisms by which multiple stressors, both natural and human made (anthropogenic), affect a measured component, and/or the ability to achieve a desired outcome for that component. This understanding is then used to adjust the stressors acting on the component using an adaptive management approach. This is typically achieved through application of mitigation measures or collaborative management approaches so that the integrity of the component is not compromised by human action (Duinker & Greig, 2006). Monitoring of the effectiveness of mitigation measures and management approaches is an important means of determining what works well, and what needs to be improved. Cumulative effects assessment (CEA) is integrated into the SEA such that it takes into account the entirety of development in the area, rather than individual projects, at an appropriate temporal and spatial scale, using best available information. The approach to CEA is focused on land-use planning and environmental management, where the cumulative effects of human activity are also taken into account. A high-level, qualitative cumulative effects assessment was undertaken in order to gain an understanding of the potential effects on the desired outcomes for the WBNP over the next thirty years from likely future changes in climate, along with proposed and reasonably foreseeable development in the region. Current stressors and trends already being observed in WBNP were used as the baseline to which the potential cumulative effects of future development and climate change were added.

In order to evaluate the impact of potential cumulative effects on the desired outcomes for the WBNP, it was first necessary to determine the level and types of industrial, commercial, and municipal development already present in the region. Existing development in the region included hydroelectric dams and oil sands mines and processing plants, as well as pulp and paper facilities, industrial mines, forestry activities, and municipal development. Following this, relevant approved, planned, proposed, and reasonably foreseeable future projects in the region with the potential to affect the desired outcomes for the WBNP were identified. Information on relevant development projects was obtained from a number of sources, including government websites and literature, as well as industry websites and literature. Secondly, a summary of the projected effects from future climate change over the next thirty years specifically related to the PAD were compiled. Projections from available literature were examined in order to gain an understanding of the magnitude and direction of potential impacts on the PAD valued components from future climate change in the region, within the context of existing trends already being observed in the PAD.

Finally, the future trend was identified by examining the pathways of effects previously identified and determining how climate change and reasonably foreseeable developments would affect those pathways. To complement this analysis, existing mechanisms to manage cumulative effects were described. These mechanisms mainly involve environmental management and land use planning frameworks established by the federal and various provincial governments. Taking into account the current trends for pathways of effects, the contributions of climate change and reasonably foreseeable developments, a final projection was then made as to the likely future direction of the trends on the desired outcomes for the WBNP.

3.5 Step 4 – Develop Recommendations to Reverse or Mitigate Trends (Chapter 7)

Recommendations were generated based on the current status and projected trends related to the desired outcomes for the WBNP and the pathways of effects where changes have or may occur. Given that there are specific recommendations from the RMM which must inform the development of an Action Plan for protecting the world heritage values of Wood Buffalo National Park, the recommendations of this SEA were organized in this context. Recommendations from the SEA were therefore grouped under the RMM recommendations for consideration by the lead jurisdiction responsible for leading the related component of the Action Plan. The executive summary of the SEA and associated materials is posted at: https://www.pc.gc.ca/en/pn-np/nt/woodbuffalo/info/SEA_EES/bulletin.

Table 3-2: Elements of the OUV

Criterion – OUV Statement (verbatim text)	OUV excerpts of primary importance	Listing of Individual OUV Elements for this criterion	Interpreted meaning	Desired Outcomes	Draft Valued Components (These will be further developed and refined during the Action Plan Implementation)	Potential indicators (These will be further developed and refined during the Action Plan Implementation)
Criterion (vii): "The great concentrations of migratory wildlife are of world importance and the rare and superlative natural phenomena include a large inland delta, salt plains and gypsum karst that are equally internationally significant."	1. Great concentrations of migratory wildlife of world importance.	i. Great concentrations of migratory wildlife of world importance	Migratory wildlife means migratory waterfowl* populations which make seasonal use of WBNP. Migratory waterfowl from four continental flyways converge in great numbers on the PAD for staging and breeding habitat. *Waterfowl is understood in this context to include water birds, gulls, shorebirds, cormorants.	• Great concentrations of viable, healthy populations of migratory waterfowl species continue to use WBNP seasonally. • Adequate quantity and quality habitat, unimpaired by contamination, is available for migratory waterfowl to fulfil all key life cycle stages while present in WBNP. • Indigenous groups are able to maintain traditional harvest of waterfowl species and practice their way of life with confidence in healthy, sustainable and accessible populations of waterfowl.	Populations of waterfowl	Waterfowl survey
					Waterfowl habitat quantity	Remote sensing extent of habitat types
					Waterfowl habitat quality	Mercury and PAH levels in eggs, water, air testing
					Travel routes for Indigenous people available (Mamawi, Hay River, Pelican Creek, Lake Claire) Waterfowl harvest rates (indicative of perception and cultural/community capacity)	Waterfowl harvest by Indigenous people
	2. Rare and superlative natural phenomena including a large inland delta, salt plains and gypsum karst that are equally internationally significant.	ii. Large inland delta (Peace Athabasca Delta (PAD))	Portion of the Peace Athabasca Delta within WBNP (80%), with consideration of the portion of the PAD outside of the park. The Delta is understood to include the ecological functions and ecosystems it supports, including vegetation, wildlife and Indigenous communities within the Delta.	• Flow regimes and water quality into the PAD maintain the ecological function of the ecosystem • Flow regimes and water quality into the PAD sustain vegetation communities and healthy and abundant populations of key ecological and cultural species including waterfowl, muskrat, fish, bison and wolves. • Indigenous groups have access to the PAD and are confident enough in the health of the PAD to maintain traditional use and way of life through hunting, fishing, gathering, and cultural activities.	Indigenous access & enjoyment of the PAD	• Stream flow analysis • Assessment of vegetation communities' health and composition • Invasive plants such as Canadian thistle within acceptable thresholds • Assessment of key species' health and extent • TEK, TLU Interviews confirm groups' confidence in health of PAD and ability to exercise traditional use and way of life. Indigenous peoples
					Intact ecological function of the PAD, incl. Ice Jam & Open Water Recharge	
					Sufficient water for Indigenous people to navigate safely in the exercise of their Treaty and Aboriginal Rights	
					Peace River Seasonal Flows; Peace River Sedimentation; Athabasca River Annual & Seasonal Flows	

Criterion – OUV Statement (verbatim text)	OUV excerpts of primary importance	Listing of Individual OUV Elements for this criterion	Interpreted meaning	Desired Outcomes	Draft Valued Components (These will be further developed and refined during the Action Plan Implementation)	Potential indicators (These will be further developed and refined during the Action Plan Implementation)
					Lake Athabasca Water Levels; Central PAD Lake Water Levels Vegetation Quality & Quantity Fish Habitat, Quality & Quantity Migratory Bird Quality & Habitat Wildlife Quantity & Habitat Air Quality Groundwater Quality & Quantity	are able to "dip a cup" in PAD waters for drinking purposes again. • Recharged perched basins • Frequent PAD flood events • Abundant muskrats, and waterfowl • Water quality, (salinity, evaporation, PAHs and metals) • Fish quality (Hg and other metals) • Berry quality & abundance • Aboriginal Base/Extreme Flow • Population and quality of fish; Access to traditional medicines
		iii. Salt plains	Salt plains area within WBNP	• The salt plains remain aesthetically, ecologically and geologically unique in Canada, providing habitat for salt tolerant plants, grazing bison and nesting / staging waterfowl.	Extent of salt plains Ecological representative	Non-native species extent
		iv. Gypsum karst	Gypsum karst topography within WBNP	• Gypsum karst topography in WBNP remains intact and functioning within natural parameters. • The karst landforms in the Park continue to provide some of the finest examples of collapse and pond sinkholes in the world.		

Criterion – OUV Statement (verbatim text)	OUV excerpts of primary importance	Listing of Individual OUV Elements for this criterion	Interpreted meaning	Desired Outcomes	Draft Valued Components (These will be further developed and refined during the Action Plan Implementation)	Potential indicators (These will be further developed and refined during the Action Plan Implementation)
Criterion (ix): "Wood Buffalo National Park is the most ecologically complete and largest example of the entire Great Plains-Boreal grassland ecosystem of North America, the only place where the predator-prey relationship between wolves and wood bison has continued, unbroken, over time."	1. Great Plains-Boreal grassland ecosystem – the largest and most ecologically complete example in North America.	i. Ecologically complete Great Plains – Boreal grassland ecosystem	The boreal forests and vast sedge meadows of the PAD (the largest undisturbed grasslands in North America) and smaller but numerous meadows north of the Peace River.	• All species and community representatives of the Great Plains-Boreal grassland are present and functioning. • These grasslands continue to provide important grazing and calving areas for Wood Bison.	Vegetation communities' health and composition	Assessment of vegetation communities' health and composition
						Survey of species and community representatives of Great Plains-Boreal grassland ecosystem
					Quantity of bison habitat	Area of bison habitat
	2. Predator-prey relationship between wolves and wood bison – the only place where this relationship has continued, unbroken, over time.	i. Intact predator-prey relationship between wolves and wood bison	Intact predator-prey relationship between wolves and wood bison. Includes all bison herds that spend time in the park.	• The predator-prey relationship between wolves and wood bison that spend time in the Park remains intact and within natural ranges of variation • Populations of both species remain viable, evolve as naturally as possible and support Indigenous traditional use and ways of life.	Bison population Alternate prey populations	Bison population Calf survival rates With observed change: predation rates Moose populations in the area of the bison
					Wolf population	Wolf population With observed change: predation rates
Criterion (x): "Wood Buffalo National Park		1. Whooping crane breeding habitat		• Habitat continues to support recovery strategy goals for breeding pairs and	Whooping crane habitat	Prey availability Habitat hydrology

Criterion – OUV Statement (verbatim text)	OUV excerpts of primary importance	Listing of Individual OUV Elements for this criterion	Interpreted meaning	Desired Outcomes	Draft Valued Components (These will be further developed and refined during the Action Plan Implementation)	Potential indicators (These will be further developed and refined during the Action Plan Implementation)
contains the only breeding habitat in the world for the Whooping Crane, an endangered species brought back from the brink of extinction through careful management of the small number of breeding pairs in the Park. The Park's size (4.5 million ha), complete ecosystems and protection are essential for in-situ conservation of the Whooping Crane."	1. Only breeding habitat in the world for the Whooping Crane.		Whooping crane habitat within the WBNP. Includes habitat and population.	demonstrates resilience to climate change impacts. • Whooping crane population reaches recovery strategy goal. • Recovery and down listing from endangered status.	Whooping crane population	Whooping crane population Breeding pairs

4.0 CHAPTER 4: WBNP WORLD HERITAGE ELEMENTS EXCLUDING THE PAD

In this chapter, the pathways of effect, status and trends of salt plains, karst, boreal-grassland communities, migratory waterfowl, bison predator-prey relationship and Whooping Crane are evaluated.

4.1 SALT PLAINS


Salt Plains. Photo: Parks Canada

The WBNP Salt Plains are defined as "The inland saline wetlands (that) occupy periodically-flooded flats or terminal basins where alkali salts concentrate by evaporation" (Timoney, 2001). Alkali salts include sodium, magnesium, and calcium sulphates and chlorides. They are located on the north-eastern border of WBNP (Figure 4-1).

The salt marshes are typically featureless. They can contain plants such as slender wheat grass (C*alamagrostis stricta*), rush (*Juncus*), *Hordeum jubatum* meadows, and samphire (*Salicornia europaea*) flats. Importantly, these wetlands contain a high proportion of rare or uncommon plants due to their unique chemical environment. For example, *Carex mackenziei*, a circumpolar coastal species, is found in the salt plains. Prairies wetlands plants rare in Northern Alberta, such as *Scirpus paludosus, Atriplex subspicata*, and *Aster pauciflous* are also found in the salt plains (Timoney, 2001).

The salt plains are rich in bird life. Canada Geese (*Branta canadensis*), Sandhill Cranes (*Grus canadensis*), Least Sandpipers (*Calidris minutilla*), Western Sandpipers (*Calidris mauri*), and American White Pelicans (*Penecanus erythrorhynchos*) can be found here. Additionally, abundant aquatic invertebrates have been observed. The salt plains lack bryophytes and fen species, which are characteristic of marshes (Timoney, 2001).

4.1.1 Pathways of Effects on the Salt Plains

Potential pathways of effects on the salt plains are climate change and invasive species. Due to the unique geological formations of groundwater replenishing the plains, the salt plains could be vulnerable to changes in temperature, precipitation, and other factors as a result of climate change, but no research has been conducted on this.

Figure 4-1: Salt Plains and Gypsum Karst Topography of WBNP (Parks Canada, unpublished data)

Invasive species that thrive in saline environments could be introduced to the ecosystem. In 2016, a large population of established Perennial Sow Thistle (*Sonchus arvensis*), was located along the northern treed boundary of the Salt Plains, within walking distance of the Salt Plain's Look-out Point. Hayward (2016) reports that, "…this non-native plant spreads rapidly through its heavily seeded pappus (seed head), with thousands of seeds being released at one time and their wind and water borne capability. This, along with their underground rhizomes, which reproduce themselves if broken-off, makes it extremely difficult to eradicate." However, the saline environment of the Salt Plains seems to act as a natural barrier to the spread of the less-salt-tolerant weed species (Hayward, 2016).

4.1.2 Status and Trend of Salt Plains

No ITK was provided related to the salt plains. Invasive species are not known to have invaded the salt plains (Hayward, 2016). Anecdotal observations and limited evidence suggest that the salt plains in WBNP meet, with a neutral trend, the desired outcome:

- The salt plains remain aesthetically, ecologically and geologically unique in Canada, providing habitat for salt tolerant plants, grazing bison and nesting / staging waterfowl.

4.2 Gypsum Karst

A karst topography is generally formed by the dissolving of soluble rocks, such as gypsum. As a result of gypsum's minimal load bearing capacity, solution-pitted gypsum cavern roofs tend to collapse, particularly where there are thick deposits or other rocks on top. Spectacular looking collapse sink holes results from these large underground solution hollows that are formed in the gypsum and the overlying limestone collapses into the cave below.


Karst Topography, Grave cave, WBNP. Photo: Parks Canada

In WBNP, these formations occur discontinuously along the Salt and Little Buffalo rivers, the escarpment west of the Salt River, and within dolines, caves, and waterfalls behind the escarpment in the Northeastern region of the park (Figure 4-1). The most complete sections of karst occur along the Little Buffalo River (Tsui & Cruden, 1984).

These formations provide valuable habitat to numerous species, including bears, and bats, such as little brown myotis (*Myotis lucifugus*), northern myotis (*Myotis septentrionalis*), and big brown bats (*Eptesicus fuscus*) (Reimer et al., 2014), among other wildlife. The hydrogeology in this region forms the diatom ponds which provide the Whooping Crane habitat (Timoney et al., 1997). Some of the WBNP caves are ice caves (Rollins, 2004).

4.2.1 Pathways of Effects on the Gypsum Karst

Impacts to the gypsum karst from development around the park could be possible through changes to hydrology; however, the hydrological connections have not been researched to understand the degree to which this pathway is possible. The warming climate means ice trapped within the caves could melt, changing cave ecosystems.

4.2.2 Status and Trend of Gypsum Karst Topography

Indigenous Knowledge holders did not provide any information about the karst. Anecdotal observations suggest that the gypsum karst topography in WBNP meets, with a neutral trend, the two desired outcomes:

- Gypsum karst topography in WBNP remains intact and functioning within natural parameters.
- The karst landforms in park continue to provide some of the finest examples of collapse and pond sinkholes in the world

4.3 GREAT PLAINS BOREAL GRASSLAND


Boreal Grasslands, WBNP. Photo: Parks Canada

The Great Plains Boreal Grassland is an eco-region within the Boreal Plains Ecozone. The Boreal Plains Ecozone lies just north of the Prairies Ecozone and is 84% forested with both coniferous and deciduous trees. However, there are intermittent patches of grassland within this Ecozone (Shorthouse, 2010). WBNP is the national park representing the Northern Boreal Plains and Southern Boreal Plains & Plateau natural regions as identified by Parks Canada. The mix of boreal forest and grasslands support crucial habitat and forage for bison, as well as deer, caribou and moose.

4.3.1 Pathways of Effects on the Great Plains Boreal Grassland

The three pathways of effects that are most likely to alter the Great Plains Boreal Grasslands are those related to the dominant ecological processes: fire suppression, changes to water regime, and grazing. In addition, invasive species have the potential to bring changes to the ecosystems in the Great Plains Boreal Grasslands.

- **Fire Suppression:** Fire risks within WBNP have increased due to a transition towards more upland forest ecosystem. The total flammable biomass accumulated, climate change and historic fire suppression could cause large wildfire in the future (Thompson et al., 2017). Fire could increase the available grasslands regionally (Strong & Gates, 2009).

- **Changes to Water Regime**: Impacts to the water regime have increased willow coverage as a result of drying conditions (K. Timoney, 2006). Additionally, ITK has indicated that invasive thistles have also become dominant species in grassland ecosystems within the delta (Candler et al., 2015a). Evidence exists that quaking aspen (*Populous tremuloides*) has also invaded some grasslands in WBNP over the last 60 years (Schwarz & Wein, 1997). See Chapter 5.0 for more details.
- **Grazing:** Bison, moose, and caribou graze on vegetation in WBNP. Changes to grazing patterns are not known, but not are expected to be a significant a pathway and therefore were not further considered.
- **Invasive Species**: The incursion of natural vegetation communities by invasive plant species is widely recognized as a considerable risk associated with land disturbance (White et al., 1993). As land disturbance increases around the park, the risk of invasive species coming into the park increases.

It's willowed in all over, shrunk and there is thistle on one side. The few buffalo that come in eat have to around the thistle and then they are gone again. Buffalo may eat willow for a few years when the willows are small. But when the willows get bigger, the buffalo don't bother.

Quote context*: Willow, even what they (buffalo) do now is not normal. Buffalo don't usually bother with willow. The last 5 or 6 years that is when they are getting into the willow and in areas willows weren't growing before. A lot of the places where they used to eat the grass are now covered in thistle. These places are all getting smaller. One time they were lakes, and then they become prairie. The moose are leaving, the beaver, and the buffalo too. They are having a hard time and they sense the changes.*
Source: *Matthew Lepine*
About Matthew Lepine: *I've been on this land most of my 69 years. I was born in Fort McMurray. I lived in the bush until it got to a point. Even when I went to work in Fort McMurray I still kept up all the work. I used to come up here on weekends. The changes that have happened over 60 years are a lot. I am living on the land still. I'm going back tomorrow morning.*

4.3.2 Status and trend of Great Plains Boreal Grassland

Using the Area Burned Condition Class methodology in the National Fire Monitoring Guide (Parks Canada Agency, 2010b) the forest fire regime is in good condition (Figure 4-2). Recent research has indicated that Boreal grassland areas are decreasing. Evidence from early in the 20th century suggests how much more extensive grasslands were around WBNP, including within the Peace Point region (Schwarz & Wein, 1997; Strong & Gates, 2009).

The first desired outcome is:

- All species and community representatives of the Great Plains-Boreal grassland are present and functioning.

There is no evidence of species or communities being lost and, with fire being the most dominant process of change on the landscape over the largest area, this objective is being met with a neutral trend.

The second desired outcome is:

- These grasslands continue to provide important grazing and calving areas for Wood Bison.

In the PAD, there are concerns about the ability of grasslands to provide important grazing and calving areas for Wood Bison because of changes to shrubs and invasive species (see Section 4.5). While, at this point this factor is unlikely to limit the bison population, there is a negative trend associated with this desired outcome. ITK indicates that there has been an effect on the grasslands and as a result, this desired outcome is currently understood to not be met. Further research on this aspect would be helpful to understand the extent of the problems.

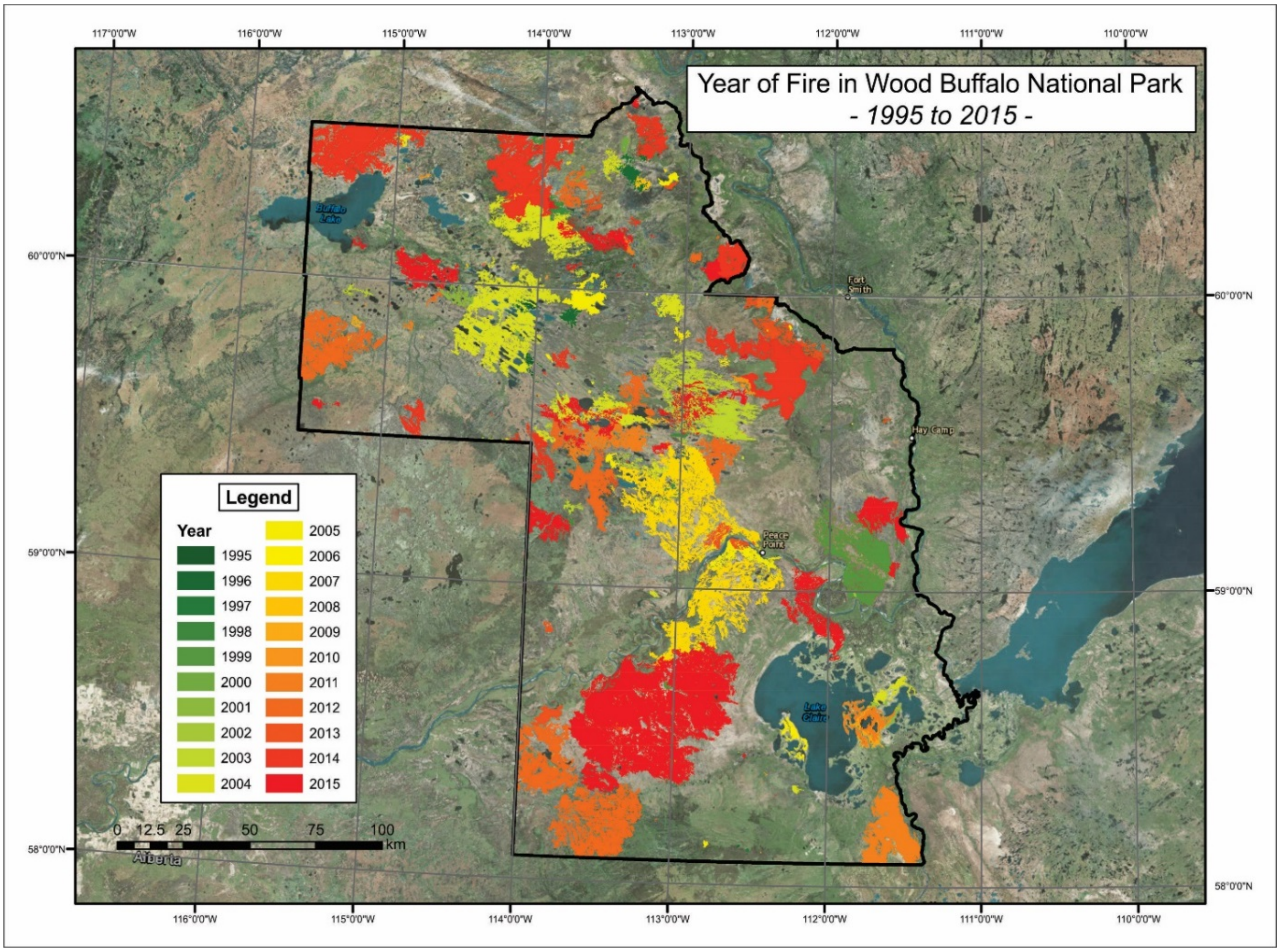


Figure 4-2: Year of Fire in WBNP (Parks Canada, Unpublished Data)

4.4 Migratory Waterfowl

Migratory waterfowl is understood in this context to include birds that are primarily associated with open water (waterbodies, watercourses) and wetland habitats – collectively known as waterbirds. These include dabbling waterfowl (e.g. ducks, geese and swans), diving birds (e.g. loons, grebes, cormorants and scaup), waders (e.g. herons, cranes, rails and shorebirds), and surface-feeders (e.g. gulls, terns). Migratory waterfowl from four continental flyways converge in great numbers on WBNP, especially the PAD, which provides critical wetland habitat for migrating, breeding, molting and staging birds, including numerous species of conservation concern (Figure 4-3).

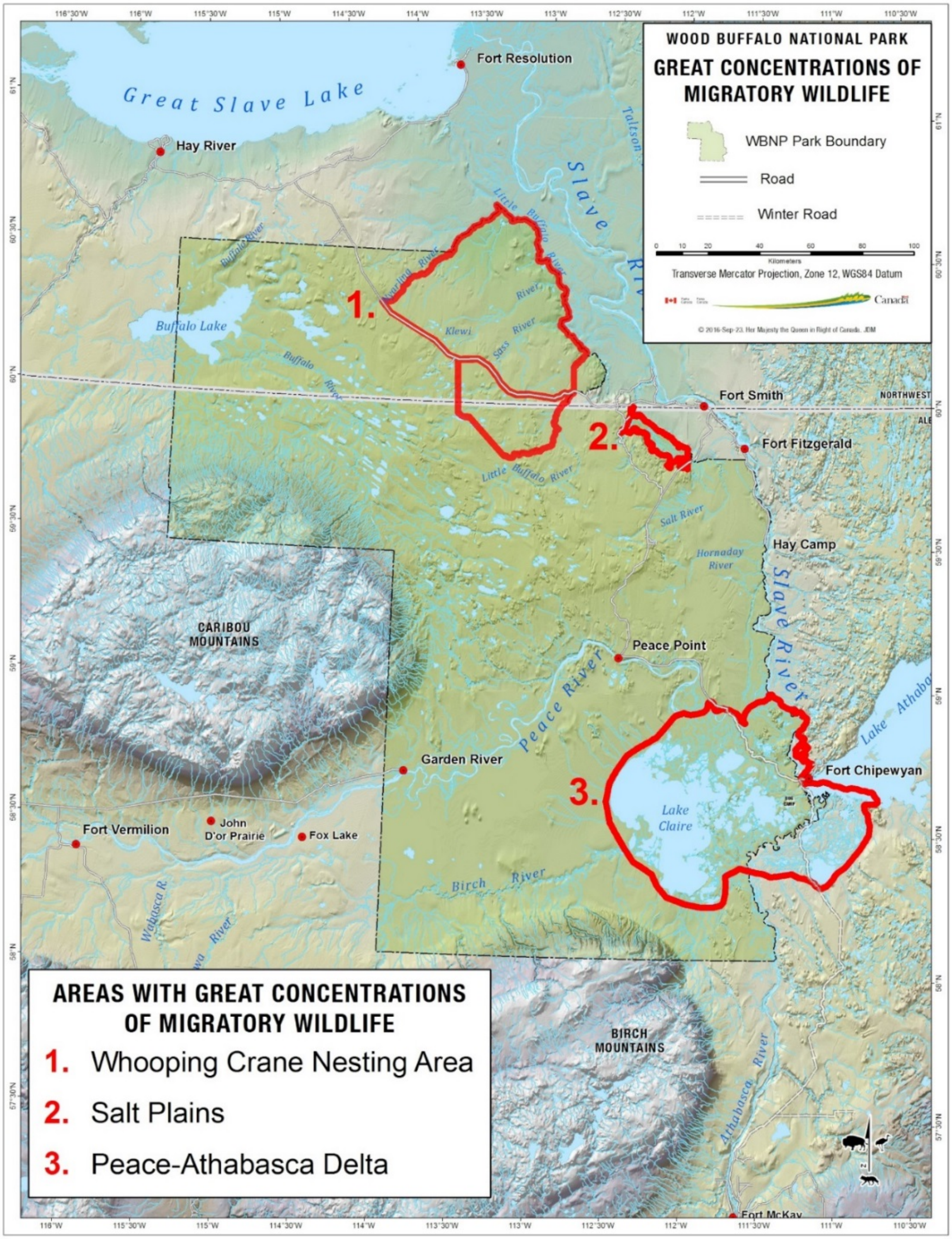


Figure 4-3: Locations of Concentrations of Migratory Waterfowl Within WBNP (Parks Canada, Unpublished Data)

4.4.1 Pathways of Effects on Migratory Waterfowl

WBNP has a high diversity of bird species with a total of 227 bird species having been recorded within the park (Parks Canada, 2010). Within WBNP, the PAD has been recognized as one of the most important waterbird areas in North America (Soper, 1951; Butterworth et al., 2002), and most research on waterfowl abundance, occurrence and diversity in WBNP is focused specifically on the PAD. Species commonly reported in the PAD include a diverse range of waterfowl (ducks, geese, swans), shorebirds, rails, herons, loons, terns, grebes, gulls, pelicans, cormorants, songbirds, and raptors. High species richness is believed to be due to the diversity and abundance of wetland habitats in the PAD (Timoney, 2013; Soper, 1951), with birds distributed according to specific habitat foraging guild requirements, and seasonal requirements for migration, breeding, brood-rearing, molting and fall staging habitats.

There are 51 species considered to be annually common and can be expected to be abundant in suitable habitat at various points during the breeding season (Timoney, 2013). For Ross's goose (traditionally known as "galoots" to local land users), the PAD is the most important migratory stopover site in Canada (Thomas, 2002). Migratory waterfowl, especially ducks and wavies (a term used to describe large groups of Lesser Snow Geese), are highly valued traditional resources for ACFN and MCFN and are harvested for food and clothing (feathers) and eggs are harvested in the spring (Candler et al., 2015a). Surveys also indicate that the PAD is regionally important for numerous species of shorebirds (Beyersbergen, 2004). Similarly, for Yellow Rails, designated as Special Concern and listed on Schedule 1 of SARA, recent surveys showed that this species is present in the PAD and that habitat around Lake Claire and Mamawi Lake may be significant for the species in Alberta (Maclean and MCFN, 2016).

Migratory waterfowl in WBNP and the PAD experience numerous natural and anthropogenic stressors throughout their annual life cycle, including overwintering, migration, and summer breeding/nesting periods, that may impact health, fitness and survival. Stressors that impact overwinter survival (outside WBNP) and fitness may act cumulatively to affect waterfowl populations in WBNP. Figure 4-4 is a diagram developed by MCFN Traditional Knowledge holders of trends and stressors for migratory waterfowl in the areas of the park in and around the PAD, including the effects on indigenous traditional use and ways of life (MCFN, 2018a). Local anthropogenic stressors to birds in WBNP and the PAD include risks associated local migratory habitat (the Mineable Oil Sands Region (MOSR)), immediately south of WBNP. Five key stressors and local pathways of effect for migratory bird in WBNP have been identified:

- Changes in habitat and food availability in the PAD
- Exposure to contaminants in water, food and sediments in the PAD
- Short-term exposures to contaminants in local migratory habitat
- Changes to habitat and food availability in local migratory habitat
- Changes in local migration routes

These key stressors, some of which originate outside of WBNP, can have direct or indirect impacts on migratory waterfowl in WBNP and can act cumulatively. Mechanisms of effect are discussed below.

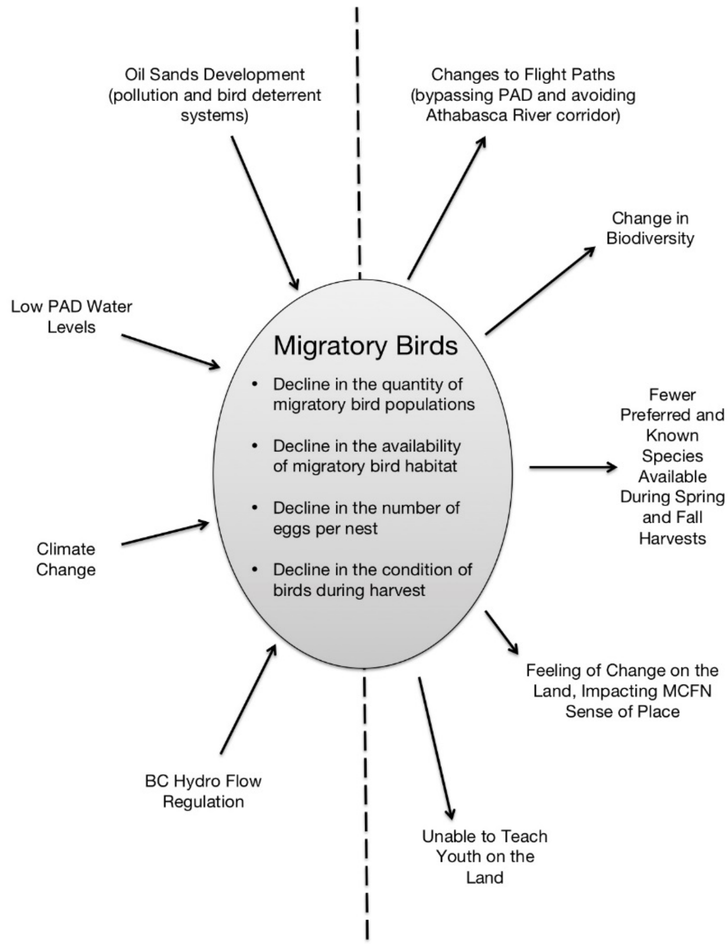


Figure 4-4: Migratory Waterfowl – Key Stressors, Conditions, and Outcomes Based on MCFN IK (MCFN, 2018a)

4.4.1.1 Changes in Habitat and Food Availability in PAD

The composition and distribution of vegetation in the PAD is principally determined by differences in moisture regime. Variations in the hydrological state of PAD water bodies, whether from natural or human causes, directly influence the amount and quality of wetland habitat and consequently the abundance, occurrence, and diversity of migratory waterfowl dependent on these habitat types (Nieman and Dirschl, 1973; Timoney, 2013). Reduced water levels can lead to a pronounced reduction in the extent of open water, shallow marsh, emergent vegetation, and wet meadow habitats used by migratory waterfowl, and the replacement of these wetland habitats by communities dominated by more upland species such as willows (Timoney, 2013) (See also Section 5.11). Hydrological changes can also result in shallower, warmer lake conditions, with subsequent effects on water chemistry, productivity, and increases in algal blooms (Timoney, 2013).

Migratory bird occurrence and distribution in the PAD appears to correlate with specific habitat and foraging guild requirements, and seasonal requirements for migration, breeding, brood-rearing, molting and fall staging habitats. Nest site availability and suitability are largely impacted by emergent vegetation and water levels. Molting birds require habitat that provides adequate water body size and depth and the presence of dense stands of emergent vegetation for avoiding/escaping predators during flightless period. For brood rearing, waterfowl need access to areas that have stable water levels. In some situations, spring breeding habitat may become sub-optimal by mid-summer due to lack of water.

All the water that shows up on these maps, half the water isn't in there now. Some of these lakes are all willows, poplars. Once we had birds landing and now it's full of willows. Where are they going to land?

Quote Context: *I can't go into Gull River now because it's grown in because of low water. Every year there is less water. That is what is happening. It's not only muskrats that we are trying to get the water for, it's our transportation. But now the water is too shallow sometimes you can't even go to Hay River. You can't go to Lake Mamwai, unless you push your boat up. That is what is happening. For birds, the bottom is growing up from the water, vegetation. Now the willows grow on top now, instead of the grass it used to have. The willows are taking over, replacing the grassy area. The lake that used to be a #1 hunting area, now there is different grass and hay.*

Source: *George Martin*

About George Martin: *I'm 76. I started trapping at 12 by myself. I've been here all my life. This is my area. I killed my first caribou at 8 years old. We had to learn in the bush.*

Staging areas are sites where migratory waterfowl prepare themselves physiologically for their next migration flight. Staging can occur in both fall and spring seasons and habitats for staging must provide reliable and abundant food sources. The PAD is typically used for staging by migratory waterfowl at the beginning of fall migration as they prepare for long flights south (Hennan & Munson, 1979). Overall, abundance and diversity of waterfowl are greatest during years when waterbodies are abundant, shorelines are extensive, and water levels are neither too high nor too low and do not change significantly over the breeding period (Timoney, 2013). In the PAD, the optimum habitat conditions need to persist from May to July for maximum waterfowl breeding success (Hennan, 1972). Therefore, changes in the PAD hydrologic regimes (natural or human-made) will impact the location and the number of breeding pairs of waterfowl, as well as numbers of staging and moulting migrating birds (Dirschl, 1972; Butterworth et al., 2002; Timoney, 2013).

4.4.1.2 Exposure to Contaminants in Water, Food and Sediments in PAD

Several of the contaminants of concern that are affecting surface waters in the MOSR and downstream in the PAD are the same as those highlighted as contaminants of concern in Oil Sands Process-affected Water (OSPW), including metals and PAHs, and PAH derivatives such as dibenzothiopene (DBT). The potential modes of transport of the contaminants from oil sands developments to the Athabasca River and downstream to the PAD include atmospheric deposition (to snow, soils, water) and waterborne transport (shallow groundwater, streams and wetlands to rivers moving downstream). Within each of these transport pathways, contaminants can be associated with airborne particulates, dissolved in water, associated with suspended sediments, or incorporated within animals and plants. Contaminants, especially organic compounds like PAHs, can also be modified or degraded during this transport process,

There are less nesting areas in the Delta than there used to be. I go out in May to get eggs, May 15 to end of May, and now I find more of two yolks in the one egg. It can be as many as one in three will have two yolks. That is different to me in past couple of years. Also nests used to have 12-15 eggs but now I'm lucky to get 6. The nests are not as full.

Quote context: *Maybe it's because of the feed, what is in the water. Maybe there is not enough of their food they normally get on the delta, the bugs and vegetation. You can't even go there now these years with a boat. I have collected eggs since I could remember. It used to be that it was unusual and I got happy when see two yokes long ago. Now I ask how come there are two yolks in one egg all the time. It's just about every second egg now has two yolks. This must be again from what the birds are eating. We have found rabbits that have two private parts. It's scary. I wonder if I should eat the eggs. And even just to go show you or anyone how to pick eggs, it's hard if there is nothing out there. It's a loss of way of life. We can't pass it on.*
Source: *Jocelyn Marten*
About Jocelyn Marten: *I have been on the land probably since I was born, 1970. I grew up with my grandparents and two uncles GM and Sammy. We lived in Doghead, in a shack, a house. Then I remember living on the Athabasca River. That is where I spent my winters, trapping with buying fur, with my whole family. I called it Embarras house, they called it Snowbird's. I saw ice break ups and jams. It was a small community like 10 families there. There was a store across the river. In spring time we'd move to Frog Creek, in the beginning of April as there was so much snow, water, and overflow. And all we had was dog teams to move with. I am still out on the land and I take my family. I help with GM's cabin. It's not experience, it was (and still is) my way of life and how I was brought up.*

and may bioaccumulate or biomagnify in biota, making source attribution challenging. Additionally, the PAD landscape is a complex system of interacting biotic and abiotic factors in a hydrologically dynamic ecosystem making toxicology studies in this environment difficult. Other upstream and regional contaminant sources that may act cumulatively with those from the oil sands include pulp and paper mills, forestry, agriculture and municipal effluent.

Local land users are seeing changes in the PAD that they attribute to contaminants coming from upstream sources, especially oil sands development. For example, land users are seeing sick and skinny birds, deformities in animals and eggs, slime in water, sheen in boiled water, etc. (MCFN, 2018a). Land users also state that "*We look at the animals to gauge the water…If fish are dying and fish are deformed, that has to affect the animals as well. And that scares people who eat traditional foods. And it means they may not be able to pass their knowledge on to future generations because of that fear and that has an impact too*." (MCFN, 2018a). Indigenous communities are also concerned about consumption advisories on fish and on gull and tern eggs in the PAD that were put in place in 2014 due to high mercury (Hg) levels (GoA, 2014a). This impacts their ability to harvest traditional foods (MCFN, 2018a).

Recent comprehensive measurements of contaminant concentrations and characteristics from multiple environmental components (biotic and abiotic) across a broad range of ecosystems in the Athabasca River and the PAD have attempted to determine the sources, form, and fate of oil sands-derived contaminants. This includes work by a Community Based Monitoring (CBM) Program which has tracked changes to water and terrestrial resources in the traditional areas of MCFN and ACFN, as well as directed studies on hunter/trapper harvested animals (including furbearers, fish, ducks and bird eggs). Results from some of this research are only recently available, but there is evidence emerging from numerous sources to indicate that exposure to some environmental contaminants, e.g. mercury, may be elevated in the PAD (Hebert et al., 2011, 2013; Dolgova et al., 2018).

In the PAD, research has focused primarily on two contaminants of key concern for bird health: metals (particularly mercury) and PAHs. Mercury bioaccumulates and biomagnifies as it is transmitted to higher food web levels in the environment and can be taken up by migratory waterfowl through foraging activities. In birds, mercury can impair reproduction and immune function, and cause detrimental behavioural changes (Whitney and Cristol, 2018). For PAHs, there is significant evidence that exposure triggers an array of pathological effects in organisms and can have teratogenic (changes to embryo/fetal development), mutagenic (changes to genetic material) and carcinogenic (cancer causing) effects in fish, amphibians, mammals and birds (Eisler, 1987). PAHs have also been identified as endocrine disruptors (Lintelmann et al., 2003) and, in birds, cause inflammation, immunosuppression, and oxidative damage to cells (Leighton, 1993; Briggs et al., 1997; Albers, 2003). In terms of the ingestion pathways of contaminants for birds in the PAD, recent data indicates that mercury and PAHs are present in water, sediments, and fish and in some cases, occur in relatively high concentrations in aquatic ecosystems in the Athabasca River and the PAD (Kelly et al., 2009; Radmanovich, 2013; Evans et al., 2016; Dolgova et al., 2018), but more data are required regarding contaminant loads in aquatic plants and invertebrates in these regions.

Mercury can be taken up from water, sediment, and food by aquatic organisms to varying degrees, depending on the type of organism, its growth rate and trophic position (Boening, 2000; Ward et al. 2010; Sandheinrich et al., 2011; Karimi et al., 2016). There is evidence that mercury is accumulating in aquatic organisms in the MOSR, some of which are food sources for migratory waterfowl that use the PAD. For example, mean total mercury concentration in an aquatic benthic invertebrate (caddisflies, *Trichoptera*) in the Athabasca River was significantly higher downstream of oil sands development compared to sample sites immediately adjacent to oil sands development or in the PAD, indicating a potentially local influence of oil sands development on the mercury burden in these invertebrates (Radmanovich, 2013). Preliminary results from a joint Environment and Climate Change Canada (ECCC) and Mikisew Cree CBM study of minnows in the Athabasca River (both up and downstream of oil sands surface mines), the PAD, and Lake Athabasca found that mercury levels were highest in minnows collected in the Athabasca River downstream of Fort McMurray and oil sands operations, and remained somewhat elevated in Mamawi Lake fish, and were lower in Lake Claire and western Lake Athabasca. However, minnows from all of these locations had higher mercury levels than fish from a reference location upstream of Fort McMurray (near Athabasca, AB) on the Athabasca River (Dolgova et al., 2018). Minnows are good indicators of local contaminant sources (Suns et al., 1993; Scheider et al., 1998) and are an important food source for many piscivorous migratory waterfowl, including gulls and terns. Concerns around the exposure of birds to contaminants in the PAD were first triggered following the reporting of mercury concentrations in gull/tern eggs in the PAD (Hebert et al., 2011, 2013). In response to these findings, the Government of Alberta issued a consumption advisory for these eggs from Lake Athabasca and Mamawi Lake in 2014 (GoA, 2014a). Research on gull and tern eggs has also led to insights into temporal and spatial trends in mercury in this region. For example, mercury concentrations in gull eggs collected at Egg Island in western Lake Athabasca are greater now than they were in 1977 (a period prior to most oil sands development). In addition, mercury in eggs from sites in receiving waters of the Athabasca River, i.e. PAD and lake Athabasca, were higher than in eggs collected from a number of other sites located further north and south in Alberta (Dolgova et al., 2018). The authors concluded that mercury appears to be more available at sites downstream of the Athabasca River, hence riverine transport of mercury is likely an important factor regulating mercury levels in birds nesting downstream in the PAD and Lake Athabasca. However, more work needs to be done to determine if these higher mercury levels are solely the result of greater mercury supply from river-associated sources of Hg (e.g. oil sands), or whether other factors, such as enhanced mercury methylation in PAD wetlands, are also important in regulating mercury availability to birds.

For PACs in the Athabasca River in 2008, concentrations were mostly undetectable or low in the river in winter and in summer. This was the case except at sites near oil sands upgrading facilities, near oil sands tailings ponds, and at sites downstream of new oil sands developments. At these locations, concentrations were elevated during certain seasons (Kelly et al., 2009). In 2015, total alkylated PAH concentrations in water in the Athabasca River and in the PAD were higher at all but one of 13 test sites near to and downstream of oil sands developments compared to a single baseline site located upstream of the oil sands on the Athabasca River (note that additional baseline data would help determine spatial trends) (RAMP/JOSM, 2016). Therefore, similar to the above noted trends in mercury in the Athabasca River, elevated alkylated PAH levels near to and downstream of the MOSR, indicate an influence of oil sands developments on regional water quality. In addition, Evans et al. (2016) found that total PAH and DBT concentrations in surface sediments were generally low and have declined over time in the Lower Athabasca River (LAR) but have increased over time in the Athabasca River Delta (part of the PAD). There is also very recent evidence of accumulation of PACs in birds from a joint ECCC and CBM program (ECCC, 2018). Researchers with ECCC have presented preliminary findings indicating that juvenile ducks (mallards, northern shovelers, American widgeons and green winged-teal) collected near bitumen upgraders in Fort McMurray and the PAD had elevated concentrations of PACs in their livers compared to juvenile ducks collected near references sites at Lac La Biche, AB (ECCC, 2018).

Contaminant levels in food sources for migratory waterfowl in the PAD, such as aquatic plants or benthic invertebrates, have not been studied. However, there is recent evidence that metals and PAHs are negatively impacting benthic invertebrate populations in the Athabasca River and its tributaries. Gerner et al. (2017) found that benthic invertebrate communities, with long generation times, and therefore sensitive to organic contaminants, were negatively correlated with calculated PAH-related toxic units in water. These results indicate that current water PAH guidelines (which are for specific individual parent PAHs rather than total or alkylated PAHs) for the protection of aquatic life appear not to be sufficiently protective in some cases, so that relying on these guidelines as regulatory goals may be inadequate.

4.4.1.3 Short-Term Exposures to Contaminants in Local Migratory Habitat

Many of the migratory waterfowl that converge annually on the PAD and WBNP fly directly over the MOSR. Bitumen surface mining operations in Alberta use hot water to process, separate and extract bitumen (a heavy, biodegraded form of crude oil) from oil sands which also contain large amounts of sand and clay (Masliyah et al., 2004). The resulting process-affected water is alkaline, slightly brackish, and acutely toxic to aquatic biota due to high concentrations of organic acids that leach from the bitumen during extraction (Allen, 2008, Li et al., 2017). The term 'oil sands process-affected water' (OSPW) is used to classify all fluids at a mine site that have been in contact with bitumen as part of the extraction process. OSPW typically contains numerous complex organic and inorganic compounds that are a concern for biotic receptors, including unrecovered bitumen, aromatic hydrocarbons (including PAHs and PACs, benzene, phenols and toluene), naphthenic acids, ammonia, metals and other dissolved compounds such as salts (Allen, 2008; Mahaffey and Dube, 2017; Li et al., 2017). Oil sands mines are not currently permitted to discharge OSPW directly into the environment due to its composition and toxicity, resulting in the need for on-site storage. The volume and area of containment ponds at oil sands mines (known as 'tailings ponds') has grown over the past 40 years to include over one billion cubic metres (m^3) of OSPW accumulated on lease sites to date (Mahaffey and Dube, 2017). Mine sites also produce and store other types of industrial wastewater, defined as fluids that have not been directly used in the bitumen extraction process, but that may contain oils, grease and other chemicals, which pose a risk to birds on contact (e.g. basal water ponds, sumps, dumps, coke and sulphur runoff collection ponds, process ponds, thickener tanks, sedimentation ponds, etc.).

The risk to migratory waterfowl in the oil sands region is escalating due to the increasing size and number of tailings ponds and industrial waterbodies on the landscape. While the average pond size is 134 ha, some tailings ponds in the oil sands are over 10 km^2 (1000 hectares, or 1000 ha) in size and, in some cases, constitute the largest waterbodies in a given area (St. Claire, 2014; Wells et al., 2008; Ronconi, 2006). Government data on total fluid tailings at all currently operating oil sands project sites shows that in 2013, the total active fluid tailings area was 88 km^2 (AEMERA portal: http://aemeris.alberta.ca/library/Dataset/Details/542. Accessed 01/10/2018). Since the initial development of surface mining in the oil sands, both industry and government biologists recognised the threat of placing tailings ponds along an internationally significant migratory bird corridor and expressed the urgent need to protect migratory waterfowl from exposure to tailings ponds (Schick & Ambrock, 1974; Hennan & Munson, 1979). To migrating waterbirds, the open water, banks, and shorelines of tailings ponds can appear as appropriate stopover habitat and can attract large numbers of migrating birds heading to and from northern breeding grounds, such as the PAD. At night, migrating birds can be attracted to the lights at a mine site and become disoriented (St. Clair, 2014). Both migrating and resident birds appear most at risk for landing on tailings ponds during early spring, when warm effluent keeps tailings ponds open while adjacent water bodies are likely still frozen, and in late autumn, when winter storms could force abrupt landing events (Ronconi, 2006; St. Clair 2014). Despite the implementation of extensive bird deterrent programs at mine sites, to date no system exists that can reliably and consistently deter all birds from landing on tailings ponds, especially during weather events (Ronconi and St. Clair, 2006; St. Clair et al., 2011; St. Clair, 2014). Overall, there is mounting evidence that current mitigation methods to protect migratory waterfowl in the MOSR are only partially effective, and the risks of exposure to contaminants remains.

Current estimates report that as many as 200,000 bird contacts or landings every year on industrial waterbodies at oil sands mines in the MOSR (St. Clair, 2014). Data also indicate that at least 60 species of migratory waterbird have landed and, in some cases, have become oiled at oil sands mine sites. The populations for some duck species that have landed on the ponds are at or above the long-term average for the population. On the other hand, species designated as endangered, threatened, or special concern under the *Species at Risk Act*, Committee on the Status of Endangered Wildlife in Canada (COSEWIC), or the Alberta *Wildlife Act*, or listed within Alberta as at risk, may be at risk, or sensitive. Additionally, at least 50 species of migratory non-waterbirds, including species of conservation concern (e.g. Horned lark), have landed and/or died at tailings ponds to date in Alberta (Timoney and Ronconi, 2010; Ronconi and St. Clair, 2006; OMEI, 2016). Importantly, some of North America's most endangered (Whooping Crane) or rapidly declining (Lesser scaup) bird species are among those that migrate over the MOSR. Scaups have experienced a 66% population decline in boreal plains ecozone, including Alberta, since the 1970s (Fast et al., 2011), and are one of the most widely reported casualties of tailings ponds in Alberta (Wells et al., 2008; OMEI 2015, 2016). While the mortality of scaups may cumulatively contribute to population declines, some have suggested that the long term survival rates are declining primarily as a result of fecundity (Arnold et al, 2016). Many of the birds most impacted by industrial waterbodies in the MOSR in terms of mortalities are also species of traditional importance to ACFN and MCFN in the PAD.

Although tailings ponds are recognized as the largest industrial waterbodies at an oil sands mine and likely pose the highest risk to migratory waterfowl, the numerous other external storage facilities for industrial wastewater at mine sites also pose additional risks. Very little information is provided regarding the composition and toxicity of the various industrial waterbodies at a mine site. As a result of this information gap, a comprehensive assessment of risks to migratory waterfowl posed by the various waterbodies at oil sands mines is not currently possible. In recent years, the number of studies looking at chemical constituents and toxicity of wastewater produced by the oil sands industry, especially the various forms of OSPW, has surged (reviewed by Mahaffey and Dube, 2017 and Li et al., 2017) but there is no consistent and/or standard sampling and assessment program for composition and toxicity of oil sands OSPW. This makes risk assessment an ongoing challenge.

Short-term, controlled exposure studies looking at effects of oil and OSPW on biotic receptors (including invertebrates, fish, amphibians, birds and mammals) indicate that exposure can lead to direct mortality or to adverse, sub-lethal, physiological changes ranging from compromised immunological function, developmental delays, impaired reproduction, endocrine system disruptions, to higher prevalence of abnormal pathologies (reviewed by Li et al., 2017). However, these studies may not be directly applicable to wild migratory bird populations because negative health outcomes resulting from exposure to OSPW are strongly influenced by age, body condition, and migratory and reproductive status at the time of contact. Environmental conditions (weather, food availability, habitat availability and quality) also appear to act cumulatively and synergistically to increase the risk of contaminant exposures and degree of physiological stress (Gentes et al. 2006; Gentes et al. 2007b). The few field studies completed in the MOSR involving exposure by resident birds to OSPW are limited in scope to aged OSPW, mostly at reclamation wetlands or recycled water ponds rather than tailings ponds (Beck et al., 2015). The level of contaminant exposure in these studies is also not comparable to that of migratory waterbirds that land on tailings ponds. Importantly, many of the studies on aged OSPW still indicate toxic effects to birds (e.g. King and Bendell-Young, 2000; Gurney et al., 2005; Gentes et al., 2006, 2007a,b; Harms et al., 2010). The potential additive and/or synergistic effects of different toxic components present in OSPW and an individual bird's body condition, age, migratory and reproductive status, along with environmental conditions, are a critical knowledge gap related to effects of OSPW exposure on migratory waterfowl.

Migrants face myriad or numerous ecological and physiological challenges during long-distance migrations. Birds arriving in the MOSR in the spring having flown thousands of kilometers and may already be under physiological stress from resource depletion. In addition to the energetic cost of flight, birds must find stopover sites to rest and refuel, cope with unfavorable weather, and deal with uncertainties of resource abundance and availability, intra- and interspecific competition, and predation pressures, all within the context of unfamiliar environments (Maggini et al., 2017). These challenges, along with broad scale anthropogenic changes in habitats and landscapes along migratory pathways, suggest that migration poses formidable hardships to many birds (Skagen, 2006). Contaminant exposure at this stage in annual life history cycle could have heightened impacts on individual fitness.

Effects pathways - When a waterbird lands on an industrial waterbody at a mine site, exposure to contaminants occurs largely via three primary effects pathways: external contact (dermal), ingestion via water and food, and inhalation. The basic effects pathways, possible outcomes, and endpoints (i.e., final disposition of affected bird) resulting from these exposure pathways are shown in Figure 4-5. Mechanisms of effect are discussed in detail below in relation to impacts on individual health and fitness (i.e., survival, growth, and reproductive success).

Direct Mortality - Acute lethal effects of contaminant exposure result in the individual not surviving the exposure, with death being relatively rapid. For waterbirds, acute lethal effects of direct exposure to oil typically result from mechanical disruption of the feather structure, which suppresses waterproofing and insulating properties and hinders thermoregulation, buoyancy and flight (Leighton, 1993, Maggini et al., 2017). In the oil sands, this is often the result of external contact with floating bitumen mats. Birds that become heavily oiled may die quickly and sink below the surface rapidly or struggle on the surface until exhaustion or hypothermia causes death or be recovered and euthanized. Mortality from tailing pond landings is reported but has also been recorded at numerous other industrial waterbodies (OMEI, 2015, 2016). Five mass casualty events at oil sands mines in Alberta where large numbers of bird mortalities occurred over a short period, including waterfowl, songbirds, and herons, have been reported since 2008. Ongoing incidental take at mine sites is reported as 150-200 mortalities annually (OMEI, 2016). However, the detection accuracy for oiled and dead birds remains uncertain and reported numbers of deaths are likely underestimated to an unknown degree (OMEI, 2015). Annual mortality has been estimated to range from 458 (Timoney and Ronconi, 2010) to as many as 100,000 birds each year if you extrapolate the estimate of landings at all ponds and assume that 90% of landed birds die (Wells et al., 2008). The large disparity in the size of the mortality estimates indicates that additional effort is needed to more accurately determine actual mortality rates of birds who land on oil sands properties. The populations for some duck species that have landed on the ponds are at or above the long-term average for the population and in that context the mortality is not desirable, but not likely a population level effect. On the other hand, for species designated federally or provincially or populations seeing declines, the mortality may be of greater concern.

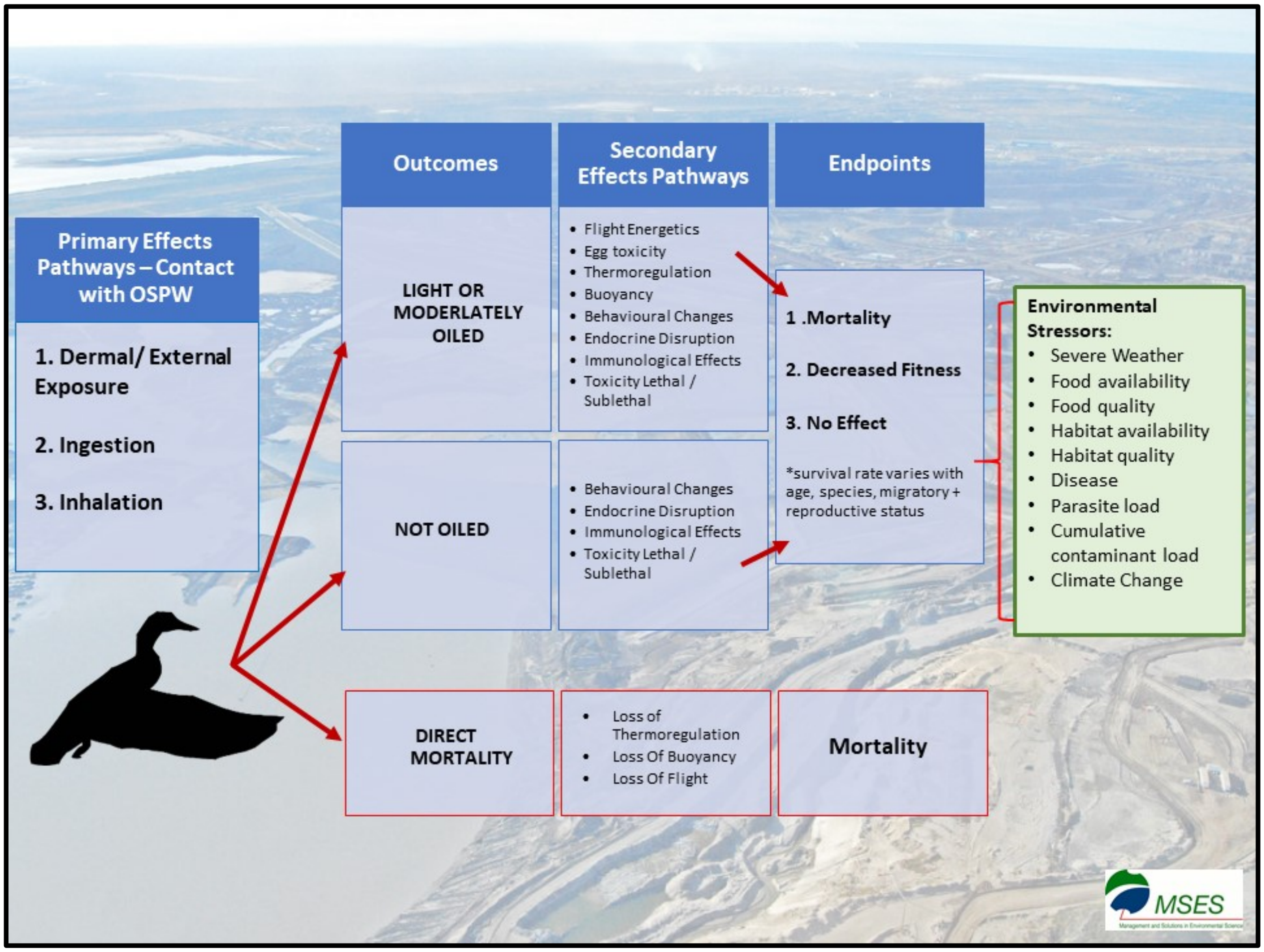


Figure 4-5: Effects Pathways, Outcomes and Endpoints for an Individual Waterbird Exposed to Bitumen, OSPW, or Industrial Wastewater in the MOSR of Alberta

Sub-lethal/Chronic Effects – Sub-lethal effects are defined as effects on individual waterbirds that survive exposure to contaminants but experience adverse effects on fitness after departure from a mine site. These effects can act quickly and severely (acute) or can occur over a long period of time (chronic) at varying degrees of severity. Sub-lethal effects are difficult to measure and often inadequately documented because of the scale of time over which they occur. Evidence suggests that birds may experience either short or long-term effects on health and fitness associated with exposure to contaminants (Beck et al., 2015). Further, hundreds of the migratory waterfowl that are landing in industrial waterbodies in the oil sands are becoming “lightly” or “moderately” oiled and flying away; the fate of these birds is unknown. A range of lethal and sub-lethal effects are reported to result from trace, light and moderate oiling of waterbirds (Leighton, 1993, Maggini et al., 2017).

Most bird mortalities in tailings ponds involve bitumen exposure, and as a result, there is an uncertainty as to whether exposure to OSPW is not toxic to birds unless it contains residual bitumen. However, there are numerous non-bitumen containing industrial waterbodies that pose a risk to migratory waterbirds including: areas of tailings ponds with aged OSPW, recycled water ponds, OSPW seeps from containment ponds into adjacent natural areas, and mature OSPW that has been incorporated into wetlands (Mahaffey and Dube 2016, Beck et al., 2015). To date, there have been no studies investigating the outcome of the thousands of migratory waterfowl that contact industrial waterbodies but fly away with no visible oil. However, contact with aged or treated OSPW has been shown to have various sub-lethal effects which manifest via diverse pathways, time periods, and locations (see discussion below, Beck et al., 2015); these birds may still become sick and die off site. Sub-lethal effects from exposure to contaminants in oil can adversely affect growth, alter organ function, reduce reproductive success, and increase risk of disease, thereby reducing fitness in individuals which can ultimately affect populations (Leighton, 1993; Cruz- Martinez and Smits, 2012; Beck et al., 2015).

A relatively new contaminant exposure route under investigation for oil sands operations is inhalation of the volatile components of oil and oil processing, which can lead to respiratory irritation and inflammation (e.g. pneumonia), emphysema, suffocation, and degradation of the central nervous system (Sanderfoot and Holloway, 2017). Birds are more sensitive to inhaled contaminants than mammals because of their unique lung structure and physiology (Olsgard et al., 2009). In the oil sands, migratory waterfowl flying through emission plumes or landing on tailings ponds would be exposed to airborne toxicants (including hydrogen sulfide, sulfur dioxide, nitrogen dioxide, ozone and particulate matter) that can compromise the health of wildlife (Cruz-Martinez and Smits, 2012; Cruz-Martinez et al., 2015a, b). To our knowledge, there have been no studies looking at the health of wild waterbirds exposed to airborne pollution from OSPW.

Little is known about the long-term health of the birds that come in contact with OSPW. This uncertainty has not been addressed by regulators or industry and, as a result, reported total mortality inventories from oil sands related industrial activity do not include an estimate of contaminated birds that have flown offsite and later died. This may result in an underestimation of the total mortality rates for migratory waterfowl and of the risk posed by oil sands operations. Contamination of migratory waterfowl is also a concern to Indigenous groups who consume waterfowl and eggs in the region. MCFN hunters and land users have seen oiled, sick, and contaminated birds in the oil sands region and in the PAD (Candler et al., 2015b, MCFN, 2018a). To date, studies related to potential health and fitness effects in birds resulting from oil sands contaminant exposures have all been short-term. To our knowledge, long-term studies of single and/or multiple OSPW-related toxin exposures have not been conducted, but they are urgently needed in order to detect latent, subtle, or cumulative effects of toxin exposure. The only published studies looking at oil sands contaminant exposure over more than 2 years were toxicology studies on gull and tern eggs in the PAD (Hebert et al., 2011, 2013). Mercury contamination in eggs of gulls and terns in the PAD provide evidence of toxicant exposure and accumulation of contaminants in the environment. Regional and downstream toxicology impacts are discussed in Section 4.4.1.2.

4.4.1.4 Changes in Habitat Availability and Quality at Stopover Sites Along Migration Route

Beyond risks associated with direct contamination at mine sites, impacts to quality and quantity of available stopover/molting habitat in the MOSR can impact survival, health and breeding success for migratory waterfowl, and may contribute to the overall decline in birds in the PAD and WBNP. The extensive network of wetlands, waterbodies, and watercourses in the MOSR is used by migratory waterfowl, including waterbirds, for breeding, staging and stopover activities. Many of the wetlands heavily utilized by spring- and fall-staging waterfowl are considered critical habitat for migratory waterfowl in the region (Hennan and Munson, 1979; Ronconi, 2006).

In the MOSR, oil and gas exploration and development and forestry practices are the primary causes of industrial disturbances. A comprehensive independent analysis of wetland habitat loss in the MOSR has not been completed to date. However, using satellite change detection analysis Komers and Stanojevic (2013) measured the rate of terrestrial land-cover change in the Alberta boreal forest and found that between 1992 and 2008, 33% of terrestrial forested habitat in the MOSR was disturbed by land clearing (including linear disturbances with zone of influence of 250 m). Although not directly measured, given the abundance of wetland habitats on the landscape in the MOSR, it is likely that a similar proportion of wetland habitat has been impact and/or lost over the same time period. Effects of fragmentation and habitat loss on migratory land birds in the MOSR, including sensory disturbance, have been studied (Wells et al., 2008), but impacts on migratory waterbirds remain largely unknown. Similarly, the effects of sensory disturbance are not well understood for waterfowl in terms of breeding or stopover use. A JOSM study investigating the potential cause-effect relationship between energy sector activities, especially linear disturbance, and the abundance and productivity of waterfowl has commenced. Some preliminary results are available; however, nothing has been published from the work to date.

The progressive loss of natural wetland habitats in the MOSR is directly linked to increased risks for migratory waterfowl in terms of landing in tailings ponds. During spring and fall migration, storms can force large flocks of birds to seek refuge on tailings pond if no safe landing options are immediately available (Ronconi, 2006). For many years, MCFN and ACFN have been concerned that the continual increase in the number and size of contaminated industrial waterbodies, coupled with cumulative regional loss of wetlands and waterfowl habitat availability will adversely affect migratory waterbirds. Studies confirmed that protecting and maintaining an extensive network of ecologically diverse, natural and undisturbed waterbodies and wetland habitats across the landscape in the MOSR, especially those that are known to be used as migratory stopover sites by waterbirds, are key components for mitigating risks associated with the presence of large tailings ponds along a significant migratory flyway (Ronconi, 2006).

In addition to loss of migratory bird habitat in the MOSR, the existing natural wetlands may be decreasing in quality due to growing oil sands development. For example, Kearl Lake, a regionally important staging area for waterfowl in the MOSR, is now surrounded by oil and gas development and forestry activities. Total PAH concentrations in sediments in Kearl Lake have increased over the long-term, particularly since the 1970s, and a large significant increase in total DBTs (dibenzothiopenes) in sediments was noted (Evans et al., 2016). At nearby McClelland Lake, alkylated-PAH concentrations increased (Evans et al., 2016). Increases in sediment PAH concentrations were even more apparent in lakes closer to development (e.g. Shipyard and Isadore's Lakes) (Evans et al., 2016) suggesting an increasing influence of oil sands mines on sediment PAH concentrations in the region.

4.4.1.5 Changes to Migration Route and Timing for Birds using the PAD

The Athabasca River, south of WBNP, is a significant migratory bird flyway. In the past, vast flocks of geese migrated along traditional northern routes, including the Athabasca River, stopping in the PAD and other locations in WBNP in the spring to eat and rest before continuing to the Arctic to breed and nest. These birds would return to the PAD for a few weeks in the fall before continuing their southward migration (Hennan and Munsen, 1979; Wayland and Arnold, 1993).

Over the past 25 years, Indigenous people have observed dramatic changes to fall and spring flock sizes, migration routes, stopover time and patterns of habitat use by migratory waterfowl, with fewer birds travelling along the Athabasca River corridor, PAD and WBNP (Candler et al., 2015b; MCFN, 2018a; ACFN, 2018b; LRRC, 2018; SLFN, 2018b; DKFN, 2018b; KFN, 2018). Indigenous land users described how in the past you could go to a particular location and wait for waterfowl to fly overhead because it was predictable. Now they need to search for the birds (ACFN, 2018b). They also describe the decrease in number of birds that could be obtained from 100 ducks in 10 days to 7-8 ducks in 4-5 days (ACFN, 2018b).

Several possible explanations for the changes in migration routes have been provided: impacts of the MOSR, lack of habitat and food in the PAD and agricultural fields attracting waterfowl.

Impacts of the MOSR on migration

ACFN and MCFN Traditional Knowledge holders have observed birds getting "*re-routed*" around oil sands mine areas and indicate that the Athabasca river is "...a *corridor of flight for geese, for our birds. They fly up the Athabasca and then into Lake Claire and Lake Mamawi, and further north… it's sort of like a gate for them when flying north. And when you start putting dust and smoke and smog into the air it affects them*" (Candler et al., 2015b, p. 105). MCFN (2018a) members indicate that birds who travel north now "*…seem to reflect around industry and bypass us as they go into the artic to have young*" and "*since the younger ones follow the older ones, over time maybe there will be nothing landing. The oil patch affects the fly over and eventually the young will have a different route*". In the 1970s, the Canadian Wildlife Service stated that tailings ponds could cause changes in migration habits (Schick & Ambrock, 1974). Similarly, researchers with the Northern River Basins Study reported that birds had shifted their migratory patterns westward (Wrona et al., 1996) and ECCC noted potential shifting patterns in migration pathways that could affect the availability of these birds in the PAD, but each recognize that more research is needed (Shell JPM JRP, 2013). Shifting flyways could alter the distribution and abundance of migratory waterfowl that use the PAD, with potential cascading ecosystem effects that threaten the OUV of WBNP (MSES, 2016).

Further, because large predictable annual aggregations of migratory waterfowl in the PAD and across WBNP are a traditional resource, changes to migration routes could impact resource use and available for local Indigenous groups. Areas where the traditional migration route for migratory waterfowl intersect with land user's ability to access them are where spring and fall bird camps are placed; these camps are of critical importance to Indigenous people for social, economic, cultural, spiritual and other purposes (Candler et al., 2015b). Local indigenous groups have repeatedly expressed their concerns to review Panels about changes to migratory bird routes, reduced population numbers, and altered distributions (Shell JPM JRP, 2013; AERCB, 2011). Although the cause of noted changes remains largely unknown, it is recognized that impacts related to oil sands development such as habitat loss, air pollution, water contamination, tailings ponds increases, and visual and audio disturbances may be contributing factors (Shell JPM JRP, 2013; AERCB, 2011). Changes to habitat in the PAD are discussed in more detail in Section 4.4.1.1.

The suggestion that migratory waterfowl are moving away from the Athabasca River flyway because of industrial development in the MOSR is plausible. Birds use a variety of sensory and environmental cues during migration, although all of the mechanisms are not fully understood (Newton, 2008). The landscape and sensory cues used by migrating birds within the Athabasca River corridor have changed in a number of ways as a result of the oil sands industry which could alter migratory behaviour:

1) **Noise (auditory) stimuli** - oil sands mines actively attempt to deter birds with loud and nearly constant noise; some mines use devices that are capable of projecting auditory stimulus over radii of several kilometres (St Clair, 2014). MCFN (2018a) members have stated that "*the birds come and the plants make noise and the birds go away and around the Park*". Noise pollution and subsequent collateral environmental damage, including detrimental effects on birds, has been noted in the MOSR (Bayne et al., 2008).

2) **Air pollution (olfactory)** - odours and/or visual obstruction from smoke/steam are believed to be a contributing factor to altered migration behaviour for birds (Newton, 2008). Large emission plumes from the mines and refineries and dust are present around the oil sands and MCFN (2018a) members state "*The birds have changed some flight patterns already because they won't fly through the smoke*." (pg. 4) as well "*I wonder how the smell affects the birds that fly over. I'm sure those smells must do something."* (MCFN, 2018a). Also, "*The air is no good for them*... " (Candler et al., 2015b).

3) **Habitat change/loss (visual)** – the visual landscape of the Athabasca river corridor has changed dramatically over the past 25 years and the quality and quantity of stopover and breeding habitats for waterbirds has declined. Navigating an altered landscape with fewer natural wetlands for use as stopover sites (rest, food, refugia during storms) could contribute to altered migration routes (Newton, 2008; Pearse et al., 2018).

These altered sensory cues may act cumulatively to alter locations, timing and length of migration routes for birds. Migration places large amounts of stress on the body of a bird; the physiological changes and adaptations to manage the stress associated with normal migration are well understood (Newton, 2008). However, the additional sources of stress experienced by populations of birds migrating through the oil sands could affect their overall fitness (survival, reproductive success) and contribute to the observed migratory bird population declines (Candler et al., 2015b). Climate change may also lead to alterations in location, timing and length of migration routes due to changes in food and habitat abundance (Pearse et al., 2018). The long-term baseline data required to show broad-scale changes to migration routes, staging/stopover sites, and breeding sites are currently lacking. In 2013, the Governments of Canada and Alberta were instructed by the Shell Joint Review Panel to investigate the noted changes to migration routes (Shell JPM JRP, 2013), but to our knowledge this investigation has not yet been completed.

Changes in food and habitat availability in the PAD

In the PAD, the reduction in habitat and food availability as a result of a drying trend has been reported as a potential cause of shifts in migratory patterns (MCFN and ACFN, 2010; Bill et al., 1996; Wrona et al., 1996, MCFN 2018a). An MCFN land user stated that changes to the food and habitat resources have resulted in birds no longer stopping in the PAD resulting in drastic reduction in numbers "… *before there's millions, now there's just a few…. … And the grass are not as good like before for them. Grass don't grow as good as before. That's what they eat, those roots, and now everything is all dried up, that's why they're flying different places*…" (Candler et al., 2015b, pg. 108). The Fort Chipewyan Métis Local 125 also reported changes in habitat as a cause of shifts in migration. Waterfowl "are not stopping anymore, because there is no water and wrong vegetation. If they stop and rest, they leave soon after to Fort Resolution instead of staying. They also do not go inland anymore. Lake Claire used to be good for birds. They used to feed lots of people. Hunters would get hundreds at a time." (Métis Local 125, 2018b). Changes to habitat in the PAD are discussed in more detail in Section 5.11.

I would see birds in from the south in spring. Some land, some come down and gradually go up. Now, most won't stop and will keep on flying. The younger ones follow the older ones and over time maybe there will be nothing landing. The oil patch that affects the fly over and eventually the younger will have a different route. The lower water levels is also a problem though because there is nothing for them to eat. They have to eat to keep going. If there is nothing to eat they will find other routes.

Quote context: *Like I said growing up on the land with my late parents, the birds used to land on the Peace River to get gravel. Now the birds don't even fly to the Peace River because it is so low. They have to find gravel probably somewhere else. And there is less birds landing as the water level is so low.*
Source: *Gerald Gibot*
About Gerald Gibot: *I was born in Fort Chip. I was raised up in the trap line with my late mom and dad. I still go on the land. I have two boys 5 and 8. In the summer when there is no school I take my boys out on my boat. My boys enjoy the life that I show them where their grandparents used to be when I grew up. I have seen a lot in my 63 years. At 5 I went to residential school. We get a lot of wisdom from other elders. Also my late father had friends about his age. We would sit down and talk about their lives and I can understand Cree so I can relate to other trappers talk about their lines in other areas.*

Agricultural fields attracting waterfowl

Indigenous people have also suggested that the agricultural fields may be attracting waterfowl away from flying and stopping over in WBNP. K'atl'odeeche First Nation (KFN) stated "Harvesters have also noticed a decline in geese populations at Ejıé Túé (Buffalo Lake) in the spring. This indicates that geese are finding other staging areas, which our harvesters attribute to increased farming in northern Alberta (i.e., the geese are now staying in farming fields for longer periods of time, rather than flying north to their traditional staging areas)". (KFN, 2018)

4.4.2 Status and Trend of Migratory Waterfowl in WBNP

The desired outcomes for migratory waterfowl are:

1) Great concentrations of viable, healthy populations of migratory waterfowl species continue to use WBNP seasonally.

2) Adequate quantity and quality of habitat, unimpaired by contamination, is available for migratory waterfowl to fulfil all key life cycle stages while present in WBNP.

3) Indigenous groups are able to maintain traditional harvest of waterfowl species and practice their way of life with confidence that populations of waterfowl will be healthy, sustainable and accessible.

As described below for each of the above desired outcomes, current information available from both western science and local ITK indicate that over the long-term, all three of the desired outcomes with respect to migratory waterfowl in WBNP are seeing downward trends and unsatisfactory status for areas within the PAD specifically.

1) Since 1955, breeding populations and production surveys for waterfowl across North America are conducted annually by the U.S. Fish and Wildlife Service (USFWS)/Canadian Wildlife Service (CWS). Long term trends in abundance of breeding waterfowl are generally difficult to detect against the background of large natural variation in abundance and productivity that is common for waterfowl populations (USFWS, 2017). The USFWS survey data provide minimal information on abundance, diversity or wetland use by birds other than waterfowl (e.g. migrant shorebirds). This data has not been analysed specifically for the PAD to indicate how the number of breeding birds compares to the long term average and in the context of populations at a continental scale.

   For fall staging, waterfowl use of the PAD used to regularly exceeds that of other notable waterfowl staging areas in Canada, with averages of 300,000 to 600,000 waterbirds each day during fall migration (Butterworth et al., 2002). In the early 1970s, fall counts of staging ducks, geese and swans totalled 1.5 million birds; in the spring up to 400,000 waterfowl used the PAD per day. No long-term scientific monitoring has been conducted of the use of the PAD by fall staging or spring migrants. However, ITK is very clear that that the number of birds stopping as part of their migration is significantly lower than previously.

   As a result, while the status and trend of breeding waterfowl is unknown, the desired outcome is clearly not being met for spring and fall migration and therefore is considered overall not to be met and experiencing a downward trend.

2) The availability of adequate quantity and quality habitat, unimpaired by contamination, for migratory waterfowl to fulfil all key life cycle stages while present in WBNP also appears to be decreasing, at least in the PAD. In the 1960s and 1970s, progressive and cumulative water level declines in the PAD resulted in plant succession converting lakes and wetlands into willow thickets and reed grass meadows, and subsequent reduction of use by waterfowl in the spring, summer, and fall (Dirschl, 1972; Nieman and Dirschl 1973). From 1996 to 2008, Parks Canada (2009) reported a general loss of emergent vegetation, encroachment of willows and other vegetation on wetlands, and an increase in invasive plant species in the Peace region of the PAD. Further, Bill et al. (1996) reported reduced use of the PAD by migratory waterfowl compared to previous years for breeding and staging as a result of reduced water levels. The Peace-Athabasca Delta Waterbird Inventory Program noted that over the four-year survey period (1998-2001), five perched basins completely dried out (Butterworth et al., 2002). Notably, in 1996 and 1997 some perched basins in the PAD were briefly flooded for the first time in 25 years and USFWS breeding survey data indicated a mean increase of breeding waterfowl pairs by 43% (compared to 5 years pre-flood) and an increase in total duck production of 89% for 1998 and 1999, followed by a decrease to pre-flood levels in 2000 (Butterworth et al., 2002).

In addition, migratory birds in the PAD may be experiencing cumulative contaminant loading from exposures during migration, on wintering grounds, and at staging/nesting grounds in the PAD. Government of Alberta issued a consumption advisory for these eggs from Lake Athabasca and Mamawi Lake in 2014 (GoA, 2014a).

As a result of the changes to habitat and the contaminant warnings, this desired outcome is considered not to be achieved and experiencing a downward trend.

3) Indigenous groups find they cannot maintain traditional harvest of waterfowl species and practice their way of life with confidence in healthy, sustainable and accessible populations of waterfowl. Local traditional land users have noted dramatic changes in the PAD over the past 25 years, including noticeable changes in the diversity of bird species, and declines in the quality and quantity of birds throughout the migratory season. The MCFN and ACFN (2010) reported that since the last major flood in the early 1970s, many of the perched basins, as well as several lakes, disappeared (Egg Lake and Pushup Lake) and that lack of water is impacting plant and animal species in the PAD. They state that "*There is nothing for the birds. Just dry lakes. No water…Once we had birds landing and now it's full of willows*". (MCFN 2018a). These changes have impacted traditional bird species population numbers, which has consequences for the availability of these species for annual harvest and egg collection by Indigenous people in traditional locations. Land users report that waterfowl no longer stop on the PAD and Lake Athabasca in the vast numbers that they once did due to loss of critical habitat or food resources (MCFN and ACFN, 2010). They state that

> "*…in fall time, there will be two weeks straight of snow geese coming over delta. But they aren't landing any more. The reason why they don't land in delta is the lack of water and also the lack of vegetation. Goose grass is what is missing in this delta. Goose grass is water dependent. The bison, ducks and geese feed on the seeds in the stems. They come to the perch basins for goose grass… Now they don't because of the lack of food which is because of lack of water*." (MCFN 2018a).

Land users also state that changes in the PAD appear to be impacting the diversity of species of migratory birds whereby new species are appearing and others have disappeared:

> *"We are now getting different birds…. hummingbirds, goshawk, and magpies that we never had….. We've gone from every kind of a bird and so many, down to literally nothing….They seem to have thinned right out…. areas where there used to be 5-6 different types of seagulls nesting on a rock island. Now they don't do that…In one area where we used to go for eggs, mud hen eggs, I don't remember the last time I saw or heard a mud hen. They used to nest in marsh lake area and we'd go egg picking. They are gone." (MCFN, 2018a) and "I've had a few ducks in my area that I don't even know the name of because I've never seen them before." (MCFN, 2018a)*

Given the status and trend of the first two desired outcomes and the experiences of Indigenous people, this desired outcome is not being achieved and experiencing a downward trend.

4.5 WOLF-BISON PREDATOR-PREY RELATIONSHIP

The wolf-bison predator-prey relationship in WBNP is recognized as a world heritage value in part because it is "the only place where the predator-prey relationship between wolves and wood bison has continued, unbroken, over time". Bison and wolves range over much of WBNP (see Figure 4-6). Some bison herds also spend part of their time in WBNP and part of their time outside the boundaries.

Wolf cub, Sweetgrass, WBNP. Photo: Parks Canada

While there have always been wolves and bison in WBNP, the relationship had significant interference between the late 1800s and late 1900s. Prior to 1922, hunting by settlers in the region considerably altered the relationship between wolves and bison. Historically the bison population in the region was abundant and the major source of food for local Indigenous communities (Parks Canada, 1984). By the 1850s, the cumulative effects of overhunting and severe winters resulted in a remaining population of approximately 250 wood bison. This severe decline in population prompted the Canadian government to establish the *Buffalo Protection Act* of 1877 to conserve and protect these remaining animals (Ball et al., 2016). The on-going conservation challenges related to bison were acknowledged as problematic in the region, and efforts were needed to protect the bison population as development came closer, as they would be seen as a cheap, easily accessible source of food. As a result, WBNP was established in 1922 and covered 27,200 square kilometres (10,500 square miles). WBNP protected approximately 1500 wood bison living within the original park boundaries (Parks Canada, 1984).

In 1925, the introduction of disease to the bison altered the relationship with wolves for some time. A decision was made to transfer thousands of plains bison from Wainwright Alberta into WBNP. The plains bison of the Wainwright herd hybridized with the wood bison of WBNP and were a source of diseases for the native bison of WNBP. These diseases include tuberculosis and brucellosis (Parks Canada, 1984).

Between 1935 and the early 1970s, the wolf population in WBNP was controlled to facilitate bison recovery (Bradley and Wilmshurst, 2011). The control of the wolf population resulted in an increase in the bison population, but also an unnatural wolf-bison predator-prey relationship. After wolf control ceased in WBNP in the early 1970s, populations of bison declined. Initially, disease in combination with predation was thought to be a pathway of effect resulting in population level changes in bison. However, more recent study concluded that declines in bison from 1971-1999 would have occurred without disease as a result of predation (Bradley and Wilmshurst, 2011). It is important to note that this conclusion was reached for the bison in WBNP who had been exposed to the diseases since 1925. Herds that are exposed to the disease for the first time may face declines. While wolf control is no longer a pathway of effect, it is not clear whether the wolf-bison populations have again reached an equilibrium.

Bison have a long history as an important component in the ways of life of the Indigenous peoples in and around WBNP. This history of Indigenous bison harvest in and around WBNP is unique as some of the longest continuous harvest relationship with wild bison populations in North America. Bison are important for social, economic, cultural, spiritual and other purposes of Indigenous communities in WBNP. The effects of park management on Indigenous community efforts to maintain their traditional connection to bison is one of the more complicated and divisive elements of the park's history.

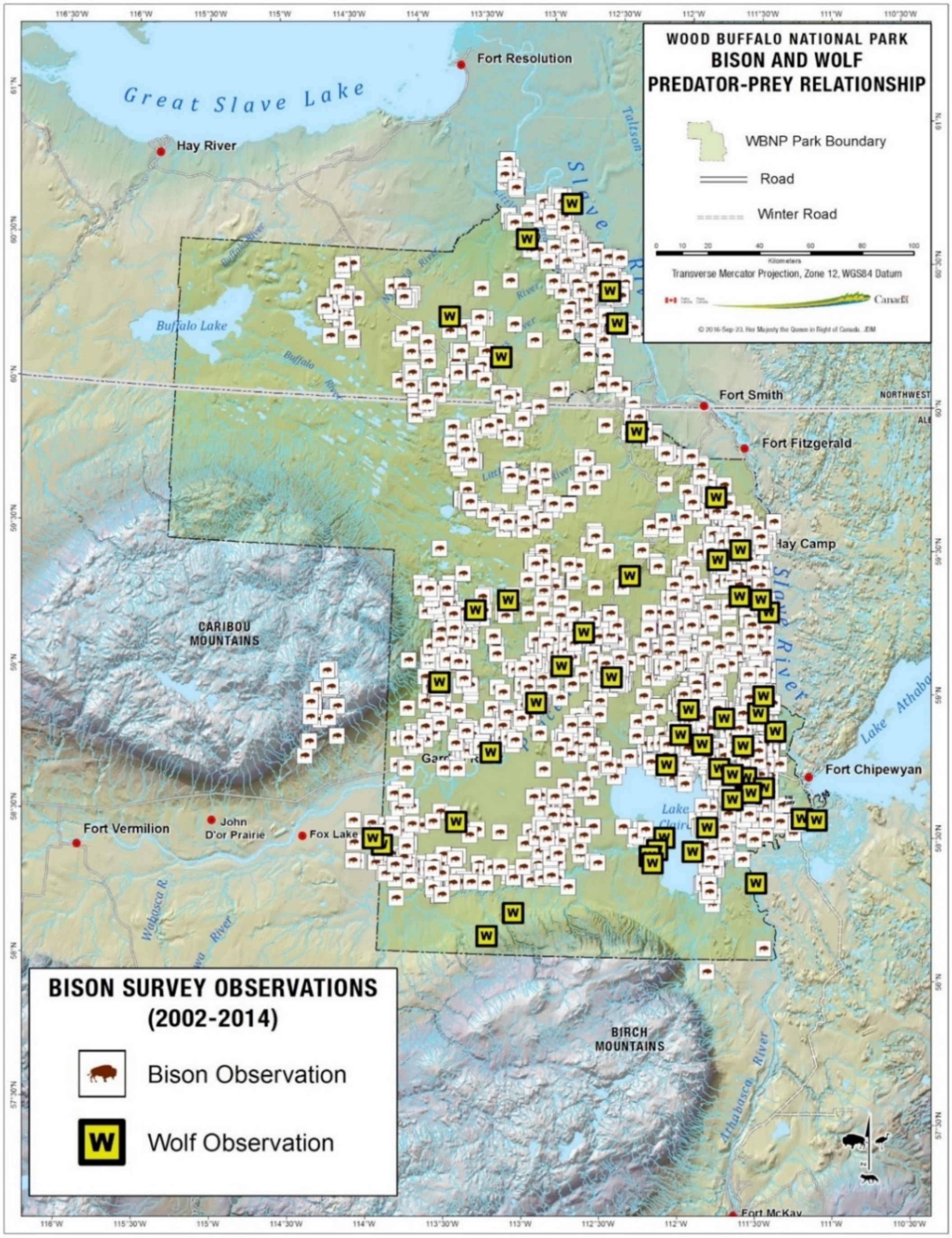


Figure 4-6: Range of Bison and Wolves

4.5.1 Pathways of Effects on Wolf-Bison Predator-Prey Relationship

There are five potential pathways of effects on the wolf-bison predator prey relationship:

- Changes resulting from drying and fewer flooding events
- Changes resulting from increased linear corridor density and habitat changes surrounding WBNP
- Changes resulting from disease management and hunting outside WBNP
- Changes resulting from changes in other prey species populations

Below is a diagram developed by MCFN Traditional Knowledge holders of trends and stressors for the wolf-bison interaction in the areas of the park in and around the PAD, including the effects on Indigenous traditional use and ways of life (Figure 4-7). We have no scientific information on noise disturbance impacts on the bison. Climate change, BC Hydro flow regulation, invasive species and low PAD levels are discussed in Section 4.5.1.1 and 5.13. Fragmentation and disease are discussed in 4.5.1.2 and hunting is discussed in Section 4.5.1.3.

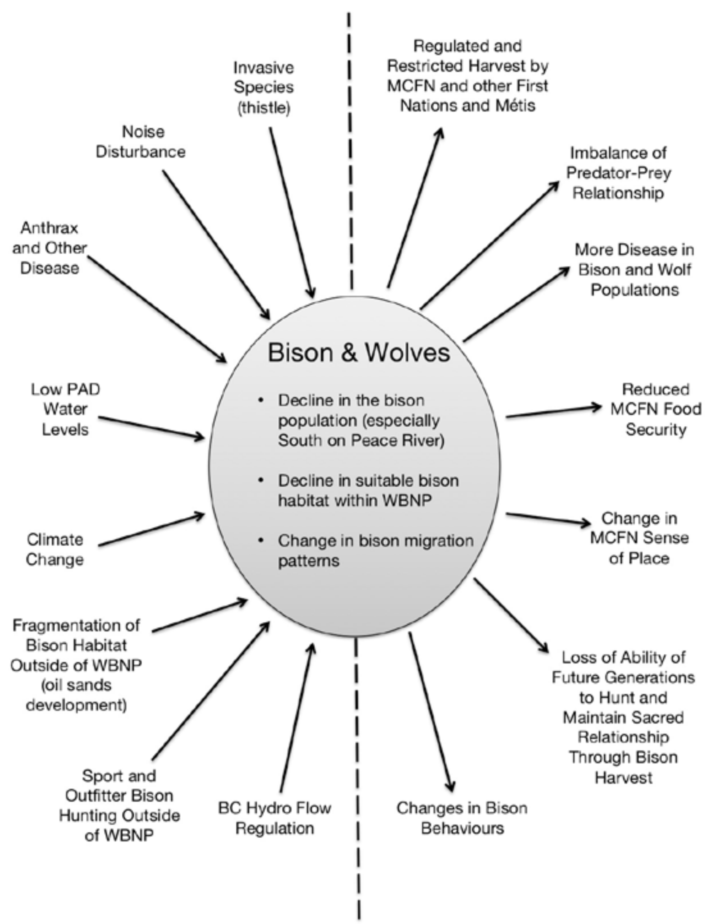


Figure 4-7: Trends and Stressors for the Wolf-Bison Interaction in the Areas of the WBNP in and Around the PAD, Developed by Mikisew Cree First Nation Elders and Land Users (MCFN, 2018a)

4.5.1.1 Risks from Drying and Fewer Flooding Events

The drying of the PAD resulted in an increase of woody vegetation and a decline in the quantity of bison habitat (see Section 4.3.1 and 5.13). Poorer habitat can cause bison to move or affect the overall population. Mikisew members have observed a correlation between PAD drying and a reduction in bison populations in the area of the PAD as bison move to high ground.

Indigenous communities have also observed that the drying of the PAD is enabling the rapid spread of invasive species, particularly Canada thistle, which exacerbates the loss of good bison habitat around the PAD. Bison do not eat Canada thistle and adjust their movement patterns to avoid it, resulting in further changes in migration patterns (see "Risks from alteration or break down of bison habitat connectivity" below). Mikisew knowledge holders agree that flooding is the primary way to combat the spread of Canada thistle. A representative example of ITK regarding the risks from drying is set out below:

> *Hunted buffalo in my younger days for my dogs and for my kids…buffalos are not around here now. That's because there's no water. They can't eat dried grass. They eat green grass…They are lost in Hay Camp. They won't come back over here, because there's nothing to eat…things growing around Lake Claire, like needles [thistle]…you can't eat those. They were not there before… maybe that's how come they move out of there…. Everything has started drying up around Lake Claire. Maybe that's how come they move out of there…*

Since 1974, the water has gone down and down so for the buffalo there isn't the vegetation they live on. The thistle is taking over the whole delta on account of there being no water. Buffalo's main food is goose grass and all the areas that used to have it are all dried up.

Quote context: *There is no Goose or Joint grass. That is what the buffalo live on. So it's all dry. If there is no water, then there is no goose grass, no muskrat, and no buffalo. The bottom line is you need water. That is the bottom line to get our vegetation or animals back to what it used to be.*
Source: *Larry Marten*
About Larry Marten: *I am 65. I quit school in 1966. That is when I started trapping. Prior to that as a kid was out there every spring with my parents. We lived out there because it's our livelihood. When I quit school, then I was trapping every year, every winter and spring. In summer time I had summer work. I am still a trapper.*

In winter, deep snow and resource scarcity may limit bison movement within their home range, whereas in the summer, thawed muskeg, wetlands, lakes and water courses may limit movement (MSES, 2017). As a result of these challenges to movement, bison likely prefer certain habitats for movement which they use to travel between food patches. However, no quantitative analyses exist for the park that identify key habitats for movement and use or how those areas have changed.

Carbyn (1992) believed that the drying of the delta may have "very significant implications for the predator/prey system" by changing the movement and aggregation patterns of bison (p.176). Bradley and Wilmshurst (2011) demonstrated that the change in habitat was not having a population wide effect. However, they also indicated that bison population decline after wolf control stopped was more significant in the PAD. They suggested that this could be because predation was more efficient in the PAD. Whether this higher efficiency is due to drying or just the different habitat in general, is not known. Indigenous knowledge holders noted that with lower water levels bison would sink in the mud, but wolves would still be able to travel freely (ACFN, 2018b). We have no further scientific or ITK about the different predation rates in the PAD.

Therefore, while the pathway of effect of a drying of the PAD has changed the habitat, it is not clear if that has had a secondary effect on the predator-prey relationship between wolves and bison. The change in movement and use of habitat has resulted in the location of bison and changes in the traditional way of life of Indigenous people.

4.5.1.2 Risks from increased linear corridor density and habitat changes surrounding WBNP

Wood Bison group, Peace-Athabasca Delta. Photo: Parks Canada

For bison herds that range beyond the park, the potential change in the predator-prey relationship due to increased linear corridor density or habitat changes is highest. Among these, the Ronald Lake Bison Herd is of particular subsistence, cultural, and spiritual importance to regional Indigenous communities. This is the only herd that uses some portion of WBNP, which is known to be disease free. It ranges primarily between the Athabasca River and the Birch Mountains from the northern extent of the oil sands mines to the south-eastern corner of WBNP. (MSES, 2017). This herd has lived in this area for thousands of years and has been hunted and managed by local Indigenous peoples throughout this time. ACFN land users suggest the population could be as low as 75-100 individuals (ACFN, 2018c).

DeMars et al. (2017) have shown that the Ronald Lake Bison Herd avoided cutblocks, with exceptions for male bison in the summer/fall. Female bison avoided disturbed areas during winter and increased avoidance when human activity was present (DeMars et al, 2017). Anthropogenic land-cover changes can also create barriers to bison movement, potentially isolating forage areas from access to bison (MSES, 2017).

Anthropogenic linear features have also been shown to change wolf behaviour and increase their hunting efficiency (Whittington et al., 2005; Dickie et al., 2016). Wolf abundance in the Alberta boreal forest has been found to increase in response to increasing linear feature density in wildlife management units south and south west of the park, while moose abundance decreased (Stewart and Komers, 2017). Wolf abundance also is likely responding to prey abundance (e.g. northward expansion of deer range) and changes in the vegetation from older to a higher predominance of early serial stage vegetation which favour deer. Wolf predation rates have also been shown to increase near human disturbance in the Alberta oils sands region (Neilson & Boutin, 2017). These studies demonstrate the changing relationship between wolves and their prey in ecosystems in the vicinity of the park. Indigenous land users in the Athabasca Delta region outside of the park have reported high numbers of wolves and raised concerns about them (ACFN, 2018a); however, other Indigenous groups have not reported concerns about high numbers of wolves suggesting this issue may currently be restricted to outside the park, but very much on the border.

4.5.1.3 Risks from Hunting Outside WBNP

Hunting bison outside the park occurs to protect cattle and non-diseased bison, and for sport and for subsistence purposes. In particular, for bison herds that range inside and outside the park, hunting if not managed appropriately could impact bison populations.

The estimated risk of transmission of bovine brucellosis or tuberculosis to the Canadian cattle population is minimal. In a recent analysis, it was determined to a 95% probability that the estimated annual probability of at least one brucellosis infection in cattle was less than 0.0018 (0.2%). This means that with 95% confidence, the risk of introduction of bovine brucellosis into the cattle population from free-ranging bison in WBNP and surrounding area is approximately 1 case within 555 years. The risk of tuberculosis transmission was estimated as 1 case within 107 years (Canadian Food Inspection Agency, 2016).

While the risk of transmission to cattle is low and the diseased condition of bison does not appear to affect the population viability of the diseased herds (Bradley and Wilmshurst, 2011), it is still desirable to avoid the spread of disease to other bison herds. The *Recovery Strategy for the Wood Bison* states a goal of "The long-term population and distribution objective is to ensure the existence of at least five disease-free, genetically diverse, connected, self-sustaining, free-ranging local populations distributed throughout their original Canadian range, with a minimum size for each local population of 1,000 animals." (ECCC, 2016).

In 1987, the Government of the Northwest Territories implemented a disease containment program to minimize contact between diseased and non-diseased bison. This program resulted in the establishment of the Bison Control Area (BCA), which originally contained lands south of the Mackenzie River, and north of the Mackenzie Highway between Mills Lake and Hay River. The BCA was expanded in 1990 to include all lands north of the provincial-territorial border and south of the Mackenzie River, between Trout River on the West and the Buffalo River and WBNP boundary to the east, encompassing 3,936,339 ha. Bison within the BCA are designated as nuisance and can be shot by an eligible hunter. The purpose of the BCA and other bison control programs are to detect and remove bison in the BCA and prevent the establishment of herds or individuals in this region. In so doing, the risk of transmission between infected and non-infested herds is reduced. Reducing contact also ensures that genetic integrity of certain populations of wood bison is protected from more hybridized or plains dominant herds (Gates & Wierzchowski, 2003).

The Government of Alberta has implemented a similar approach by monitoring a surveillance zone east of Highway 35 to limit the interactions between potentially diseased animals moving west from WBNP towards the disease free herd in the Hay-Zama region in northwestern Alberta. The Wabasca herd closer to the park is presumed to be disease free (ECCC, 2016).

To accommodate their approach, the Government of Alberta, does not consider bison found outside of WBNP, and east of highway 35, as "wildlife", and therefore they are not afforded any protections under the provincial *Wildlife Act* and can be hunted without any limits (AEP, 2017a).

The exception to this is the Ronald Lake Bison Herd, which has been granted protection as a Subject Animal under the Wildlife Regulation, Alberta Regulation 143/97 as of 2016, which closed hunting on this herd in most of its range until further notice except for subsistence purposes by Indigenous people holding constitutional rights to do so. Indigenous knowledge holders confirmed that the Ronald Lake Bison Herd had been experiencing high levels of hunting pressure over the last decade as news of their disease-free, and 'domestic animal' status, led to increases in unregulated hunting. Population declines, likely stemming from increased hunting pressure, were observed by Indigenous land users (MCFN, 2018b). While the Ronald Lake Bison Herd has been provided with this protection for most of its range, the Wabasca herd has not and hunting continues (LRRCN, 2018).

4.5.1.4 Changes from Changes in Populations of Other Species

As described in Section 4.5.1.2, evidence of changes to wolves and moose abundance and predation rates has been observed south of WBNP (Stewart & Komers, 2017; Neilson & Boutin, 2017). Caribou populations are also known to have declined in the region (Environment Canada, 2012). Indigenous knowledge holders have also expressed concerns about declines in the moose population in some places in the park (MCFN, 2018a, Jim Webb Pers. Comm. February 2, 2018).

Given that both these species are also fed on by wolves, there may be effects on these species from changes in the predator-prey dynamics between wolves and bison or changes in these populations may affect the relationship. However, no research has been conducted in this area to determine how these dynamics may be changing.

4.5.2 Status and Trend of Bison-Wolf Predator-Prey Relationship

The desired outcomes are:

- The predator-prey relationship between wolves and wood bison that spend time in the park remains intact and within natural ranges of variation
- Populations of both species remain viable, evolve as naturally as possible and support Indigenous traditional use and ways of life.

The status of the first desired outcome is unknown. Overall, the predator-prey relationship between wolves and bison has improved in the last 15 years in comparison to the previous 100 years as without wolf control it is now a more natural relationship. It is unknown if that trend is continuing to improve, staying the same or worsening at this time. While bison population data exists, unfortunately it has not been analyzed for this purpose taking into consideration the population changes that would occur after wolves populations were allowed to naturally fluctuate. Therefore, the status remains unknown. While there have been declines in the population recently, it is not clear if they are a negative trend in the context of a population in equilibrium. The population of wolves is not known. There is ITK of wolves that wolves are looking less healthy, as well as, observations of healthy packs (MCFN, 2018a). The overall status and trend for this desired outcome is unknown.

The second desired outcome is not being met because Indigenous traditional use and ways of life are not being met. Hunting of bison within the park has not been permitted for generations and, at times, Indigenous peoples have been prosecuted and expelled from the park for hunting wood bison.

Furthermore, while the diseased condition of bison no longer appears to affect the population viability of the herds that have been exposed since the 1920's directly, it does affect the Indigenous traditional use and ways of life. While bovine tuberculosis does not transfer easily between bison and people, the Canadian Food Inspection Agency recommends taking biosecurity measures in handling the carcass and cooking meat well (Canadian Food Inspection Agency, 2011, 2012, 2013, and 2015). Given this recommendation, some Indigenous people may be hesitant to eat bison.

The drying trend and spread of invasive species are resulting in considerably fewer bison in areas around the PAD, further impacting the prospect of Indigenous communities located in and around the PAD being able to maintain traditional practices relating to bison. Reduced bison populations and/or presence in and around the PAD impact the Indigenous way of life by reducing food security, altering sense of place, and removing the ability of future generations to hunt and maintain sacred relationships through bison harvest.

In summary, Indigenous traditional use and ways of life have been negatively impacted by lack of access to bison, and the movement of bison away from the places they traditionally use. In addition, the quality of bison as a resource has been reduced or compromised by disease.

4.6 Whooping Crane

The Whooping Crane (*Grus americana*) is listed as Endangered under *the Species at Risk Act* (SARA) and is protected under the *Migratory Birds Convention Act* (MBCA). The Recovery Strategy for Whooping Crane in Canada was finalized in 2007 (Environment Canada, 2007). The overall recovery goal is to protect, restore and manage the species to be self-sustaining in the wild. To achieve this goal, the long-term recovery objective is to establish 1000 Whooping Cranes (250 breeding pairs) in the Aransas-Wood Buffalo Population of Whooping Cranes (AWBP) by 2035 (Environment Canada, 2007), if reintroduced populations in the U.S. are not self-sustaining. In winter 2016-17, the AWBP was estimated to contain approximately 431 individuals (95% CI 371-493; Butler and Harrell 2017).

Adult Whooping Crane. Photo: Parks Canada

4.6.1 Pathways of Effects on Whooping Crane

There are five potential pathways of effects on Whooping Crane:

- Short-term exposures to contaminants in local migratory habitat

- Changes to habitat and food availability in local migratory habitat
- Possible changes in migration routes
- Exposure to contaminants in water, food and sediments in nesting habitat
- Changes in habitat and food availability in nesting habitat

4.6.1.1 Short-Term Exposures to Contaminants in Local Migratory Habitat

Whooping crane migration areas between their wintering grounds in Aransas National Wildlife Refuge, Texas and their breeding grounds at the north end of Wood Buffalo National Park have been defined and monitored since at least the late 1970s. The most recent description of the migration routes identifies a consistent corridor directly over the MOSR and entering WBNP at its southern boundary (Pearse et al., 2018). Local Indigenous knowledge identifies Whooping Cranes landing in the PAD to rest during fall and spring migrations (MCFN, 2018a).

Ongoing monitoring of Whooping Cranes during migration, conducted via satellite telemetry by the Canadian Wildlife Service, Parks Canada, and their partners, demonstrated that some cranes stop over for 1-2 nights in the MOSR during spring and fall migrations and some of these stopovers occurred on or adjacent to tailings areas at active oil sands mines (Bidwell et al., 2016). Bidwell et al. (2016) states that, on average, 72% of the marked (satellite-tracked) population flew over the MOSR in the spring, and 92% in the fall. Previous to this study, aerial tracking data for Whooping Cranes from 1981-1984 showed the most cranes follow the Athabasca River south from their breeding grounds in WBNP during the fall migration (Kuyt, 1992).

This presents a plausible link between Whooping cranes and known risks to waterbirds associated with industrial waterbodies present on mine sites in terms of direct mortality and/or contamination through contact, ingestion, and inhalation pathways (see Section 4.4). These pathways may be associated with impacts on health, survival, and breeding success of individual birds (i.e., fitness), and thus could have population-level impacts, although these have not yet been demonstrated for Whooping Cranes.

There are no official records of Whooping cranes becoming oiled or contaminated in the oil sands region. Group size during migration in the MOSR is not known with certainty but is assumed to be small (2-4 individuals) so mass mortality events where large numbers of individuals die in tailings ponds are not expected. However, the MOSR is completely contained within Whooping Crane migration corridor (Pearse et al., 2016). Most cranes migrate through the MOSR in spring and fall (Bidwell et al., 2016) and some of these lands and stop overnight near oil sands mine sites (Bidwell et al., 2016). A recent mass oiling and mortality incident of 31 Great Blue Herons (listed as sensitive in Alberta) dying in a sump pond at a Syncrude mine site indicates that all waterbird species, including large diurnal migrants, are at risk of coming into direct contact with tailings ponds and contaminants. Whooping cranes can be present in the MOSR from mid-April through early November, and could thus be present during inclement weather (e.g. late winter storms in spring) which could result in an increased probability of landing during both spring and fall migrations (Bidwell et al., 2016). While stopovers in the MOSR are usually short and far from tailings ponds, there have been some cases where cranes have landed on or adjacent to tailings ponds or other industrial waterbodies (Bidwell et al., 2016). As discussed in Section 4.4.1, despite the implementation of extensive bird deterrent programs at oil sands mine sites, to date no system exists that can reliably and consistently deter all birds from landing on tailings ponds, especially during extreme weather events (St. Clair, 2011; St. Claire, 2014). Seven years of standardized monitoring as part of the Oil Sands Bird Contact Monitoring Program shows that even with deterrents in place, landings continue to occur by the tens of thousands annually, with mortalities in the hundreds (detected) and likely thousands (estimated). Overall, there is mounting evidence that current mitigation methods to protect migratory birds, including Whooping cranes, in the MOSR are ineffective, and the risks of exposure to contaminants in industrial waterbodies at oil sands mines remains high. Although crane survival appears high during migration through the MOSR (Bidwell et al., 2016), the degree of risk posed to Whooping cranes from contaminant exposures in the MOSR, and the potential for sublethal effects, remain unknown.

4.6.1.2 Changes to Habitat and Food Availability in Local Migratory Habitat

During migration, Whooping Cranes use a variety of habitats for roosting and foraging, including wetlands (fen, marsh), open water, rivers and croplands (Pearse et al. 2018, Hall et al. 2012a). Cranes tend to prefer temporary and seasonal wetland mosaics in the spring and more permanent wetlands in the fall (COSEWIC, 2010). The loss and degradation of migratory stopover habitat is a current threat to the recovery of Whooping crane (Environment Canada, 2007) because the suitability of roosting sites and availability of food may influence survival and health during migration and subsequent reproduction in nesting areas (Pearse et al., 2018; Hall et al., 2012). Habitat loss at stopover sites may also interfere with Whooping crane migration patterns in terms of routes or timing. Further, navigating altered landscapes in the MOSR with fewer natural wetlands for use as stopover sites for rest, food, or refugia during storms could increase stress for migratory birds. Whooping cranes appear to use visual cues such as landscape features to locate suitable landing sites during migration, perhaps recognizing features from other previous visits to a particular site (Kuyt, 1992). This is deduced from abrupt changes in flight course shortly before cranes landed, and weather conditions could not account for these changes. Instances have been recorded of cranes locating sites used during previous migrations (Kuyt, 1992), so it is plausible that the removal of wetlands and the placement of large tailings ponds on the landscape in MOSR could interfere with the cues cranes are using to navigate during migration. This could result in accidental landings and subsequent contamination, where previously suitable habitat was present, or shifts in stopover site locations (displacement) during migration through the oil sands region.

Human disturbance and presence in and around Whooping Crane stopover habitat may also pose a threat during migration by reducing stopover habitat quality (Hall et al., 2012). Whooping crane intolerance to human disturbance suggests that stopover habitat in proximity to human activity may be of reduced quality and could create stress for migrating individuals (Hall et al., 2012). Changes in stopover habitat quality could relate to a number of parameters including, but not limited to visual changes, odour, noise, and contamination. Habitat alteration through the addition of infrastructure is also likely to pose a threat to migrating Whooping Cranes stopping in the MOSR. Collisions with powerlines have been identified as a substantial source of injury and mortality during Whooping Crane migration (Environment Canada, 2007; Hall et al., 2012).

During migration in the MOSR, Whooping Cranes tend to use areas containing open water, marsh and fen habitats and avoid those containing upland habitats and anthropogenic disturbance (Bidwell et al., 2016). Sample sizes from ongoing monitoring, however, are too small to make strong inference about patterns of habitat selection (i.e., relative to available habitat) or to determine what constitutes suitable stopover habitat (M. Bidwell, pers. comm.). Whooping Cranes are omnivores but it is not well understood what birds consume at stopover sites in boreal regions of migration route, although some documented foods include frogs, fish, plants, grains, and insects (EC, 2007). These types of information are required in order to understand why cranes may select particular stopover sites and, in turn, develop effective mitigation measures to prevent landings in risky areas, such as the MOSR.

4.6.1.3 Possible Changes in Migration Routes

While local ITK indicates that bird migration routes over WBNP are changing (see Section 4.4.1.5), there is no evidence that this is affecting Whooping Crane specifically. As a result, this pathway of effect is not carried further in the analysis.

4.6.1.4 Exposure to Contaminants in Nesting Habitat

There is limited information available on the potential for Whooping Crane exposure to contaminants within their nesting grounds in WBNP. No environmental sampling for contaminants has been done or is planned within WBNP where nesting sites occur, although a research project has been proposed to sample blood and feathers of juvenile Whooping Cranes for contaminants (M. Bidwell, pers. comm.). At the moment, it is assumed there is no pathway of effect through contaminants in the nesting habitat.

4.6.1.5 Changes in Habitat and Food Availability in Nesting Habitat

Whooping crane nesting habitat at the north end of WBNP is an isolated, unique wetland complex containing marshy areas with numerous shallow potholes (COSEWIC, 2010; Environment Canada, 2007). Whooping cranes appear to use the shallow potholes with soft substrate for feeding, as opposed to deeper water, and require the presence of bulrush for use as nesting material (Novakowski, 1966; Hall et al., 2012). The breeding habitat is relatively undisturbed by humans and it is thought that cranes do not readily adapt to increased disturbance, evidenced by the extirpation of prairie and aspen parkland populations (1800 and 1900s) likely due to human activities such as egg collection, wetland draining, and hunting (COSEWIC, 2010; Environment Canada, 2007; Hall et al., 2012). Whooping cranes may not be breeding in the southern end of WBNP simply due to the loss of isolated wetland habitats (COSEWIC, 2010). While the amount of nesting habitat is not currently considered to be a limiting factor for cranes (Hall et al., 2012), they are identified as being sensitive to changes in nesting habitat quality. A decrease in breeding habitat quality at the north end of WBNP could lead to decreases in fecundity and/or summer growth and condition (Hall et al., 2012).

Altered hydrologic regimes due to anthropogenic change and/or climate change have been identified as threats to Whooping Crane nesting habitat. Environment Canada (2007) identified "*radical or lasting alterations to normal hydrological regimes*" as one example of an activity that is likely to result in the destruction of critical Whooping Crane breeding habitat. This concern is echoed by Hall et al. (2012). Changes to water levels, if occurring within nesting habitat, could also have consequences for Whooping

Crane mortality through increased predation (e.g. wolf, wolverine, fox, black bear), although the overall impact of predation on recruitment is uncertain (Environment Canada, 2007). Whooping crane mortality on breeding grounds (from 1981-1984) often occurred before cranes had fledged and it is suspected that this was largely due to wolf predation. Wolf access to breeding sites may have improved under drought conditions present during that time period (Kuyt, 1992).

During the 2015 breeding season, habitat conditions in the Whooping Crane nesting area were reported as “exceptionally dry”, with water levels in nesting areas and breeding-area ponds being reported as low or dry (Bidwell et al., 2016). These warm and dry conditions can also contribute to increased wildfire risk (Bidwell et al., 2016), possibly reduced chick production and survival (COSEWIC, 2010), and decreases in fecundity and summer condition (Hall et al., 2012). It is possible that changes in hydrology could influence food availability via changes to wetland condition though information on food status and trends on the nesting grounds is inadequate. This topic would benefit from further detailed studies specific to the Whooping Crane breeding grounds.

4.6.2 Status and Trend of Whooping Crane

The desired outcomes for Whooping Crane are:

- Habitat continues to support recovery strategy goals for breeding pairs and demonstrates resilience to climate change impacts.
- Whooping crane population reaches recovery strategy goal.
- Recovery and down listing from endangered status.

The first desired outcome is considered to be achieved because the population continues to increase and there is no evidence of a current pathway of effect impacting the habitat. The last two desired outcomes have not yet been reached, but the trend is positive. The recovery strategy goal is 1000 Whooping Cranes (250 breeding pairs) in the AWBP by 2035 (Environment Canada, 2007). In the winter of 2016-2017, a population of 431 (95% CI 371-493; Butler and Harrell, 2017) Whooping Cranes was estimated with an upward trend (Butler and Harrell, 2017).

4.7 Summary Of Evaluation Of Desired Outcomes

Table 4-1: Summary of Evaluation of Desired Outcomes

Desired Outcome	Current Trends And Stressors	Trend Direction
The salt plains remain aesthetically, ecologically and geologically unique in Canada, providing habitat for salt tolerant plants, grazing bison and nesting / staging waterfowl.	Invasive species are known to be on the border of the salt plains, but there is no evidence they have entered the salt plains or that they can ecologically.	→
Gypsum karst topography in WBNP remains intact and functioning within natural parameters.	No evidence to suggest that karst hydrological processes have changed.	→
The karst landforms in the park continue to provide some of the finest examples of collapse and pond sinkholes in the world.	No evidence to suggest that karst features have changed.	→
All species and community representatives of the Great Plains-Boreal grassland are present and functioning.	Declines are being seen in the grassland extent due to changes in water regime. Forest fire regime is within natural parameters. Due to the small extent of changes to vegetation composition, the trend is still overall neutral.	→
Grasslands continue to provide important grazing and calving areas for Wood Bison	Bison habitat is being negatively impacted by the change in flooding regime facilitating the increase in thistles and change in food.	↓
Great concentrations of viable, healthy populations of migratory waterfowl species continue to use WBNP seasonally.	Populations of waterfowl using the WBNP during migration are decreasing.	↓
Adequate quantity and quality habitat, unimpaired by contamination, is available for migratory waterfowl to fulfil all key life cycle stages while present in WBNP.	Habitat for waterfowl is declining in quantity and quality, particularly due to changes in water regime.	↓
Indigenous groups are able to maintain traditional harvest of waterfowl species and practice their way of life with confidence in healthy, sustainable and accessible populations of waterfowl	The ability of Indigenous groups to practice their traditional way of life with waterfowl is being negatively impacted.	↓
The predator-prey relationship between wolves and wood bison that spend time in the park remains intact and within natural ranges of variation	While as a whole, the park predator-prey relationship of wolves and bison has improved since wolf control ceased in the 1970s, the current status and trend remain unknown as data has not been analyzed in that context. Bison habitat and movement in the PAD has changed, but it is not clear that there is a population level effect resulting from this. Bison habitat is being impacted by changes in water regime and development around the park. These pressures	?

Desired Outcome	Current Trends And Stressors	Trend Direction
	on habitat are likely starting to put pressure on the bison-wolf relationship.	
Populations of both species remain viable, evolve as naturally as possible and support Indigenous traditional use and ways of life.	Bison are not supporting Indigenous traditional way of life and there is no change in this.	
Whooping Crane habitat continues to support recovery strategy goals for breeding pairs and demonstrates resilience to climate change impacts.	Habitat continues to support an increasing population.	
Whooping crane population reaches recovery strategy goal.	Population of Whooping Cranes has not met the recovery strategy goal but is increasing.	
Recovery and down listing from endangered status.	Whooping cranes have not yet been down listed, but their population is increasing.	

5.0 CHAPTER 5: CURRENT STATE OF THE PAD SYSTEM – TRENDS AND STRESSORS

In this chapter, the current state of the PAD system is evaluated, including pathways of effects, trends, and stressors in relation to the following desired outcomes:

1) Flow regimes and water quality into the PAD maintain the ecological function of the ecosystem.
2) Flow regimes and water quality into the PAD sustain vegetation communities and healthy and abundant populations of key ecological and cultural species including waterfowl, muskrat, fish, bison and wolves.
3) Indigenous groups have access to the PAD and are confident in the health of the PAD to maintain traditional use and way of life through hunting, fishing, gathering, and cultural activities.

The chapter begins with an introduction to the PAD by those who know it best, followed by an explanation of hydrologic recharge mechanisms in the PAD. Then the trends, causes and effects of hydrologic recharge are examined. Next, the valued components of the hydrologic system, including surface water quality, sedimentation and sediment quality, air quality and groundwater are discussed. Finally, the impacts of these changes on Indigenous way of life, muskrat and beaver, vegetation, migratory waterfowl, bison, moose and fish are evaluated. Finally, a pathways of effects diagram is presented to illustrate the relationships between human activities, environmental pressures, and impacts in the PAD.

5.1 INTRODUCTION

The PAD is one of the world's largest inland deltas and arguably the largest boreal delta in the world. It is formed by a unique hydrological system created by the convergence of the Peace and Athabasca Rivers, along with many smaller rivers and creeks, on the west side of Lake Athabasca. The PAD is made up of three large lakes (Lake Claire, Mamawi Lake, and Baril Lake), as well as more than 1,000 smaller lakes. It is a flood dependent ecosystem that supports rich biodiversity, including wood bison, muskrat and migratory waterfowl. The Delta is understood to include the ecological functions and ecosystems it supports, including vegetation, wildlife and Indigenous communities within the Delta.

The Indigenous peoples of Fort Chipewyan introduce the PAD, or Ayapaskaw in Cree, in a much different way. Their stories about the PAD make it clear that the PAD is their home, their grocery story, their classroom, their church, their highway, their photo album, and the place where their happiest memories live. For many land-user and Elders, how they think and how see the world comes from the PAD.

> *We were all born in different areas out on the land…[in] the delta, that's why I love the delta so much…this is where you're born and it's such a beautiful feeling when you go out there. It's like going home…[Our house out there] was nothing fancy. But…there was such a tremendous amount of connection with Mother Earth and the people living around there, the people of the land. And culture was there, it was just your way of life…It was sacred…We all lived the same life.*

> *It's a good feeling when you go out there, you feel good. I just put my hand in the water and…you're back home and it's beautiful. It's hard to imagine that you'd have that kind of feeling just by putting your hand in the water and going on a boat, if somebody didn't know, if somebody didn't have that experience. But because we were raised out there, born and raised out there, that's the feeling we have…it's that connectedness with feelings. It's that beautiful feeling that you're home, that you're connected...The closeness is so close to the heart, it's part of you. That's who we are.*

First Nations and Métis express a profound gratitude for what Mother Earth and the Creator provided in the PAD. They explain that a healthy PAD is what the animals love — muskrat, beaver, moose, bison, fish, birds, and other living things – and what sustains the connection between all living things. Indigenous peoples utilize the PAD in all seasons, for fishing in summer and winter, hunting moose, bear, caribou and other large game, trapping muskrat, beaver and other fur, harvesting ducks, geese and other birds in spring and fall, collecting eggs in the spring and connecting to the land. The resources in the PAD sustain Indigenous livelihoods, lifestyles, cultures and rights.

Anyone who experiences the PAD with the Indigenous peoples of Fort Chipewyan will be quickly introduced to the Cree phrase nipî tapîtum or its English equivalent, "water is boss". This phrase is a summation of generations of accumulated ITK about how the waters that create the PAD interact to create a vibrant ecosystem. It also describes how important water is to the ways of life of Indigenous communities that depend on the PAD. Clean, abundant water provides for safe drinking and healthy wildlife and vegetation, supports the ecosystem in the PAD, and is what is needed for Indigenous peoples to travel throughout the area. To understand the PAD and what it means to Indigenous ways of life is to understand that "water is boss."

Indigenous Elders and land-users, the traditional stewards of the PAD, have explained that they have witnessed natural flooding, the lifeblood of the PAD, fade away and the spirit of the water stagnate and suffer. Any depletion and diminishment of quality water flowing into the PAD threatens both the ecosystem and the family, cultural and spiritual connections to the PAD. Below is a diagram developed by MCFN Traditional Knowledge holders of trends and stressors for the state of the PAD, including the effects on Indigenous traditional use and ways of life (Figure 5-1).

Figure 5-1: Peace Athabasca Delta – Key Stressors and Trends (MCFN, 2018a)

5.2 HYDROLOGIC RECHARGE MECHANISMS

The Peace-Athabasca delta (PAD) is comprised of two separate deltas, the Peace delta and the Athabasca delta, each with its own distinct hydrologic regime. The Peace River Delta is primarily fed by flows from the Peace River basin arriving from the west, while the Athabasca delta's main source is Athabasca River flows from the south. The Peace delta is located approximately 40 kms north of the Athabasca delta. The relationship between them is complex - they can function independently of each other or, alternately, work in concert to flood the entire PAD system when the combined flows of both systems collectively inundate large portions of the whole Peace-Athabasca Delta system. In any given year or flood season, depending on the hydrologic conditions on the Peace and Athabasca rivers, each delta experiences separate types of flooding conditions. In general, the main hydrologic mechanism experienced in the Peace delta is ice jam flooding, while the Athabasca delta experiences mainly open water flooding, with occasional ice jam flooding. However, when favourable hydrologic conditions align at the same time in each delta, the two systems function together to flood the entire Peace-Athabasca Delta. The pressures on each of the river systems are also different. Regulation of flows for hydroelectric production and climate variability influence the Peace River flow regime, while climate variability and removal of water for municipal and industrial purposes influence Athabasca River flows. These pressures have influenced the hydrologic regime of each of the separate delta systems, and subsequently, have also influenced the hydrologic regime of the PAD.

Hydrologic recharge of PAD lakes and basins is caused by a complex process of hydraulic damming, flow reversals, and ice jam flooding in the Peace River. The open-water recharge mechanisms of hydraulic damming and flow reversals occur if and when the Peace River is higher in elevation than the central PAD lakes and Lake Athabasca. If the Peace River is higher in elevation than Lake Athabasca during spring freshet and high summer flows, it prevents outflows from the PAD and 'pushes' water from the Peace River into the PAD.

If major ice jams occur during spring break up, they can flood the high elevation perched basins that the open water mechanism cannot reach directly through the interaction of the two rivers alone. The jams impede the northward movement of the Peace River into the Slave River system, promoting hydraulic damming and flow reversals in the PAD. Major ice jam events produce the over-bank flooding required to recharge the more isolated, higher-level perched basins in the PAD. The ice jam mechanism is, therefore, a lifeline for the perched basins, as they would not receive recharge water otherwise. Figure 5-2 below shows the movement of water within the PAD, where the black arrows indicate the flow direction and the two-headed black arrows indicate the potential for flow reversals.

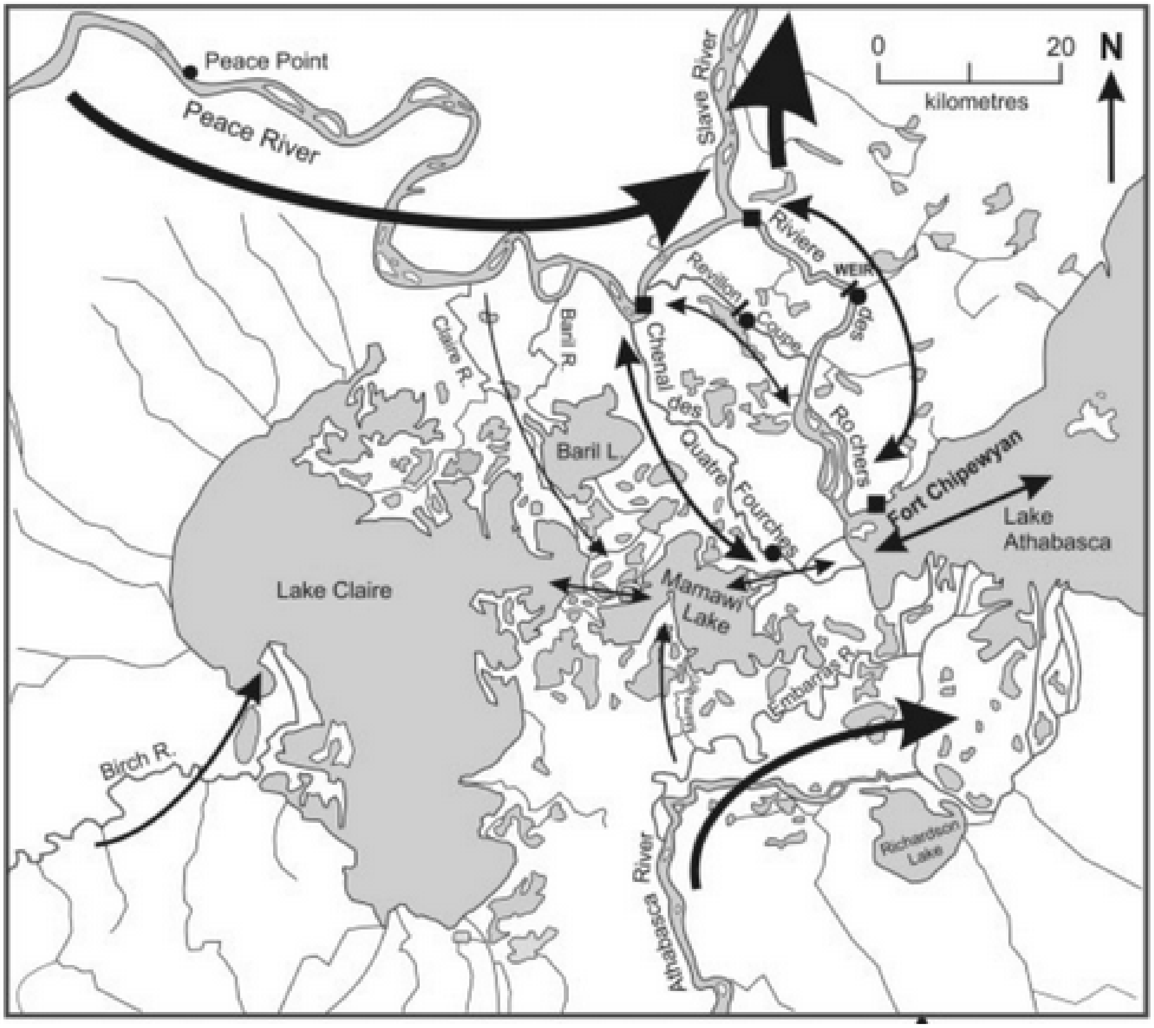


Figure 5-2: Peace Athabasca Delta Flow System (Peters and Buttle, 2010)

5.2.1 Open Water Mechanism

The open water mechanism consists of hydraulic damming and flow reversals. Hydraulic damming can occur during spring ice break up and summer high flows when the water level on the Peace River is higher than the central PAD lakes and Lake Athabasca. If the water levels are higher on the Peace River than in Lake Athabasca, water that would normally flow northward from Lake Athabasca to the Slave River system (via the Chenal du Quatre Fourches and the Rivière des Rochers) is prevented from doing so (aka hydraulic damming), causing reversal flow of water and flooding of the central PAD lakes and adjacent or connected basins. There are two types of open water flood mechanisms: i) flood flow through delta channels that spills over the banks and ii) filling of large central PAD lakes (Lake Claire and Mamawi Lake) that swell beyond the shoreline into PAD floodplains.

5.2.2 Ice Jam Mechanism

Ice jams occur when the lower Peace River is blocked by ice rubble during the mechanical break-up of its ice cover in the Delta reach (the lowest 50 km of the river), typically in late April and early May. At about the same time, spring runoff generally produces high flow rates and high water levels in the Peace River, and the water levels in Lake Athabasca rise due to runoff received from the Athabasca River and the Fond du Lac Rivers. Further aiding the ice jam process is the spring break up of ice cover on the Athabasca and Slave Rivers, as well as other smaller waterways such as Chenal du Quatre Fourches and the Rivière des Rochers. If the ice cover physically breaks up (rather than melting in place), spring flows can move it downstream to form ice jams where the ice floes pile up against intact ice cover. These jams impede the northward movement of water into the Slave River system, causing water levels to rise in those waterways and further promoting hydraulic damming and flow reversal. Major ice jam events produce the over-bank flooding required to recharge the more isolated, higher-level perched basins in the PAD.

Beltaos (2014) explains how the ice jam process develops along many rivers; in the Peace River, it can recharge the PAD's perched basins. The author notes "ice jams can stay in place for a few minutes or for many days; they can be a few hundred meters or many kilometers long. Owing to characteristically large aggregate thickness and underside roughness, ice jams can cause very high water levels, many meters above the equivalent-discharge, open-water flow stages. When a jam lets go, a large amount of water comes out of storage in short time, producing a 'jave' (short for 'wave generated by the release of an ice jam'). The water level drops precipitously upstream of the jam, but rises rapidly downstream; at the same time, water speeds can increase to extreme values while the wave propagates at even higher rates. Intact ice cover may be broken up and carried by the jave; if it is still very competent, it may stay in place and initiate another jam. In this manner, more and more ice is broken up and carried down the river, until the final jam releases" (p. 3).

More specifically, Beltaos et al. (2006b) notes that three conditions must exist for ice jam flooding in the PAD to occur, including a mechanical ice break-up (as opposed to melting), Peace River flow of at least 4,000 m^3/s (at Peace Point), and formation of an ice jam within the last 50 km of the Peace River. Observations indicate that the lodgment point or the "toe" of the jam may be located in the Peace River itself or in the Slave River. Prowse et al. (2006) add that low freeze up elevations and high spring flows help to promote mechanical ice break-up. Indigenous Knowledge holders note a number of conditions that aid in creating a large scale ice jam flood sufficient to flood the PAD, including:

1) clear, thick ice,
2) consistent temperatures of between -5^{o}C and -10^{o}C, and
3) an ice jam duration of at least a week to ten days at critical pinch points such as 30th Baseline,
4) a strong 'push' of water from upstream, and
5) presence of rubble such as logs and branches (MCFN, 2018b).

5.3 Recharge Trends and Causes

5.3.1 River Flows

Flows on the Peace and Athabasca Rivers have changed over the past sixty years, with differing causes. As a result of changes in the quantity and timing of flow on these two main rivers, water levels in the PAD are being affected. As the Firelight Group et al. (2018) points out "the timing and magnitude of spring freshet on the Peace River, alongside ice dam formation, are the primary factors that determine spring flooding. Simultaneous high flows on the Peace and Athabasca rivers are what reliably produce hydraulic dam conditions on the PAD, and flow regulation by BC Hydro on the Peace River and upstream withdrawals from the Athabasca River are considered major factors in reducing spring flows. Healthy wetland and muskeg areas adjacent to the Peace and Athabasca rivers are considered essential to maintaining high water through summer and into fall, and MCFN knowledge holders point to the removal of large areas of muskeg as a contributing factor to lower summer and fall flows. Reduced snow and ice melt from mountain areas in summer (due to climate change), combined with the impoundment of headwater areas (for power generation), is also reported to reduce summer and fall flows and result in increasingly frequent low PAD water levels, especially in the late summer and fall periods" (p. 3).

All the places we used to go and hunt now in the fall, the water is too shallow to go there. I still take my grandkids for a hunt, but not everything out there anymore. I used to tell them stories of what had happened. I tell them you have to try to carry on the traditional life, making moose hide.

Quote context: *A about 5 or 6 fall seasons ago my wife and I went out. The water was low already. Our friends had two small motors and took off. The first time we tried to go out we couldn't. We turned back and tried one more time. The third time I said we might as well turn around but we finally made it. After we got a moose, we loaded and took off. We barely made it to the river. We took off to Lake Mamawi. The mud was flying and we kept on going. Finally after 3 times we made it to the river mouth. The motor was just steaming. I opened the hood and put water on it. The water is very pitiful. It will get worse.*
Source: *Sloan Whiteknife*
About Sloan Whiteknife: *I am George Sloan Whiteknife. I was born and raised in the bush. Ever since then I've always been in the bush. I was taught from my dad to trap and to hunting moose, geese etc. I was always with him and he always used to tell me things. I learned quite a bit from my dad in my past life, and my uncles. I went out with all my relations. We need water. When I say something has to be done, I mean we need more water.*

Peace River

The Peace River is the largest river in the PAD system and the water flow conditions on the Peace, to a large extent, dictate the water level conditions for the PAD. The Peace River experienced natural flow conditions until 1968, when construction of the WAC Bennett dam was completed and reservoir filling began. Flow rates on the Peace River have become much less variable since the regulation of natural flow conditions in 1968, resulting in decreased summer flows and increased winter flows (Peters and Buttle, 2010; Peters and Prowse, 2006; Prowse et al., 2006; Prowse and Conly, 2002; Prowse et al., 2002a; Peters and Prowse, 2001). Indigenous Knowledge holders also report the Peace River is the main river that floods the PAD. Since regulation began, flows on the river have increased in the winter and decreased in the summer and, because the water is held back, the river now does not have the power to replenish PAD water bodies, including Lake Claire and smaller associated back channels (MCFN, 2017a, 2018a, 2018b).


Roche River, weir at Little Rapids, August 2017. Photo: Parks Canada

Prowse et al. (2002a) conclude "regulation of the Peace River has shifted the pattern of seasonal flows and damped flow extremes creating a less variable annual regime" (p. 429). More specifically, Peters and Prowse (2001) report "post-regulation mean winter flows were 250% higher and annual peaks (1-, 15-, and 30-day highs) were in the order of 35–39% lower than those that would have occurred under a natural regime. Regulation of the Peace headwaters has also reduced the downstream flow variability" (p. 3193). Further, Peters and Prowse (2006) note "analysis of the Peace River at Peace Point historical record revealed that there is a shift to lower peak discharge and an increased dependence on downstream tributaries for the generation of peak flows after 1968" (p. 4190). More recently, Peters and Buttle (2010) report "storage of spring/summer mountain runoff and subsequent releases over the fall/winter months has increased winter (>500m^3/s) and decreased summer (>2000m^3/s) flows compared to those estimated for the Peace and Slave Rivers without flow regulation" (p. 1072).

Other scientists and consultants also conclude that regulation of the Peace River has reduced the variability of flows on the Peace River (Peters, 2016; Eaton & Church, 2015; Dube & Wilson, 2013; Timoney, 2013; Golder Associates, 2012; Teck Resources, 2011c; Candler et al., 2010; Glozier et al., 2009). However, it is important to note these studies, as described below, may have included two different climate periods in their analysis. Therefore, it is more likely these studies illustrate that flow regulation on the Peace River, in conjunction with climate variability, have influenced the variability of flows on the Peace River.

Both the Teck Frontier Oil Sands Mine project (Teck Resources, 2011c) and the Jackpine Mine Expansion project (Golder Associates, 2012) Environmental Impact Statement (EIS) include an analysis of hydrometric data of the mean seasonal flows as measured at the Peace Point station from 1959 to 2010. As shown in Table 5-1, Golder's analysis illustrates less variable flows on the Peace River between the two time periods, with mean winter flows between January and March increasing by 200% and mean summer flows decreasing between April and June by 31% (Golder Associates, 2012). Mean annual flow has also dropped by 9%.

Table 5-1: Difference in Flow Statistics on Peace River

Parameter (m^3/s)	Pre-1968[1]	Post-1971[2]	Change (%)
Mean annual	2,300	2,100	-9
2-year	10,000	5,400	-46
5-year	11,000	7,400	-32
10-year	11,500	8,800	-23
Mean Summer	3,500	2,400	-31
Mean Winter	500	1,500	+200
Note: As measured at Peace Point (Golder, 2012, p. 12), 1: from 1960 to 1967, 2: 1972 to 2010.			

Eaton and Church (2015) also note, after flow regulation was introduced, "mean annual flood (MAF) in the river immediately downstream from the dam was reduced from 5,843 to 1,927 m^3/s, a reduction to one-third of its former value. Even at the distal end of the river, more than 1,200 km downstream in the Peace-Athabasca Delta, MAF was reduced to just over half its former value of 9,817 m^3/s" (p. 251). Carver (2013) illustrates these changes to the Peace River hydrograph in Figure 5-3.

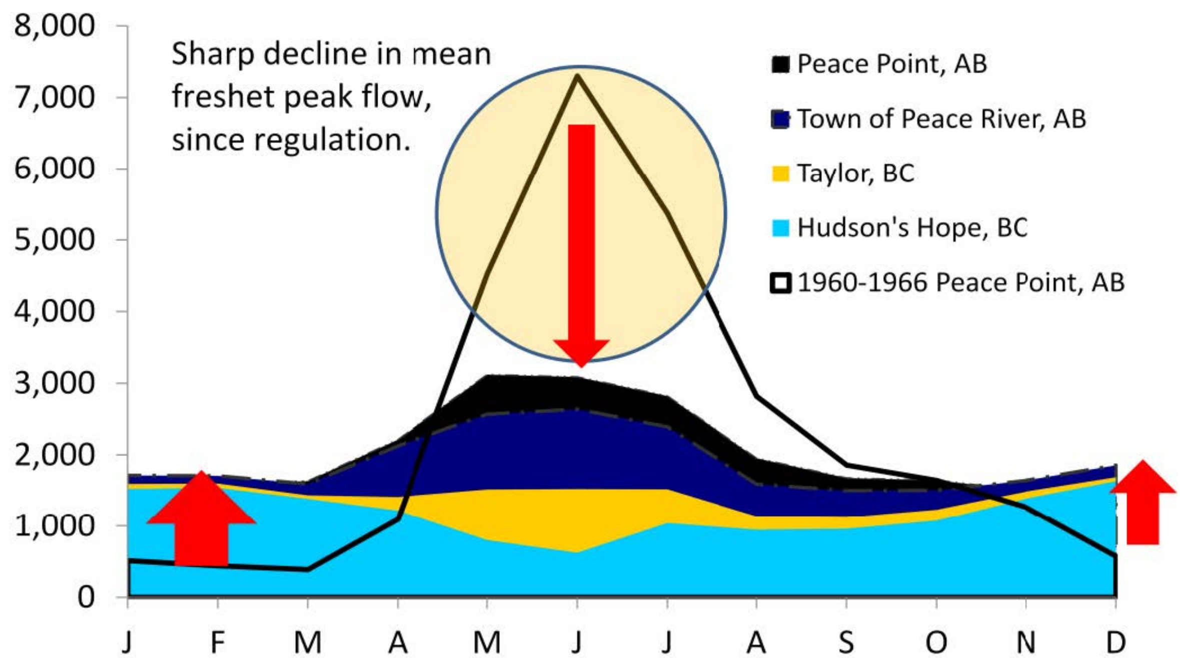


Figure 5-3: Mean Regulated Hydrograph at Hudson's Hope, Taylor, Town of Peace River and Peace Point (1992 – 2012) Contrasted with the Mean Unregulated Hydrograph (1960 – 1966), Highlighting the Seasonal Hydrograph Changes (Carver, 2013, p. 18).

(Note: X-axis tick marks represent the middle of the month)

Slave River

The Slave River originates at the confluence of the Peace and the Rivière des Rochers, where the Peace River contributes approximately 60% of flow volume (Sanderson et al., 2012). Unless the Peace River is high enough to prevent water from entering the Slave River system from Lake Athabasca, the Slave River receives the water from both the Peace and Athabasca systems. This would be typical for most of the year, with the exception of spring runoff conditions, although even during spring runoff, flow rates may not be high enough in the Peace River to prevent Athabasca water from entering the Slave River system.

A number of scientists and consultants report that flow rates on the Slave River have been reduced since regulation of the Peace River began (Dube and Wilson, 2013; Sanderson et al., 2012; Teck Resources, 2011a; Davidson and Hurley, 2007). In their analysis of Slave River hydrometric data from 1930 to 2009 for the Frontier oil sands project EIS, Teck Resources notes higher mean winter flows by around 40% and lower summer flows by about 30% due to the regulation of the Peace River (Teck Resources, 2011a). Sanderson et al. (2012) also report "since regulation… mean winter low flows have increased by 75% and mean spring peak flows have been reduced by 20%" (p. v) and note that while the total amount of water flowing into the Northwest Territories has remained stable, the timing of water arrival has changed. More recently, Dube and Wilson (2013) report "a lower relative contribution of peak flows and potential flood conditions from the Peace to the Slave since the dam was constructed" and note "peak flows (on the Slave River) are significantly lower than they were before oil sands development" (p. 421). However, as noted in the previous paragraph, the studies described above may have included two different climate periods in their analysis. Therefore, it is more likely these studies illustrate that flow regulation on the Peace River, in conjunction with climate variability, have reduced the variability of flows on the Slave River.

Athabasca River

The Athabasca River flows northeastward through Alberta past Fort McMurray and Fort McKay, draining into Lake Athabasca, and is the second largest river flowing into the PAD system. The Athabasca River and its tributaries contribute the largest amount of water to Lake Athabasca. Teck Resources reports, as part of its Frontier project EIS in 2011, at Fort McMurray, the average streamflow discharge on the Athabasca River during winter, spring, summer, and fall is 180 m^3/s, 535 m^3/s, 1,225 m^3/s, and 567 m^3/s, respectively (Teck Resources, 2011b). Mean runoff is 155 mm/year near Fort McMurray (Peters and Prowse, 2006). Alberta Environment and Parks (2017b) reports "actual water withdrawn by oil sands mines in 2016 was less than 1% of the average annual flow - approximately 111.5 million m^3, or an average of 3.53 m^3/s" (p. 1). Further, as noted by Islam and Leibel (2018), "in 2016, weekly water withdrawal by mineable and in situ oil sands producers from the Athabasca River ranged from 0.63% to 3.18% of the measured flow during the winter period, and from 0.21% to 0.83% of measured flow during the open water period" (p. 15).

Relevant literature reviewed indicates that annual, winter, and summer flow rates on the Athabasca River have declined over the past fifty years (Sauchyn et al., 2015; Gill and Rood, 2009 (in Lebel et al., 2009); Glozier et al., 2009; Davidson and Hurley, 2007; Bruce and Tin, 2006; Schindler and Donahue, 2006). Glozier et al. (2009) report annual average discharge in the Athabasca River below Fort McMurray declined over the 1960 to 2006 monitoring period, with lower flows observed from the 1998 to 2006 period compared to earlier decades. Further, Gill and Rood (2009, in Lebel et al., 2009) note annual, winter, and summer flow declines of 26%, 18%, and 17%, respectively, in the Athabasca River below Fort McMurray from 1958 to 2007 (resulting from declines in mean annual discharge, winter flow, and summer flows of about 0.5%, 0.4%, and 0.4% per year, respectively, over the same time period). Further, Sauchyn et al. (2015) report a reduction in annual flow of 0.56% per year on the Athabasca River at Fort McMurray from 1958 to 2012. Bruce and Tin (2006) further note a 20% reduction in annual flow in the Athabasca River from 1953 to 2003.

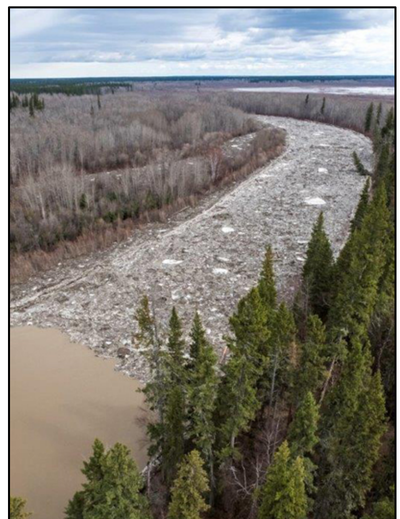
With regard to summer flows, Davidson and Hurley (2007) report that "summer (May-Aug) flows in the Athabasca River at Fort McMurray had declined by 29% between 1970 and 2005" and further commented that "flows have been well below average for most years since 1980" (p. 2). Further, Schindler and Donahue (2006) report 19.8% reductions in summer flow (May to August) on the Athabasca River downstream of Fort McMurray from 1958-2003 and a 33.3% reduction since 1970.

The reported causes of the flow rate declines in the Athabasca River are water withdrawals, changes in climate, or a combination of both (Peters, 2016; Bawden et al., 2014; Dube and Wilson, 2013; Timoney, 2013; Candler et al., 2010; Glozier et al., 2009; Lebel et al., 2009; Davidson and Hurley, 2007; Bruce and Tin, 2006; Bill et al., 1996). As part of the Northern River Basins Study TEK report, Bill et al. (1996) report "the change in flow patterns of (the Peace and Athabasca) rivers is attributed to either the damming of the rivers or diversion of waters for industrial or municipal use" (p. 327). Gill and Rood (2009, in Lebel et al., 2009) note a "decline in river flows upstream from the oil sands withdrawals, but at least part of this reduction could be associated with (climate change)" (p. 30).

More recently, Timoney (2013) reports that the "decline in annual discharge of the Athabasca River is exacerbated by industrial water withdrawals downstream of Fort McMurray" (p. 417)). More recently, Dube and Wilson (2013) determined the peak flows in the Lower Athabasca River (LAR) were "significantly lower…in the post-oil sands period compared to the pre-oil sands period", but did not attempt to attribute a cause to the change (p. 420). Peters et al. (2013) further report "significant ($p<0.05$) declines in annual and open-water season median/mean runoff indices over 1958–2009" for the Lower Athabasca River, however the authors note "variation in precipitation explained >67% of the annual median/mean LAR runoff variability since 1958" (p. 1915). The authors also identified "the drainage area between (the Town of) Athabasca and Fort McMurray as a zone that influenced runoff declines observed at the LAR watershed scale since 1958, which warrants further investigation with competent hydrological models" (p. 1915). While the studies indicate some combination of climate change and water withdrawals are causing the declines, they do not provide clarity about the relative contributions.

5.3.2 Ice Jam Flooding

Many scientists, consultants, and Indigenous knowledge keepers have determined that ice jamming and subsequent flood-induced recharge of perched water basins in the PAD has been decreasing since the 1970s (MCFN, 2017a, 2018a, 2018b; Firelight Group, 2018; Beltaos, 2018; Beltaos, 2016; Beltaos, 2014; Candler et al., 2013a; Dube and Wilson, 2013; AECOM, 2010; Peters & Buttle, 2010; Beltaos et al., 2008; Davidson & Hurley, 2007; Beltaos et al., 2006b; Prowse et al., 2006; Prowse & Conly, 2002; Prowse and Conly, 1998; Wrona et al., 1996; Peterson and Courtorielle, 1992; The PAD Project Group, 1972). In order to understand the pathways of effects related to this trend, this section begins with an examination of the role higher winter flows and ice elevations have played in reducing ice jam frequency. It then examines the role of and decreased snowpack runoff from tributaries to the Peace River due to climate change.


Ice Jam, Roche River. May 2018.
Photo: Pierre-Emmanuel Chaillon

Thick ice is 6-10 ft. thick blue or white ice. When that ice broke, my grandpa stayed a week before and there would be a big bang and a few days the ice shoots down the river, the water is high, and everything is clearing the river. When that ice stopped, the ice is thick, big as building, blue, thick, white ice. It would take two days for us to cross the river to go to the store to go shopping there was so much ice! Now when the ice stops, the ice still doesn't hold anything back. Because of the bad quality of ice it melts away faster today.

Quote context: *In the past the ice was blue, white, like glass. It really thickened. You know when the ice is solid when you see that blue ice. Now it's a foam ice. There is a lot of air in the ice. Its not good ice like when I was growing up. You cannot really just cross anywhere without double checking ice, especially on the rivers. If you are on the rivers you can go through and get sucked under. In a slue you have a chance as it doesn't flow. On the river you are toast if you go through the ice. That danger is more now, especially in spring. The ice melts quicker because of the pollution from oil and the Peace River and Athabasca Rivers. The ice is thin and the water level is low. In the old days there was water all over, and the ice jammed for a week. We had fresh water every few years. Now it's stale water I can see in summer, and dead plants and dead animals. I can't live from that.*
Source: *Gerald Gibot*
About Gerald Gibot: *I was born in Fort Chip. I was raised up in the trap line with my late mom and dad. I still go on the land. I have two boys 5 and 8. In the summer when there is no school I take my boys out on my boat. My boys enjoy the life that I show them where their grandparents used to be when I grew up. I have seen a lot in my 63 years. At 5 I went to residential school. We get a lot of wisdom from other elders. Also my late father had friends about his age. We would sit down and talk about their lives and I can understand Cree so I can relate to other trappers talk about their lines in other areas.*

Indigenous knowledge holders have observed poorer quality and thin ice cover, in combination with the lower strength of the Peace River flow in the spring. They see these change as preventing the large ice jams that are needed to flood the PAD in the spring and replace water in lakes and channels in order to keep the PAD healthy. The ice used to be upwards of 18 to 20 feet in height at Rocky Point (and other locations), but now there are no large chunks of ice to build up. There needs to be thick, clear "blue ice" to produce the ice jams to fill the PAD's lakes and creeks, which no longer happens. Indigenous people along the Peace had a history of building platforms, called stages, to a height of 10 feet above the banks of the river to store their important belongings until the ice floods receded. This is no longer necessary (MCFN, 2018a). Firelight Group et al. (2018) also reported ITK indicating alteration of Peace River flows is a primary stressor resulting in reductions in ice jam flooding frequency and duration. The authors note "higher winter flows during ice formation on the lower Peace River results in weaker ice, often with more silt and impurities. Combined with weaker spring flows at breakup, this poor quality ice tends to rot and drift without forming substantial ice dams. While other factors, including climate change and natural annual variation in snow load are recognized, MCFN knowledge holders generally consider flow regulation to be the most significant driver for the negative trend in ice jam frequency" (Firelight Group et al., 2018, p. 2-3).

Scientists have been examining the effects of flows and ice elevation and quality over the past several decades. In 1996, Wrona et al. report "the major effect of regulation on the occurrence of break-up ice jamming near the PAD is…the higher flows and freeze-up elevation of the ice cover throughout the winter period" (p. 11). In 1998, Prowse and Conly report the increased flow on the Peace in the winter due to regulation impairs the flooding and recharge in the PAD because the increased winter base flow means the winter ice sits at a higher elevation and increases the magnitude of the flow required for mechanical spring ice break-up to create jams capable of flooding perched basins. In other words, “the higher a freeze-up cover is stabilized, the greater the flows it can withstand without breaking” (Prowse and Conly, 1998, p. 1607). In addition, Prowse and Conly (1998) also note, along with declines in spring snowpack, “elevated ice levels and winter flows resulting from regulation have further reduced the potential of tributary runoff to produce severe break-up floods”.

In 2018, Beltaos, as shown in Figure 5-4, used newly developed methodology that examines the slope of the cumulative number of floods in the PAD from 1900 to 2017 reveals an abrupt and sizeable reduction in ice jam flooding frequency after 1968 (Beltaos, 2018). This result is statistically significant and suggests that “regulation has been a contributing factor” to reduced flood frequency. (p. 73).

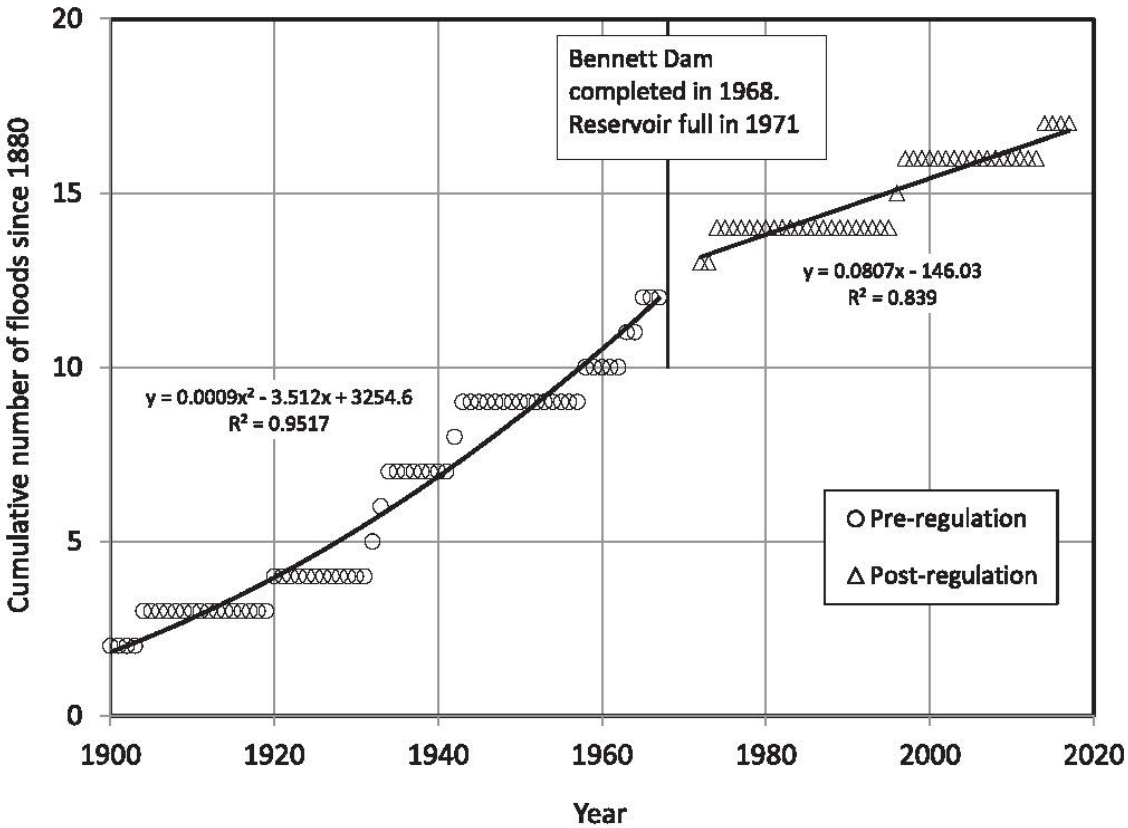


Figure 5-4: Recent History of Large Ice-Jam floods of the PAD, Including the 2014 Event (Beltaos, 2018)

Note: by definition, frequency = slope of cumulative number graph. Flood numbers up to 2008 derive from the comprehensive compilation by Timoney (2009).

Many scientists also report changing climatic conditions contribute to the reduction in frequency of ice jam floods (Beltaos, 2014; Dube and Wilson, 2013; Beltaos et al., 2008; Beltaos et al., 2006a; Prowse et al., 2006; Prowse et al. 2002b; Prowse and Conly, 1998). As early as 1996, Prowse and Conly (1996, 1998) indicated “the absence of a high-order event between 1974 and 1992 seems to be related to a combined effect of flow regulation and the vagaries of climate” (Prowse and Conly, 1998, p. 1589). Later, Beltaos et al. (2008) report “ice jam flooding is shown to depend on freeze-up stage and spring flow. The former has increased as a result of flow regulation; the latter has decreased due to recent climatic trends…contribut(ing) to less frequent ice-jam flooding” (p. 345). More recently, Dube and Wilson (2013) indicate that “before the dam, variability between peak flows and low flows was much higher, with large floods (including ice jam floods) occurring more frequently than post-regulation” and note that “a combination of higher winter flows (from regulation) and reduced spring runoff (effect of climate warming, reducing snowpack depth) have made ice jam floods scarce (only 4 since 1968)” (p. 420). Beltaos (2014) concludes that “regulation accounts for nearly two-thirds of the reduction in ice jam flood frequency”, with the balance as a result of climate change (p. 57).

Other authors further highlight the contributions of climate change to the declining trend in ice jam recharge frequency. Peters and Prowse (2006) indicate the absence of large-scale ice-jam flooding in the Peace Delta is largely due to a decreased magnitude of winter snowpack. Timoney et al. (1997) studied historic PAD records of flood data from 1826 to 1995 and report “climatic change or oscillation likely underlies the drying trend observed in recent decades in the Peace-Athabasca Delta” (p. 463). However, AECOM (2010) studied Timoney et al. (1997) work and determined that “a more recent analysis of these data from 1850 to 2008 indicates that the median time period between large-scale floods (magnitude three) has increased, when comparing pre-dam to post-dam data…confirm(ing) the observations documented by Traditional Knowledge” (AECOM, 2010, p. 18).

Additionally, Wolfe et al. (2006) analyzed lake sediments over the past 180-300 years in two basins located in the northern PAD. Based on this work, they infer “flood frequency has been highly variable over the past 300 years but in decline for many decades beginning as early as the late nineteenth century...” and note “several multi-decadal intervals without a major flood have occurred during the past 300 years” (p. 4131). On the other hand, Beltaos (2016) estimated the occurrence of pristine ice jam floods (the flood regime that would have prevailed had there been no regulation introduced), noting “unregulated flood frequency is at least 55% greater than regulated frequency”, based on a flood once every six years pre-regulation (1923-1967) versus once every nine years post-regulation (1972-2016) (p. 3). Furthermore, based on their own data sources, Beltaos (2016) and AECOM (2010) concluded that regulation has significantly reduced ice jam flooding, which aligns with the extensive body of authoritative physical modelling studies that consistently point to the significant role regulation has played in lowering ice jam flooding frequency since the late 1960s (see Part 4 of Carver, 2016b for a listing of relevant publications) and the accumulated direct experience provided through ITK (reported in Candler et al., 2013a).

5.3.3 Open Water Flooding

Numerous scientists report the open water flooding mechanism has decreased with regulation of the Peace River (Candler, 2013a; Carver, 2013a; Peters and Buttle, 2010; Prowse et al., 2006). Candler et al. (2013a) note "MCFN knowledge holders estimated that the frequency of hydraulic damming on the Peace resulting in reversed flows in the delta prior to the WAC Bennett dam was in the order of one in every four to five years (approximately 20% likelihood). Since WAC Bennett was built, MCFN knowledge holders indicated that Peace River levels have been sufficient to cause reverse flows in only three (1974, 1997, and this spring, 2013) in forty-four years (approximately a 7% likelihood)" (p. 17). In 2006, Prowse et al. concluded "the frequency of (spring) reverse-flow events did decrease after regulation" (p. 191) and Carver (2013a) further report "flow reversals were abundant in the years prior to the closing of the Bennett Dam (an equivalent mean flow throughout the year of 121 m^3/s), all but halted during the filling period (3.1 m^3/s), and then resumed at a much reduced rate (21 m^3/s)…During the regulated period, flow reversals have been 83% below what they had been during the monitored pre-regulated period" (p. 19). 'Closing' of the dam in this context means when the control gates were closed in order to fill the reservoir.

In the early 60's, there were floods all the time. Lots of water. My brother Harvey, comes out north of Peace River, we could hardly see the spruce trees with all the ice and sticks. That was clear ice in them days and all that water backed up all the way to Lake Claire. That used to happen every 3-4 years.

Quote context: *It (the water) was way high, that is what I mean. The ice jam would have spruce and timber, ice, logs, everything. Ice then didn't have pollution. Not the brown ice like today. It was blue then and thick. When it jammed it didn't crush, it piled up. When the ice jams it goes into the Pine River and it starts on the Peace. It comes out at Lake Claire. This used to happen every 3 to 4 years. Then there were a lot of rats. Those were the good old days. The Peace River was high in those days.*
Source: *Archie Antoine*
About Archive Antoine
I am 81. I have been on the land all my life. I started trapping at 15 at Garden River on the Peace River. I have been here 65 years and I am still out on the land. I was born and raised on the land but worked in the summer and trapped in winter. I take out two young boys to teach traditions to, Chance and Robert Jr. They learned fast but I lost one of them not too long ago.

There have also reportedly been changes to open water reverse-flow events into Lake Athabasca resulting from regulation of the Peace River. Peters and Buttle (2010) report "during the summer period, (Athabasca) lake level was linked to sustained high flows on the Peace River. The (Peace) River obstructed outflow and contributed reverse flow to the LA-PAD in each year prior to 1968. Following regulation, however, more than half the years did not experience any open-water obstruction and/or reversal, and those that did were characterized by smaller events. The average estimated duration of obstruction was more than two weeks shorter and reverse flow volume was reduced by 90% under a regulated regime compared to a simulated naturalized flow regime" (p. 1065).

One author also reports effects to open water flood recharge efficacy in the PAD due to changes in flow rates on both the Athabasca and Peace Rivers, in combination with climate change. Carver (2013) reports "declining trends in annual peak flows due to climate change and oil sands water withdrawals (on the Athabasca River) interplay with changes occurring in the Peace River due to regulation and climate change. A consequence of this reduced inflow is a general decline in the amount of recharge for a given hydraulic damming event by the Peace River. It is important to note, the interactions between the two river systems are complex and additional study is needed to clarify how the Peace and Athabasca Rivers interact in order to generate flooding events in the PAD.

5.3.4 Clarifications on Observations and Causes of PAD Flooding Reductions


Flooded PAD creeks, May 2018. Photo: Pierre-Emmanuel Chaillon

Apparent disagreements can be found in the literature from some researchers regarding the pattern and characterization of PAD drying, including variation in ice-jam frequency, in both recent history (two or three centuries before present) and over longer time (going back thousands of years) and the role of regulation in the perceived patterns. In general, it can be said that the perceived differences may be more about time scale and the analytical methods used, rather than about diverging findings. A discussion of some specifics found in the scientific literature is provided below, including clarifications on ice jam flooding and the significance and detectability of comparing the effects of regulation with long-term recharge variability over recent history and longer.

Ice Jam Flooding: Storage Release Hypothesis

Jasek (2016) presented a hypothesis (originally put forth in a conference paper by Ashton) that enhanced storage-release breakup flows resulting from increased freeze up levels and winter releases compensate for the initial negative effect on ice-jam occurrence of the increased freeze up levels associated with regulation. If true, this hypothesis would imply that the widely understood mechanism for regulation to reduce the likelihood of ice jam flooding was incorrect, thereby opening the door to other explanations for the PAD's recent drying trend. However, Beltaos (2016) notes that hydrometric data at Peace Point does not support this hypothesis, further stating "excess storage release will be zero or minimal in cases where the freeze up level is high enough to prevent ice cover dislodgment by the incoming breakup flow, even when the latter is potentially of flood magnitude" (p. 5). Comprehensive technical details of storage-release hydrodynamics and excess release flows can be found in Beltaos (2016).

PAD Long-Term Recharge Variability

Several researchers have placed the reduced recharge experienced by the PAD since regulation within the context of the long-term range of variability for the landscape by extending the timeline of study to several thousand years using paleo-climate techniques. The argument made is that the effects of introducing flow regulation on the Peace River are insignificant because the resulting declines observed in ice jam flooding frequency are within the long-term range of variability looking back over millennia. Although these types of studies shed light on the long-term history of the PAD, they have also contributed to confusion regarding effects detectability based on the timeframe under consideration and do not consider the undisputed conclusions regarding regulation based on well-established data.

Variability in climate over the past millennia are not relevant to reaching conclusions regarding changes in ice jam flooding frequency over the past century in relation to contemporary stressors. Jasek (2016) reports the "long term average is one flood every 16 years since circa CE 883" and further note "ice jam floods were more frequent during the 20th century than at most other times during the last millennium. One flood every 6 years" (p. 7). However, the lower frequency associated with a climate from a thousand years ago is unrelated to the evaluation of regulation. As noted by Beltaos (2018), if the time period selected for comparison is too long, it may be influenced by climatic regimes of long ago that have little resemblance to that of the period of regulation.

Observations made by application of paleo research techniques can, however, be used to help put the present moisture regime in a long-term context regarding ecological resiliency in response to present-day stressors. For example, the long-term and well-known role of climate variability to hydrology in systems worldwide is emphasized by Wolfe et al. (2012) who document how "climate variability exerts…overwhelming influence on the delivery of water to the PAD" within the context of a 5200-year reconstruction of Lake Athabasca water-level history (p. 191). Wolfe et al. (2012) use their reconstruction to speculate that "the inaccurate perception of normal conditions…have likely contributed to the incorrect paradigm that the delta is drying and dying by unnatural causes. To the contrary, the PAD continues to evolve as a natural floodplain landscape" (p. 208). These comments are similar to those of Timoney (2002) who identifies variations in the natural PAD hydrologic regime as being caused by "climatic variation and change, normal wetland dynamism, stochasticity, flow regulation, weirs, dredging, avulsions and their prevention, influxes of weeds and contaminants, delta evolution, and cultural change" (p. 282).

Ultimately, whereas the partial interpretations from paleo-research provide additional ways to place the drying that has been occurring since regulation in context, peer-reviewed literature on this topic remains unavailable. Thus, it is inappropriate to use the paleo-research to dispute the validity of the 25 years of broad-based peer-reviewed physical modelling work undertaken by a wide range of researchers and supports the observation that the paleo methods are being misapplied to detect effects that they are not suited to detect.

5.4 EFFECTS OF RECHARGE TRENDS ON WATER LEVELS

The net effect of water recharge changes described in Section 5.3 above has resulted in what has become a critical situation for Lake Athabasca and the central PAD lakes. The reductions in ice jam and open water flooding have reduced water levels in the PAD, leading to declines in water depth and resulting in a loss of resilience and function in both ecological and human communities. Water levels on Lake Athabasca and central PAD lakes, and weirs as a mitigation measure, are discussed in the following paragraphs.

Numerous scientists and Indigenous knowledge holders report that changes in the flow regime on the Peace River resulting from regulation, in combination with climate change effects, have caused water levels and spatial extents in the PAD to decrease, resulting in a drying trend over the past fifty years

(MCFN, 2016a; Beltaos, 2014; Schindler and Donahue, 2006; Wiacek and Westworth, 1999). As reported by Candler et al. (2013b) "Traditional Knowledge indicates that the PAD as a whole is drying, and that this drying has coincided with BC Hydro regulation of the Peace" (p. 20). In 1999, Wiacek and Westworth report "regulation of Peace River flows, in conjunction with natural declines in snow pack in tributary headwaters, have contributed to a protracted drying trend in the PAD that began approximately in 1975". More recently, Schindler and Donahue (2006) report "delta wetlands are already exhibiting negative effects of declining water supply from climate change and the Bennett Dam on the Peace" (p. 7213) and in 2014, Beltaos stated that both regulation and climate change have "resulted in prolonged dry periods and considerable reduction in the area covered by lakes and ponds that provide habitat for aquatic life in the PAD region" (p. 1).

In 2016, MCFN (2016a) report "while Mikisew oral histories recall large scale flooding occurring every few years prior to damming of the Peace River in the late 1960s, the frequency and intensity of spring floods has declined since. When there is not enough water flowing in the Peace River, or when ice dams fail to form, the rivers of the delta do not reverse, the flow of the Athabasca and other tributaries isn't held back, and the delta continues to empty. Lakes and channels are not recharged and over successive dry years, the 'sponge' of the delta becomes empty. Sedges and wetland grasses are replaced by willows and other plants that take over lakeshores and creek beds. The land dries up" (p. 13-14). The MCFN further reports "the Peace River used to be three and a half times the flow of the Athabasca River – now it no longer empties those quantities into Lake Athabasca, which further contributes to decreasing water levels" (MSES, 2010, p. 18-19).

Importantly, hydraulic damming "leads to higher water levels on Lake Athabasca and supports increases in water levels in the central (PAD) lakes area" (Carver, 2013, p. 13). A number of scientists, Indigenous knowledge keepers, and consultants, however, report specific decreases in Lake Athabasca water levels due to the regulation of flows on the Peace River (Teck Resources, 2011a; Parks Canada, 2009; Peterson and Courtorielle, 1992). In their analysis of Lake Athabasca water levels from 1930 to 1991, Peterson and Courtorielle (1992) report a 0.5 m decrease in the mean high water level in the lake after flow regulation started on the Peace River. Similarly, Teck Resources note "a noticeable decrease in the average seasonal water levels during the July-September period because of the effects of the regulation of the Peace River from the dam" in their analysis of hydrometric data of Lake Athabasca for the Frontier oil sands project (Teck Resources, 2011a, p. 7A-9). Similarly, Parks Canada (2009) report "water levels in Lake Athabasca have fluctuated across a range of about 3.4 metres between 1940 to the present…and since 2000, summer lake levels have been five to 95 centimetres below the long term average" (p. 18).

Carver and Maclean (2016) review the compounding effects of deltaic processes in their examination of PAD water depths. They note "Delta progradation (forward movement of the leading edge of deltaic sedimentation) is generally accompanied by aggradation as sedimentation proceeds. All other things being equal, the excess of sediment supply above and beyond what gets removed shapes the pace and magnitude of aggradation" (p. 47). Whereas PAD recharge is known to have declined, subsequent interpretation of changes in water depth require additional consideration of these deltaic processes. According to Carver and Maclean (2016), the onset of the increased rate of aggradation in the three PAD locations reviewed in Timoney (2016) coincides with the beginning of Peace River regulation. They explain "regulation has resulted in diminished hydrologic recharge to the PAD and thus a potentially reduced likelihood that sediment inputs will be removed or reorganized locally, leading to accelerated aggradation" (p. 47). In other words, examples of deltaic sedimentation reviewed by Timoney (2016) appear to support the view that regulation has not only diminished water levels directly due to a loss in recharge but is also associated with an increase in sedimentation that can exacerbate declines in water depth due to declining recharge.

5.4.1 Weir Effects

In response to declining water levels in the PAD, a temporary dam was installed in the Quatre Fourches river in the fall of 1971 to immediately raise water levels while more permanent solutions were being investigated (PADIC, 1987). The temporary dam was damaged in 1974 flood and removed in 1975, following completion of the Rivière des Rochers weir.

The two permanent submerged outflow weirs were constructed in two smaller tributary rivers, which are widely regarded as an important intervention to at least partially restore water levels in the PAD. The submerged rock fill notched weirs were constructed on the Rivière des Rochers (aka 'Little Rapids') and the Revillon Coupé River in 1975 and 1976 as a joint effort by the Federal, Alberta, and Saskatchewan governments (PADIC, 1987). The locations of the two existing weirs are shown by thick red arrows in Figure 5-5.

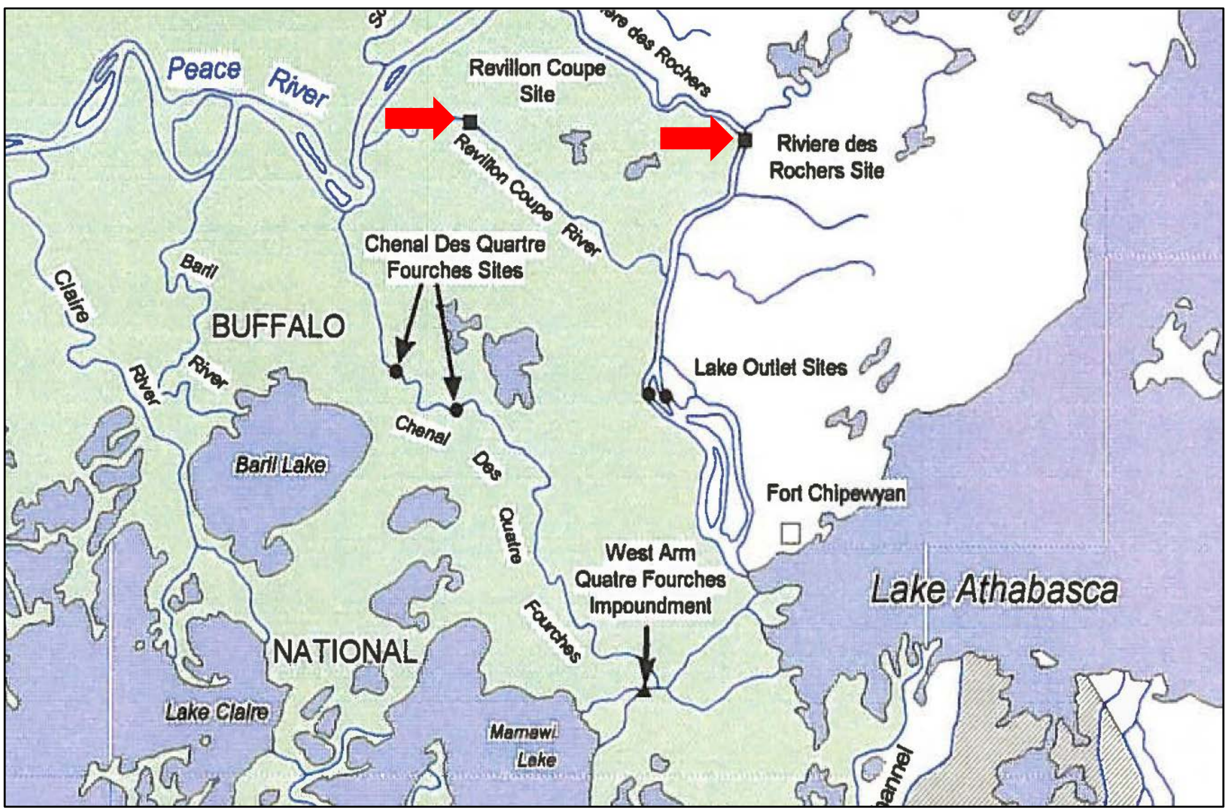


Figure 5-5: Location of Remedial Works That Were Investigated and Implemented (DeBoer, 1996)

The two existing weirs have apparently been partially successful in restoring water levels in Lake Athabasca and the central PAD lakes, such as Lake Claire and Mamawi Lake. As noted by Prowse and Conly (1996), “the effect of regulation and the restoration effect of the weirs are evident for all lakes and most pronounced for Lake Athabasca” (p. 57). With the weirs in place, as shown in Figure 5-6, the water levels in Lake Athabasca have increased by 0.50 m in summer and 0.56 m in winter, as compared to dam-regulated levels (resulting from upstream hydroelectric development) (DeBoer, 1996).

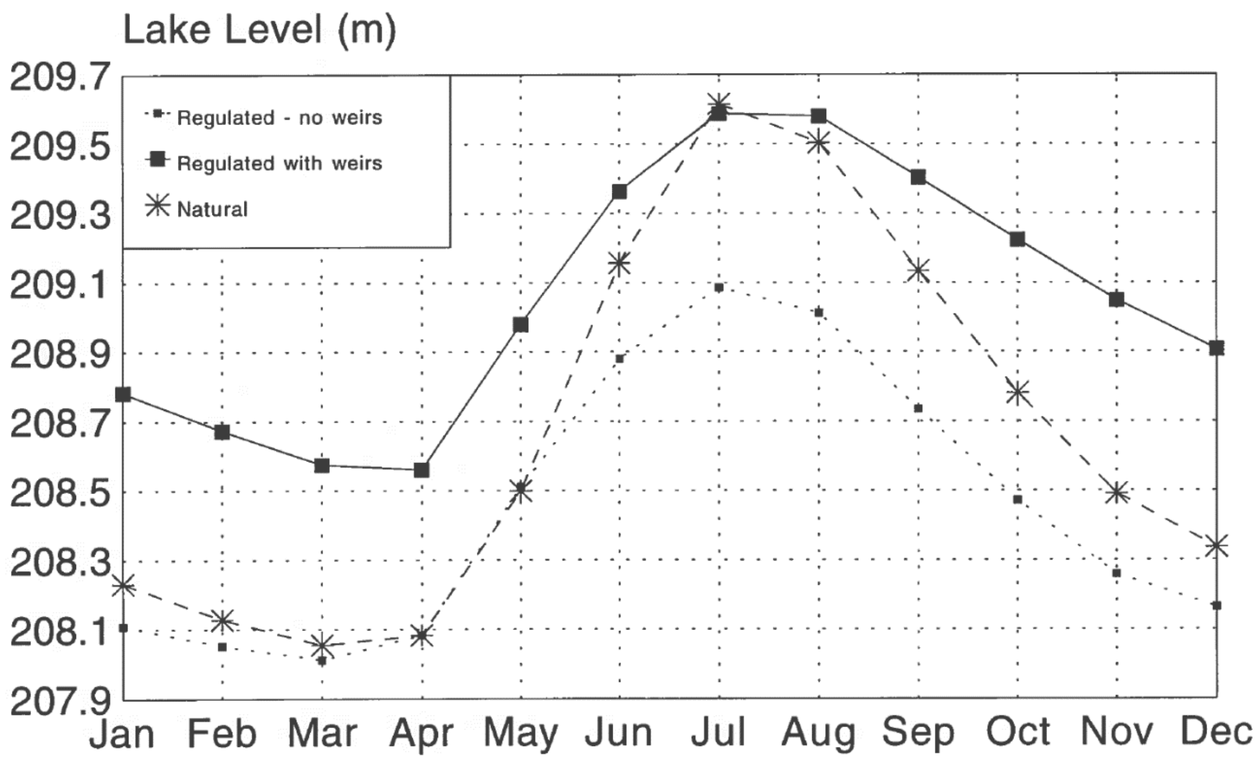


Figure 5-6: Lake Athabasca at Crackingstone Point, Mean Monthly Lake Level Estimates (1960 to 1984) (DeBoer, 1996)

As illustrated in Figure 5-6, a number of researchers confirm the weirs increase both mean summer and winter water levels in Lake Athabasca (as compared to dam-regulated levels). Aitken and Sapach (1994) report “the weirs have restored the peak annual water levels on the large delta lakes to what they were prior to the Dam being built, but in so doing have also raised the mean and minimum water levels above what they would have been under natural conditions” (p. ii). In 1996, DeBoer reports “although the weirs have closely restored the peak summer levels in the Delta, winter levels have (also) been increased” (p. 9). Importantly, as a result, “the weirs have eliminated critical, seasonal drawdowns in water levels that produce unique near-shore vegetation/habitat and waterfowl staging zones” (Prowse and Conly, 1996, p. 57).

The introduction of flow regulation by both dams (from upstream hydroelectric development) and weirs also produces a less variable water level regime in Lake Athabasca. As illustrated in Figure 5-6, the amplitude in Lake Athabasca water levels is about 0.5 m lower for regulated conditions, as compared to natural conditions (for the dam alone, as well as weirs and dam). Interestingly, the difference in amplitude between dam regulation with weirs and dam regulation without weirs is approximately 6.2 cm, indicating the weirs have had minimal influence on water level amplitude in Lake Athabasca (DeBoer, 1996). As noted by DeBoer (1996), "the amplitude between the summer peaks and the winter lows is lower for both the (dam) regulated and regulated with weirs scenario".

Interestingly, several groups report that the weirs have not fully restored water levels in Lake Athabasca and the central PAD lakes, such as Lake Claire and Mamawi Lake (MCFN, 2018a; Parks Canada, 2009; Indian Claims Commission, 1998; Farley and Cheng, 1986). Perhaps most importantly, as Farley and Cheng (1986) note, water is not being replenished as often in the perched basins, even with the weirs in place. The Indian Claims Commission (1998) reports "the weirs were not successful in restoring peak summer levels to pre-dam conditions in Lake Athabasca" (p. 45) and further notes "the summer peak levels…are 0.5 metres below average" (p. 49). For Lake Claire, Parks Canada (2009) reports "although rock weirs on the Rochers and Revillon Coupé rivers have maintained elevated lake levels, they do not allow for extreme seasonal rise and fall of the natural regime. Currently water levels are higher in winter (September to May) and lower in summer as compared to an unregulated regime" (p. 18). Farley and Cheng (1986) also note "the weirs have been effective in maintaining mean natural levels on Lake Athabasca and the delta lakes. However, simulated peak and observed peak levels for lakes Claire, Mamawi, and Baril for the weirs in place and Bennett Dam regulation are about 0.3 m lower than the simulated and observed natural levels" (p. 26). Similar to Farley and Cheng's (1986) conclusion, the Indian Claims Commission (1998) report the weirs have been "unsuccessful in restoring water levels in the delta to pre-dam conditions. Most significantly, they did not have the desired effect of recharging the elevated lakes or perched basins" (p. 97).

Figure 5-6 also illustrates that flow regulation in the Peace River (without weirs) appears to have lowered both summer and winter water levels in Lake Athabasca, although winter levels have not been reduced as much (a reduction of 0.04 m in March and a reduction of 0.53 m in July). As noted by DeBoer (1996), "the results show that Bennett Dam regulation, without the existing weirs, would result in significantly lower peak levels in the summer than would occur under the natural regime, while lake levels experienced in the late winter are approximately the same".

The long term effect of the weirs, in conjunction with flow regulation, has been to increase summer levels on Lake Athabasca by about 0.5 m, thus closely restoring natural mean summer water levels, but also increasing winter levels by about 0.5 m, as compared to natural levels (without flow regulation or weirs in place). It is important to note this is for average conditions, rather than dry or wet years. Prowse and Conly (1996) further note the weirs have their greatest effect on winter and spring water levels, particularly immediately upstream. These results indicate the weirs have produced higher winter water levels in Lake Athabasca, which may be exacerbating the problem of increased winter flows from the Peace River increasing winter freeze up levels and reducing ice jam flooding frequency in the PAD.

5.5 SURFACE WATER QUALITY

Long term water quality monitoring has been conducted by Parks Canada and Environment Canada at three locations on the Athabasca, Peace, and Slave Rivers in WBNP since 1989, 1960, and 1967, respectively (Glozier et al., 2009), as shown in Figure 5-7.

Figure 5-7: Long Term Water Quality Monitoring Locations Since 1989 (Glozier et al., 2009)

In 2011, the Governments of Canada and Alberta established JOSM in response to concerns regarding the effect of oil sands development in the Athabasca River basin. The JOSM focused on "monitoring of water quality in the main stem of the lower Athabasca River (LAR), its tributaries, and the deltaic and wetland ecosystems at the mouth of the river from April 2012 to March 2015" (Glozier et al., 2018, p. ii). Parameters measured included major ions, nutrients, mercury, metals, and PACs. The sampling sites established in the Lower Athabasca River and the PAD are shown in Figure 5-8 and Figure 5-9, respectively.

Surface water quality changes in PAD lakes and rivers have been reported by many scientists, consultants, and Indigenous knowledge holders, mainly attributed to oil sands, pulp and paper, agricultural (pesticides), and municipal effluents, as well as changes to flow rates in the PAD rivers. As expressed by Baird et al. (2016), "when combined with drivers from other developments (e.g. hydrology shifts caused by hydro development on the Peace River), a potential for cumulative effects from multiple stressors (e.g. oil sands mining) exists" (p. 3).

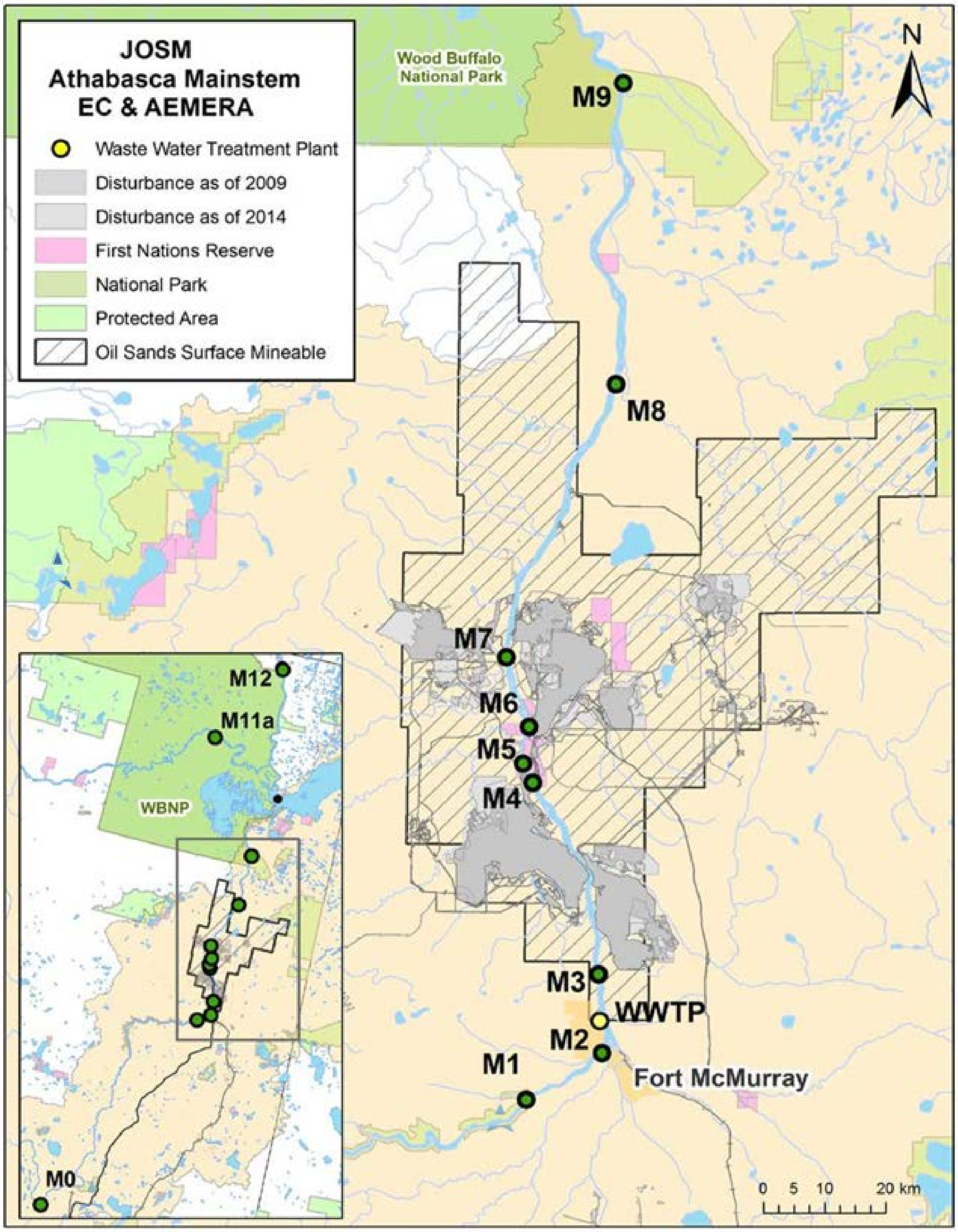


Figure 5-8: Water Quality Monitoring Sites in the Lower Athabasca River (LAR) (Glozier et al., 2018)

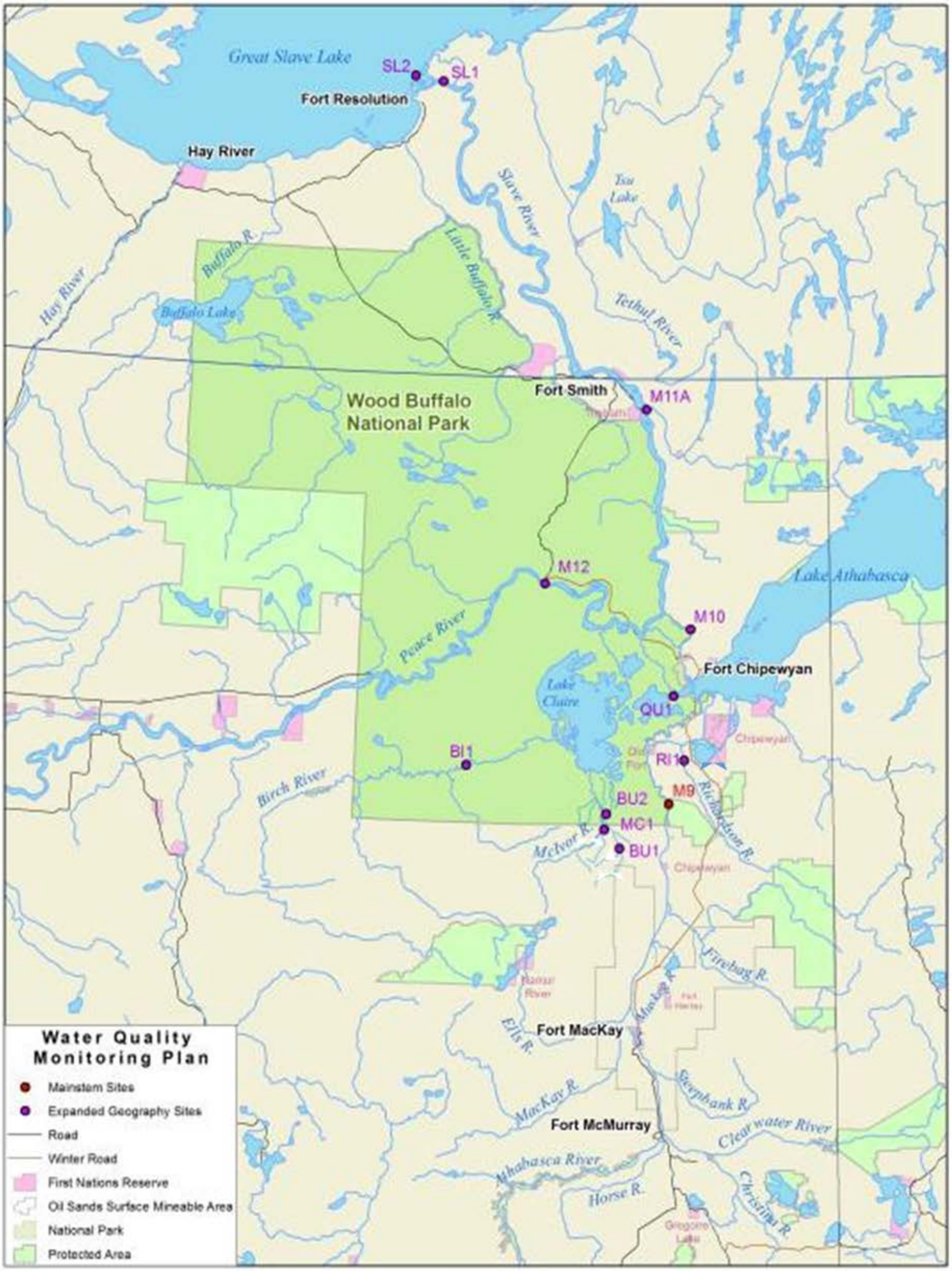


Figure 5-9: Water Quality Monitoring Sites in the Tributaries of the PAD (Glozier et al., 2018)

5.5.1 Monitoring Issues

Numerous academics and researchers report water quality effects in the PAD are difficult to quantify for a number of reasons including:

1) shifting dissolved and total parameter concentrations with changing flow rates and sediment loading in the PAD rivers (Peace, Athabasca and Slave rivers);

2) changes in PAD river flow rates over time;

3) a lack of information about water quality prior to development; and

4) difficulties in consistent monitoring (in terms of geographic location and the use of a common set of parameters).

Each of these is discussed in the following paragraphs. The first monitoring issue is that the total nutrient and metal concentrations varies with flow, making guidelines problematic to apply. Total nutrient and metals concentrations increase in PAD rivers during high flow volumes in relation to high suspended sediment loading (Glozier et al., 2009). Glozier et al. (2018) report "particulate associated parameters (such as metals) generally had higher concentrations during high flow spring/summer periods when suspended sediment loads were high" (p. iv). The variation in total nutrient and metals concentrations, in particular, may present problems in referencing provincial and federal guideline concentration limits, which may not be appropriate during high sediment loading periods (AECOM, 2010; Parks Canada, 2009) and AECOM (2010) concluded "the status of nutrient concentrations in the PAD cannot be assessed because appropriate guidelines for the highly sediment-laden Athabasca and Peace Rivers are not available at this point" (p. 22).

The second monitoring issue involves the challenge of determining water quality trends given the changes resulting from alterations in PAD river flow rates over time. As part of the JOSM program, Glozier et al. (2009) studied the water quality on the Athabasca, Peace, and Slave rivers at the boundaries of Wood Buffalo National Park between 1989 and 2006. They report changes in the seasonal patterns of dissolved parameters (metals, major ions, and nutrients) in both the Peace and Slave rivers due to the changes in river discharge patterns related to regulation of the Peace River. Further, the authors report increasing nutrient levels, especially phosphorus (total phosphorus or TP), in the Athabasca and Slave rivers from 1989 to 2006 with decreasing river discharge. Similarly, Parks Canada (2009) also found "the seasonal patterns of dissolved metals and ions in the Peace and Slave Rivers have been substantially changed from natural patterns in unregulated rivers. Normally, peak concentrations would occur in winter when a river is ice covered and flow rate is at its lowest. Currently, peak concentrations are occurring in the open water period (spring to fall), with minimum concentrations in winter" (p. 30). More recently, Glozier et al. (2018) note the potential linkage between lack of trends in concentrations of dissolved iron, most major ions, several nutrients, total suspended solids (TSS), and turbidity in relation to "changes in flow due to water withdrawal" (p. iv).

The third issue with monitoring, is the problem of determining water quality objectives and changes in the PAD without water quality data from the 'pre-development' era on the Athabasca and Peace Rivers. This includes regulation of the Peace River, as well as water withdrawals from and effluents discharged into the Athabasca River from the oil sands, agriculture, municipalities, and pulp and paper mills. Dube and Wilson (2013) report that, while "lower Peace River had adequate long-term discharge data, it completely lacked in pre-regulation water quality monitoring data (federal or provincial)" (p. 420) and Timoney (2013) notes "there are, in fact, virtually no pre-development environmental baseline data, which makes it difficult to assess change" in the PAD (p. 432). Although there is limited data from the Slave River pre-1967 (Glozier et al., 2018), many water quality programs undergo periodic review and, as a consequence, data gaps or changes to frequency are not uncommon.

The final issue regarding water quality monitoring is that there have reportedly been gaps in terms of using a comprehensive set of water quality parameters and a lack of sufficient monitoring in the PAD Glozier et al. (2009) note that, in part, because the water monitoring program had a focus on nutrient enrichment identified during earlier studies (Northern River Basins Study, NRBS, 1996), the water quality monitoring program for Wood Buffalo National Park did not include dioxins, furans, and sulphur compounds from pulp and paper effluents, as well as PAHs, naphthenic acids, and chlorinated phenols from oil and gas activities. In their State of the Park report, Parks Canada (2009) also report "these existing data do not provide the opportunity to describe the occurrence and abundance of a broad suite of petroleum and oil-based contaminants" (p. 30). In response to concerns regarding inadequate water quality parameters and sampling locations, the recently expanded JOSM monitoring program sampled for a broader range of contaminants of concern and added sampling locations in the Athabasca River and PAD connecting channels (Glozier et al., 2018; Baird et al., 2016).

5.5.2 Trends in the PAD

The Community Based Monitoring (CBM) program established by the MCFN and ACFN in 2011 has monitored surface water quality at 26 sites within the PAD from 2011 to 2016, utilizing the Canada Council of Ministers of the Environment (CCME) Water Quality Index (WQI) Calculator to assess water quality (e.g. for the protection of aquatic life) (MCFN and ACFN, 2017a). In the absence of parameter specific guidelines for PAHs, the WQI allows users at a community level to reliably, rapidly, and cost-efficiently screen water bodies that could be causing adverse effects to humans, animals and plants. The WQI used by the CBM program in the PAD incorporates 60 parameters, including nutrients, physical parameters, major ions, organics (VOCs, PAHs) and metals, in its calculations. Coupled with a robust community-based water monitoring program, the WQI Calculator is an excellent tool to simplify complex data to a format that is easily understood by the wider community.

From 2011 to 2016, an average CCME Water Quality Index (WQI) of Fair (74.4) was reported for all sites monitored in the PAD over the six year study period, where "water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels" (MCFN and ACFN, 2017a, p. 12). The authors identified a number of parameters as substantial contributors to poor water quality in the PAD, including iron, phosphorus, manganese, nitrite, lead, aluminum, copper, and methylmercury over the monitoring period (MCFN and ACFN, 2017a). The CBM program in the PAD reports the following results:

- On average since 2011, study sites in the Peace-Athabasca Delta had "Fair" overall water quality, as compared to "Good" overall water quality at the reference sites.

- Iron, manganese and phosphorous are the compounds that most often exceeded water quality guidelines; 2013, a consistent rise in aluminum and turbidity was detected at the study sites.

- Some sites did poorly, or marginally poor in terms of water quality, but these poor readings were only over a single year and were not consistent through the years.

The authors did not perform a trend analysis of the results over the six year monitoring period.

Effects to local Indigenous people's health and welfare resulting from water quality changes in the PAD are also being seen. Indigenous Knowledge holders describe the quality of the water in the PAD as so poor the people cannot drink it (MCFN, 2018a, 2018b). They must now carry drinking water with them when they go out on the land. This means they only have the capacity to go out on the land for as long as the water lasts. In addition, they have to transport the water, which adds weight to the boats. If the boat sits lower in the water, it is even more difficult to access channels and lakes in the PAD. The water is undrinkable from the lakes because spring water is not coming through to flush the water, and it has a stagnant, foul smell, along with scums, foams, films and algae. There is concern about the contamination that may be coming down the rivers from municipal, agricultural and industrial development. In the winter, people will no longer melt snow for water because it has a sheen to it when melted and does not taste good. People have also noticed skims of yellow between layers of snow in Lake Claire. Contaminants in the water are causing deformed fish, which the people will not eat when they catch them, and mercury has also been found in high levels in fish and bird eggs, so consumption limits were set by the government, further limiting people's access to food sources and further eroding confidence in local foods.

The MCFN further note "without flooding, water that remains in rivers, wetlands, and muskegs is often 'dead' or dirty. There is often oil sheen visible on the surface and strange deposits left on boats. The water from many areas is no longer considered safe to drink" (MCFN, 2016a, p. 22). Timoney (2007) also reports "the people and biota of the Athabasca River Delta and western Lake Athabasca are exposed to higher levels of metals than those upstream", with arsenic being of particular concern (p. 68). More recently, the Firelight Group et al. (2018) report "MCFN land users have observed an increase in scums and films in the PAD (noticeable on boats and in drinking water), decreased quality and taste or texture of fish, changes in taste and smell of water, changes in fish and animal health, including deformities, and changes in aquatic invertebrate presence. Taken together, these changes have led to an overall perception of risk and loss of confidence in the use of water and wildlife in many areas of the PAD, resulting in serious impact to MCFN way of life for many MCFN families" (p. 4).

The identification of the overall water quality trend for the PAD requires consideration of both scientific research and ITK. The CBM monitoring information has not been presented in terms of trends, rather the results indicate a consistent "fair" water quality index (WQI) and a number of CCME exceedances over a relatively short monitoring period (MCFN and ACFN, 2017a). ITK indicates an observed negative trend in water quality in the PAD over the past several decades. Since the CBM information is limited in regard to its ability to identify trends over a long monitoring period, it is possible there is consistency between the ITK and the CBM findings. The ITK trend does align with the declining trend observed in

Athabasca water quality detailed in the following paragraphs and further highlights the need for improved scientific information regarding water quality in the PAD in the future.

Numerous scientists and researchers also report spatial and temporal water quality changes in the Peace, Athabasca, and Slave Rivers, compiled below in Table 5-2 (Glozier et al., 2018; Jautzy et al., 2015a; Timoney and Lee, 2011; Sanderson et al., 2012; Candler et al., 2010; Kelly et al., 2009; Squires et al., 2010; Glozier et al., 2009). The trends discussed in the following paragraphs refer mainly to the JOSM program results from Glozier et al. (2009) and Glozier et al. (2018).

Table 5-2: Spatial and Temporal Trends for Typical Water Quality Parameters in PAD Rivers

Parameter	Peace River	Athabasca River	Slave River
Total P	→[1a,1b]	↑[1a,1a*,2,4a] →[1b,4b,4b*,12]	↑[1a] →[1b]
Dissolved P	→[1a,1b]	↑[1a,3] →[1a*,1b,4a] ↓[2,4b,4b*]	↑[1a,3] →[1b]
Dissolved N	→[1a,1b]	→[1a,1a*,1b,4a,4b,4b*]	↓[1a,1b]
Dissolved NH_3	→[1a,1b]	↑[1a] →[1a*,4a] ↓[1b,4b,4b*]	→[1a,1b]
SO_3	↑[1a] →[1b]	↑[1a,2,4a] →[1a*,1b,4b,4b*]	↑[1a,3] →[1b]
Mg	→[1a,1b]	↑[4b*] →[1a,1b,4a,4b] ↓[1a*]	→[1a,1b]
Cl	↓[1a,1b]	↑[2] →[1a, 1b, 4a,4b*] ↓[1a*,4b]	↓[1a,1b]
Na	↓[1a,1b]	↑[2,4b*] →[1a,1b, 1a*,4a, 4b]	→[1a,1b] ↑[3]
TDS	→[1a,1b]	→[1a,1a*,1b,4a,4b,4b*]	→[1a] ↓[1b,3]
Dissolved As		↑[4b,4b*] →[1a,1a*]	
Dissolved Cu	→[1b]	→[1b,1b*,4b,4b*]	
Dissolved Fe	→[1b]	→[1b,1b*,4b] ↑[4b*]	
Dissolved Al		↑[4b,4b*]	

Parameter	Peace River	Athabasca River	Slave River
Dissolved Se, V		→[4b,4b*]	
Total Cu, Fe, Ni	→[1a]	→[1a*,4b,4b*] ↓[1a]	
Total Pb	↓[1a]	↓[1a,1a*] →[4b,4b*]	
Total Zn	→[1a]	→[1a*] ↓[1a,4b,4b*]	
Total Se		↑[4b,4b*]	
Total Al		→[4b,4b*]	↓[3]
Total V	→[1a]	→[1a,1a*,4b,4b*]	
Other		Measurable PACs[4] ↑ PACs[6] ↑ PAHs[5,7]	↓Mb,Cr[3]

Notes: 1a: Glozier et al. (2009) from 1989 to 2006, 1a*: Glozier et al. (2009) from 1989 to 2006 flow adjusted values; 1b: Glozier et al. (2009) from 1997 to 2006, 2: Squires et al. (2010); 3: Sanderson et al. (2012) from 1972 to 2010, 4: Glozier et al. (2018), 4a: Glozier et al. (2018) from 1989 to 2014, 4a*: Glozier et al. (2009) from 1989 to 2014 flow adjusted values, 4b: Glozier et al. (2018) from 2000 to 2014, 4b*: Glozier et al. (2009) from 2000 to 2014 flow adjusted values, 5: Timoney and Lee (2011), 6: Kelly et al. (2009); 7: Jautzy et al. (2015a)

Abbreviations - Al: Aluminum, As: Arsenic, Cl: Chloride, Cr: Chromium, Cu: Copper, Fe: Iron, Pb: Lead, Mg: Magnesium, Mn: Manganese, Mb: Molybdenum, Ni: Nickel, N: Nitrogen, NH_3: Ammonia, P: Phosphorus, PAH: Poly Aromatic hydrocarbons, PACs: Polycyclic Aromatic Compounds, Na: Sodium, Se: Selenium, SO_3: Sulfate, TDS: Total Dissolved Solids, V: Vanadium, Zn: Zinc

5.5.3 Trends in the Peace River

As illustrated in Table 5-2, the JOSM results indicate the concentrations of all relevant parameters of interest in the Peace River reportedly exhibited either stable or decreasing trends with time. From 1989 to 2006, concentrations of total phosphorus, dissolved phosphorus, dissolved nitrogen, magnesium, ammonia, and total dissolved solids (TDS), as well as total copper, iron, nickel, zinc, and vanadium reportedly showed a stable trend in the Peace River (Fe from 1993 to 2006) (Glozier et al., 2009). In addition, dissolved copper and iron have shown stable concentrations from 1999 to 2006. Sulfate has reportedly increased over the 1989 to 2006 period, but showed a stable trend from 1997 to 2006 (Glozier et al., 2009). Parameters such as chloride, sodium, and total lead showed a decreasing trend from 1989 to 2006 (Glozier et al., 2009).

5.5.4 Trends in the Athabasca River

As illustrated in Table 5-2, the JOSM results indicate concentrations of most relevant nutrients in the Athabasca River reportedly exhibited stable to decreasing trends. Parameters showing an increasing trend with time in the Athabasca River included magnesium, sodium, dissolved aluminum, total selenium, dissolved iron, and dissolved arsenic. From 1989 to 2014, concentrations of magnesium, once adjusted for flow, showed a decreasing trend from 1989 to 2006, but an increasing trend from

2000 to 2014 (Glozier et al., 2018; Glozier et al., 2009). Concentrations of sodium exhibited a stable trend from 1989 to 2014, but showed an increasing trend from 2000 to 2014 when adjusted for flow (Glozier et al., 2018; Glozier et al., 2009). Dissolved aluminum and total selenium showed an increasing trend from 2000 to 2014 and, adjusting for flow, dissolved iron showed an increasing trend for the same time period (Glozier et al., 2018; Glozier et al., 2009). Dissolved arsenic, while stable from 1989 to 2002, showed an increasing trend from 2000 to 2014 (Glozier et al., 2018; Glozier et al., 2009).

Nutrients such as total phosphorous exhibited an increasing trend from 1989 to 2014, with stable trends from 1997 to 2006 and 2000 to 2014 (Glozier et al., 2018; Glozier et al., 2009). Dissolved phosphorus exhibited a stable trend from 1989 to 2014 (adjusted for flow from 1989 to 2006), with a decreasing trend from 2000 to 2014 (Glozier et al., 2018; Glozier et al., 2009). Concentrations of dissolved ammonia showed stable trend from 1989 to 2014 (adjusted for flow from 1989 to 2006), with a decreasing trend from 1997 to 2014 (Glozier et al., 2018; Glozier et al., 2009). Concentrations of dissolved nitrogen and total dissolved solids showed a stable trend from 1989 to 2014 (Glozier et al., 2018; Glozier et al., 2009). Sulfate exhibited an increasing trend from 1989 to 2014, but a stable trend once adjusted for flow for the same time period (Glozier et al., 2018; Glozier et al., 2009). Chloride exhibited a stable trend from 1989 to 2014, but showed a decreasing trend once adjusted for flow from 1989 to 2006 and from 2000 to 2014 (Glozier et al., 2018; Glozier et al., 2009). Further, Squires et al. (2010) report "dissolved Na, sulfate, chloride, and total P concentrations (from 1996 to 2006) were greater than, and in some cases double, the 90th percentiles (from 1966 to 1976) in the lower part of the (Athabasca) river" (p. 119).

Metals such as dissolved copper and dissolved iron reportedly exhibited a stable trend from 1999 to 2006 and 2000 to 2014, while dissolved selenium, dissolved vanadium, and total aluminum showed a stable trend from 2000 to 2014 (Glozier et al., 2018; Glozier et al., 2009). Concentrations of total copper, iron and nickel showed a decreasing trend from 1989 to 2006, however adjusting for flow from 1989 to 2006 and from 2000 to 2014, a stable trend was seen (Glozier et al., 2018; Glozier et al., 2009). Total zinc showed a stable trend from 1989 to 2006 (once adjusted for flow) and a decreasing trend from 2000 to 2014 (Glozier et al., 2018; Glozier et al., 2009). Concentrations of total lead showed a decreasing trend from 1989 to 2006 and a stable trend from 2000 to 2014, while total vanadium showed a stable trend from 1989 to 2006 and 2000 to 2014 (Glozier et al., 2018; Glozier et al., 2009).

With respect to federal and provincial guideline value exceedances, the key findings from the long-term water monitoring up to 2006 for the Athabasca, Peace, and Slave Rivers, as identified by Glozier et al. (2009), found exceedances of CCME guideline values (for aquatic life) for total metal concentration related to flow rate changes. The authors also note total phosphorus and nitrogen showed exceedances to Alberta guideline values in the Athabasca River, however site-specific objectives for three parameters (dissolved oxygen, sulphate, total dissolved solids) developed under the Northern River Systems Initiative (NREI) were met within the expected frequency. Later, Glozier et al. (2018) report, in PAD tributaries from 2011 to 2014, "evaluation of the data against 39 water quality guidelines revealed that nineteen of the parameters showed no values above guidelines (i.e., no exceedances). Some metals (namely iron and aluminum) commonly (>75%) showed values higher than the guideline, particularly during periods of high suspended sediment concentrations. Total mercury samples showed occasional (<6%) exceedances but, similar to total metals, these values were associated with high suspended sediment values" (p. iv). The authors further stated "site specific guidelines may be more appropriate and provide a better warning of changes to water quality, particularly for parameters which are associated with the commonly occurring high suspended sediments" (Glozier et al., 2018, p. iv).

PAHs and PACs in the Athabasca River and the PAD

PAHs (a subclass of PACs) are released from a variety of sources in the Lower Athabasca river basin, including natural releases from oil sands deposits and extraction and upgrading of oil sands, as well as forest fires, urban runoff, and deposition from long-range, atmospheric transport from urban and industrial activities (Ohiozebau et al., 2016). As Dolgova et al. (2018) note "the Athabasca River is a significant source of water and sediment to the PAD, and therefore, is important in terms of regulating possible riverine transport of contaminants to the delta" (p. 15). Several researchers specifically attribute increases in PACs and PAHs in the Athabasca River to oil sands and other industrial and municipal development in the region. Kelly et al. (2009) found "dissolved PAC concentrations in tributaries to the Athabasca (River) increased from 0.009 µg/L upstream of oil sands development to 0.023 µg/L in winter and to 0.202 µg/L in summer downstream. In the Athabasca (River), (total) dissolved PAC concentrations were mostly <0.025 µg/L in winter and 0.030 µg/L in summer, except near oil sands upgrading facilities and tailings ponds in winter (0.031–0.083 µg/L) and downstream of new development in summer (0.063–0.135 µg/L)" (p. 22346). Similarly, Kurek et al. (2013) studied six lakes in the Athabasca oil sands region, reporting "PAHs within lake sediments, particularly C1-C4–alkylated PAHs, increased significantly after development of the bitumen resource began, followed by significant increases in dibenzothiophenes" and "PAH ratios indicate temporal shifts from primarily wood combustion to petrogenic sources that coincide with greater oil sands development" (p. 1).

In addition to monitoring surface water quality in tributaries that drain into the PAD, the Mikisew Cree First Nation's Community Based Monitoring Program characterizes PAHs at various surface water locations in the PAD (MCFN, 2015). The report characterizes both alkylated petroleum derived PAHs (indicative of bitumen upgrading and oil sands sources) and parent, non-alkylated PAHS associated with wood combustion (most likely a reflection of forest fire activity and/or residential wood burning). The author reports "sites in the Athabasca River, at the mouth of the Athabasca River, and the Quatres Fourches sites are influenced by petroleum derived PAHs" and added "PAHs were found far downstream the Athabasca River at two sites inside the Peace-Athabasca Delta and Wood Buffalo National Park" (p. 5). The report notes, however "levels of PAHs in the PAD are lower than those found throughout the Athabasca River (with the exception at the mouth of the Athabasca River site)". MCFN (2015) further notes the "Quatres Fourches and the Athabasca River mouth were the only two sites in the PAD where this (petroleum-derived) fingerprint was detected. At these two sites, PAHs reflect an oil sands influence. However, at every other site in the PAD, detected PAHs are suggesting a wood and coal combustion input. These patterns are in accordance with forest fire activity in the region, the use of wood for residential heating, and the fact that the Quatres Fourches and the Athabasca River mouth sites were more closely connected to the Athabasca River, so subject to the influence of any PAHs from the oil sands flowing down river" (p. 23). Continued monitoring of PAHs at Quatres Fourches and mouth of the Athabasca reveals slight elevations (non-significant) in PAH concentrations (MCFN and ACFN, 2017b). Jautzy et al. (2015a) also report an increase in (specifically oil sands derived) PAH concentrations in a lake from the Athabasca sector of the PAD situated ∼150 km downstream of mining operations. More recently, and as shown in Figure 5-10. Glozier et al. (2018) found measurable concentrations of PACs (specifically C4-Phenanthrenes/Anthracenes) in the Athabasca River at the southeast tip of the WBNP (M9) that retained the oil sands chemical fingerprint. Also, the authors also found EGA (expanded geographical area) "tributaries within the PAD (Richardson, Quatre Fourches, and Birch rivers) also contained measurable concentrations of PACs" (p. 37), although PACs were non-detectable in two PAD wetland sites. It is interesting to note, however, what appear to be 'background' levels of PACs in areas where oil sands mining is not taking place. As shown in Figure 5-10, the Peace River station (M12) and a station on the Athabasca River far upstream of Fort McMurray (M0) also show detectable concentrations of PACs, which could likely be considered background or control locations for future comparison of monitoring results.

In summary, the Athabasca River and certain sections of the PAD have experienced an increasing trend in concentrations of magnesium, sodium, dissolved aluminum, total selenium, dissolved iron, and dissolved arsenic, as well as PAHs and PACs (Glozier et al., 2018). Elevated PAC concentrations retaining an oil sands chemical signature were found in the lower reaches of the Athabasca River near the southeastern tip of the WBNP and the Richardson, Quatre Fourches, and Birch Rivers (tributary EMP sites) also showed slightly elevated PAC levels in comparison to background values (Glozier et al., 2018). Elevated PAH levels were also found in at least one PAD lake (Jautzy et al., 2015a). As a result, the overall trend of the Athabasca water quality is decreasing.

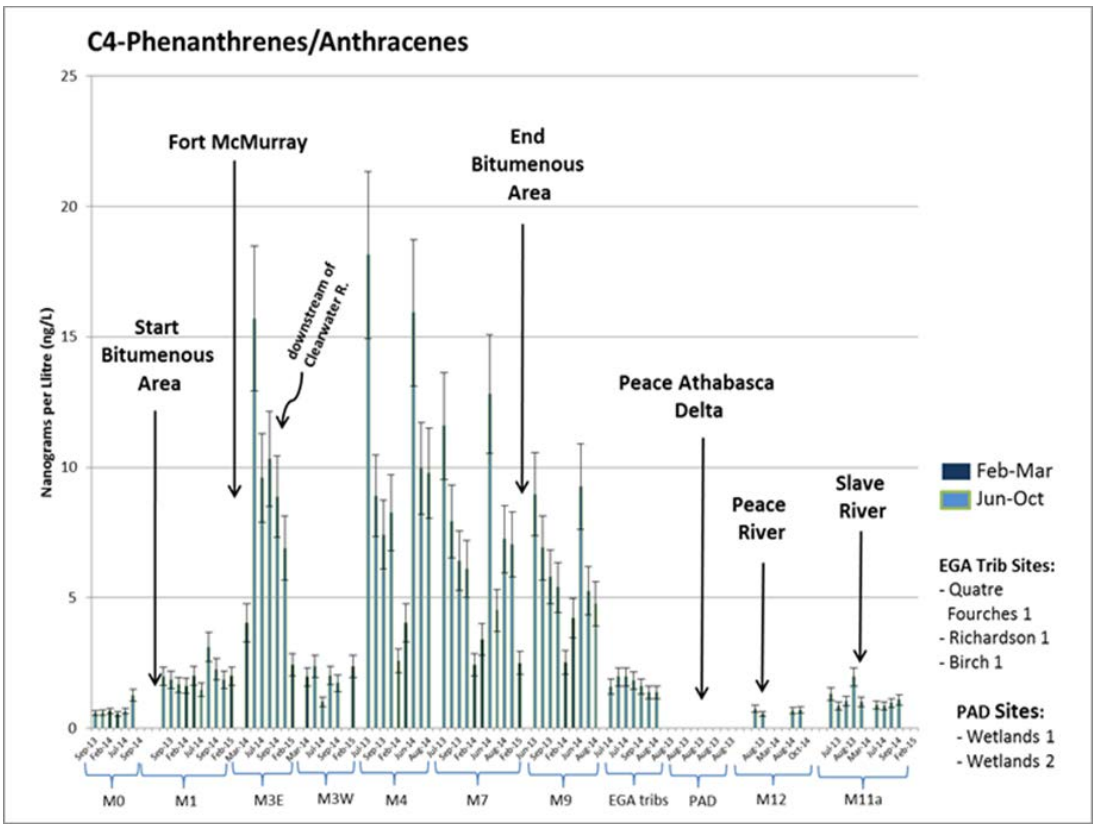


Figure 5-10: Concentration of C4-Phenanthrenes/Anthracenes (ng/L) From 2013 to 2015 at Eight Main Stem Sites, M0 Through M11A, Tributaries and Wetlands in the Peace-Athabasca Delta (PAD) (Glozier et al., 2018)

Notes: EGA: Expanded Geographical Area.

5.5.5 Stressors in the Athabasca River

While changes to water quality have been seen in the Athabasca River over time, it appears researchers cannot clearly attribute those changes to specific types of development. For example, Davidson and Hurley (2007) note it was unclear if the water quality decreased in the Athabasca River are due to oil sands mining activity. Hebben (2009) indicated the upward nutrient and metal trends in the Athabasca River may be linked to lower flow rates, which would increase the concentrations from point source pollutants (such as municipal wastewater treatments plants and pulp mills). Additionally, the authors note that the trend “may be linked to basin development and anthropogenic disturbance. Agriculture, forestry and resource extraction activities, for example, could contribute to higher levels of nutrients and metals in non-point source runoff” (Hebben, 2009, p. 15). Timoney (2013) also reports the primary source of increases in nutrients in the Athabasca River are “probably pulp mills, municipal discharges, and the bitumen industry” (p. 431). Further, Glozier et al. (2009) attribute increases in TP in the PAD to “many cumulative inputs, including 10 pulp mills which have been discharging effluent into these rivers since 1957, a large growth in municipal population, particularly in Grande Prairie and Fort McMurray, as well as the activities surrounding the oil sands which can also contribute to nutrient loadings in the Athabasca River” (p. 68).

Other researchers report water quality changes associated with specific types of development on the Athabasca River, including the oil sands and agriculture. Kelly et al. (2010) report water quality effects resulting from oil sands development in the PAD, reporting “at sites downstream of development and within the Athabasca Delta, concentrations of 11 (metals, including antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, thallium, and zinc…were) greater than upstream of development” and indicated that “Canada’s or Alberta’s guidelines for the protection of aquatic life were exceeded for seven metals, including cadmium, copper, lead, mercury, nickel, silver, and zinc in melted snow and/or water collected near or downstream of development” (p. 16178). The same authors note “concentrations of some metals at one location in Lake Athabasca near Fort Chipewyan were also greater than concentrations in the Athabasca River upstream of development” (Kelly et al., 2010, p. 16178).

More recently, Culp (2016) notes municipal effluents, urban runoff, camp effluent, and land clearing for oil sands operations have contributed to increased nutrients (N and P) in the lower Athabasca River. The author also reports that pre-mining land clearing and oil sands operations have contributed to increased PACs and metals in the lower Athabasca River (Culp, 2016). In addition, Shotyk et al. (2017) report “vanadium, nickel, molybdenum, and rhenium concentrations were all significantly ($p<0.05$) greater downstream of industry” (p. 660) in the Athabasca River. Further, Alexander and Chambers (2016) compiled a 38-year dataset (1972 to 2010) to evaluate changes in water chemistry over time due to oil sands mining activities. They demonstrated that concentrations of the three focal elements (dissolved selenium, dissolved arsenic, total vanadium) and 17 other variables either associated with bitumen or consider priority pollutants were significantly greater post oil sands development compared to reference values, and were typically greatest during the early exploration and land clearing stage of mine development. These changes could not be attributed to bitumen-bearing geologic formation or natural background. The authors concluded that erosion and subsequent runoff associated with land clearing, construction, and early operational activities have affected water quality in the oil sands region.

Glozier et al. (2018), however, state “for several major ions and dissolved metals which displayed increasing trends at M9 (the southeast tip of the WBNP), results were similar when we examined trends at other sites in northern areas of Canada not directly downstream of the OSMA (oil sands mineable area). As such, the increasing trends reported may have a broader regional pattern and are thus not likely directly related to upstream oil sands activities” (p. iv). The same authors also note all major ions, nutrients, mercury, and metals, except Se, had consistent concentrations along the Athabasca River from upstream of major oil sands developments to the southeast tip of the WBNP (Glozier et al., 2018). The authors concluded “spatial patterns (other than for dissolved selenium) that were observed were attributed to changes in non-oil sands related inputs, such as municipal or other industrial inputs, or differences in geological sources” (Glozier et al., 2018, p. ii). Further, Kirk et al. (2014) also report “in the Peace Athabasca Delta, both (mercury and methyl mercury) were near background levels” in snowpack (p. 7) and Shotyk et al. (2017) note “concentrations of silver, cadmium, lead, antimony, and thallium were extremely low, not significantly more abundant downstream of industry and probably reflect ‘background’ values” in the Athabasca River (p. 660).

5.5.6 Trends in Lake Athabasca

The Eastern Athabasca Regional Monitoring Program (EARMP) monitored long-term changes in the aquatic environment far downstream of uranium mining and milling operations in the Eastern Athabasca region of northern Saskatchewan from 2011 to 2015. CanNorth reports “water chemistry, sediment chemistry, benthic invertebrate community, and fish tissue chemistry endpoints were assessed against the baseline monitoring period data, available guidelines, and the reference range to establish if endpoints are currently within expected background levels of the region” (p. vii). The author notes “with few exceptions, endpoints were found to be similar to baseline, below guidelines, and/or within the reference range” (CanNorth, 2016, p. vii).

Smithson (1993) studied radionuclide concentrations (lead-210, polonium-210, radium-226, and thorium isotopes) in northern pike, lake whitefish, white suckers, and longnose suckers in western Lake Athabasca as part of the northern river basins study (NRBS). Radioisotope levels were very low and consumption of these fish were determined to pose no health risk.

5.5.7 Trends in the Slave River

As illustrated in Table 5-2, the JOSM results indicate concentrations of most relevant parameters of interest in the Slave River are reportedly exhibiting either stable or decreasing trends. Concentrations of dissolved phosphorus, total phosphorus, and sulfate reportedly showed an increasing trend from 1989 to 2010, but showed a stable trend from 1997 to 2006 (Glozier et al., 2018; Glozier et al., 2009). Parameters such as dissolved nitrogen and chloride showed a decreasing trend from 1989 to 2006, while magnesium, sodium, and ammonia showed a stable trend over the same time period (Glozier et al., 2018; Glozier et al., 2009). Concentrations of total dissolved solids showed a stable trend from 1989 to 2006 and decreased over the 1997 to 2006 time period (Glozier et al., 2018; Glozier et al., 2009). From 1990 to 2010, dissolved phosphorus, sulfate, and dissolved sodium concentrations reportedly increased, while total dissolved solids, total aluminum, molybdenum, and chromium concentrations decreased (Sanderson et al., 2013).

For the Slave River, polychlorinated biphenyls (PCBs), PAHs, and others were either not found or found at levels below the below CCME guidelines for the protection of aquatic life (measured at Fort Smith, NWT) (Sanderson et al., 2012). Glozier et al. (2018) found detectable concentrations of PACs in the Slave River (as shown in Figure 5-10); however, the levels appear similar to background.

5.6 SEDIMENTATION AND SEDIMENT QUALITY

A number of researchers have reported changes to the fluvial geomorphology and sediment transport regime in the PAD resulting from flow rate changes on the Peace River due to regulation (Culp, 2016; Eaton and Church, 2015; Carver, 2013; Prowse and Conly, 1996; Wrona et al., 1996). In 1996, Wrona et al. report that due to regulation on the Peace, “the physical structure of the delta and mainstem has been changed by the formation of new sand bars and related habitat” (p. 39). More specifically, they note “the erosional force of the Peace River…has been reduced as a result of changes in flow regime…(causing) increased sediment deposition, channel narrowing, abandonment of secondary channels, and in-channel shoaling. Sand and silt deposit along channel edges and former back-channels now provide new habitat for semi- aquatic shoreline and riparian vegetation” (Wrona et al., 1996, p. 10). Prowse and Conly (1996) also report “the sediment load at Fitzgerald (Slave River) has decreased by almost one-half after regulation (of the Peace River) for the open-water period, with the most pronounced changes being during the main flow months of June and July…due to the reduction in peak flows during this period” (p. 98).

More recently, Carver (2013) further reports that regulation causes “reduced capacity of the river to transport the sediment load delivered to it by the tributaries and the valley sidewalls. This diminished competence is expected to aggrade the channel and limit its ability to transport its bed material. Over long periods, Peace River is developing a new morphology…making the ice jam mechanism less likely through time” (p. 27). In 2013, Candler et al. note “the blue, clear ice that used to form on the Peace is (now) thinner and full of sediment, making the ice weaker and melt faster which prevents the ice jams from forming” (2013a, p. 8). More recently, the Firelight Group et al. (2018) report both flow regulation and weirs are impacting sedimentation levels in the PAD. They note “in particular, MCFN members have observed the build-up of sediment from weirs and increased sediment in the Peace River during winter freeze up. Secondary effects include negative changes to fish spawning, as well as sediment-loaded ice, which is lower quality and faster melting” (p. 4-5).

Several scientists also report high levels of contaminants in sediments in PAD water bodies from a number of sources (Evans et al., 2016; Kelly et al., 2009; Timoney, 2007; Wrona et al., 1996). Wrona et al. (1996) report “higher levels of PCBs, CL-RAs (chlorinated resin acids) and PAHs were found in (the sediments of) the Peace River upstream of the confluence of the Smoky River” (p. 16). Timoney (2007) further reports “constituents of concern (in PAD sediments) include arsenic, cadmium, a variety of PAHs, and resin acids” (p. 69) and notes that “the majority of the Athabasca River Delta, one-half of the Athabasca River, and one-third of its western tributaries were characterized by high metal concentrations (and) high PAH concentrations showing little variability” (p. 70). The same author reports “metal levels tend to increase downstream from the Athabasca River mainstem to its delta then to Lake Athabasca as finer-textured suspended sediments carry the metals to areas of deposition” and he further notes that “mercury, cadmium, and arsenic concentrations of all sediment samples exceeded potential effect levels of the Canadian Sediment Guidelines for the Protection of Aquatic Life” in the Slave River delta (Timoney, 2007, p. 68). Kelly et al. (2009) further note “PAC-contaminated sediments in the Athabasca Delta and Lake Athabasca are consistent with long-range atmospheric and fluvial transport of particulate” from oil sands development (p. 22350). More recently, Evans et al. (2016) report that total PAH and DBT concentrations in surface sediments were generally low and have declined over time in the lower Athabasca River, but have increased over time in the Athabasca River Delta portion of the PAD.

On the other hand, several researchers have found PAD sediments are not affected by contaminants from the oil sands. Hall et al. (2012b) report “the Athabasca Delta has been a natural repository of PACs carried by the Athabasca River for at least the past two centuries. We detect no measurable increase in the concentration and proportion of river-transported bitumen-associated indicator PACs in sediments deposited in a flood-prone lake since onset of oil sands development” (p. 1). Evans et al. (2002) also note “there is little or no evidence of temporal trends of increasing PAH concentrations in sediment cores collected in Lake Athabasca and the Athabasca Delta lakes, suggesting no or minimal effect from the oil sands operations. Some PAHs exceed interim sediment quality guidelines and some bioassay studies have shown evidence of toxicity, particularly in the Athabasca Delta. However, there is no evidence that this is associated with the oil sands industry”, possibly reflecting the natural erosion of bitumen deposits by the Athabasca River and its many tributaries (p. 365). In addition, Wiklund et al. (2014) report “little to no evidence of pollution by the oil sands development in downstream surficial bottom sediments of the Athabasca River” at sites located 200 km downstream of oil sands facilities (p. 4).

As described in the above paragraphs, the current trend for sedimentation in the Peace River is downward (i.e. sedimentation in the Peace River is increasing due to the reduced erosional force of the river resulting from changes in flow regime). However, given the differences regarding the current state of sediment quality in the PAD, the trend for sediment quality is considered unknown.

5.7 AIR QUALITY

An AEP air quality station in Fort Chipewyan, located on the shore of Lake Athabasca, measures sulfur dioxide (SO_2), oxides of nitrogen (NOx), nitrogen dioxide (NO_2), ozone (O_3), and fine particulate matter ($PM_{2.5}$) (WBEA, 2018). Together, they comprise the Air Quality Health Index (AQHI). As noted by Parks Canada (2009), "an index of zero to 25 indicates good air quality, 26 to 50 is fair, 51 to 100 is poor, and more than 100 is very poor" and "between November 2000 and August 2008, air quality was reported as good 75 to 90% of the time" (p. 25). Parks Canada also report "there was an obvious seasonal trend where air quality was good over the winter, good or fair in early summer and improved again in fall. The air quality index was poor less than 0.2 per cent of the time (<20 hours a year). Brief periods of poor air quality index occurred in June and July. At this time of year, higher levels of particles and ozone are associated with poor index ratings. Likely sources of these pollutants include industrial activity and forest fires" (p. 25). In addition, air quality monitoring data for the Fort Chipewyan station showed no exceedances to Alberta Ambient Air Quality Objectives (AAAQO) for nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) from 2012 to 2015 (Adams and Wentworth, 2015).

Indigenous Knowledge holders also report impacts to air quality as a result of industrial impacts surrounding WBNP. Local Indigenous people who live in Fort Chipewyan and in the southern PAD report experiencing ongoing air quality impacts and in particular, the "oil sands smell" is especially noticeable when southern winds blow up the Athabasca River valley (MCFN, 2018a). Candler et al. (2015b) also report "poor air quality, smoke, and industrial smells from industry perceived as far as Fort Chipewyan when wind is from the south" (p. 44). The authors also note "Mikisew members with cabins near Fort Chipewyan and on Lake Claire indicate that existing levels of oil sand development are already visible at night as a result of a low glow of industrial light visible in the south, and unpleasant smells associated with oil sand production carried on the wind" (Candler et al. 2015b, p. 53).

> ***When there is a south wind from industry. We used to smell in March two plants. Now there are more plants so as soon as you get a south wind you can smell a different odor in the air. We see skins of yellow in between snow levels on Lake Claire and a film in between layers of snow.***
>
> ***Quote context:*** *In March when it starts warming up you get a south wind and then you know spring is coming. That is when we get Sulphur and other odors in the air from the tar sands. Now there is more oil plants coming up, and more frequently. Now all through summer we get that smell every time there is a south wind. At night it seems to be mixed with Sulphur, it's the smell of burnt eggs. Whatever is in air falls in the snow, and in water, and accumulates over time. Any odor that is brought in has to have some effects over time on animals, water, snow, and the people that depend and eat animals and drink that water.*
> ***Source:*** *Ron Campbell*
> ***About Ron Campbell:*** *I was born in Fort Chip. I have and still do spend a lot of time in the delta. I've been trapping muskrats since I was a kid. And I do spring hunts and moose hunting etc. Everything I got was once natural and country food. We spent a lot of time in the bush, and learned about life from the traditional users.*

In summary, both science and ITK have indicated a downward air quality trend resulting from poorer air quality at certain times of the year. This reduced air quality could result in deposition to snow and water within the PAD, as discussed below.

5.7.1 Air Deposition of Contaminants

As noted by Kirk et al. (2014) “chemicals in snowpacks enter terrestrial and aquatic ecosystems at spring snowmelt, where they may impact biological communities in the Athabasca River basin” (p. 7381). The authors report low levels of spring-time snowpack THg (total mercury) concentrations at nine sites in the PAD, ranging from 0.95 to 1.43 ng/L, with an average of 1.19 ng/L, and note “the guideline for Al was exceeded at 8 of the 9 distal sites in the PAD” (p. 7381). The authors also found MeHg (methylmercury) “results just above the method detection limit of 0.015 ng/L in the PAD and at several distal sites (average = 0.016 ± 0.002 ng/L in the PAD)” (Kirk et al., 2014, p.7378).

Due to the potential for long-range atmospheric transport of contaminants, such as PAHs, from the oil sands region to the PAD, several studies researching the geographical extent of air deposition of contaminants from the oil sands region were examined. Manzano et al. (2017) studied air, snow, and lake sediment deposition of PAHs in the oil sands development region. They report while “heterocyclic aromatics diminished with distance, some were detected at large distances (>100 km) in snow and surface lake sediments, suggesting that the impact of industry can extend >50 km” (p. 5445). The northernmost site in the study was near Fort McKay, located less than 125 km from the southeast extent of the WBNP and 150 km from the PAD. Kirk et al. (2014) add “given that snowpacks provide a direct measure of atmospheric deposition, these results suggest that oil sands developments are a source of airborne THg and MeHg emissions to local landscapes and water bodies” (p. 7378). The authors did note, however “further work linking snowpack loadings to hydrology is needed to determine the relative importance of atmospheric deposition in driving observed trends in river water contaminant concentrations” (Kirk et al., 2014, p. 7382).

Kirk et al. (2014) and a growing number of other recent peer reviewed studies (Willis et al. 2018, Cooke et al. 2017, Landis et al. 2017, Manzano et al. 2016, Landis et al. 2012) demonstrate that the numerous toxic metals and PACs are currently deposited within 50-75 km of the major oil sands developments and that these contaminants originate from bitumen upgrading facilities and fugitive dusts originating from a number of sources, including open pit mines, tailings ponds, and haul roads. Currently, the authors suggest that metals and PACs deposition in the PAD are near background levels. However, these studies strongly imply that new oil sands developments, including upgrading facilities, open pit mines, new roads, and tailings ponds will generate metals and PACs emissions that will only be deposited to the landscape within 50-75 km of these new developments.

Other air quality studies indicate impacts from oil sands development resulting from acidic deposition, such as potential critical load exceedances. ECCC’s air quality prediction model was used to predict ecosystem impacts in northern Alberta and Saskatchewan, including parts of the WBNP region (Makar et al., 2018). Model runs for August 2013 through July 2014 predicted the exceedances of critical loads for sulphur, and for sulphur plus nitrogen, for a variety of ecosystems (forest, terrestrial, and aquatic ecosystems) in different parts of Alberta, Saskatchewan and the southern Northwest Territories. The model predictions showed how emissions of sulphur and nitrogen-containing compounds can be carried far downwind from the sources, chemically transformed en-route, and deposited, causing potential ecosystem damage. These model simulations also predicted critical load exceedances within the WBNP for: (a) terrestrial ecosystems, along the south-western border, (b) aquatic ecosystems with respect to sulphur deposition, in the park’s south and south-western portions, and (c) aquatic ecosystems in throughout much of the park. Further, satellite measurements were used to gather information about air pollutants, which indicated background levels for NO_2 in WBNP, except for the south-eastern boundary region.

On the other hand, Cooke et al. (2017) report "no evidence that oil sands emissions have resulted in trace element deposition beyond 50 km, and Hg deposition appears to reflective of global-scale patterns in atmospheric Hg emissions" (p. 8). Similarly, Wiklund et al. (2012) note "although Pb and Hg currently remain above background levels, decreasing trends during the period of increasing oil sands production similarly imply that this industry is not a major far-field source of airborne Pb and Hg" (p. 381). The same authors also point out "no measurable evidence of related far-field airborne metal contamination in the Peace–Athabasca Delta, located ~200 km to the north (of industry)" and add "current industrial emissions from the Alberta oil sands are not measurably increasing airborne Sb and As to the delta" (Wiklund et al., 2012, p. 381). More recently, Parrott et al. (2018) report "aerial deposition of fugitive dust particles and aerosols from oil sands mines, coke piles, and stacks can result in snowmelt that is toxic to larval fish", however they add "the dilution of the contaminants in snow as it melts in the spring and mixes with river water is currently sufficient to confer a protective effect for larval fish in local rivers" (p. 272-273).

5.8 GROUNDWATER IN THE LOWER ATHABASCA RIVER BASIN

The municipal, agricultural, and industrial use of groundwater in the province of Alberta is governed by the provincial *Water Act* (through the issuance of water allocation licenses) and industrial activities that may impact groundwater are assessed as part of Alberta's *Environmental Protection and Enhancement Act* (Government of Alberta, 2012). In 2012, the Government of Alberta established a groundwater management framework for both the Northern Athabasca Oil Sands area (NAOS - north of Fort McMurray) and Southern Athabasca Oil Sands area (SAOS - south of Fort McMurray) as part of the Lower Athabasca Regional Plan (LARP) (Government of Alberta, 2012). The PAD is located approximately 100 km north of the northernmost boundary of the NAOS area. No groundwater quantity or quality information could be found for the PAD itself.

Groundwater conditions have been monitored in the lower Athabasca region for the last 20 to 30 years, including monitoring at individual oil sands facilities and as part of the Groundwater Observation Well Network (GOWN) (Government of Alberta, 2012). For the NAOS, the Groundwater Management Framework report "no significant trends in key indicators have been recorded since initial sampling in 1975", noting "there is poor to fair knowledge of groundwater quality in the surficial sands and buried channels within the NAOS area as well as the Basal McMurray area" (Government of Alberta, 2012, p. 20). For the SAOS, it was determined "groundwater quality conditions in the various key aquifers beneath the SAOS area is limited both from a temporal and spatial perspective" (Government of Alberta, 2012, p. 21).

The Groundwater Management Framework outlined a number of challenges to groundwater management in both the NAOS and SAOS areas from oil sands mining, as well as other activities, such as municipal development, agriculture, forestry, aggregate mining, and natural phenomenon. Activities that may negatively affect groundwater in the region include the following (from Government of Alberta, 2012):

- Physical disturbance of the landscape and alteration to natural drainage and recharge patterns from conventional oil sand mining activities.
- Drawdown effects from dewatering of overburden aquifers and bedrock formations to facilitate safe, conventional oil sands mine development.
- Potential seepage of contaminants from conventional oil sands process waste containment structures (tailings ponds, tailings impoundments).
- Leaching of contaminants from conventional oil sands mining overburden waste dumps and material stockpiles.
- Pressure effects and contaminant migration following deep well injection of oil sands depressurization water and process wastewater.
- Spills and leaks of chemicals and hydrocarbons at processing facilities and active conventional oil sands mining areas.
- Disruption and creation of pathways to groundwater from in-situ oil sands extraction activities;
- Release of production fluids from casing failures or annual leakage from in-situ oil sands extraction activities.
- Spills, leaks, and uncontrolled releases of chemicals and hydrocarbons from in-situ oil sands extraction activities.
- Natural discharge of saline waters from bedrock formations into local water bodies and aquifers.
- Leaching of hydrocarbons, salts, and trace elements from exposed bedrock formations and muskeg deposits into local water bodies.
- Leaching of hydrocarbons, salts, and trace elements to the local groundwater from segments of oil sands deposited within the overburden deposits, and from buried channels eroding into underlying oil sands deposits.
- Leaching of pesticide and fertilizer residues into shallow aquifers.
- Upstream oil and gas activity (effects of gas production on the Cretaceous bedrock aquifer water levels).
- Effects of natural disturbance such as forest fires and climate variability on regional groundwater levels and quality.
- Natural climate cycles affecting basin hydrology and groundwater levels.

5.8.1 Groundwater Quality

As noted by Droppo et al. (2011), "the most significant groundwater quality issue associated with oil sands development relates to the seepage of OSPW (oil sands process-affected water) from the tailings ponds that are distributed throughout the region" (p. 40). The authors further report "the main stem of the Athabasca seems to have relatively small groundwater inputs…however, tributaries such as the Clearwater, Steepbank and Firebag Rivers appear to have intermediate to high groundwater inputs, suggesting that they may be more vulnerable to groundwater changes associated with oil sands developments (e.g. seepage from tailings facilities) than the main stem" (Droppo et al., 2011, p. 39).

Frank et al. (2014) sampled groundwater near several tailings ponds in the Athabasca oil sands region, suggesting "oil sands process-affected groundwater (OSPW) is reaching the Athabasca River system" (p. 2660). Oiffer et al. (2009) examined a tailings pond groundwater plume in a shallow sand aquifer, reporting elevated levels of HCO_3, SO_4, Na, and Cl, as well as NA (naphthenic acid) persistence. Ferguson et al. (2009) also studied a large tailings impoundment (pond) in the Athabasca oil sands. The authors report tailings ponds are intrinsically permeable structures with the potential to contaminate surface and groundwater. However, they note the hydraulic barrier formed by the thick layer of fine sediment tailings at the base of the pond restricted seepage into the foundation of the pond, which, in combination with a collection and recirculation system for seepage water from the dykes (pond walls), significantly reduced the potential for process-affected water to enter the river system (Ferguson et al., 2009). The authors further concluded "the potential for flow of tailings process water into the foundation and river initially appeared to be high; however, more detailed analysis revealed that hydraulic barriers to process water flow existed within the system" (p. 1458). Ferguson et al. (2009) did note, however, "although this helped reduce the fluxes observed through the foundation and into the drains, it has resulted in a long-term environmental concern, as this water and fine tailings will have to be managed and eventually reclaimed" (p. 1459, Ferguson et al., 2009).

5.8.2 Groundwater Quantity

As part of the LARP groundwater management framework developed by the Government of Alberta in 2012, the available drawdown estimated in the various aquifers in the lower Athabasca region was assessed as substantial (Government of Alberta, 2013). Further, for the NAOS "initial high-level estimates of groundwater volumes and recharge in the Lower Athabasca Region suggest a significant and sufficient volume to accommodate the current level of development and water use. However, additional data is required from future monitoring and assessment initiatives to refine these estimates and help facilitate future determination of sustainable yields for the regional aquifers in the NAOS area" (Government of Alberta, 2012, p. 20).

In 2007, Davidson and Hurley report "only three of the major oil sands projects were operating in 2005, including Suncor, Syncrude and Albian Sands. These three projects are allowed to withdraw up to 191,375 dam^3 from the Athabasca River, 9,015 dam^3 from tributaries, 8,932 dam^3 from groundwater, and 20,124 dam^3 from surface water run-off" (p. 3). In 2011, eight industrial bodies held groundwater withdrawal licenses of greater than 1,000 dam^3/year in the Fort McMurray and Fort McKay regions (Hatfield, 2011). However, it is unclear what the allocation of groundwater resources are in the oil sands currently and what proportion of the total water allocation for oil sands activities may be.

Given the limited knowledge regarding the current state of groundwater quantity and quality in the PAD, the trend is considered unknown.

5.9 Impacts On Indigenous Ways Of Life

Indigenous Knowledge holders emphatically assert that to the people who were born there and live on the land, the PAD is not simply a place, it is who they are (MCFN, 2018a). The local Indigenous people are intricately tied to the land and they remember how the PAD used to be. They have seen dramatic drops in water levels in the PAD over the past forty plus years. As the water levels go down and the PAD becomes drier, both the natural environment and their Indigenous way of life are being impacted, as they are inseparable. Everything is connected: water, vegetation, insects, frogs, fish, birds, beavers, muskrats, bison, wolf, moose and the Indigenous way of life. The people identify themselves as part of the land. They are connected to it physically and spiritually.

A large body of relevant literature reviewed indicates that the decreasing trends in water levels and water quality in the PAD are negatively affecting muskrat populations, vegetation, fish communities, water birds, and ultimately, local Indigenous communities. In 1972, the PAD Project Group predicted that the continued regulation of the Peace River would result in effects involving a redistribution of the PAD's plant communities, as well as a decrease in muskrat populations and waterfowl production, thereby affecting the Indigenous peoples who hunt and fish in the PAD, as well as present and future generations of the Canadian public (The PAD Project Group, 1972).

This prediction is supported by more recent research that reports "drying of the delta results in shifting vegetation with less grass and more willow, increased sand bars and islands in the Peace River, and drying of wetlands and muskegs well back from the main course of the river, especially those that depend on seasonal flooding for renewal. Drying results in less habitat for muskrat, waterfowl, and other species, reduced ability to travel or hunt in the delta, and changes in other resources and parameters critical to MCFN use" (Candler, 2013b, p. 20). Wiacek and Westworth (1999) also note "drying of perched basins has negatively affected populations of waterfowl, muskrats, and other wetland wildlife on the delta" (p. 1). More recently, the Firelight Group et al. (2018) report "MCFN members have observed a number of secondary effects related to declining water levels and changes in the pattern of flows, including expansion of invasive species, expansion of willows and trees into former flood maintained grasslands, loss of biodiversity, loss of perched basins, reduced water quality, decline in migratory bird presence, decline in muskrat populations, decreased quality of semi-aquatic mammal fur, disruption of bison-wolf relationships, loss of access, and overall impairment of MCFN way of life" (p. 4). Further, Indigenous Knowledge holders emphasize they no longer hear or see insects, frogs, or song birds (MCFN, 2018a).

5.9.1 Sufficient Water for Indigenous People to Navigate Safely in the Exercise of Their Treaty and Aboriginal Rights

As noted by Carver and Maclean (2016), “the waterbodies within the PAD provide critical access to Indigenous territory for the ACFN and MCFN” (p. 16) and boat access is the preferred means by which MCFN members choose to exercise rights such as hunting, trapping, and fishing, mainly due to MCFN member’s familiarity with water navigation for subsistence and their water-based knowledge (Candler et al., 2010). Frequent transportation routes, as used by ACFN and MCFN members, are shown in Figure 5-11.

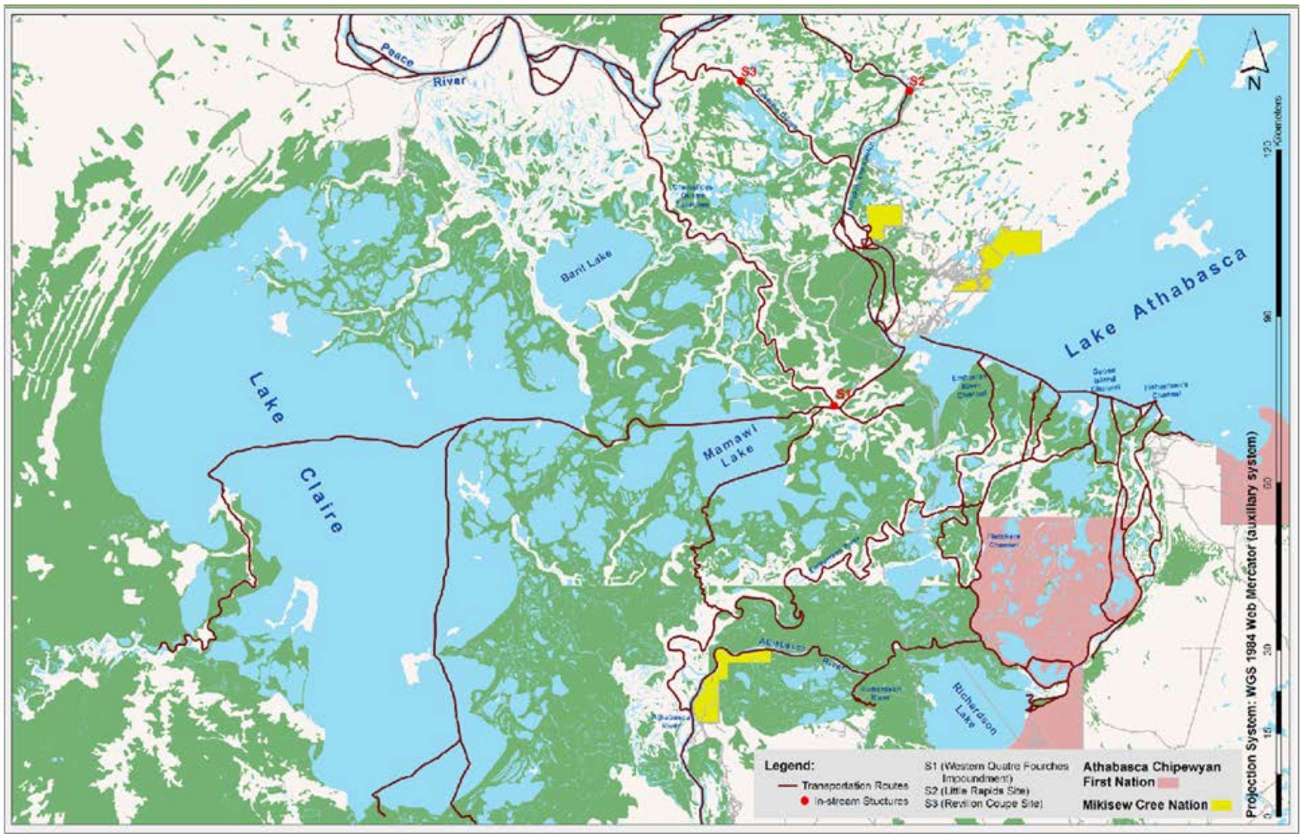


Figure 5-11: Frequent Transportation Routes, as Used by ACFN and MCFN, and Structures Constructed Within Selected Reversing Channels (Carver and Maclean, 2016)

Notes: Red dots S2 and S3 show weir locations, S1 no longer exists.

Local Indigenous people report serious difficulties in accessing traditional lands resulting from lower water levels in the PAD, and Indigenous Knowledge holders report it is now impossible to reach some areas of the PAD by boat (MCFN, 2018a, 2018b; ACFN, 2018a). The best hunting locations tend to be those accessible by boat alongside channels, tributaries, and on the far side of islands away from the main channel because large game like to be near lakes and creeks, but tend to avoid the main channels of large rivers. However, “these smaller channels and tributaries are especially vulnerable to loss of access due to low water levels” (Candler et al., 2010, p. 14). As a result, lower water levels in Lake Athabasca and other PAD lakes have led to “lost access to traditional Use Areas for hunting, fishing, collecting, spiritual use” in the PAD (Maclean, 2016, p. 3).

The MCFN report “low water levels have depleted local waterways to the point that they are no longer traversable. Few waterways can be traveled; those that are still useable for transportation are so low that community members frequently encounter travel delays as a result of impediments such as sandbars” (MSES, 2010, p. 17). The MCFN also note “it’s difficult to fish, trap, hunt, pick berries, enjoy the land, and visit spiritually important places because lower water levels often make it impossible to travel” (MCFN, 2016a, p. 22). Further, Candler et al. (2010) report low water levels on Richardson River, Jackfish Creek, Richardson Lake, Lake Mamawi, and Lake Claire, are creating access issues, thereby preventing local Indigenous people from practicing their trapping, hunting, fishing and cultural rights. Figure 5-12 below shows the areas of the PAD that have become inaccessible to boats during low water levels.

If the water levels in Lake Mamawi go as low as a foot of water or lower, we can’t access our territory because people in Fort Chip have outboard motors with props, so need at least 2 ft. of water to get across Mamawi to Claire Lake. So low water really limits travel to access our traditional territory. In the summer months, Lake Mamawi is a gateway those rivers. If it’s low, the gate is closed for us to pick eggs, fish, hunt, and teach our youth. Sometimes water levels are so low the ice freezes right to the bottom at Lake Mamawi that the fish run out of oxygen and there are fish kills.

Quote Context: *It seems like all our concerns, and everyone’s concerns are all intertwined. There are less frequent floods. The ice is different, it’s not as thick. We used to get flooding every 3 to 6 years before the Bennet Dam and now its way far in between. Its 20 years in between floods now. Lake Mamawi is an example. When we go to hunt or trap our traditional food, it’s like a gateway to the delta where you have to pass in summer months by outboard motor. If it doesn’t flood we get really drying trends and can’t even access our traditional area as water is so low. There are years where my uncle and I had to literally jump in water an push our boat for 3km to get to Lake Mamawi. And you try to go out for weekend, loaded with gas, drinking water, and you have to get in water and push boat 3 kms. That wastes one day right there. Those kinds of things affect our way of life and impact or social and mental well-being! We can’t access our traditional food, our healthy food. The biggest thing to rectify the problem or save part of the delta in PAD area, we have to get our water back!*
Source: *Ron Campbell*
About Ron Campbell: *I was born in Fort Chip. I have and still do spend a lot of time in the delta. I’ve been trapping muskrats since I was a kid. And I do spring hunts and moose hunting etc. Everything I got was once natural and country food. We spent a lot of time in the bush, and learned about life from the traditional users.*

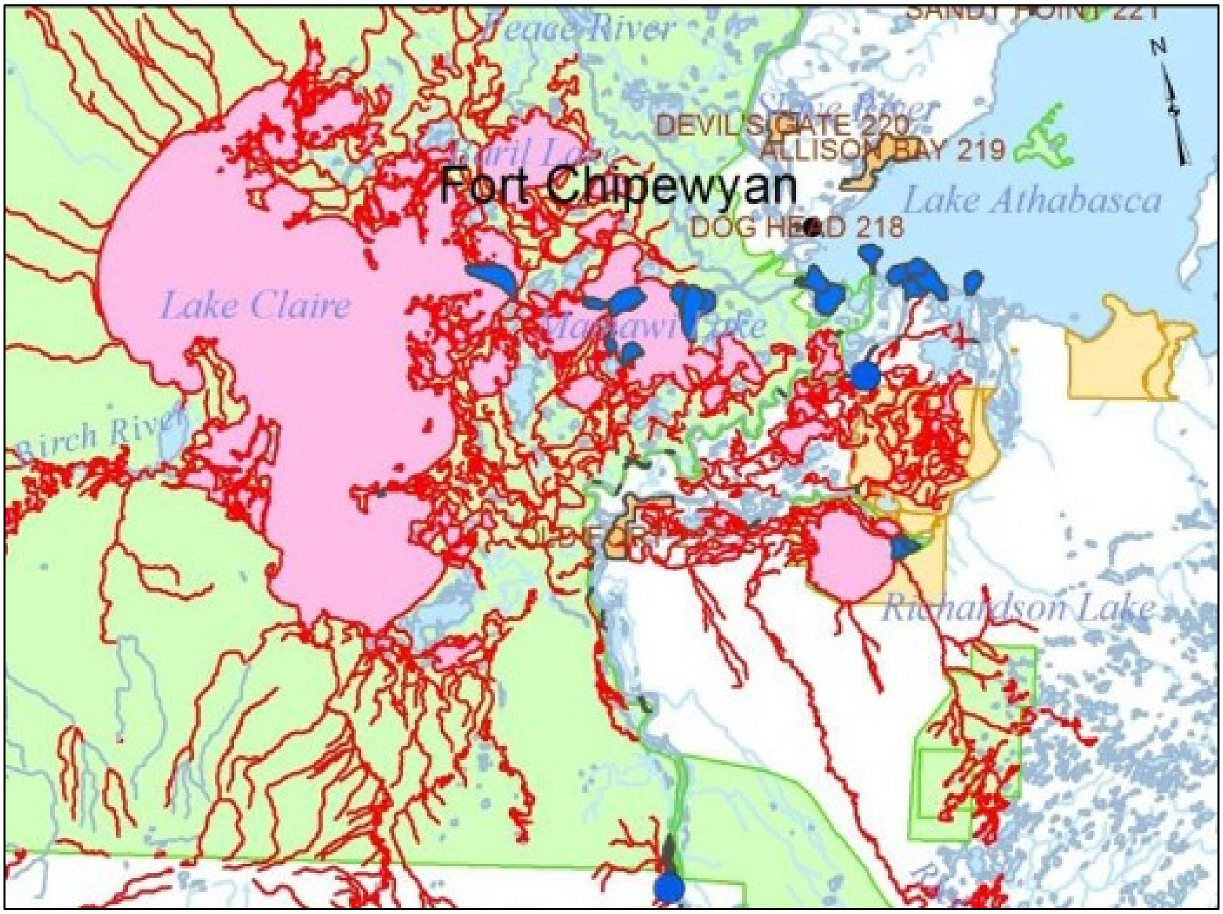


Figure 5-12: PAD Areas with no Boat Access at Extreme Low Water Levels (from Candler et al., 2010)

(Notes: Red represents areas with no access at flows <400 m^3/s in to the PAD)

Indigenous Knowledge holders indicate when water levels are too low, the PAD lakes and channels become inaccessible and the people cannot reach their traditional lands to hunt, fish, trap, and collect eggs and plants because their boats get stuck in the shallow water and mud (MCFN, 2018a, 2018b). This forces them to find other ways to get to their lands, such as walking, buying expensive equipment for their boats, or taking much longer routes to get to their land (if they can find another access route), which requires more money, time, and effort. When a strong wind blows from the East, the water level in Prairie River (the main access point to Lake Claire) decreases even further and the boats get stuck.

Indigenous Knowledge holders also report if they cannot access their lands at all, they are forced to concentrate their activities and to hunt and trap on other's land (MCFN, 2018a, 2018b; ACFN, 2018a). Traditional family lands have been handed down from generation to generation and they are integral to the identity of those families. Having to ask to hunt and trap on someone else's land can be humiliating and demoralizing. Some people are too proud to ask to hunt on someone else's land, while others have had to abandon the cabins in their traditional territory and build cabins in other areas that are accessible. If the people do end up hunting and trapping on someone else's land, they don't know the land like they know their own and it's harder to be successful. It can also be more dangerous and stressful.

Indigenous Knowledge holders also note if the people cannot access their land, they cannot exercise their treaty rights (MCFN, 2018a). If they catch a moose when they are out on the land, they cannot easily transport it back home because it weighs down the boat and they have even more trouble traversing the low waters of the PAD. The meat could go bad in the process of trying to get boats unstuck, which is stressful to hunters. The outboard motors on their boats need at least two feet of water to operate properly and often there is not enough water to run the motor. Many expensive motors are destroyed trying to get through waterways filled with mud and weeds and sometimes people are stuck for hours before they free themselves.

Perhaps most importantly, Indigenous Knowledge holders report a loss of culture and transfer of knowledge resulting from reduced access to traditional lands in the PAD (MCFN, 2018a). The Cree language is connected to the land itself and it is place-based. When on traditional lands, stories and legends are told to children in the native language to teach them lessons and explain culture and history. The local people connect the language to the place and the activities they are doing. The place-based stories and knowledge are lost if the people cannot access their traditional lands because there are different stories told in different areas of the PAD.

Access Issues Related to Weirs

Carver and Maclean (2016) note two weirs installed in the 1970s on the Rivière des Rochers and Revillon Coupé are also creating access and navigation issues for the local Indigenous people (shown as S2 and S3, respectively, in 11). In particular, Carver and Maclean (2016) note the channel at the north end of the Rivière des Rochers weir is “too shallow at many times of the year to provide safe passage” and the Revillon Coupé weir “remains a serious barrier to navigation at low-to-medium flows and expert knowledge of the river is needed to safely pass through the weir” (p. 17).

Access Issues Specifically Related to the Athabasca River

Dredging occurred on the Athabasca River between 1945 and 1996 to facilitate commercial barge traffic. Dredging in summer until September or water levels fell, they created a channel 60 m wide and 1.2 m deep. Dredging occurred for different periods of time on Big Point Channel, Fisherman’s Channel, Goose Island Channel and the Athabasca River between the delta and Fort McMurray (Timoney, 2013).

More recently, since dredging ceased, changes to flow rates in the Athabasca River are preventing Indigenous people from accessing their traditional lands in and around the PAD (Carver and Maclean, 2016; Candler et al., 2010). Candler et al. (2010) report several local Indigenous groups (including the ACFN and MCFN) either had difficulty accessing or could not access their traditional lands because the low water levels on the Athabasca River created sand bars and log jams and exposed rocks and other hazards for boats. This results in increased travel time and expense, damaged boats, engines and equipment, and reduced ability for local Indigenous people to live, hunt and fish on traditional lands, thus preventing them from exercising their Treaty rights by water. Carver and Maclean (2016) monitored water flow and depth in the PAD from 2011 to 2015, reporting “extensive losses of traditional use during the five-year monitoring period” due to declining water depths throughout the PAD (p. 8). The authors attribute this decline mainly to lowered incoming flows from the Athabasca River, especially in the southern PAD and, to a lesser extent, Lake Mamawi, which is particularly evident during fall hunting season, when "a general average flow decline of 100-200 m^3/s is evident" in the Athabasca River (Carver and Maclean, 2016, p. 19).

Candler et al. (2010) defines Aboriginal Base Flow (ABF) as a minimum flow rate that "reflects a level on the Athabasca River and adjacent streams where MCFN members are able to practice their rights, and access their territories fully", while Aboriginal Extreme Flow (AXF) "reflects a level at which widespread and extreme disruption of Treaty and Indigenous rights occurs along the Athabasca river, delta, and tributaries due to a loss of access related to low waters" (Candler et al., 2010, p. 24). As shown in Figure 5-13, weekly average flow rates on the Athabasca River are consistently below the ABF. Flow rates are also below the AXF in spring and approaching the AXF in fall. Additionally, instantaneous flows can occur that are much lower than the weekly average flows. As noted by Carver and Maclean (2016), this presents substantial difficulties for Indigenous people in accessing traditional lands during early spring (generally weeks 16 to 20) and fall hunting season (generally weeks 39 to 43).

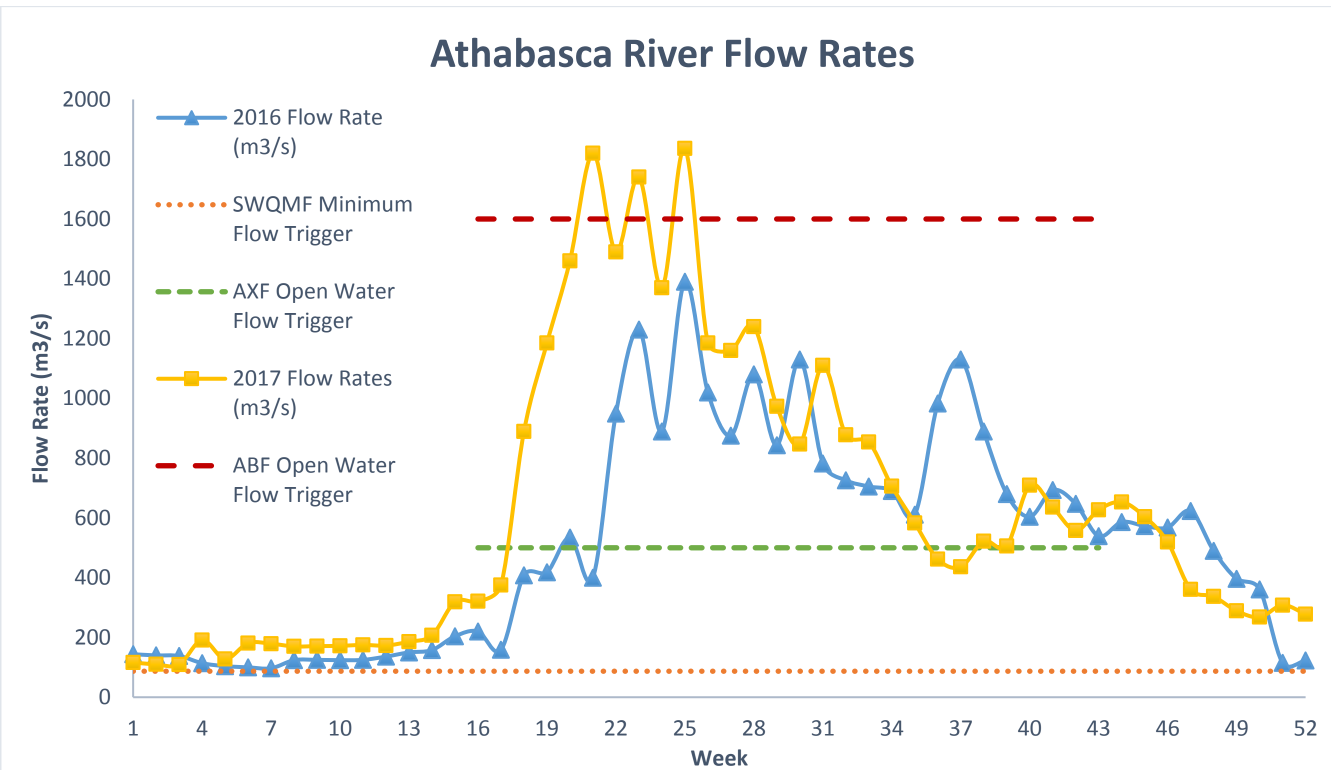


Figure 5-13: Weekly Athabasca River Flow Rates for 2016 and 2017[1]

[1] (2017, flow rates and SWQMF trigger from http://Www.environment.alberta.ca/apps/OSEM/ATHMCM.aspx; ABF and AXF open water flow discharge thresholds from Carver and Maclean, 2016) (Notes: winter weeks 44 to 15, spring weeks 16 to 23, summer weeks 24 to 38, fall weeks 39 to 43, open water season from weeks 16 to 43)

Access Issues Related to Winter Water Levels

Indigenous Knowledge holders also describe considerable difficulties in accessing traditional lands due to higher winter flows on the Peace River (MCFN, 2018a, 2018b; ACFN, 2018). The winter water releases degrade the ramps from the river onto the winter road, which is both a lifeline to other communities in the north, as well as a key way the local people access the land. The overflow affects snowmobile and vehicle access to the road for several weeks to a month. The winter releases decrease the quality and thickness of ice on the river by adding dirty water (with sediment) on top of ice that has already formed. The ice is no longer pure. The darker color of the sediment in the new ice layer promotes melting from the sun. This melting ice sinks into the ice layer below and creates holes in the ice ("candle ice"), as well as poor quality, slushy ice. People can get trapped in this ice and they cannot access their traditional lands because the ice will not support the weight of the snowmobiles. There are also open water areas on the Athabasca River during the winter due to water discharges from industry, which are thought to result from increased temperatures and/or contaminants in the discharge water, further reducing access to back channels on the river (ACFN, 2018).

Increased winter water levels and changes to the ice composition and quality have also made winter travel increasingly unpredictable for MCFN members, impairing their ability to access their traditional lands and to pass on ITK to the younger generation. Candler et al. (2013a) report "the high waters from the springtime flood are critical in order to create the ice jams and damming in the winter. Since the Bennett dam, ice quality and quantity has significantly decreased and made access and travel to lands difficult and increasingly dangerous" (p. 8). Candler et al. (2013b) further note "overflow in the winter on the Peace and adjacent creeks makes it impossible to use snowmobiles at key places, such as creek crossings, and dangerous or impossible to travel on the Peace River ice in particular locations, including near Rocky Point and Peace Point rapids, due to weak ice and persistent open water" (p. 5). More recently, the Firelight Group et al. (2018) reported "effects observed by MCFN members related to declining ice jam frequency include unpredictable flooding and ice melt in winter, low quality candle ice, silty or dirty ice, rapid melting in spring, and absence of jamming at key locations including the 30th Baseline and at Rocky Point. These changes have created unpredictable flooding and ice melts which results in loss of reliable access for MCFN members and land users, as well as inability to teach youth on the land and pass on MCFN knowledge to younger generations" (p. 3).

Métis Local 125 (2018b) based in Fort Chipewyan also reported challenges with winter access noting: "the increasing difficulty of travel in the PAD in winter and … specifically on the thin and changing ice, from too many contaminants in the water, and the different pressure, which is why it drops so easy. The shore ice is gone, so you have to get to the center ice channels. It is tough to cross Mamawi and get around Lake Claire."

The difficulties in accessing traditional lands and preferred harvest areas during the winter also has social and economic impacts on local Indigenous people. Candler et al. (2013b) note *"*changes in ice quality, including increasing sediment in Peace River ice, and winter releases of water (especially in November)…reduce the chance of ice damming and create dangerous conditions for travel by MCFN members that restricts access to traplines, sometimes destroys traps where these are set on the Peace River or nearby creeks or rivers, and kills or disturbs animal dens, especially muskrat and beaver*"* (p. 22). Further, Candler et al. (2013b) also report *"*we have records where we have had to close the road because the water came up. As Indigenous people, we never saw water come up in the winter. That's human caused[d], that's man cause[d], to get their power, so we have to close our road. It's just a headache in itself [for] getting groceries and living our lifestyle and getting parts for our snowmobiles and for our traps, it gives us a headache…Not only is it just the delta, it affects us socially as well." (p. 6).

5.10 Muskrat and Beaver

As noted by Candler et al. (2015b), "trapping (of muskrat) is important for social, economic, spiritual and other purposes. MCFN members rely on family trapping areas as a refuge for a wide range of cultural activities" (p. 114). Muskrat habitat preferences are mainly based on water depth and "high spring and summer water levels are important for maintaining adequate habitat for breeding and overwinter survival" (Hood et al., 2009, p. 27). The habitat provided by perched basins in the PAD is also of great importance to muskrats, as Hood et al. (2009) pointed out "of 9,071 ha classified and mapped on 24 study basins within Wood Buffalo National Park (1978 to 1979), perched basins accounted for 27.3% of the area, but contained 64.2% of the muskrat houses" (p. 26).

Indigenous Knowledge holders describe drastic reductions in muskrat populations in the PAD due to the lack of flooding and encroachment of invasive plant species (MCFN, 2018b; ACFN, 2018a). A favourite food source for muskrat (and other animals and birds in the PAD) is "goose grass", however it requires 2 to 5 feet of water to grow in. As the water levels go down and dryness is sustained, the goose grass, also known as joint grass, water horsetail, or river horsetail (*Equisetum fluviatile*), is replaced by thistle, willow, and poplar. This is disrupting the food chain because goose grass is a favourite food source for muskrat, bison, and migratory waterfowl. If the goose grass is gone, the animals either starve or go somewhere else.

My father said it used to flood every 3 or 4 years. Old water would get washed out and always fresh water from the Peace River, muskrats lots! A chain reaction: muskrats, otter, to wolves and buffalo. Now less animals because the rats are gone so that chain reaction is broken! Water is not as good as back then. Something has to be done.

Quote context: *All the lakes that would get replenished every few years, that hasn't been going on now. Now water is stale. The muskrats are not there anymore. Where there were once lakes is dried up. There are no more muskrats. Without water you have no muskrats. You need water for all animals from the mice up to the buffalo! It's a chain reaction! In the old days 300k muskrats were trapped in the delta and PAD. That is in the written history. Today not even a 100. Usually I get a few, this year I got nothing. It's the same with beavers. There is one lake where I always found a few beaver, that lake is now dried up and the beaver left. What needs to be done, first of all water is #1.*
Source: *Gerald Gibot*

In 1996, Bill et al. report "reduced flow patterns of the rivers forming the Peace-Athabasca Delta are attributed as the cause for significant reductions in muskrat populations over the past twenty years, but most noticeably in the last ten years" (p. 332). More recently, Straka et al. (2018) report "Elders and Indigenous land-users in the PAD have observed a dramatic decline in relative abundance of muskrat in recent decades (~1935-2014)…(due to) reduction in suitable habitat as a result of decades without ice jam flooding on the Peace River" (p. 3). The same authors also note "delta lakes formerly supporting high densities of wildlife, including muskrat, are now dry (p. 39) and the Indian Claims Commission (1998) indicated "muskrat have declined substantially since the operation of the Bennett dam" (p. 49).

Swimming muskrat. Photo: Tom Koemer, US Fish and Wildlife Service

McLachlan (2016) further report there were "muskrats, years ago, in the 70s. Even early 70s and 60s. There were lots of muskrat around this area. People used to kill 3000 or 4000 rats in a trapping season. I guess the reason there was lots of rats in those days was there was lots of water. Water was high. Always water out in the lakes and ponds and that. Lots of muskrats all over. Once the water started going down, once the water dropped. Every year after the Bennett Dam, the water is worse than ever. Now there's no muskrats anymore. They're gone" (p. 31). Finally, the MCFN (2016b) report "we have no muskrats, they just disappear. Nowhere to live, no water, and no feed. You've got to have water in order for the proper grass to grow for the muskrats to survive with in the lakes, ponds, lakes or where, and sloughs. But now…after the Bennett Dam, the delta is dried up where there used to be 3-4 feet of water" (p. 32).

Indigenous knowledge holders indicate winter releases of water on the Peace River raise winter ice levels in the PAD, drowning muskrat and beavers where they have made their homes (MCFN, 2018a, 2018b). UNESCO (2017) also reports wildlife effects from increased winter flows resulting from regulation of the Peace River, noting "beavers build a house when (the) river is low in October. Now Bennett releases water in November, around November 20. That water flows over the beaver lodges and they're forced out in search of warmth and food. They usually starve and freeze" (p. 74). In addition, the MCFN (2016b) report "because of hydro dams, more water is released in the winter, and less in the spring, causing problems with ice formation, making the rivers dangerous for humans, and causing animals to freeze or drown, including beavers and muskrats" (p. 22).

5.11 VEGETATION AND INVASIVE SPECIES

Lower water levels in the PAD are reportedly causing increases in vegetation cover and invasive species over time, along with a decrease in the availability of traditional plants and berries. Parks Canada (2009) report a "loss of flooded vegetation, in-growth of willows, and an increase in invasive plant species, primarily in the Peace sector of the delta" (p. 22) from 1996 to 2008, however they also note a great deal

> ***Since 1974, the water has gone down and down so for the buffalo there isn't the vegetation they live on. The thistle is taking over the whole delta on account of there being no water.***
>
> ***Quote context:*** *From 1974 the water dropped. There are trees now growing in the lakes. If there is water the thistle doesn't grow. Where it doesn't flood there is thistle. Lower in the bay there is nothing. Thistle doesn't grow in wet ground, only where it is dry. Thistle came in 96-97. That is when it really picked up. There was a bit starting before that but not as bad. Now it's really dry! It's hard to walk around.*
> ***Source:*** *Larry Marten*
> ***About Larry Marten:*** *I am 65. I quit school in 1966. That is when I started trapping. Prior to that as a kid was out there every spring with my parents. We lived out there because it's our livelihood. When I quit school, then I was trapping every year, every winter and spring. In summer time I had summer work. I am still a trapper.*

of variability within vegetative communities across the PAD. Indigenous Knowledge holders emphatically stress water levels in the PAD are lower than they should be (MCFN, 2017a, 2018a, 2018b; ACFN, 2018a; Métis Local 125, 2018 a,c). As a result, the water levels in the lakes and channels are too low and more land around the edges is exposed or completely dried out. In addition, the low water levels in the lakes and channels are also causing invasive plant species to replace traditional plants and medicines that are harvested by the people. The plants are becoming harder to find and the Traditional Knowledge of how to harvest and use the plants is being lost.


Canada Thistle. Photo: Parks Canada

In 1996, Bill et al. reported "stabilization of the flows of these major rivers (Athabasca and Peace) is considered by those having Traditional Knowledge of the region as contributing to a reduction in the productivity of the lands that were historically flooded and marked encroachment of plant species that are not tolerant to flooding" (p. 327). The ACFN and MCFN (2010) also report, since the last major flood in 1974, "many perched basins are disappearing and two (Egg Lake and Pushup Lake) have disappeared. Willows and other vegetation are encroaching on wetlands. These changes have an effect on the number of species and the population of species (plant and animal) that ACFN members harvest" (p. 27). More recently, the MCFN report "Mikisew members have observed an increase in thistle populations when flooding events are infrequent" (MCFN, 2016b, p. 33) and UNESCO reports "willows are invading because the water is too low", "…there are too many willows", and "all the healthy vegetation is gone" (p. 73). Similarly Fort Chipewyan Métis Council 125 reported (Métis Local 125, 2018b) "The plains are described as filling up with willow and poplar because there is no water. Willow is filling in dried areas which when grow tall obscure landmarks for land users. Thistle chokes out feed for bison and keeps them north because they cannot get past it. It is a natural barrier."

The ACFN and the MCFN (2010) also report that "changing moisture regimes and flooding cycles alter plant communities in traditional plant collection areas" due to declining water levels in the Athabasca River and Lake Athabasca (p.23). In the PAD itself, the MCFN (2016b) note "our berries and medicines are absent or poor quality in places where they were previously abundant (especially wetland areas)" (p. 22) and Candler et al. (2015b) report "reduced water levels in the PAD and along the Athabasca River are report to have resulted in berry patches 'drying out' with smaller and less abundant fruit" (p. 112). Further, the Indian Claims Commission (1998) report "changes in vegetation as a result of the drying out of the Athabasca Delta has led to reduced availability of some medicinal and food plants for the Chipewyan people, as well as reductions in the availability of productive wetland and meadow habitats and ecosystem integrity" (p. 50). Candler et al. (2015b) note "drying of muskegs and the Athabasca River mean that muskrat and many important species of plants are now often rare or hard to find" (p. 87).

5.12 MIGRATORY WATERFOWL

Migratory waterfowl are also discussed in Section 4.4. Impacts to migratory waterfowl creates challenges for Indigenous communities. As noted by Candler et al. (2015b) "migratory birds, especially ducks and geese, use the Athabasca River, wider PAD, and inland lakes as staging areas in the spring and fall as they move between more southern ranges and the Athabasca Delta or other nesting and summering areas further to the north" (p. 104). This movement of migratory waterfowl along the Athabasca River and through the PAD "supports spring and fall bird hunts of critical importance to MCFN for social, economic, cultural, spiritual and other purposes" (Candler et al., 2015b, p. 104). However, "in recent years (since about 2000), MCFN knowledge holders have observed changes in the patterns of migratory birds, including ducks and geese, with fewer birds travelling the Athabasca River corridor, and more travelling east and west around Oil Sand mine areas. Fewer birds are flying along migration routes near the Athabasca River and more are bypassing the Peace-Athabasca Delta, possibly to avoid impacts from oil sands development, including pollution and bird deterrent systems, and because of reducing feeding habitat due to low water levels in the PAD" (Candler et al., 2015b, p. 105).

Indigenous Knowledge holders note less water in the PAD means fewer birds (MCFN, 2018a, 2018b; ACFN, 2018a). There are far fewer owls, yellow rails, blackbirds, seagulls, American coots (mud hens), whiskey jacks, ducks, and geese than there used to be. The birds also land in places where they did not before. Migratory waterfowl that used to land and feed in the PAD by the thousands are not coming anymore. Instead of stopping in the PAD, they are either flying right over it or going around it to other areas to rest and feed.

The Firelight Group et al. (2018) note reductions in the quantity of migratory waterfowl utilizing WBNP and the availability of quality migratory habitat. The authors further report "observed trends include the declining number of eggs per nest and declining condition of migratory birds during harvest. The absence of migratory bird and the decline of preferred bird species impacts the important spring and fall harvest periods, as well as MCFN member's sense of place and their ability to teach younger generations on the land" (Firelight Group et al., 2018, p. 6-7). Indigenous Knowledge holders have heard geese and ducks flying overhead during the spring and fall migrations, but they no longer stop in the PAD in the same numbers as they used to. Instead, the birds stay for a shorter period of time or fly around the PAD all together (MCFN, 2018b; ACFN, 2018a). Since there are fewer birds in the PAD to hunt, local Indigenous people are no longer able to provide as much food for their families. Where hunters used to get 60 birds in a few hours, now they get only around 10 birds and it takes all day to get them. ECCC, as part of the Joint Review Panel for Shell's Jackpine Mine project, note the shifting patterns in waterfowl migration pathways and comment "the migration routes of birds may be changing and this change could affect the availability of these birds in the PAD" (AER and CEAA, 2013, p. 161). However, ECCC also note that the cause of the changes in migration routes were not clear and more study is required (AER and CEAA, 2013).

With regard to reductions in water bird populations due to reduced water levels in the PAD, Bill et al. (1996) report "migratory bird use of the PAD is also considered to be much reduced for both breeding and staging during the spring and fall migrations…the reduction in use of this area is believed to be caused by reduced water levels" (p. 333). MCFN (2016b) also report "now you don't even see half the waterfowl you used to see years ago. There's places where they used to do their nesting laying eggs, they don't do that, they can't, there's nothing there it's all dry…The migratory birds for one thing there's nowhere near what used to fly over here. In the fall, like come September, October, well into September I guess the birds going south, you don't even know when they go by, there gone in a day. Years ago we used to hunt migratory birds in the spring and in the fall to stock up for the winter like you know bird hunting, now we don't do that because the birds are not there anymore" (p. 34). The MCFN (2016b) also report "the birds, the birds have pretty much changed their fly-way because different vegetation…it's what we see, it's what we know. The ducks have left because there's no water, there's nothing" (p. 33, 34).

With regard to loss of the quantity and quality of natural habitat, Wrona et al. (1996) report "birds have shifted their migratory patterns westward perhaps in response to improved feeding opportunities in the agricultural areas, but also because of the significant reduction in breeding and staging habitat in the delta" (p. 39). The Indian Claims Commission (1998) note "numbers of waterfowl throughout the Athabasca and Peace deltas are believed to have declined as a result of reduced nesting and brood rearing habitat, and the loss of large areas of suitable fall staging habitat" (p. 49). The MCFN and ACFN also report "waterfowl no longer stop on the PAD and Lake Athabasca in the vast numbers that they once did. The decline in waterfowl is, in part, related to reduction in habitat quality incurred as a result of decreasing water flows in the PAD" (MCFN and ACFN, 2010, p. 19).

Bird Eggs

Indigenous Knowledge holders indicate the number, i.e. clutch size (total number of eggs laid per nest by a single female), and quality of bird eggs is also changing (MCFN, 2018a). Where up to 15 eggs were collected from a nest, now there are only about 6 to 8. In addition, up to 1/3 of coot eggs harvested now have two yolks in them, the yolks are darker in colour and they have visible veins on them. Researchers have also investigated mercury levels in bird eggs in the PAD/Lake Athabasca. Hebert et al. (2011) report that mercury levels in gull eggs from Egg Island, Lake Athabasca increased 40% from 1977 to 2009, however the authors note "more research is required to evaluate temporal trends in levels of environmental contaminants and to identify sources" (Hebert et al. 2011, p. 1178).

In 2013, Hebert et al. report that mercury concentrations in gull eggs collected from the PAD and Lake Athabasca in 2012 were statistically greater than levels in eggs collected from earlier years. As part of the ongoing oil sands monitoring program, ECCC and partners continue to study contaminant levels in bird eggs from the PAD (and several other sites). Eggs have been collected annually from 2009-2017 (with the exception of 2010). Through this work, temporal trends in egg mercury levels are becoming clearer. For example, inter-year differences in egg mercury levels are apparent, but there are no clear temporal trends in egg mercury levels. However, recent research (Hebert, 2018, pers.comm.) indicates that annual egg mercury levels are affected by inter-year differences in the flow of the Athabasca River. Hebert et al. (2011, 2013) note that eggs collected from sites in closer proximity to the Athabasca River had greater levels of some contaminants and further commented that "changes in oil sands-related sources of Hg could be responsible for the egg Hg trends described here" (Hebert et al. 2013, p. 11791), but indicated the need for further corroboration of evidence. More recently, Dolgova et al. (2018) compared mercury levels in gull eggs from 12 sites in Alberta, Saskatchewan, and Northwest Territories spanning 14 degrees of latitude. They note that "egg Hg levels were greatest at sites in receiving waters of the Athabasca River", such as Mamawi Lake and Lake Athabasca (Dolgova et al. 2018, abstract), compared to more northerly or southerly sites. All of these egg results taken together provide evidence to support the hypothesis that the Athabasca River is an important source of contaminants, especially mercury, to downstream ecosystems (e.g. the PAD).

In response to the results from the JOSM monitoring program indicating relatively high mercury levels in gull and tern eggs, the Alberta Government issued egg consumption advisories for Lake Athabasca and Mamawi Lake. Alberta's Chief Medical Officer highlighted the fact that "if fish are regularly consumed from these lakes or from lakes where there is a fish consumption advisory in effect, no eggs should be consumed by children or adults" (Government of Alberta, 2014). This essentially precludes egg consumption by consumers of traditional foods because it is highly likely that anyone contemplating the consumption of eggs would also be eating fish.

5.13 BISON AND MOOSE

Bull Moose in Fall Rut, WBNP. Photo: Parks Canada

In brief, a number of researchers and Indigenous groups report the lower bison numbers stem from low water flows and a drying PAD (MCFN, 2017a, 2018a, 2018b; MCFN, 2016b; Candler et al., 2015a; Bill et al., 1996; Wrona et al., 1996). In 1996, Wrona et al. noted "the observed decline of wood bison in the PAD is implicated by the Indigenous people as being a result of drying in the delta" (p. 39). In the same year, Bill et al. (1996) also reported "low water flows are thought to have caused the decline in bison (buffalo) on the Peace-Athabasca Delta" (p. 333). The MCFN (2016b) report "bison are moving away from the Delta because habitat is drying out and being replaced with thistle" (p. 16) and "…buffalos are not around here now. That's because there's no water. They can't eat dried grass. They eat green grass…" (p. 33). Later, Candler et al. (2015a) report "key changes to bison habitat and bison populations in southern WBNP over time. Several MCFN participants indicated that the main herds of bison in the park are moving north. Knowledge holders connected this to a decrease in suitability of habitat south of Lake Claire because of invasive 'cactus like' thistles caused by lower water levels and the lack of seasonal flooding in the Athabasca Delta and especially around the south end of Lake Claire" (p. 32).

More recently, the Firelight Group et al. (2018) report "based on Indigenous knowledge and observation, MCFN members report that key stressors include invasive species (most importantly thistles) colonizing former bison habitat within WBNP, unregulated hunting by sport hunters and outfitters outside WBNP,

Its moose that I am trying to save! A moose has a better chance of surviving over a wolf when there is deep snow as the wolves can't catch up to them. What I am trying to say today, or bring back. Aside to the water, all these other animals. We are losing them.

Quote context: *You know, that is true that even the moose are less now. And when we go hunting at Birch River I found out that moose are going away because they have less feed. It's very hard for animals. And the moose are getting skinnier. And the buffalo are going away. If there is no water then there is no grass. If we have no water everything will be gone. If there is no water then there is nothing else. Animals are smart too. Wolves, if they try to jump on them on non-frozen snow they won't reach the moose. If they jump on packed snow, then it's like a spring on hard snow.*
Source: *Sloan Whiteknife*

No water then no willows. Moose won't eat dry willow! It has to be nice AND green. The moose eats another grass in fall where hardly no water. I don't know what it is called hey like it in fall. It's a grinder for the stomach after eating willows. There is no more of that now! All kinds of ways animals know!

Quote context: *Like I told you before, the moose won't eat dry willows. Another thing that moose eat in fall, its white stuff like can see it in grass. The moose eats that. In the prairie there is nothing of that so that is why moose left places here. They go further inland as in that muskeg they can eat that and the grass that buffalo like too. I'm pretty sure that is why the buffalo is gone to and moose are starting to leave the area around Birch River as there is better feed in the muskeg.*
Quote source: *Sloan Whiteknife*
About Sloan Whiteknife: *I am George Sloan Whiteknife. I was born and raised in the bush. Ever since then I've always been in the bush. I was taught from my dad to trap and to hunting moose, geese etc. I was always with him and he always used to tell me things. I learned quite a bit from my dad in my past life, and my uncles. I went out with all my relations. We need water. When I say something has to be done, I mean we need more water.*

as well as anthrax disease, noise disturbance, and climate change. BC Hydro regulation of river flows and low PAD water levels are considered to be primary factors resulting in alteration of bison habitats and decreased habitat suitability. MCFN members note secondary effects of bison decline, including the regulation and restriction of bison harvest by MCFN members and other First Nation and Métis communities, and imbalance of the predator-prey relationship between bison and wolves resulting in more disease within the bison and wolf populations. Reduced bison populations impact the MCFN way of life by reducing food security, altering sense of place, and removing the ability of future generations to hunt and maintain scared relationships through bison harvest" (p. 5-6).

Indigenous Knowledge holders describe a substantial decline in bison numbers in the PAD (MCFN, 2018a, 2018b; ACFN, 2018). The low water levels allow for encroachment of willows and thistle, forcing the bison to leave the PAD. This causes wolves to begin hunting other types of large game, such as moose, which is causing a dramatic reduction in moose numbers in the PAD and in a few other areas of the park (MCFN, 2018b; LRRCN, 2018). Moose inhabit the inland PAD lakes, back channels, and wetland areas in order to find young willows for food and to avoid being hunted by wolves. Due to low water levels, the moose are forced out of these areas and exposed to increased predation by packs of wolves, which are becoming dominant. Several participants also added when they attempt to call moose, they will not come into the area because they can hear the wolves (ACFN, 2018b, MCFN, 2018b). Since moose are a preferred food source for local Indigenous people, the decline of moose is of great concern.

5.14 FISH

As part of the Northern River Basins Study, Wrona et al. (1996) stated "traditional users report a decline in the quantity and quality of fish from the lower Peace and Athabasca Rivers, and from the PAD" attributed to contaminant exposure, a reduction in the availability of critical spawning and rearing habitat (resulting from changes in flow regime and flooding frequency), and/or over-fishing (p. 45). Specific to the Athabasca River, Candler et al. (2010) note that the local Indigenous community has seen a decrease in the Athabasca River water quality with time, including taste, smell, presence of foams and films on the water, and the absence of insects. Later, Candler et al. (2015b) further report Indigenous people's use of aquatic resources, including fishing, has been impacted along the Athabasca River and into the Athabasca portion of the PAD, including "contaminants, fish deformities, and changes in fish quality and taste" (p. 109). Further, the authors note "current (wildlife) harvest levels have been impacted by industrial change and contaminant concerns, and that existing levels of harvest reflect an unacceptable level of impact on the ability of Mikisew families to rely on lands and waters for subsistence and cultural use. Knowledge holders also indicated concern that, with existing levels of industrial impact and concern, many Mikisew families and young Mikisew members are not able to learn the knowledge and skills necessary to carry on harvesting into the future" (Candler et al., 2015b, p. 95).

Now we see changed vegetation and oily sheen on lakes on a calm day. When you slide out your fishing nets, there is a different smell from net, deformed fish, spotted fish, heads huge but body is skinny, a lot of deformed fish.

Quote Context: *The biggest change I have seen in vegetation is the Canada thistle and sow thistle. Because the delta is so low and dry, this invasive species of grass came in and took over natural native species of grass. No animals feed on it. And the bison, muskrat, moose depend on the vegetation and water. It is changing their routes and migration. In the past the delta and the food was healthy. The fish was healthy. They used to commercial fishing in lake Athabasca, Lake Claire, and the PAD in the 50's. So there were healthy fish and the market for it was there. Whitefish and Pickerel were fished in Lake Athabasca and Lake Claire. They shut that down. There is no more commercial fishing so that tells me something is happening as well too. The change in fish health as well there, as people are turned away from eating fish from there.*
Source: *Ron Campbell*
About Ron Campbell: *I was born in Fort Chip. I have and still do spend a lot of time in the delta. I've been trapping muskrats since I was a kid. And I do spring hunts and moose hunting etc. Everything I got was once natural and country food. We spent a lot of time in the bush, and learned about life from the traditional users.*

Candler et al. (2015b) report "fishing for species including goldeye, jackfish, whitefish, pickerel, suckers, and mariah remains important to many Mikisew members for social, economic, cultural, spiritual and other purposes. When conditions are appropriate, fishing provides a critical and reliable source of protein, especially in the winter and early spring when it's most needed...(and) in the past, fish were a critical source of food when other kinds of food (e.g. moose, bison, caribou) were scarce" (p. 108). Fish populations and ecology in the PAD, however, are reportedly being affected from low water levels and lack of recharge, and Indigenous Knowledge holders describe numerous instances of recent fish kills in the PAD caused by stagnant water, a lack of oxygen in the water, and lakes freezing right to the bottom (MCFN, 2018b; Métis Local 125, 2017a).

Wrona et al. (1996) report “the drying up of the channels, perched lakes and marshes has directly affected fish ecology: both wintering and spawning habitat have been altered or lost” (p. 39). Loo (2007) also report “fewer channels for Walleye to reach their spawning grounds and for juvenile fish to reach important nursery areas. If they got there, there was often less food available for them, further compromising their survival” (p. 904, citing Green, no date). The MCFN (2016b) also report “the fish, the numbers of fish and that in our areas have dwindled. One of our Elders still has a net out in the traditional land, depends on that, and yet he’s having a hard time getting enough for himself” (p. 33). With regard to siltation and sedimentation effects, the MCFN report “the substantially lowered waters of the Athabasca River results in the build-up of silt that prevents fish from entering Lake Claire and Jackfish Lake to spawn” (MSES, 2010, p. 19). More recently, the MCFN (2016b) also note “some elders have observed that silt is not washed into or through the lakes the same way as pre-regulation which has spillover effects on ice jamming, fish spawning and habitat availability. Some fish (Goldeye) are not able to spawn the same way because channels and lakes have silted in. Lake Mamawi began to silt in, which in turn, impacts the spawning of fish, such as Jackfish, as there are fewer shallows for them to spawn in” (p. 30).

Contaminant and Nutrient Levels

Candler et al. (2015b) report “fish are considered an especially sensitive indicator of the health of an area” (p. 108) and note “Mikisew members have widespread concerns regarding the health of fish, and the safety of eating them. These widespread concerns have resulted in most Mikisew members now limiting or avoiding harvest or consumption of fish from the Athabasca River and many becoming distrustful of fish caught in the wider PAD” (p. 109). However, there is currently no long-term contaminant monitoring program for fish in western Lake Athabasca, Mamawi Lake, or Lake Claire, despite the fact that fish are important in local diets and there has been an intermittent commercial fishery.

A number of researchers also report an increased prevalence of malformations and deformations in fish resulting from water quality changes in the Athabasca River and the PAD (McLachlan, 2016; Maclean, 2016; Timoney, 2013; Candler et al., 2010; Bill et al., 1996). In 1996, Bill et al. reported “in recent years, the jackfish in the Pine Creek area have begun to exhibit wart-like growths and their blood vessels appear more blue (in) colour. Fish livers and intestines historically were eaten regularly by the Indigenous people in the Delta area. However, in recent years, the livers of fish have had spots, growths, and inconsistent colour and the intestines have a very yellow liquid in them. As a result, these parts of the fish are now only rarely eaten by the people in the area” (p. 335-336). More recently, Candler et al. (2010) further observe that the decrease in Athabasca River water quality has resulted in physical abnormalities in hunted game and fish, which has caused loss of subsistence use of the Athabasca River for Indigenous people and Timoney (2013) also reports “increased rates of fish abnormalities have been observed by local fishermen” (p. 432). Maclean (2016) reports “increase(s) in observations of deformed fish” (p. 3) in the PAD. McLachlan (2016) also compiled comments from Traditional Knowledge holders in the PAD, including “I have quit eating fish, I will not eat fish from Lake Athabasca” (p. 32) and note that many Indigenous people in the PAD are worried about environmental contaminants in the traditional foods that they consume.

More recently, as part of the ongoing JOSM program, ECCC (2018) studied contaminant levels in fish in the PAD from 2012 to 2018. Of the 23 fish collected, "55% of them had visible skin and/or liver lesions as well as other physical signs of impaired health" and "pickerel often had the greatest number of malformations and skin lesions, perhaps a reflection of their diet as top carnivores" (p. 2). However, it is unclear if this result is statistically significant due to the small sample size. The Firelight Group et al. (2018) also report a negative trend in quality and quantity of fish in the PAD "related to the decline of water quality and quantity within the PAD resulting from BC Hydro regulation of flow and contamination from upstream development, as well as potential sediment build up around weirs. MCFN members have observed changes in the taste and color of fish, deformities, the inability of fish to access spawning sites due to siltation and low water, and low water level induced fish kills. In addition to deformities and poor taste or texture, there are also concerns for high levels of mercury and other PAD contaminants within fish resulting in avoidance by many MCFN members due to potential contamination and health concerns" (p. 6).

A number of scientists also report increasing contaminant and nutrient levels in fish in the lower Athabasca River and the PAD, such as nitrogen, phosphorus, mercury, PCBs, and PAHs (Dolgova et al., 2018; Baird et al., 2016; Culp, 2016; Ohiozebau et al., 2016; Timoney, 2007; Scheider et al., 1998; Wrona et al., 1996; Suns et al., 1993). Wrona et al. report, from 1977 to 1992, mean total mercury levels in walleye were high in the lower end of the Athabasca River. Timoney (2007) also notes "mercury levels in fish used for human consumption present a serious concern. If US EPA standards are applied, all walleye (pickerel), all female whitefish, and ~90 % of male whitefish exceed subsistence fisher guidelines for mercury consumption" in the lower Athabasca River (p. 4).

Small fish or minnows are good indicators of local contaminant sources (Suns et al., 1993; Scheider et al., 1998). A joint ECCC and Mikisew Cree CBM study of minnows in the Athabasca River (both up and downstream of oil sands surface mines), the PAD, and Lake Athabasca found that mercury levels were highest in fish collected in the Athabasca River immediately downstream of Fort McMurray and oil sands operations, remained somewhat elevated in Mamawi Lake fish, and were lower in Lake Claire and western Lake Athabasca. However, minnows from all of these locations had higher mercury levels than fish from a reference location upstream of Fort McMurray (near Athabasca, AB) on the Athabasca River (Dolgova et al., 2018). The authors note "elevated levels in fish from Mamawi Lake may have reflected that site's closer connection with the Athabasca River or other processes regulating the bioavailability of mercury at that site, e.g. Hg methylation" (Dolgova et al. 2018, p. 16). In response to increasing mercury levels in fish, the Alberta Government set fish consumption limits for a number of lakes and rivers in Alberta, including the Athabasca River (downstream of Fort McMurray), Lake Athabasca, and Richardson Lake (2018, from https://mywildalberta.ca/fishing/advisories-closures/documents/FishConsumptionLimitsAlberta-Feb24-2016.pdf).

In 1996, Wrona et al. reported "anomalously high levels of PCBs were observed in burbot collected…in the Athabasca River downstream of Hinton…and in the Peace River above the confluence of the Smoky" (p.36). More recently, Culp (2016) notes municipal effluents, urban runoff, camp effluent, and land clearing for oil sands operations have contributed to increased nutrients (N and P) in the lower Athabasca River, which have led to increased fish size and body mass index changes in fish. Similarly, Baird et al. (2016) report an increase in condition factor (fish weight), liver size, and PAC levels in fish in the

Athabasca River downstream of oil sands development that may be related to nutrient enrichment and contaminants. Gewurtz et al. (2011) also report Canadian Federal Environmental Quality Guideline exceedances for polybrominated diphenyl ethers (PBDEs) in lake trout from Lake Athabasca, however they note similar exceedances were found in lakes across Canada. More recently, ECCC (2018) report "fish mercury levels were slightly higher in the PAD (at 0.26 ppm on average), but not significantly different than fish collected further south in Lac La Biche, Alberta" (p. 2). In addition, ECCC notes in "2013 minnow samples, mercury levels were higher in fish collected in the surface mineable area of the oil sands in the Athabasca River…(and) levels measured in Mamawi Lake were intermediate" (p. 5).

A number of researchers have found increased PAC and PAH levels in a variety of fish species in the Athabasca River and the PAD. Culp (2016) reports that pre-mining land clearing and oil sands operations have contributed to increased PACs and Ethoxyresorufin-O-deethylase (EROD) activity, a well-established biomarker of fish exposure to certain classes of PAH compounds, in fish in the lower Athabasca River. Ohiozebau et al. (2016, 2017) studied PAH concentrations in Goldeneye, Whitefish, Northern Pike and Burbot species in the Athabasca and Slave Rivers from the summer of 2011 to the spring of 2012, including Fort McMurray, Fort McKay, Fort Chipewyan, Fort Smith, and Fort Resolution. They found measurable concentrations of PAHs (both spatially and temporally) in all of the fish species studied and note "fishes from upstream reaches of the Athabasca River, close to oil sands extraction and upgrading activities, contained greater concentrations of individual PAHs than concentrations in muscle of fishes from further downstream in the Slave River" (2017, p. 1). Ohiozebau et al. (2016) further note "facilities where oil sands are processed are located just upstream from Fort McKay, which could explain why Fort McKay and Fort Chipewyan had greater concentrations of the sum of PBPAHs (products of biotransformation of PAHs) that were studied" (p. 586). However, the authors note, in addition to aerial deposition of PAHs from processing of oil sands, the source of PBPAHs in the study area might also be from municipal runoff effluents, from incomplete combustion of organic matter and fossil fuel, or forest fires (Ohiozebau et al., 2016) and Ohiozebau et al. (2017) further report PAH concentrations in fish in the Athabasca and Slave Rivers are "likely not a health risk to human consumers in the area" (2017, p. 17).

On the other hand, a number of scientists report no evidence that increasing oil sands activity has influenced a detectable increase in PAH and metal concentrations in the PAD and western Lake Athabasca (Hall et al. 2012b, Wiklund et al. 2012, Jautzy et al. 2015b, Evans et al. 2016). In addition, Evans (no date) reports mercury trends in fish in western Lake Athabasca, including in walleye, lake trout, northern pike and burbot, were below commercial sale guidelines and the author further notes "there was no evidence of increasing Hg concentrations with the expansion of the oil sands industry" (p. 1). Further, Evans and Talbot (2012) conducted a review of all available data for mercury in fish from the Athabasca River north of Fort McMurray to the PAD, as well as western Lake Athabasca, concluding there was no evidence that oil sands activities were resulting in increased mercury concentrations in fish. The authors note "while mercury emissions rates have increased with oil sands development and the landscape become more disturbed, mercury concentrations remained low in water and sediments in the Athabasca River and its tributaries and similar to concentrations observed outside the development areas and in earlier decades", although the authors note future monitoring programs should be more rigorous in their design (Evans and Talbot, 2012, p. 1989).

5.15 CONCLUSIONS

5.15.1 Stressors and Trends

The proceeding sections describe the current state of the PAD system as a result of trends and stressors observed over the past sixty years on various valued components in the PAD, as reported by researchers, scientists, and Indigenous knowledge holders. These results are summarized and presented below in Table 5-3.

Table 5-3: Current Stressors and Trends in the PAD

Valued Component	Current Trends and Stressors in the PAD	Trend Direction
Peace River Seasonal Flows	Seasonal flow rates in the Peace have become much less variable due to flow regulation on the river and (past) climate change, resulting in decreased summer flows and increased winter flows.	↓
Peace River Sedimentation	Sedimentation in the Peace River is increasing due to the reduced erosional force of the river resulting from changes in flow regime.	↓
Ice Jam Recharge	Increased winter flows on the Peace River have increased freeze up elevations, resulting in decreased ice jamming flooding frequency, and reduced recharge of perched water basins. Winter releases of water have resulted in poorer quality ice.	↓
Open Water Recharge	Reduced summer flows in the Peace River and reduced flows in the Athabasca, in combination with (past) climate change, have decreased open water recharge.	↓
Lake Athabasca Water Levels	Reduced summer flows on the Peace and reduced seasonal flows on the Athabasca have decreased water levels in Lake Athabasca. Weir operation has increased winter water levels and produced a less variable water regime.	↓
Central PAD Lake Water Levels	Reduced summer flows on the Peace and reduced seasonal flows on the Athabasca, in conjunction with (past) climate change, have decreased water levels and extents.	↓
Athabasca River Annual & Seasonal Flows	Annual and seasonal flows have declined over the past fifty years due to a combination of water withdrawals and (past) climate change.	↓
PAD Water Quality	ITK indicates decreased water quality over the long term, while the WQI indicates a consistent 'Fair' trend over the last 6 years.	↓ →
Athabasca River Water Quality	Increasing concentrations of magnesium, sodium, dissolved aluminum, total selenium, dissolved iron, dissolved arsenic, and PAHs and PACs have reduced water quality.	↓
Groundwater Quality & Quantity	Information is limited. It is unclear if groundwater quality and quantity are issues.	?
Air Quality	ITK and science indicate contaminants from industrial sources and forest fires have reduced air quality at certain times of the year.	↓

Valued Component	Current Trends and Stressors in the PAD	Trend Direction
Sufficient Water for Indigenous People to Navigate Safely in the Exercise of their Treaty & Aboriginal Rights	Winter water releases on the Peace River have resulted in reduced quality and quantity of ice, reducing or eliminating access to areas of the PAD in winter. Lower water levels have reduced or eliminated access to the inland PAD lakes and back channels. Flow rates on the Athabasca River are consistently below the ABF, below the AXF in early spring, and approaching the AXF in fall, preventing and/or limiting access to traditional lands during early spring and fall hunting season.	⬇
Indigenous Access and Enjoyment of the PAD	Decreased quality and quantity of fish, increased exposure to toxins and pathogens, films, and foams on water. Inability to transfer knowledge and skills between generations	⬇
Wildlife Quantity and Habitat	Reduced water levels have caused drastic declines in muskrat populations. Reduced water levels and increased invasive species have caused declines in bison populations. Increased winter water releases have caused decreases in beaver and muskrat populations.	⬇
Migratory Bird Quantity, Quality and Habitat	Lowered water levels have reduced water bird habitat, causing water birds to shift their migratory patterns. Increased mercury levels have been found in bird eggs, resulting in consumption advisories.	⬇
Vegetation Quantity and Quality	Lowered water levels have increased vegetation cover and invasive species, such as thistle and willows. Lowered water levels have reduced availability of medicinal and food plants.	⬇
Fish Quantity, Quality and Habitat	Lowered water levels have reduced fish populations and habitat. Water quality changes have produced malformations and abnormalities and increased contaminant levels in fish. Increased mercury levels have been found in fish, resulting in consumption advisories. Silting of PAD lakes has affected fish spawning.	⬇

5.15.2 Pathway of Effects

As shown in Table 3-2, the three desired outcomes for the PAD are as follows:

- Flow regimes and water quality into the PAD maintain the ecological function of the ecosystem.
- Flow regimes and water quality into the PAD sustain vegetation communities and healthy and abundant populations of key ecological and cultural species including waterfowl, muskrat, fish, bison and wolves.

- Indigenous groups have access to the PAD and are confident enough in the health of the PAD to maintain traditional use and way of life through hunting, fishing, gathering, and cultural activities.

Based the current trends in the PAD as outlined in Table 5-3, none of the three desired outcomes are currently being achieved and the trend direction is negative. With regard to the desired outcome that flow regimes and water quality into the PAD maintain the ecological function of the ecosystem, the trend direction was based on the valued components of:

1) Peace River seasonal flows;
2) Peace River sedimentation;
3) Ice jam recharge;
4) Open water recharge;
5) Athabasca River annual and seasonal flows.

The trend direction for all of these valued components is negative, thus the desired outcome is not currently being achieved and the trend direction for the desired outcome is negative.

With regard to the desired outcome that flow regimes and water quality into the PAD sustain vegetation communities and healthy and abundant populations of key ecological and cultural species including waterfowl, muskrat, fish, bison and wolves, the trend direction was based on the valued components of:

1) Lake Athabasca water levels;
2) Central PAD lake water levels;
3) PAD water quality;
4) Athabasca River water quality;
5) Wildlife quantity and habitat;
6) Migratory bird quantity, quality and habitat;
7) Vegetation quantity and quality; and
8) Fish quantity, quality and habitat.

The trend direction for all, except one mixed trend, of these is negative; thus the desired outcome is not currently being achieved and the trend direction for the desired outcome is negative.

Finally, with regard to the desired outcome that Indigenous groups have access to the PAD and are confident enough in the health of the PAD to maintain traditional use and way of life through hunting, fishing, gathering, and cultural activities, the trend direction was based on the valued components of:

1) Sufficient water for Indigenous people to navigate safely in the exercise of their Treaty and Aboriginal rights; and

2) The implications of the above desired outcomes not being met result in inadequate resource quantity and quality needed for traditional way of life and Indigenous access and enjoyment of the PAD.

The trend direction for these valued components is negative, thus the desired outcome is not currently being achieved and the trend direction for the desired outcome is negative.

From a holistic systems perspective, the activities and pressures that influence the PAD valued components, along with the resulting effects, are illustrated below in Figure 5-14. The overall effect of human activity, such as Peace River regulation, Athabasca River withdrawals, and climate change, influences valued components of the PAD, including Peace River flows, ice jam and open water recharge, and Athabasca River flows and water quality. These changes then affect other PAD valued components, including water levels and extents, sedimentation and sediment quality, and vegetation and habitat, as well as fish, wildlife, and migratory bird populations, all of which impact local Indigenous people's health and welfare and access to traditional lands, and ultimately the world heritage value of the PAD.

Indigenous Knowledge holders underscore the importance of the PAD to their culture and way of life (MCFN, 2018a, 2018b). The people were born on the land and they want to continue to live on the land. Indigenous people are proud of the traditions and culture they have lived for thousands of years. ITK has been passed down from generation to generation, and it is now being lost because the PAD is drying. If people cannot access their traditional lands to hunt, fish, trap, and collect plants, berries, and eggs, they lose their connection to the land and to their culture. For Indigenous people, the land is their school and the Elders are the teachers. They bring their children and grandchildren to their land to teach them the ways of their people. If they cannot access the lands they know intimately and have lived on for many past generations, they cannot pass on important traditions and stories to future generations.

Indigenous Knowledge holders also emphatically stress the PAD needs more water to support life (ACFN, 2018a; MCFN, 2017a, 2018a, 2018b; Métis Local 125, 2017a). The local Indigenous people want a more natural water cycle restored, with more water coming into PAD in the spring and summer and less in the winter, like the natural cycle has always been. If the water comes back, the local people hope the animals, plants, birds, and fish will return and the natural balance of the system will be restored. Then they can continue to live on the land where they are happy, healthy, and proud, and where they can pass their ITK, culture, and identity on to future generations and preserve their homelands and their way of life for the future.

The PAD depends on recharge of its lakes and basins in order to retain its world heritage value as an internationally significant rare and superlative natural phenomenon. Currently, hydrologic recharge in the PAD is decreasing. Without immediate intervention, this trend will likely continue, and the world heritage values of the PAD will be lost.

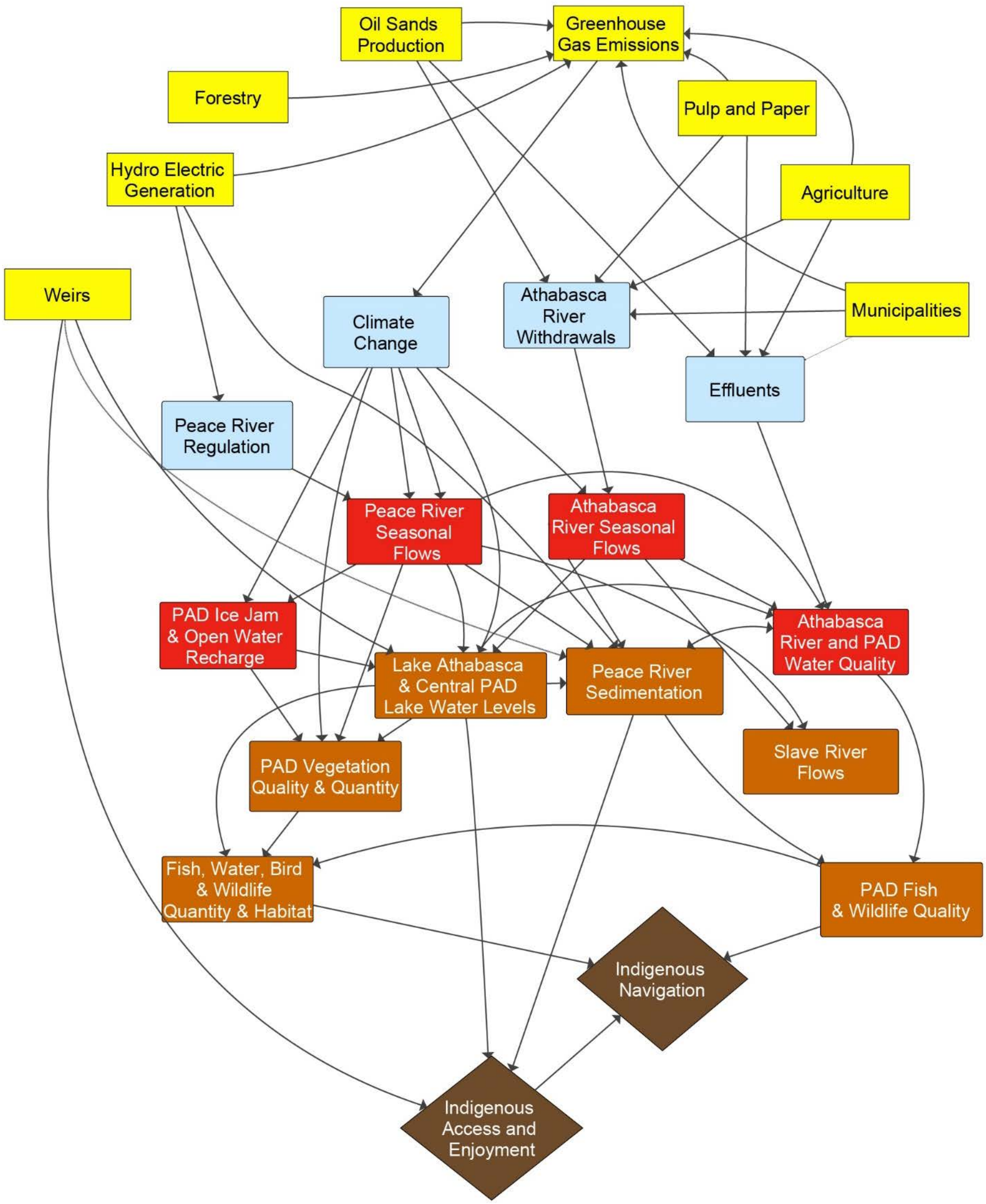


Figure 5-14: Pathways of Effects System Diagram

6.0 CHAPTER 6: CUMULATIVE EFFECTS ASSESSMENT ON THE WORLD HERITAGE VALUES OF THE WBNP

6.1 INTRODUCTION

This chapter considers the future challenges to the world heritage values that industrial development and climate change around WBNP could generate. This chapter begins with identifying existing, proposed and reasonably foreseeable activities that could impact world heritage values. The second section examines predicted impacts of climate change specifically on the PAD. The chapter concludes with a high-level projection of cumulative effects trends that combines both foreseeable industrial development and climate change, in the context of understanding some of the tools intended to manage cumulative effects on the World Heritage Values.

6.2 EXISTING, PROPOSED, AND REASONABLY FORESEEABLE ACTIVITIES WITH THE POTENTIAL TO AFFECT THE WORLD HERITAGE VALUES OF WBNP

In order to assess the effects stemming from future development on the world heritage values of WBNP, the existing, proposed, and reasonably foreseeable future developments in the WBNP area with the potential to affect the world heritage values of the WBNP were identified. As outlined in the SEA scope of work request, relevant development in the region with the potential to impact WBNP includes hydroelectric development and oil sands development, as well as pulp and paper facilities, industrial mines, forestry activities, and municipal development. Relevant information for these projects was then reviewed and compiled, as detailed below.

6.2.1 Hydropower Projects on the Peace River

6.2.1.1 Existing Projects

The WAC Bennett Dam is a 2,730 Megawatt (MW) capacity earth fill dam operating on the Peace River since 1968 and the Peace Canyon Hydroelectric Dam is a 694 MW capacity concrete dam operating since 1980 (2017, from https://www.bchydro.com/energy-in-bc/operations/our-facilities/peace.html). The Bennett and Peace Canyon dams are located on the Peace River in northeastern British Columbia, west of Hudson's Hope. The Peace Canyon dam is located 23 km downstream of the Bennett dam on the Peace River. The two hydroelectric facilities have a total capacity of about 3,424 MW and the combined power from the Peace region facilities averages about 17,500 GWh/year (38% of BC Hydro's total 46,000 GWh) (BC Hydro, 2018). The Bennett Dam is one of the world's biggest earth fill dams, standing 183 m (660 ft) high, 800 m wide, and 2 km long (Mackenzie and District Museum, 2016). The spillway capacity of the dam is 9,205 m^3/s. The Williston reservoir covers a total area of 1,761 km^2 (251 km long and 155 km at its widest point), making it the largest lake in British Columbia and the seventh largest reservoir (by volume) in the world. Filling of the reservoir from 1968 to 1971 flooded the Parsnip, Finlay, and Peace River valleys upstream of the dam.

6.2.1.2 Approved Projects

Site C (BC Hydro) is a 1,100 MW capacity earth fill hydroelectric dam currently under construction in British Columbia. As shown by a red arrow in Figure 6-1, it is located 85 km downstream from the Peace

Canyon Dam and approximately 115 km downstream from the W.A.C. Bennett Dam. Site C will be the third dam and generating station on the Peace River in northeast BC and will provide 5,100 GWh of energy each year. Site C "will gain significant efficiencies by taking advantage of water already stored in the Williston Reservoir. This means that Site C will generate approximately 35 per cent of the energy produced at W.A.C. Bennett Dam, with only five per cent of the reservoir area" (Site C Clean Energy Project, 2017).

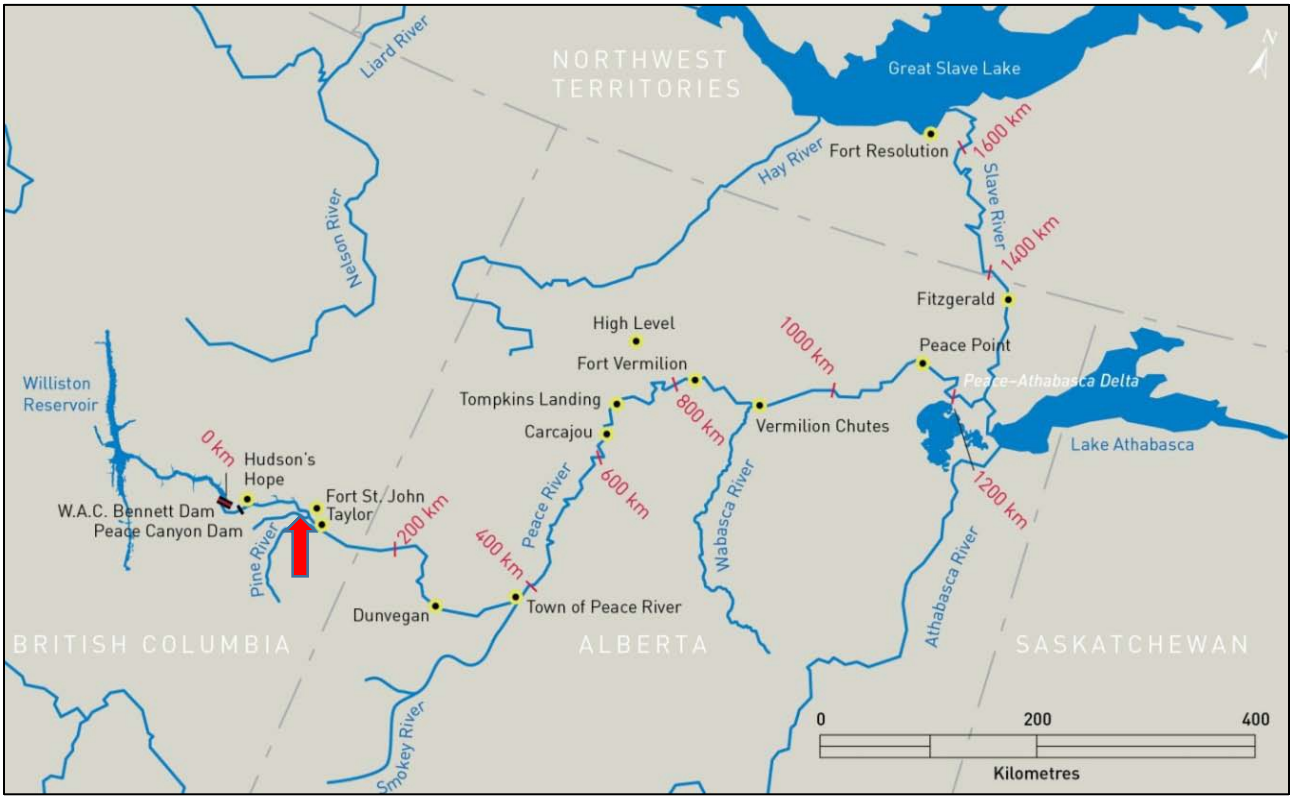


Figure 6-1: Map of the Peace River (BC Hydro, 2016).

Note: The red arrow shows the location of the Site C dam, currently under construction

The Dunvegan Hydroelectric Project (Glacier Power) is a 100 MW capacity run-of-river (ROR) project located near Dunvegan, AB (shown in Figure 6-1). It was approved through the Federal Environmental Assessment process in 2008, but will likely not be constructed due to geotechnical issues with the proposed site location. The proposed project is a low-head, run-of-river hydroelectric development, including a powerhouse, a seven bay control weir, two rock-fill ramp fishways, seven fish sluiceways, and a navigation lock (Northwest Hydraulic Consultants, 2018).

6.2.1.3 Reasonably Foreseeable Projects

The Amisk Hydroelectric Project (Concord Green Energy) is a 370 MW capacity run-of-river project near Dunvegan, AB. The Federal government has referred the proposed project to an independent review panel and an Environmental Impact Statement is not expected until 2020. The consideration of the potential effects of the project on the world heritage of the park, including the PAD, will be considered in the assessment. The Amisk facility is proposing to operate with a limited extent of active storage (i.e., less than 48 hours retention time in the reservoir, which is a slower and deeper upstream section of water created by the presence of the hydroelectric facility). The head pond would extend roughly 77 km upstream. The water level at the dam would be raised approximately 24 m by the structure and river flows would pass through powerhouses equipped with turbine units to generate electricity, or released through a spillway during times of high water flow (Amisk Hydroelectric Project, 2015).

6.2.2 Hydropower Projects on the Athabasca River

6.2.2.1 Existing Projects

No hydroelectric projects currently exist on the Athabasca River.

6.2.2.2 Proposed Projects

Proposed hydroelectric projects in the area include **Innergex's Sundog and Pelican** projects located on the Athabasca River upstream of Fort McMurray. Alberta Environment and Parks has determined that, in compliance with the Alberta *Environmental Protection and Enhancement Act*, an Environmental Impact Assessment (EIA) is required (NRCB, 2017). The proposed projects were also recently determined to be designated projects by the federal Minister of Environment and are subject to review under the Environmental Assessment process of the *Canadian Environmental Assessment Act, 2012*. On January 19, 2018, the Canadian Environmental Assessment Agency (the Agency) received correspondence from (Innergex) that they "do not intend to carry out either the Sundog or Pelican Renewable Generation Station (RGS) Projects and requested that the Agency end the federal environmental assessment process" (Teague, 2018).

6.2.3 Oil Sands Projects in the Athabasca River Basin

The Regional Aquatics Monitoring Program described the geology of the oil sands region as follows (RAMP, n.d.): "The Athabasca oil sands deposit is the largest Cretaceous oil sands deposit in Alberta, covering an area of about 46,000 km^2 (Conly et al., 2002). Most of the bitumen deposits are found in the McMurray Formation, a layer of shale, sandstone, and oil-impregnated sands formed during the Cretaceous period by river and ocean processes. The McMurray Formation, up to 150 m thick, lies over a layer of shale and limestone (the Devonian Waterways Formation) and beneath the Clearwater Formation, a layer of marine shale and sandstone. The McMurray Formation overlies a landscape of valleys and ridges. The Formation is almost absent where the Devonian layer rises in a ridge, cutting through the McMurray Formation. North of Fort McMurray the Formation can be found within 75 m of the surface and is exposed at the surface where the Athabasca River and its tributaries have incised into the landscape. The McMurray Formation is first exposed in the Athabasca riverbed at Boiler Rapids, 50 km upstream of Fort McMurray, and again near the MacKay River (Conly et al., 2002). Oil sands exposed at the earth's surface are a widespread natural source of hydrocarbons entering the aquatic ecosystems of the area."

There are currently 37 oil sands facilities operating in the Athabasca River Basin (ARB), with an additional 47 projects proposed, in construction, under regulatory review, or recently announced (Alberta Energy, 2017). There are 3 operating upgraders in the ARB, with an additional facility approved and 2 at the application stage. All of these projects are located in the Athabasca River drainage basin, which flows directly in to the southeast corner of the PAD in the WBNP.

6.2.3.1 Existing Projects

Existing oil sands projects and upgraders located within the ARB are presented below in Figure 6-2 and Table 6-1 and Table 6-2. The numbers for individual projects shown in Figure 6-3 correspond to the project details given in Table 6-1 and Table 6-2. As of September 2017, there are currently 38 oil sands facilities producing bitumen and/or oil sands product as of the last period (Alberta Energy, 2017). Approximately half of the existing oil sands projects are thermal in-situ projects. Three operating oil sands upgraders also exist in the Athabasca River basin (2017, from (http://www.energy.alberta.ca/LandAccess/pdfs/OilSands_Projects.pdf).

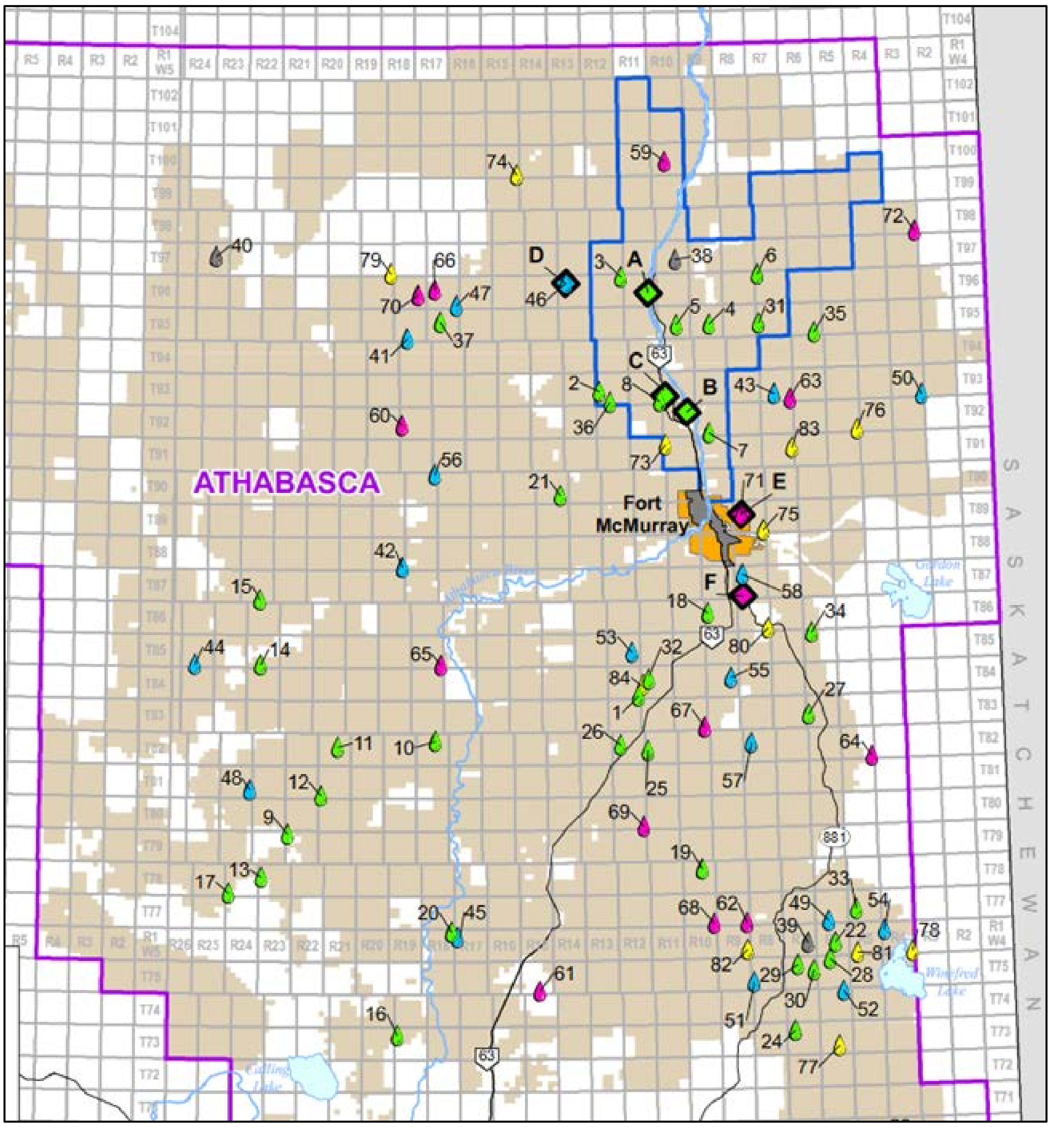


Figure 6-2: Alberta's Oil Sands Projects and Upgraders in The Athabasca River Basin Area (as of Sept. 2017, Alberta Energy).

Notes: Blue Outline: Surface Mineable Oil Sands Area, Diamonds (upgraders), Oil Drops (oil sands projects), Green (operating), Blue (approved), Grey (under construction), Pink (application stage), Yellow (announced).

Table 6-1: List of Operating Athabasca Oil Sands Projects (as of Sept. 2017, Alberta Energy)

Facility	Owner	Facility Name	Facility Type	Status
1	N-Solv Corporation	Suncor Dover Lease Pilot	Experimental	Operating
2	Suncor	Dover Demonstration	Experimental	Operating
3	CNRL	Horizon	Mining	Operating
4	CNRL	Jackpine Mine	Mining	Operating
5	CNRL	Muskeg River Mine	Mining	Operating
6	Imperial Oil	Kearl	Mining	Operating
7	Suncor	Suncor Oil Sands	Mining	Operating
8	Syncrude	Syncrude Mine	Mining	Operating
9	Bronco Energy	Brintnell 9774	Primary	Operating
10	CNRL	Pelican Lake III	Primary	Operating
11	CNRL	Brintnell	Primary	Operating
12	CNRL	South Brintnell	Primary	Operating
13	CNRL	South Wabasca	Primary	Operating
14	CNRL	Wabasca North	Primary	Operating
15	CNRL	Woodenhouse	Primary	Operating
16	Husky	Amadou	Primary	Operating
17	Husky	McMullen Primary Heavy Oil	Primary	Operating
18	Athabasca Oil Sands	Hangingstone	Thermal	Operating
19	Athabasca Oil Sands	Leismer Demonstration Project	Thermal	Operating
20	Black Pearl Resources	Blackrod SAGD Pilot	Thermal	Operating
21	Brion Energy	MacKay River Commercial Project	Thermal	Operating
22	Cenovus	Christina Lake Thermal	Thermal	Operating
23	Cenovus	Foster Creek	Thermal	Operating
24	CNRL	Kirby South	Thermal	Operating
25	Connacher	Algar	Thermal	Operating
26	Connacher	Great Divide	Thermal	Operating
27	Conoco Phillips	Surmont	Thermal	Operating
28	Devon	Jackfish SAGD Thermal Project	Thermal	Operating
29	Devon	Jackfish 2 SAGD Thermal Project	Thermal	Operating
30	Devon	Jackfish 3 SAGD Project	Thermal	Operating
31	Husky	Sunrise Thermal	Thermal	Operating
32	JACOS	Hangingstone Expansion Project	Thermal	Operating
33	MEG Energy	Christina Lake Regional	Thermal	Operating
34	Nexen	Long Lake	Thermal	Operating
35	Suncor	Firebag	Thermal	Operating
36	Suncor	MacKay River	Thermal	Operating
37	Sunshine Oilsands	West Ells	Thermal	Operating
38	Suncor	Fort Hills Oil Sands Project	Mining	Start-up

Table 6-2: List of Operating and Approved Athabasca Upgraders (as of Sept. 2017, from Alberta Energy)

Facility	Owner	Facility Name	Facility Type	Status
A	CNRL	Horizon	Upgrader	Operating
B	Suncor	Base and Millennium	Upgrader	Operating
C	Syncrude	Mildred Lake	Upgrader	Operating
D	BP P.L.C.	Terre de Grace Pilot	Upgrader	Approved
E	Value Creation	Advanced Tri-Star	Upgrader	Application
F	Value Creation	Demonstration of Excellence (DOEx)	Upgrader	Application

Oil Sands Production

Bitumen from the oil sands in Alberta is produced mainly through conventional open pit surface mining and thermal in-situ techniques. In conventional surface mining, large trucks and shovels are used to extract a mixture of bitumen, sand, and clays, while in-situ techniques inject steam into the reservoir to heat the bitumen so it can be pumped to the surface (Suncor, 2018). Only 20% of all oil sands are close enough to the surface to be mined and thermal in-situ bitumen production is expected to surpass production from surface mining in the next few years (Oil Sands Magazine, 2018a).

There are two common thermal in-situ techniques employed in the oil sands, including Cyclic Steam Stimulation (CSS) and Steam-Assisted Gravity Drainage (SAGD) (Oil Sands Magazine 2018a). Both CSS and SAGD have identical central processing facilities, however they have different positioning and number of wellheads. In-situ facilities consist of the following basic unit operations, as follows (Oil Sands Magazine, 2018a):

- A series of well pads scattered throughout the oil sands deposit;
- A steam and power generation plant which provides power for the facility and high-pressure steam for injection into the wellheads;
- A central processing plant where the oil and water emulsion produced at the injection wells is separated;
- A water treatment plant where the recovered water is cleaned and recycled back into the process; and
- A product storage facility where the bitumen is diluted with condensate for storage and transportation via pipeline.

An in-situ processing plant is generally much smaller and simpler than an oil sands mining facility. However, bitumen can only be extracted in-situ if the oil sands deposit is deep below the surface. Most in-situ deposits lie at least 200 meters below grade.

Primary production of bitumen is a method most similar to conventional oil wells and requires no steam. Primary oil recovery is the first phase, which happens once a well has been drilled from the surface to an underground reserve. Gravity, along with the pressure inside the reservoir, forces the oil into the wellbore. From the wellbore, the oil is brought to the surface through mechanical means, such as a pump jack. The primary phase of oil recovery continues until the pressure inside the well is no longer enough to produce oil in quantities that make it financially worthwhile. Primary production facilities are small scale projects (K. Zariffa, pers. comm., 2018).

Oil Sands Water Use and Waste Production

Conventional mining operations use warm water and alkali to separate the bitumen from the sand and clay, while in-situ drilling operations use water to generate steam to heat the bitumen reservoir to enable it to flow to production wells. On average, in-situ operations require 0.4 barrels of fresh water for every barrel of bitumen produced, while conventional mining requires, on average, 3.1 barrels of fresh water for every barrel of bitumen produced (CAPP, 2018). Oil sands mining operations in northern Alberta recycle over 80 to 95% of the water they use. The Athabasca River is the primary source of fresh water for the oil sands, however in order to further decrease fresh water consumption, some producers use brackish or saline groundwater as an alternative to fresh water. In some in-situ projects, fresh water is entirely replaced with non-fresh water (CAPP, 2018).

Conventional oil sand mining activities result in the accumulation of large amounts of residual waste known as tailings, which contain a mixture of water, clay, unrecovered bitumen and solvent, and dissolved chemicals, including some organic compounds that are toxic to the environment (NRCAN, 2016). These tailings are stored in large ponds, where the solids settle to the bottom and remain as mud in the ponds almost indefinitely. The water released from the ponds can be recycled and reused in oil sands processing. As shown in Figure 6-3, all tailings ponds have groundwater monitoring facilities that are designed to capture and recycle material that may seep from the ponds and producers are also required to take steps to prevent waterfowl from landing in the tailings ponds (Government of Canada, 2015). In-situ oil sands operations do not produce tailings and do not require large waste storage facilities such as tailings ponds (Government of Canada, 2015).

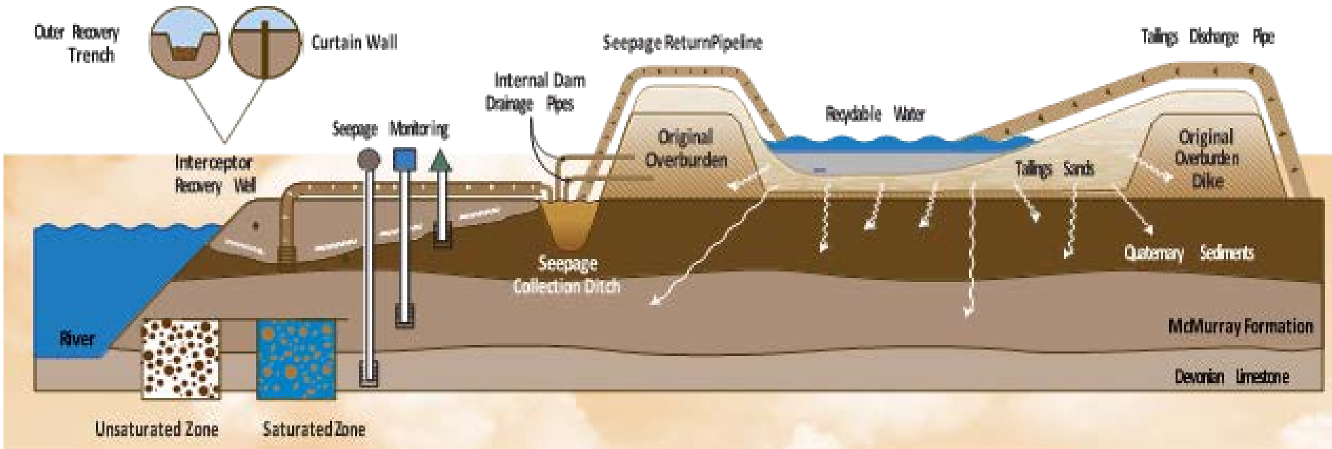


Figure 6-3: Cross-Section View of Tailings Seepage Recapture and Monitoring Systems (Government of Canada, 2015)

Since bitumen extracted from the oil sands can contain as much as 2% water and solids, as well as heavy metals and sulfur, it is upgraded into light oil through a process of distillation/fractionation and chemical (hydrocracking) treatment (Oilsands Magazine, 2018b). About 40% of Alberta's oil sands bitumen is upgraded into light/sweet synthetic crude before being sold to downstream refineries. Upgraders also use water, in the form of steam, to heat the bitumen and the oil products for processing and to generate electricity as a by-product (CAPP 2018).

Oil sands processing and upgrading produces greenhouse gas (GHG) and other air emissions. In 2014, the oil sands contributed about 9.3% of Canada's total GHG emissions (NRCAN, 2016). In 2009, oil sands production constituted approximately 4% of national sulphur oxides (SOx) emissions, 1% of national nitrogen oxides (NOx) emissions, 2% of national volatile organic compounds (VOC) emissions, and 3% of Canada's greenhouse gas (GHG) emissions (NRCAN, 2013). Poly Aromatic Hydrocarbons (PAHs) and other Polycyclic Aromatic Compounds (PACs) are VOCs, in addition to light hydrocarbons from diluent and bitumen and reduced sulfur compounds (RSC).

6.2.3.2 Approved Projects

Approved oil sands projects and upgraders located within the ARB are also presented in Figure 6-2, Table 6-2, and Table 6-3 (below). As of September 2017, 19 projects have received regulatory approvals required to operate and two projects have commenced on-site construction (Alberta Energy, 2017). A majority of these are thermal in-situ projects. One additional upgrader has received regulatory approval.

Table 6-3: List of Approved and Under Construction Athabasca Oil Sands Projects (as of Sept. 2017, Alberta Energy

Facility	Owner	Facility Name	Facility Type	Status
39	Harvest Operations	BlackGold	Thermal	Construction
40	Sunshine Oilsands	Harper	Thermal	Construction
41	Athabasca Oil Sands	Dover West Carbonates (Leduc)	Experimental	Approved
42	Husky	Saleski Carbonate Pilot	Experimental	Approved
43	Oak Point Energy	Lewis SAGD Pilot	Experimental	Approved
44	Renergy Petroleum	Muskwa Pilot	Experimental	Approved
45	Black Pearl Resources	Blackrod Commercial	Thermal	Approved
46	BP P.L.C.	Terre de Grace	Thermal	Approved
47	Brion Energy	Dover Commercial Project	Thermal	Approved
48	Cavalier Energy Inc	Hoole	Thermal	Approved
49	Cenovus	Narrows Lake	Thermal	Approved
50	Cenovus	Telephone Lake Borealis	Thermal	Approved
51	CNRL	Kirby Expansion (North)	Thermal	Approved
52	Devon	Pike	Thermal	Approved
53	Grizzly Oil Sands	May River	Thermal	Approved
54	MEG Energy	Christina Lake Regional Project Phase 3 SE	Thermal	Approved
55	Suncor	Meadow Creek East	Thermal	Approved
56	Sunshine Oilsands	Thickwood	Thermal	Approved
57	Surmont Energy	Wildwood	Thermal	Approved
58	Value Creation	Demonstration of Excellence (DOEx)	Thermal	Approved
NA	CNRL	Jackpine Mine Expansion	Mining	Approved

Shell's Jackpine Mine Expansion project (#4 in Table 6-2 and Figure 6-3), would increase the capacity of its existing oil sands mine by 100,000 barrels per day (15,900 m^3/d), bringing the total bitumen production capacity of the mining facility to 300,000 barrels per day (CEAA, 2017).

6.2.3.3 Reasonably Foreseeable Projects

Reasonably foreseeable oil sands projects located within the ARB are also presented in Figure 6-2 and below in Table 6-4. As of September 2017, 14 project applications are currently being reviewed by the Alberta Energy Regulator and/or Alberta Environment and Parks, in addition to 10 projects where the operator has disclosed intent to construct (Alberta Energy, 2017). A majority of these are thermal in-situ projects.

Table 6-4: List of Applied for and Announced Athabasca Oil Sands Projects (as of Sept. 2017, Alberta Energy)

Facility	Owner	Facility Name	Facility Type	Status
59	Teck Resources	Frontier	Mining	Application
60	Athabasca Oil Sands	Dover West Sands & Clastics	Thermal	Application
61	CNRL	Grouse	Thermal	Application
62	Grizzly Oil Sands	May River	Thermal	Application
63	Imperial Oil	Aspen	Thermal	Application
64	MEG Energy	Surmont	Thermal	Application
65	OSUM	Sepiko Kesik	Thermal	Application
66	Prosper Petroleum Ltd.	Rigel	Thermal	Application
67	PTT Exploration and Production	Mariana-Hangingstone	Thermal	Application
68	PTT Exploration and Production	Mariana-South Leismer	Thermal	Application
69	PTT Exploration and Production	Mariana-Thornbury	Thermal	Application
70	Sunshine Oilsands	Legend Lake	Thermal	Application
71	Value Creation	Advanced TriStar	Thermal	Application
72	Value Creation	Audet Pilot	Thermal	Application
73	Suncor	Voyageur South	Mining	Suspended
74	Athabasca Oil Sands	Birch	Thermal	Announced
75	Cenovus	East McMurray	Thermal	Announced
76	Cenovus	Steepbank	Thermal	Announced
77	Cenovus	West Kirby	Thermal	Announced
78	Cenovus	Winefred Lake	Thermal	Announced
79	CNRL	Birch Mountain	Thermal	Cancelled
80	CNRL	Gregoire Lake	Thermal	Cancelled
81	Devon	Jackfish East	Thermal	Announced
82	MEG Energy	May River	Thermal	Announced
83	Suncor	Lewis	Thermal	Announced
84	Suncor	Meadow Creek West	Thermal	Announced

The Frontier Oil Sands Mine project (#59 in Figure 6-2 and Table 6-4) is a proposed 292 km^2 (29,217 ha) conventional 'truck-and-shovel' surface oil sands mine located approximately 30 km from the south boundary of the WBNP. It would consist of surface mining operations, an ore preparation plant, a bitumen processing plant, tailings preparation & management facilities, cogeneration facilities, water management facilities, disposal and storage areas, river water intake, a fish habitat compensation lake, access roads and 7 watercourse crossings, including an Athabasca River bridge crossing, roads, airfield and camp facilities. Water withdrawals from the Athabasca River are estimated at 98 million cubic meters per year for an eight-year period during start up, then 60 million cubic meters per year for the remaining 49 year period for mining operations (Teck, 2015). Frontier is expected to produce 3 billion barrels of bitumen over the life of the mine, with 260,000 barrels per day at full production to be transported via pipeline (Teck, 2015). External tailings areas (ETA) are expected to have a peak fine fluid tailings (FFT) inventory of approximately 242 Mm^3 in Year 12 (Teck, 2015).

6.2.4 Oil Sands Projects in the Peace River Basin

As shown in Table 6-5 and Figure 6-4, there are currently 25 oil sands projects operating in the Peace River basin. The closest project is located 250 km southwest of the WBNP boundary and is an approved thermal project. The remaining 25 operating projects are located more than 300 km from the WBNP boundary, comprising 19 conventional projects, 5 thermal projects, and one experimental project.

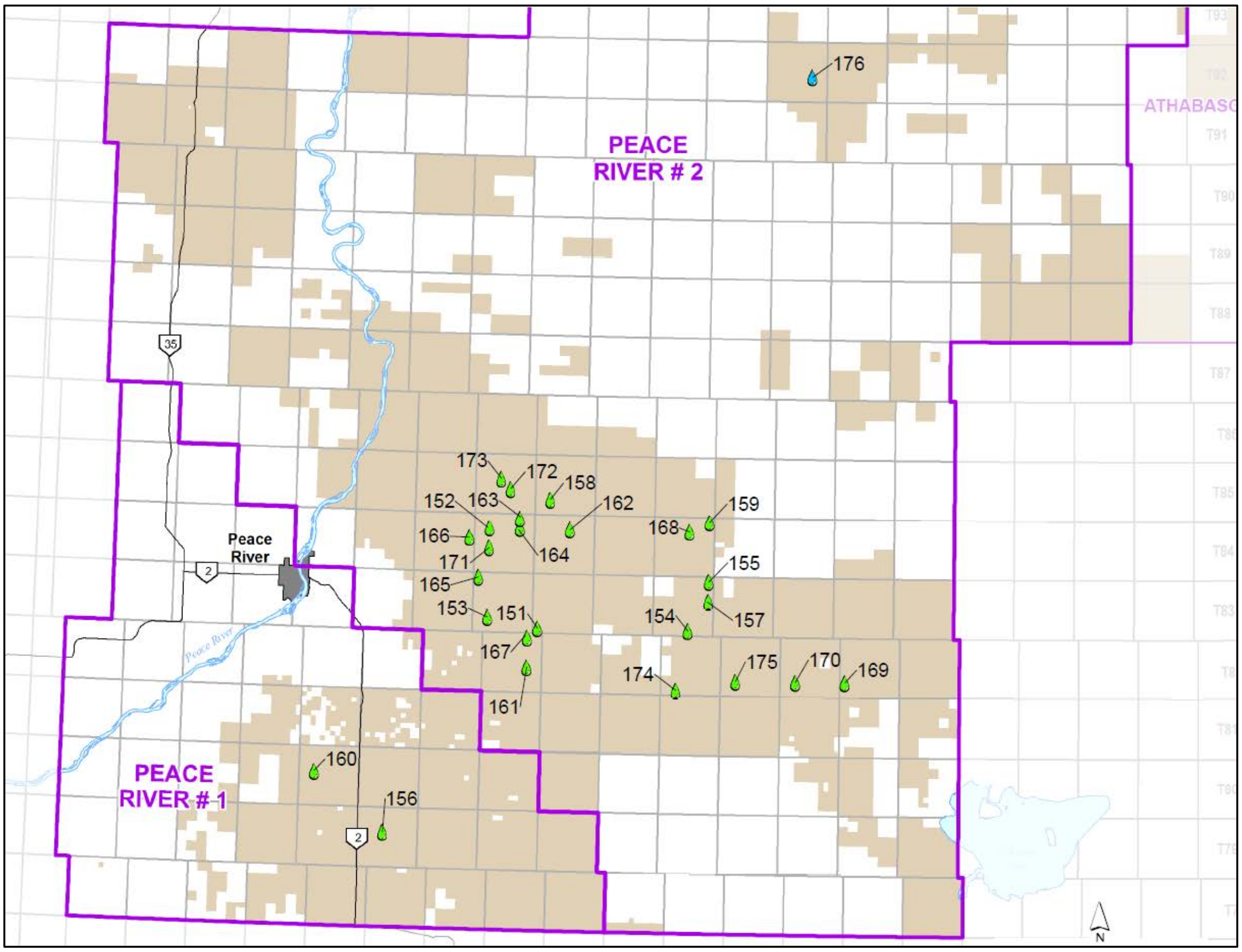


Figure 6-4: Alberta's Oil Sands Projects and Upgraders in the Peace River Basin Area (as of Sept. 2017, Alberta Energy).

Notes: Oil Drops (oil sands projects), Green (operating), Blue (approved)

Table 6-5: List of Operating and Approved Peace River Oil Sands Projects (as of Sept. 2017, Alberta Energy)

Facility	Owner	Facility Name	Facility Type	Status
151	Obsidian Energy	Seal Harmon Valley South Thermal Pilot	Primary	Operating
152	Baytex	Cadotte Heavy Oil	Primary	Operating
153	Baytex	Harmon Valley Bluesky	Primary	Operating
154	Baytex	Murphy Seal	Primary	Operating
155	Baytex	Peace River	Primary	Operating
156	Baytex	Reno	Primary	Operating
157	Baytex	Seal I	Primary	Operating
158	Baytex	Seal Cadotte	Primary	Operating
159	Baytex	Seal – Northern Cadotte Block	Primary	Operating
160	Baytex	Tangent 11437	Primary	Operating
161	Baytex	Walrus	Primary	Operating
162	CNRL	Cliffdale	Primary	Operating
163	CNRL	Galloway	Primary	Operating
164	Murphy Oil	Murphy Cliffdale	Primary	Operating
165	Obsidian Energy	Harmon Valley	Primary	Operating
166	Obsidian Energy	Seal Cadotte	Primary	Operating
167	Obsidian Energy	Seal Harmon Valley South	Primary	Operating
168	Obsidian Energy	Seal North	Primary	Operating
169	Prosper Petroleum Ltd.	Chipmunk	Primary	Operating
170	Prosper Petroleum Ltd.	Chipmunk II	Primary	Operating
171	Baytex	Harmon Valley – Pilot	Thermal	Operating
172	CNRL	Peace River Bluesky	Thermal	Operating
173	CNRL	Peace River	Thermal	Operating
174	Obsidian Energy	Dawson Seal	Thermal	Operating
175	Obsidian Energy	Seal Main East	Thermal	Operating
176	Northern Alberta Oil	Swan Lake	Thermal	Approved

6.2.5 Pulp and Paper/Forestry Projects

6.2.5.1 Existing Projects

Eleven pulp and paper mills are located in the Peace and Athabasca River basins, with five in the Athabasca basin and six in the Peace River basin, as outlined in Table 6-6. Three bleach kraft pulp mills currently operate on the Peace River, along with two CTMP (chemical thermo-mechanical pulping) mills and one mechanical pulp newsprint facility (Glozier et al., 2009). In the Athabasca River basin, two bleach kraft pulp mills currently operate, along with three CTMP mills. The main contaminants discharged to rivers from these facilities include total phosphorus (TP) and ammonia (NH_3) and, in 2006, loadings from these facilities ranged from 1 to 148 tonnes of NH_3 and 0.2 to 45 tonnes of TP (Glozier et al., 2009).

Table 6-6: List of Pulp and Paper Mills within the Peace and Athabasca River Basins (Glozier et al., 2009)

Company Name/ Pulp Mill	Details					
	Receiving Water	Location	Start Up	Product	2006 Loadings (Tonnes)	
					TP	NH_3
Athabasca River Watershed						
West Fraser Mills, Ltd/Hinton Pulp	Athabasca River	Hinton, AB	1957	Bleached Kraft pulp	45	140
Alberta Newsprint Co. Ltd.	Athabasca River	Whitecourt, AB	1990	Thermomechanical pulp, de-inked paper	4	0.5
Millar Western Industries Ltd.	Athabasca River	Whitecourt, AB	1988	Bleached chemi-thermomechanical pulp	NA	1.0
Slave Lake Pulp Corporation	Lesser Slave River	Slave Lake, AB	1991	Bleached chemi-thermomechanical pulp	14	2.0
Alberta Pacific Forest Industries Inc.	Athabasca River	Near Grassland, AB	1993		41	148
Peace River Watershed						
Pope and Talbot Ltd. /Mackenzie Pulp	Williston Lake	Mackenzie, BC	1972	Bleached Kraft Pulp	31	19.5
Abitibi Bowater Inc /Mackenzie Paper	Williston Lake	Mackenzie, BC	1969	Mechanical Pulp, newsprint	0.2	10
Louisiana-Pacific	NA	Chetwynd, BC	1991	Bleached chemi-thermomechanical pulp	--	--
Canfor Forest Products Ltd. / Taylor Pulp	Peace River	Taylor, BC	1988	Bleached chemi-thermomechanical pulp	27	NA
Weyerhaeuser Canada / Grande Prairie Operations	Wapiti River	Grande Prairie, AB	1973	Bleached Kraft Pulp	24	48
Daishowa-Marubeni	Peace River	Peace River, AB	1990	Bleached Kraft Pulp	NA	19.1

6.2.5.2 Proposed/Reasonably Foreseeable Projects

There are no new pulp and paper projects being proposed or planned at the current time.

6.2.6 Mineral Mine Projects

6.2.6.1 Existing Projects

As shown in Figure 6-5, there are four industrial mineral mines located near the WBNP and the PAD. Three limestone mines are located 105 km from the southeast boundary of the WBNP, while one silica sand mine is located approximately 300 km from the southwest corner of the WBNP (2018, Alberta Energy Regulator Interactive Minerals Map, from http://ags-aer.maps.arcgis.com/apps/webappviewer/index.html?id=cfb4ed4a8d7d43a9a5ff766fb8d0aee5).

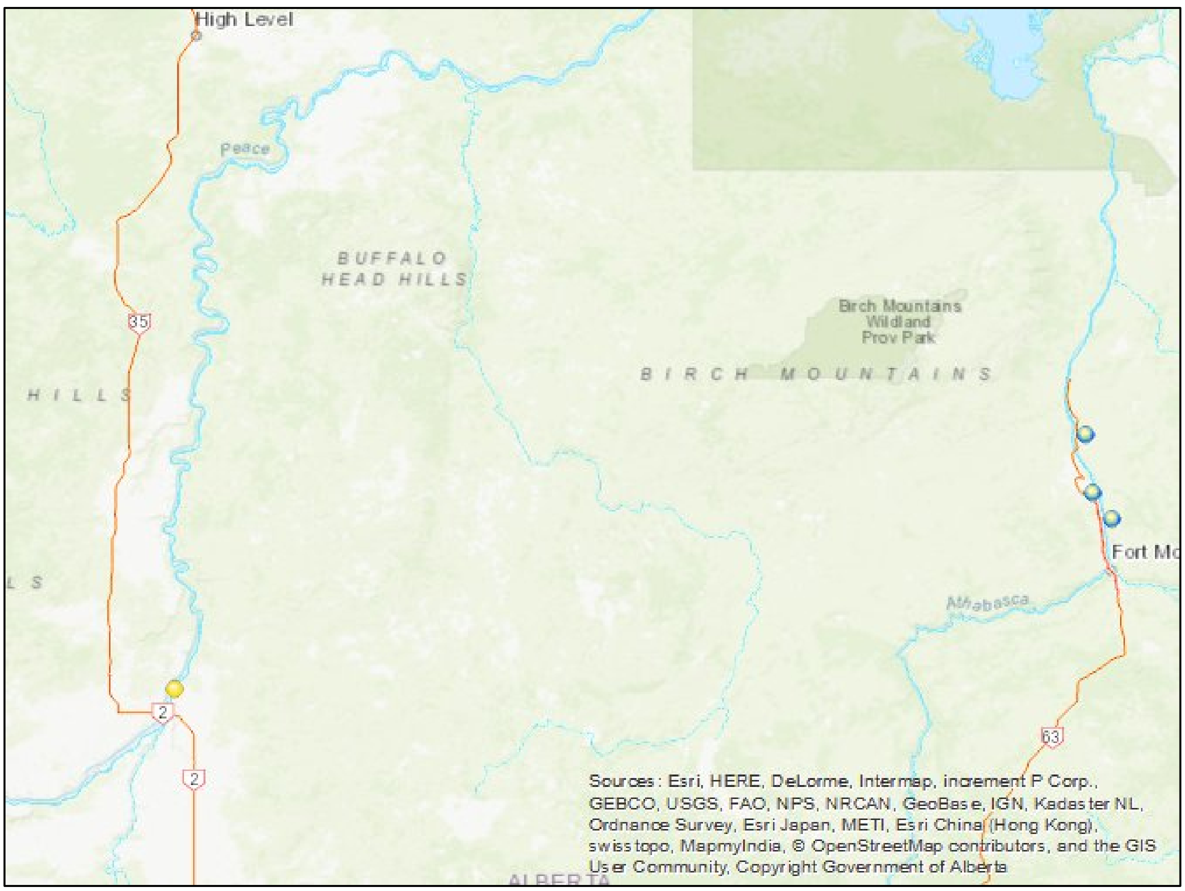


Figure 6-5: Locations of Minerals Mines Near Wood Buffalo National Park

(from** http://ags-aer.maps.arcgis.com/apps/webappviewer/index.html?id=cfb4ed4a8d7d43a9a5ff766fb8d0aee5**; Notes: Yellow: Silica sand mine, Grey: Limestone mine)

There are four decommissioned uranium mines around Lake Athabasca in Saskatchewan: Beaver Lodge, Lorado, Gunnar and Areva (Canadian Nuclear Safety Commission, 2018).

6.2.6.2 Proposed Projects

The former Pine Point lead-zinc mine located on the south shore of the Great Slave Lake is not currently in operation. A preliminary economic assessment has been conducted to reopen the mine, however no applications have been submitted (Pine Point Mining Limited, 2018). Similarly, mineral exploration is occurring around Lake Athabasca in Saskatchewan and in Alberta just south of WBNP, but no projects have been applied for. As a result, there are no new industrial mineral mine projects being proposed or planned at the current time.

6.2.7 Forestry Projects

Current forest management areas in the Northern Alberta region are provided below in Figure 6-6, along with the annual allowable cuts for each of the management areas in Table 6-7.

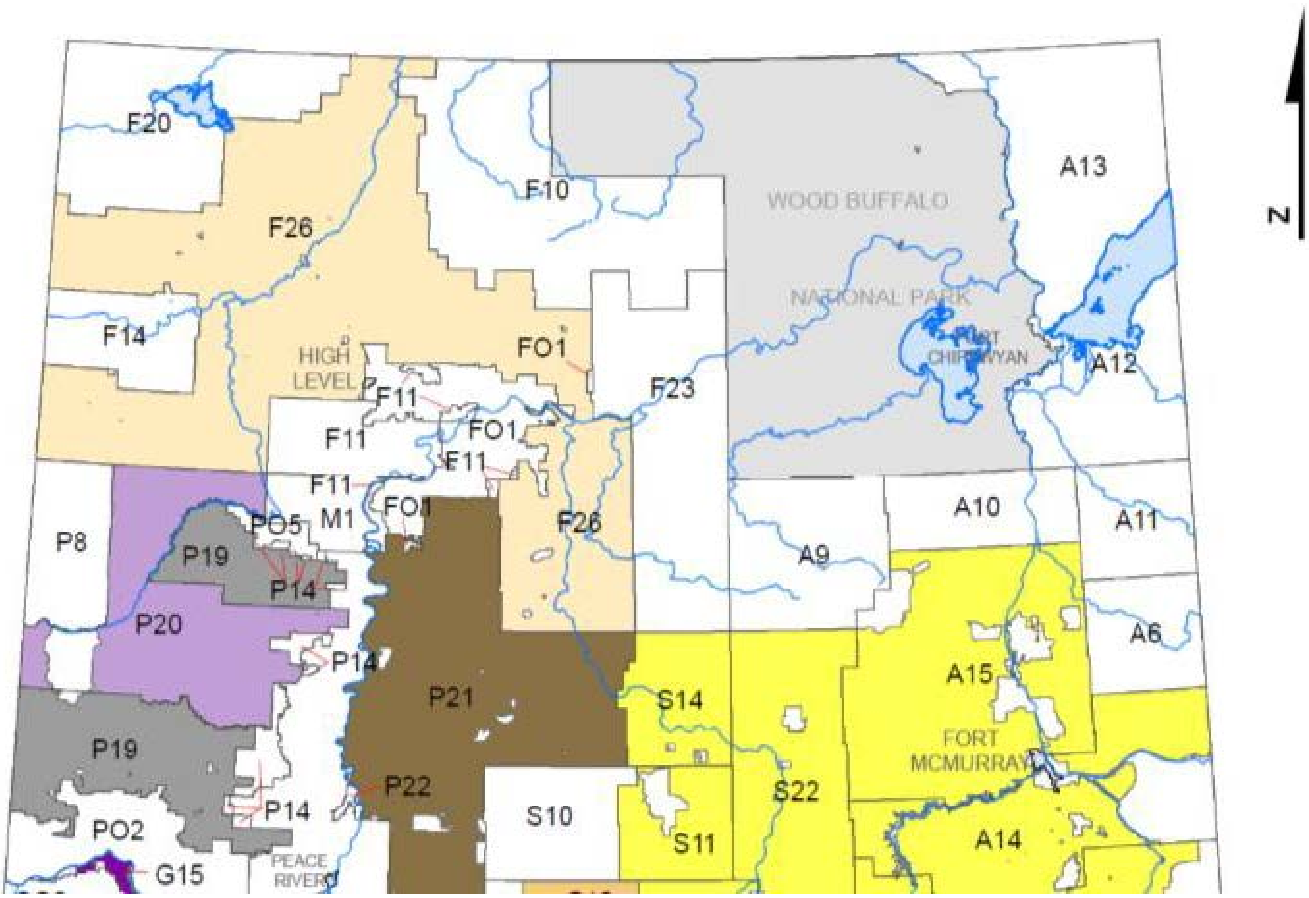


Figure 6-6: Forest Management Agreements in Northern Alberta (Government of Alberta, 2014a)

Table 6-7: Annual Allowable Cuts for Management Areas in Northern Alberta

Forest Management Unit	Annual Allowable Cut	Company
F10	No harvest	
F23	550,100 m^3	Askee Development Corp (Little Red River Cree First Nation)
A9	31,912 m^3	Netaskinan Development (GP) Ltd.
A10	6,900 m^3	Northland Forest Products Ltd.
A11	No harvest	
A12	No harvest	
A13	No harvest	

Current timber harvest planning areas in the Northwest Territories are provided below in Figure 6-7. A forest agreement for Timberworks, owned by the Deninu Kue First Nation and Fort Resolution Métis Council, in an area located adjacent to the park. Harvesting has yet to begin in this area.

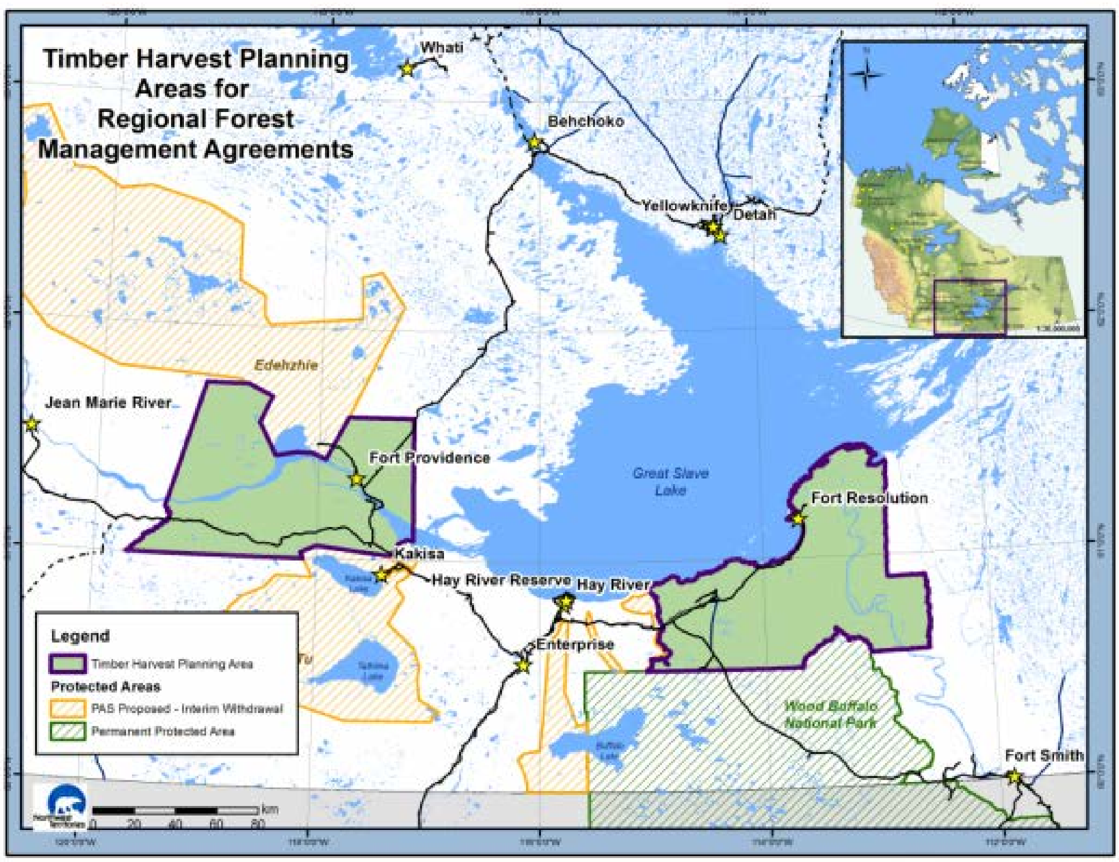


Figure 6-7: Timber Harvest Planning Areas for NWT Regional Forest Management Agreements (Government of the Northwest Territories, n.d.)

6.2.8 Conservation Areas

A number of provincial parks, conservation areas or public land-use zones exist or have been proposed around the park. Caribou Mountains Wildland Provincial Park, Richardson River Dunes Wildland Provincial Park and La Butte Creek Wetland Provincial Park are existing provincial parks that border WBNP. Additional areas proposed for protection include Kazan Wildland Park and Richardson Wildland Park on the eastern border of WBNP. In addition, there is a proposal or a Birch River Conservation Area on the southern border of WBNP (Government of Alberta, 2012).

6.3 POTENTIAL CUMULATIVE EFFECTS ON THE PAD FROM FUTURE CLIMATE CHANGE

6.3.1 Climate Change Projections Relating to the PAD

Climate change projections from available literature were compiled in order to gain an understanding of the magnitude of potential cumulative risk to the desired outcomes for the PAD from future climate change in the region over the next thirty years. The potential cumulative effects were assessed in relation to the flow regime desired outcome for the PAD, including river flow rates, lake water levels, and ice jam flooding frequency.

Available literature relevant to climate change influences on the PAD over the next 30+ years (within the context of existing levels of development) generally falls within one of three categories, as follows:

- Examining the exacerbating effects that future climate change may have on the PAD in conjunction with current levels of project development (e.g. Davidson and Hurley, 2007).
- Modelling potential climate induced change to ice-jam flooding frequency and other hydrologic processes in the PAD in the future (e.g. Eum et al., 2017).
- Discussing historical changes in the PAD and providing hypotheses regarding likely effects from future climate change, recognizing that projections using past trends over less than 100 years is somewhat unreliable (e.g. Timoney, 2013)

Numerous researchers report the potential for significant climate-related changes to ice-jam flooding frequency, river flows, and water levels in the Peace and Athabasca River basins in the future (Eum et al., 2017; Shrethsa et al., 2017; Peters, 2016; Carver, 2013; Timoney, 2013; Teck Resources, 2011c; Timoney, 2009; Andrishak and Hicks, 2008; Beltaos et al., 2008; Davidson and Hurley, 2007; Beltaos et al., 2006; Beltaos et al., 2006a; Pietroniro et al., 2006; Toth et al., 2006; Prowse et al., 2006). Table 6-8 presents a summary of available literature, which will be discussed in the following sections.

Table 6-8: Climate Change Projections for the PAD

Area of Interest	Decreases	Increases	Other
Peace Athabasca Basin (and PAD)	↓ Snowpack[1,3,8,11,12,15] ↓ Glacier meltwater[11] ↓ Tributary snowmelt[19] ↓ Spring peak water levels by 1.0 m[(3)] ↓ Avg annual peak levels by 0.1-0.6 m[(3)] ↓ Summer levels by 0.5 m (PR)[3]	↑ Temperature[3,8,16] ↑ Winter levels[3] ↑ Winter & Spring melt[3] ↑ Snowmelt (PR)[1] ↑ Winter flows (PR)[7]	Midwinter thaws/melt[1,8,15] Earlier spring peak water levels by 20-30 days[3] Earlier melt (PR)[7] Wide variations in wetness[8]
PAD Lakes	↓ Spring water levels by 0.15-0.4 m (LA)[3] ↓ Lake levels by 2 to 3 m (LA)[22]	↑ Pre-melt spring levels[3] ↑ Shallowing of lakes[8] ↑ Spring water levels by 0.1-0.25 m (LA)[3]	Earlier peak water levels by 40-50 days (LA, Mamawi and Claire)[3]
PAD Ice Jams & Flooding	↓ Ice season by 2-4 weeks[2,8,10,15] ↓ Ice cover thickness by up to 20% (Peace Pt)[10] ↓ Max extent of ice cover[14] ↓ Duration of ice cover by 28 days or 31%[14] ↓ Ice-jam flooding frequency[2,6,10,12,13,15] ↓ Perched basin recharge[2] ↓ Flow reversals[6]	↑ Dry period between floods[8] ↑ Thermal ice breakups[6] ↑ Dry periods between floods[8]	Ice cover slightly thinner[15]
Athabasca River Basin	↓ Summer flows[2,21] ↓ Summer flows by up to 21%[4] ↓ Summer flows by 14.3%[17] ↓ Summer levels by 0.2 m[(3)] ↓ Summer flows by 16%[23] ↓ Runoff by 30%[18] ↓ Low winter flows by 7-10%[18] ↓ Winter flows by 58.6%[17] ↓ Winter flows by 6%[23]	↑ Precipitation[4,5] ↑ Precipitation by 1% per decade[23] ↑ Winter precipitation[20] ↑ Evapotranspiration[4,5,9] ↑ Winter flows[2,4,7,20,21] ↑ Spring flows[2,4,20] ↑ Peak flow by 30%[20] ↑ Flow by 16-54%[9] ↑ Annual melt volumes[3] ↑ Frequency of summer low flows[21]	Warmer by 2-5.4°[(9)] Warmer by 0.4°C per decade[23] Wetter by 21-34%[9] Wetter in lower elevations[3] Earlier onset spring freshet[3] Extended spring freshet[4] Earlier snowmelt[7]

Notes : LA : Lake Athabasca ; PR : Peace River ; 1: Beltaos et al. (2006b); 2: Peters (2016); 3: Pietroniro et al. (2006); 4: Eum et al. (2017); 5: Davidson and Hurley (2007); 6: Carver (2013); 7: Toth et al. (2006); 8: Timoney (2009); 9: Shrethsa et al. (2017); 10: Beltaos et al. (2006a); 11: Timoney (2013); 12: Prowse et al. (2006); 13: Teck Resources (2011c); 14: Andrishak and Hicks (2008); 15: Beltaos et al. (2008), 16: BC Hydro (2011); 17: Burn (2009, in Lebel et al., 2009); 18: Bruce and Tin (2006); 19: Prowse and Conly (1998); 20: Alberta WaterSMART (2017); 21: Leong and Donner (2015); 22: Rasouli et al. (2013); 23: Lebel et al. (2009)

6.3.2 Potential Climate Change Effects on the PAD

As shown in Table 6-8, the majority of relevant literature indicated future climate changes in the PAD over the next thirty (plus) years will likely cause less surface water to be available and what is available will reach PAD water bodies earlier in the spring. This reportedly stems from a number of factors. Increases in temperature will potentially produce thinner snowpack in the headwater and tributary areas of the PAD, which in turn will produce less snowmelt. As a result, average annual peak, spring peak, and summer flows will all likely be reduced in the future. Anticipated increases in air temperature also may produce mid-winter thaws, causing the snowpack that is available to melt sooner in the year, resulting in earlier delivery of meltwater to the PAD. This may cause winter flows and winter water/ice levels to further increase from current levels. In addition, the decrease in the volume of water delivered to the Peace River will likely cause less water to be delivered to PAD lakes and it will arrive earlier in the spring. The literature is unclear whether overall water levels in the lakes will be lower or higher as a result of this.

A number of authors project increased air temperatures, a thinner snowpack, mid-winter thaws, and less glacier meltwater in the Peace Athabasca basin as a result of climate change. BC Hydro (2011) report "air temperatures in the Peace region have increased approximately 1.2°C over the past century, and are projected to increase 1.9°C to 2.5°C by the 2050s and 2.5°C to 3.9°C by the 2080s. The increase in mean air temperatures has been, and is expected to be, mostly due to warmer temperatures in winter" (p. 11-118).

Pietroniro et al. (2006) report increased temperature would result in increased winter melt events, which, in turn, would reduce the snow pack and accelerate spring melt. Beltaos et al. (2006a) also report "a large part of the Peace River basin is expected to experience frequent and sustained mid-winter thaws, leading to significant melt and depleted snowpacks in the spring" into the 2080s (p. 4031). Wolfe et al. (2008) studied the climatic driven shifts in the PAD over the past 1,000 years, indicating "Recent climate-driven hydrological change appears to be on a trajectory to even lower levels as high-elevation snow and glacier meltwater contributions both continue to decline." (p. 1). More recently, Timoney (2013) also reports that the PAD will be warmer and drier in future decades with depleted snowpacks and mid-winter thaws. Beltaos et al. (2006a) also projected a decrease in spring snowpack in the 2080s due to extensive mid-winter melt. Finally, Timoney (2009) also note "portions of the Delta will flood periodically, but the dry period between floods may become more prolonged and intense" (p. 511).

One set of researchers also report that climate change will likely cause water levels in PAD rivers and lakes to peak earlier and be lower overall. Pietroniro et al. (2006) indicated spring peak water levels in the PAD rivers could be lowered by up to 1.0 m and occur 20 to 30 days earlier and average annual peak elevations for PAD rivers could be lowered by 0.1 to 0.6 m. The same authors also projected summer water levels in the Peace River would be lowered by 0.5 m (on average) and water levels in Lakes Athabasca, Claire and Mamawi could peak 40 to 50 days earlier than at present. More recently, Timoney (2013) also notes that there is the potential for shallowing of lakes in the PAD due to a warming climate. Several groups of researchers also indicated a strong likelihood of "higher winter levels in the PAD system, which cause elevated pre-melt spring levels in the lakes of the PAD" (Pietroniro et al., 2006, p. 4237). Toth et al. (2006) echoed this projection, noting a "significant shift towards an earlier melt season as well as elevated winter flows for both (Peace and Athabasca) river systems" (p. 4197). Further, Rasouli et al. (2013) report the level of Lake Athabasca "may drop 2 to 3 m by 2100" (p. 1681).

Changes experienced by the PAD in the future will depend on the severity and speed of changes in the climate within these watershed basins. Leconte et al. (2006) modelled four climate scenarios (mild to severe winters) with varying flow conditions (low, average and high hydraulic regimes) in the PAD and found a reduction in winter severity caused lowered lake levels and river flows and, as a result, the flow reversal effect was diminished. More specifically, they found "extending the ice-cover season (severe winter) by 14 days resulted in an increase of up to 5 cm in water level of large lakes in the PAD, while reducing it by 28 days (mild winter) lowered the levels by almost 10 cm" (p. 4215).

One group of researchers also projected the effect climate change would have on the filling of the W.A.C. Bennett Dam reservoir at Williston Lake. Pietroniro et al. (2006) note "The inflows to the Williston Reservoir will also be subjected to an increase in winter flows and a shift in seasonality, but the spring freshet and subsequent summer flow input will be reduced under climate change. This may have a significant effect in the early autumn months as the Peace struggles to refill the reservoir before the higher winter flows accumulate the necessary recharge volume" (p. 4236).

6.3.3 Potential Climate Change Effects on Athabasca River

The potential effects of climate change upon the Athabasca River basin appear varied. Climate projections depend on the relative strength of the temperature and precipitation trends, the seasonal distribution of these trends across the seasons (i.e. how much of the warming occurs in winter versus summer), and how the hydrologic cycle would respond (e.g. evaporation, precipitation as snow versus rain, etc.) (Lebel et al., 2009). Some researchers have projected a warmer and wetter basin, producing increased winter melt and winter flows, along with greater spring and annual flow volumes. However, other researchers project lower summer flows and levels, along with decreasing low winter flows.

Several researchers project an increase in air temperatures, precipitation, and annual flow volumes in the Athabasca River basin as a result of climate change. Davidson and Hurley (2007) note Fort Chipewyan air temperature has increased by more than 3^{o}C and "is projected to undergo a further 4.8^{o}C increase, with coincidental increases in precipitation of 32 mm. However, potential evapotranspiration is projected to be substantially higher than any projected increases in precipitation, as a result of warmer temperatures and longer summers" (p. 8). Shrestha et al. (2017) report the Athabasca River Basin will be warmer by 2–5.4°C and wetter by 21–34% in the future, thus producing increases in annual average water flow in the Athabasca River basin by 16–54% (p. 425). Pietroniro et al. (2006) also project increased annual melt volumes in the Athabasca River basin and specifically note "the wetland and lower elevations of the Athabasca basin will be significantly wetter" (p. 4236). Pietroniro et al. (2006) also found, depending on the model, spring water levels in Lake Athabasca could vary from an increase of between 0.1 m and 0.25 m to a decrease of between 0.15 to 0.4 m. Numerous scientists report that the increased volumes experienced in the basin would involve earlier melts and elevated winter and spring flows. Toth et al. (2006) note a "significant shift towards an earlier melt season as well as elevated winter flows" (p. 4197) and Pietroniro et al. (2006) also projected earlier onset spring freshet and increased winter and spring flow for the Athabasca River.

More recently, Eum et al. (2017) projected “spring and winter flows within the Athabasca River basin will increase, resulting in an extended period of spring freshet, with a higher rate of increase at the upper reach of the river due to the combined effects of increased precipitation and earlier snowmelt resulting from a warming climate” (p. 327). Alberta WaterSMART (2017) modelled streamflow for the Athabasca River from Athabasca to Fort McMurray and the Embarrass River for a 30-year period under two scenarios, one based on future precipitation and air temperature under projected climate change conditions, and the other under drought conditions. Under the climate change scenario, large increases in peak flow (~30%), higher winter flows, and increased spring flows are projected, with no change to the timing of spring freshet. The author also notes “increased winter precipitation led to a large increase in snowpack, which melted rapidly during the long late-spring days” (p. 90). Under the drought scenario, peak flow was reduced by approximately 20% on average throughout the summer and winter months.

In contrast to the above, several researchers project a decrease in runoff and winter flows in the Athabasca River basin. Based on a 20% reduction in Athabasca River flows from 1953 to 2003 and a 1.5 to 1.8°C increase in temperatures from 1961 to 2000, Bruce and Tin (2006) projects “minimum flows in the Athabasca River are likely to diminish by 7 to 10%” into 2060 (p. 2). Davidson and Hurley (2007) project a “decrease in runoff from the Athabasca River basin below Fort McMurray of about 30% by the mid-21st century” (p. 6), as shown in Figure 6-8. It is important to note that Davidson and Hurley (2007) used a relatively short record (less than 100 years) and may reflect a period when the flow rates are decreasing due to factors other than climate change.

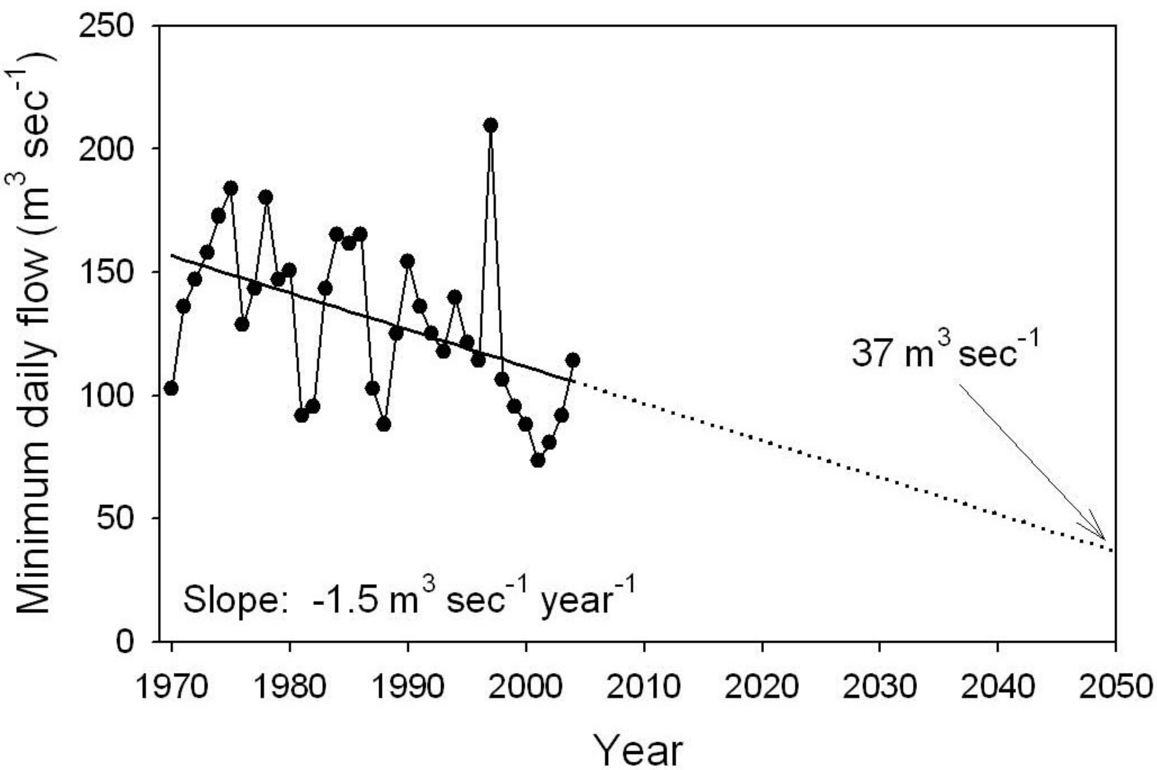


Figure 6-8: Trend Over Time in Lowest Winter Flows in the Athabasca River (Davidson and Hurley, 2007).

Lebel et al. (2009) use four major climate change models to develop flow projections for the Athabasca River for 2010 to 2039 (based on flows during the period 1957-2007) to project a mean decrease in minimum winter flows of 5.8% and mean summer flows of 16.3%. Burn (2009, in Lebel et al., 2009) reports the "projected reduction in future streamflow values, as estimated by extrapolating the trend slopes, ranges from 14.3% of the long term median streamflow for summer for the year 2022 to 58.6% for winter streamflow for the year 2037" for the Athabasca River below McMurray (p. 46). Pietroniro et al. (2006) also project lower summer levels in the Athabasca River, on average by 0.2 m (p. 4244). Kerkhoven and Gan (2011) note "the shortened snowfall season and increased sublimation together lead to a decline in the spring snowpack, and mean annual flows are expected to decline with the runoff coefficient dropping by about 8% per ◦C rise in temperature" in the ARB (p. 583). More recently, Eum et al. (2017) report "summer flows in the Athabasca River basin are projected to decrease by up to 21% because of earlier snowmelt, increased evapotranspiration, and no significant increase in summer precipitation" (p. 327).

In addition, Leong and Donner (2015) examine the response of streamflow in the ARB to climate change this century, the impacts of which are "projected to be the primary driver of future low flow occurrences" (p. 651). The authors indicate "future climate change is projected to increase winter flows and decrease summer flows, with the frequency of summer low flows projected to rise by up to 85% in the highest future emissions scenario by the end of the century" (p. 651), which they note "could interrupt oil sands water withdrawals and subsequent daily bitumen production for an additional 2–3 months each year by mid-century" (p. 651).

6.3.4 Potential Climate Change Effects on Ice Jam Frequency in the PAD

Several researchers have projected significant changes to ice-jam flooding frequency in the PAD as a result of climate change in the future. Overall, as temperatures increase and snowmelt contributions to the PAD decrease, a shorter ice season, less ice cover, and increased thermal ice break-ups are likely to result. They report that, as a result of climate change, the ice season duration in the PAD is likely to be reduced by 2 to 4 weeks (Peters, 2016; Timoney, 2013; Andrishak and Hicks, 2008; Beltaos et al., 2008; Beltaos et al., 2006) and the maximum extent of ice cover on the Peace River will also likely be reduced (Andrishak and Hicks, 2008). Ice cover is also projected to be thinner than current levels (Beltaos et al., 2008; Beltaos et al., 2006a). Based on future climate modelling of future (2070-99) versus recent (1961-90) climate, Beltaos et al. (2006a) estimated the ice cover thickness at Peace Point would be reduced by up to 20%.

As mentioned earlier, "a large part of the Peace River basin is expected to experience frequent and sustained mid-winter thaws" (Beltaos et al., 2008, p. 345). In combination with reductions in ice season duration and ice cover thickness, this will cause "significant melt and depleted snowpack in the spring, leading to severe reduction in the frequency of ice-jam flooding" (p. 345). Prowse et al. (2006) also projected the frequency of ice jams in the PAD would be further reduced because of reduced snowpack. The projected reduction in ice-jam flooding frequency in the PAD will likely produce "significant declines in the effectiveness and frequency of the ice-jam mechanism in causing flooding in the perched basins of the PAD and similar declines in flow reversals due to the demise of the hydraulic damming effect of the Peace River" (Carver, 2013, p.31), which will severely limit the replenishment of highly elevated perched basins in PAD. This reduction in flow reversals and perched basin recharge, in turn, will likely "accelerate the loss of aquatic habitat in the PAD region" (Beltaos et al., 2006a, p. 4031). Prowse and Conly (1998) also note, in the future, climate factors could "favour the development of thermal over dynamic break-ups, and hence reduce the probability of severe ice-induced flooding" (p. 1606).

6.4 PROJECTED FUTURE TRENDS FOR THE DESIRED OUTCOMES

The assessment of cumulative effects on the desired outcomes for the WBNP includes past activities (and past climate change), in conjunction with other reasonably foreseeable future activities and future climate change. As illustrated in Figure 6-9, the methodological approach to assess the cumulative impact to the desired outcomes for the WBNP consists of the following steps:

- Document the pathways of effects and trends currently being experienced on desired outcomes for the WBNP resulting from existing levels of development (see Chapters 4 and 5 and summarized in Table 6-9);
- Identify the reasonably foreseeable future projects that may contribute to pathways of effects; (see Section 6.2)
- Determine the potential effects on PAD valued components from future climate change (see Section 6.3); and
- For each primary pathway of effect and desired outcome for WBNP, project the likely future trends resulting from future climate change and reasonably foreseeable development.

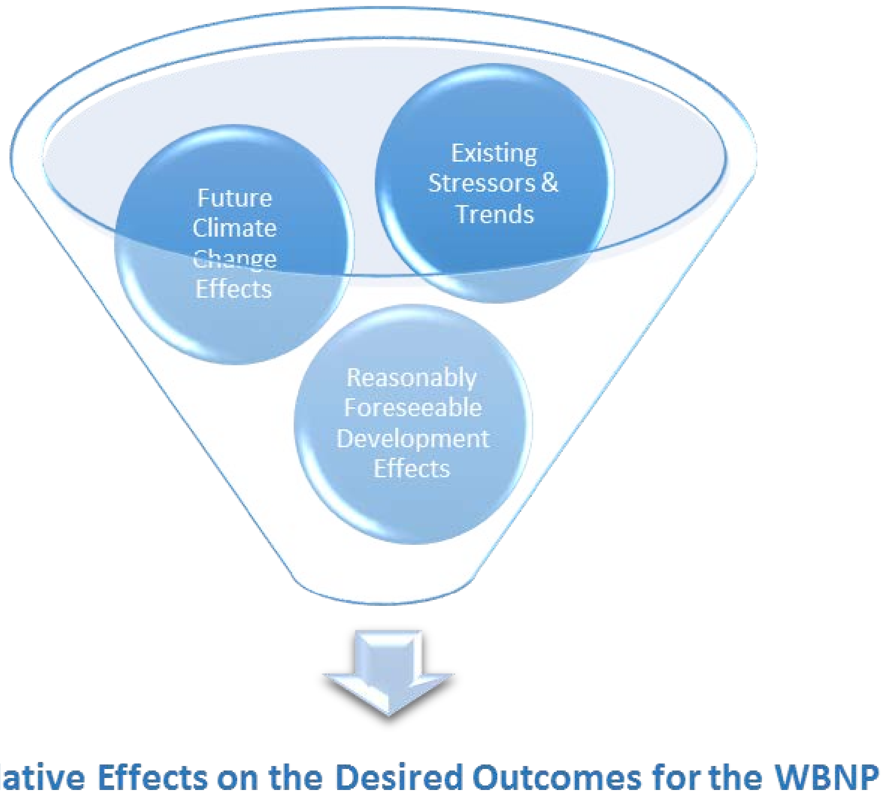


Figure 6-9: Contributory Factors in Creating Cumulative Impact to the World Heritage Values of the WBNP.

The potential cumulative effects are managed using a suite of tools with the objective of keeping the impacts within levels deemed acceptable. For example, in the Northwest Territories, a framework illustrated in Figure 6-10 was used to demonstrate the suite of tools that were used to manage cumulative effects (Indian and Northern Affairs Canada, 2007). While a full explanation of the existing and proposed tools being used to manage cumulative effects is beyond the scope of this assessment, some explanation of the cumulative effects management tools is helpful context. It is important to note that the tools are developed and applied by the various responsible jurisdictions.

Figure 6-10: Environmental Stewardship Framework Used in the Northwest Territories (Indian and Northern Affairs Canada 2007)

Table 6-9: Pathways of Effects Identified in Chapter 4 and 5

Primary Pathway of Effect	Secondary Pathway of Effect	Receptor
Peace River Seasonal Flows Athabasca River Annual & Seasonal Flows Groundwater Quality & Quantity in Athabasca Basin	• Invasive species • Changes in habitat and food availability for migratory waterfowl • Changes in bison habitat from drying and fewer flooding events • Ice jam and open water recharge • PAD Water Quality	Great Plains Boreal Grasslands Migratory waterfowl Wolf-Bison Relationship Indigenous people
Groundwater Quality & Quantity in Athabasca Basin Air Quality Athabasca River Water Quality	• PAD Water Quality • Exposure to contaminants in water, food and sediments in the PAD of migratory waterfowl	Migratory waterfowl Indigenous people
Fire suppression		Great Plains Boreal Grasslands
Increased linear corridor density and habitat changes surrounding WBNP		Wolf-Bison Relationship
Disease management and hunting outside WBNP	• Changes resulting from changes in other prey species populations	Wolf-Bison Relationship
Hydrological changes in karst/Whooping Crane nesting area	• Changes in habitat and food availability in nesting habitat for Whooping Crane	Karst Whooping Crane
Short-term exposures to contaminants in local migratory habitat		Migratory waterfowl Whooping Crane
Changes to habitat and food availability in local migratory habitat		Migratory waterfowl Whooping Crane
Invasive species		Great Plains Boreal Grasslands Salt plains
Changes in local migration routes		Migratory waterfowl

6.4.1 Peace River Seasonal Flows

Potential Future Impacts from Development and Climate Change

The reasonably foreseeable projects on the Peace River, as described in Section 6.2, include one proposed oil sands project in the Peace River Basin, as well as the Site C project (currently under construction) and the proposed Amisk hydroelectric project.

The Site C EIS did not assess the cumulative effects of existing hydroelectric development on the hydrologic flow regime in the Peace River. In its review of the Site C project, the Joint Review Panel (the Panel) report the cumulative effects assessment by BC Hydro “did not provide the Panel with a full understanding of past activities that cumulatively interact with present and future ones” (Government of Canada, 2014, p. 259). The Panel notes that existing hydroelectric developments, particularly the Bennett Dam, had a large impact during initial construction and operation and that some of those effects are ongoing and would act cumulatively with the Site C project. The Panel also determined that the assessment should have considered effects using a pre-industrial baseline starting around 1950, before the construction of the Bennett Dam, and notes “an assessment based on existing environmental conditions does not accurately reflect incremental effects on VCs” (Government of Canada, 2014, p. 259). Further, the Panel notes that the assessment should have included the Bennett and Peace Canyon Dams in order to take into account the “effects that occurred in the past that may not be reflected in the current baseline (e.g. loss of riparian habitat)” (p. 259). Finally, the Panel concludes that, considering the information available on the Bennett and Peace Canyon Dams (including first-hand and second-hand Traditional Knowledge, anthropological studies, air photos, environmental impact studies, research from various provincial and independent bodies, and historic maps of changing land tenure), “BC Hydro could have done more to provide the ‘qualitative analysis and conclusions’ that are missing in the assessment” (Government of Canada, 2014, p. 259).

As noted in Chapter 5 of this report, seasonal flow rates on the Peace River have become much less variable due to flow regulation on the river and (past) climate change, resulting in decreased summer flows and increased winter flows (Peters, 2016; Dube and Wilson, 2013; Carver, 2016; Carver, 2013; Timoney, 2013; Golder Associates, 2012; Teck Resources, 2011c; Candler et al., 2010; Glozier et al., 2009; Prowse et al., 2006; Schindler and Donahue, 2006; Prowse and Conly, 2002; Prowse et al., 2002a, Peters and Prowse, 2001). The changes to the winter flow regime in the Peace River and (past) climate change have decreased ice jam flooding frequency (Beltaos, 2018; Beltaos, 2016; Carver, 2016; Beltaos, 2014; Carver, 2013; Dube and Wilson, 2013; AECOM, 2010; Peters and Buttle, 2010; Beltaos et al., 2008; Davidson and Hurley, 2007; Beltaos et al., 2006; Peters and Prowse, 2006; Prowse et al., 2006; Prowse and Conly, 2002; Prowse and Conly, 1998; Wrona et al., 1996; Peterson and Courtorielle, 1992), resulting in higher freeze up elevations, decreased ice jam flooding frequency, and reduced flooding of perched water basins in the PAD.

As noted in Section 6.3.2, relevant literature indicates future climate changes will likely cause less water to be available in the PAD due to reduced average annual peak, spring peak, and summer flows on the Peace River. In addition, mid-winter thaws and earlier delivery of meltwater to the PAD may cause winter flows and winter water/ice levels to further increase from current levels. In addition, several researchers have predicted major changes to ice-jam flooding frequency in the PAD as a result of climate change in the future. Predictions include a shorter ice season, less extensive ice cover, thinner ice cover, and increased thermal ice break-ups. This may result in the reduced hydraulic damming effect of the Peace River, which could further reduce the frequency of ice-jam flooding, and perched basin recharge in the PAD. These effects may accelerate the loss of aquatic habitat in the PAD region, presenting a potential risk to the normal ecological function of the PAD in the future.

The documented changes to the flow regime in the Peace River to date, in conjunction with the potential changes from reasonably foreseeable hydroelectric development and future climate change, could further affect seasonal flow rates on the Peace River, ice jam flooding frequency, and perched basin recharge in the PAD. Thus, the projected trend for the desired outcome of both 1) flow regimes and water quality into the PAD maintain the ecological function of the ecosystem and 2) flow regimes into the PAD sustain vegetation communities and healthy and abundant populations of key ecological and cultural species including waterfowl, muskrat, fish, bison and wolves are negative.

Currently, some of the management tools in place include: the Mackenzie River Basin Transboundary Waters Master Agreement, monitoring and reporting of surface water flow rates on the Peace River, groundwater and surface water allocations, water licences and environmental approvals for individual projects. In addition, two management tools focused more on cumulative effects have been proposed to manage flows on the Peace River. The Lower Peace Region Regional Plan and the associated surface water quantity framework is proposed to manage surface water flows within Alberta. A British Columbia – Alberta Bilateral Water Management Agreement could be used to manage the cumulative flows from British Columbia.

6.4.2 Athabasca River Seasonal Flows

Future Development Water Use Predictions

In 2011, the estimated net use of surface water in the Athabasca River basin was 143,483,558 m^3/year, or 4.6 m^3/s (Government of Alberta, 2015a). The majority of surface water used was 3.3 m^3/s (102,686,300 m^3/year) used by the oil sands and 1.3 m^3/s (10,197,258 m^3/year) used for other purposes (Government of Alberta, 2015a). The actual surface water withdrawn by conventional oil sands mines in 2016 from the mainstem Athabasca River was approximately 111.5 million m^3/year, or an average of 3.53 m^3/s (AEP, 2017b and Islam and Leibel, 2018). It is projected that by 2030, the oil sands will have an average demand of 16 m^3/s (505 million m^3/year), with an associated peak demand rate of 29 m^3/s in the summer and fall seasons (Ohlson et al., 2010).

It is unclear whether surface water withdrawal rates listed above for oil sands facilities are only for the Athabasca River mainstem and, as a result, may not include tributaries such as Firebag, Muskeg, and Ells Rivers, which are not captured by the hydrologic station at Fort McMurray. Thus, actual withdrawal rates affecting the Athabasca River system may be greater. In addition, rain water and water from muskeg and peat lands is also being collected and stored for use by oil sands facilities, which may be lowering surface water runoff volumes into the Athabasca River system. As discussed by Gibson et al. (2016), surface water runoff into the Athabasca River from drainage from peat lands is widely important and dominant in three tributaries, including the Clearwater River, Mackay River, and Ells River, accounting for 45–81% of annual streamflow. Additional information regarding current surface water withdrawal rates from Athabasca tributary rivers, as well as surface water diversion volumes, is needed to further assess the effect on surface water quantities in the Athabasca River system from existing facilities.

Projections of Climate Change and Development Impacts to Ecological PAD Values

Currently, some of the management tools in place include: the Mackenzie River Basin Transboundary Waters Master Agreement, monitoring and reporting of surface water flow rates on the Athabasca River, groundwater and surface water allocations, water licences and environmental approvals for individual projects.

In 2015, the Government of Alberta introduced the Lower Athabasca Region Surface Water Quantity Framework for the Lower Athabasca River (SWQMF) (Government of Alberta, 2015a). The SWQMF's objective is to "manage cumulative water withdrawals to support both human and ecosystem needs, while balancing social, environmental and economic interests" (Government of Alberta, 2015a). Weekly flows of the Athabasca River measured at the McMurray station (Water Survey of Canada gauge 07DA001) are compared to the management triggers to determine the applicable limits on how much water is available for cumulative mineable oil sands water withdrawal for each week of the year. The weekly management triggers and water withdrawal limits are divided into five seasons: Mid Winter, Early Spring, Late Spring, Summer/Fall, and Early Winter. Each of these seasons has distinct weekly flow triggers and corresponding cumulative water withdrawal limits (AEP, 2017b).

Based on projections of future water withdrawals, the SWQMF puts in place weekly cumulative water withdrawal restrictions for the Athabasca River, where peak withdrawals of 29 m^3/s would be allowed only in summer and fall when weekly flow rates in the river are greater than 111.6 m^3/s (AEP, 2017b). AEP further notes "cumulatively, licensed pumping capacity for mineable oil sands projects may eventually exceed this (peak 29 m^3/s) limit. Water sharing agreements will identify how water management decisions will help ensure maintenance of the limit" (AEP, 2017b). It is also important to note the following:

1) Some existing conventional oil sands projects will likely be decommissioned before new projects begin production;

2) All but three of the reasonably foreseeable projects are thermal, in-situ projects with limited surface water requirements;

3) New processing technologies will likely be developed to decrease water demands for the three proposed conventional mining projects, however there are significant start up water volume requirements for these projects;

4) The thermal projects will likely draw groundwater, rather than surface water from the Athabasca River; and

5) Some oil sands facilities store water during high flow periods for use during low flow periods

In the SQWMF, cumulative water withdrawal limits are based from weekly flow rates in the Athabasca

River and when flow rates fall below trigger values during low flow periods, total water withdrawals are reduced, potentially requiring some operators to 'pro-rate' their withdrawals based on the flow rate in the Athabasca River (Government of Alberta, 2015a). Surface water withdrawals during low flow periods are also of concern in relation to future projects on the Athabasca River, particularly in relation to fall and winter periods. If weekly winter flow rates in the Athabasca River fall below 87 m^3/s (shown in Figure 6-11, as per the SWQMF minimum flow trigger), the cumulative water withdrawals from the river are limited to 4.4 m^3/s (AEP, 2017b). From 1965 to 2010, the lowest winter flows in the Athabasca River ranged from 90 to 250 m^3/s and the lowest weekly flow experienced since monitoring began was 88 m^3/s (Government of Alberta, 2012a). This represents, as Carver (2013) reports in several low flow months from 2005 to 2008, withdrawals ranging from 4 to 6% of monthly Lower Athabasca River flows.

As described in Section 6.3.3, future climate change may cause increased winter melt and winter flows, greater spring and annual flow volumes, lower summer flows and levels, and/or decreasing low winter flows in the Athabasca River. While the cumulative water withdrawal limits set for oil sands projects would likely not have an effect on the Athabasca River during increased spring and winter flows, they could have a substantial effect during periods of decreased winter, spring, summer, and fall flows. As shown in Figure 6-11 (based on Figure 5-13), summer flows in the Athabasca River could decrease by up to 21% in the future due to climate change, as projected by Eum et al. (2017).

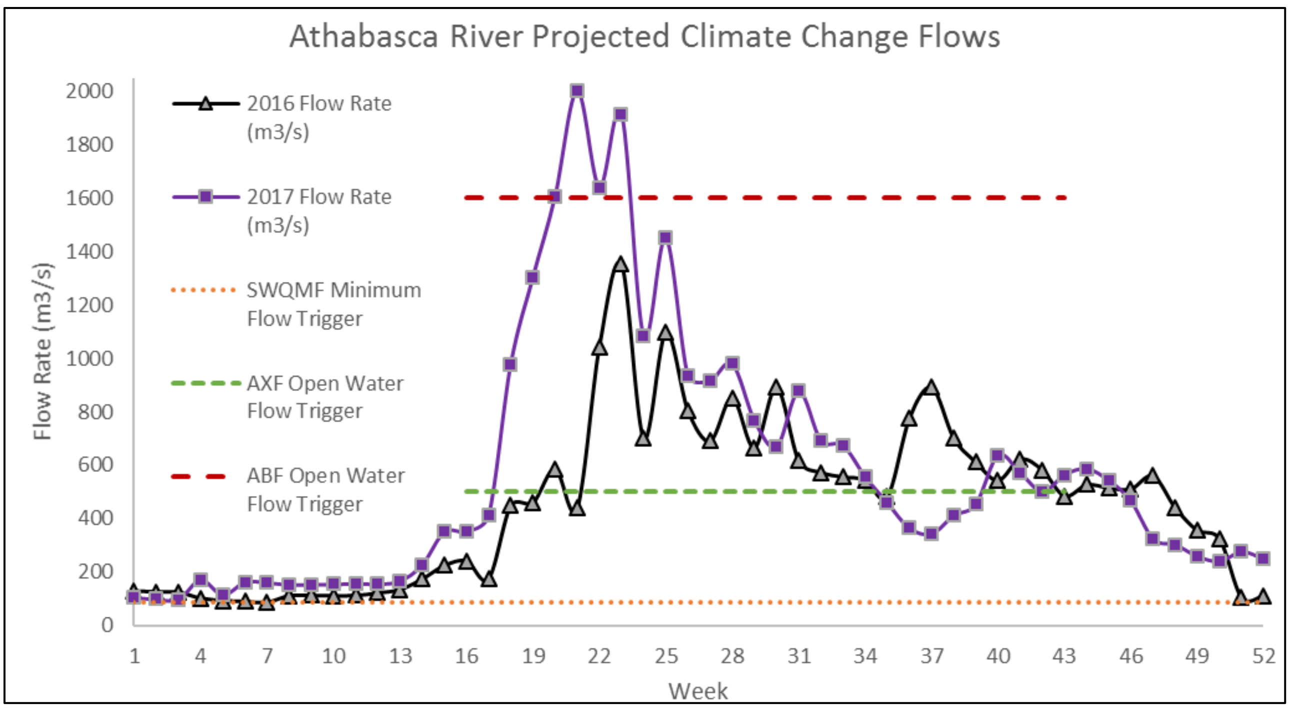


Figure 6-11: Weekly Athabasca River Flow Rates for 2016 and 2017 Under a Climate Change Modified Flow Regime*

(Notes: 21% reduced summer flows as per Eum et al., 2017; 10% reduced winter flows as per Bruce, 2006; earlier spring freshet by 2 weeks as per Pietroniro et al., 2006, 10% reduced fall flows (estimate), 10% increased spring flows as per Eum et al., 2017 and Pietroniro et al., 2006; winter weeks 44 to 13, spring weeks 14 to 23, summer weeks 24 to 38, fall weeks 39 to 43, open water season from 16 to 43; *not considered year over year reductions/additions in flow)

In addition, an extended spring freshet could begin two weeks earlier and could increase spring flows in the Athabasca by up to 10% in the future due to climate change, as projected by Eum et al. (2017) and Pietroniro et al. (2006). Finally, winter flows could decline by up to 10%, as estimated by Bruce and Tin (2006). In this case, flow rates could reach or fall below the weekly winter flow rate trigger of 87 m^3/s, when water withdrawals from the river are allowed, up to a total limit of 4.4 m^3/s. Further, as shown in Figure 6-8, the low flows in the Athabasca River could potentially be as low as 37 m^3/s by 2050 (Bruce, 2006). If future cumulative water withdrawal limits are kept at current levels of 4.4 m^3/s, this is equivalent to almost 12% of weekly flow (and rising as flow declines), which will likely have downstream effects on the PAD. If withdrawal limits are set at 5% of low flow, the cumulative water withdrawal limits during low flow periods in the future will be approximately 1.9 m^3/s. It is unlikely this is a practical or achievable rate for future oil sands demands, considering a projected four-fold increase in average water demand from future oil sands development by 2030 alone.

Thus, the potential additional withdrawals of water from reasonably foreseeable oil sands projects, in conjunction with projected climate change, could further negatively impact the water flows in the Athabasca River and the PAD. Thus, the projected future trend for the desired outcome of both 1) flow regimes and water quality into the PAD maintain the ecological function of the ecosystem and 2) flow regimes into the PAD sustain vegetation communities and healthy and abundant populations of key ecological and cultural species including waterfowl, muskrat, fish, bison and wolves is negative.

The withdrawal limits discussed above from the SWQMF (Government of Alberta, 2015a) provide mitigation for the world heritage values, but the limits were set with limited knowledge about the implications for the world heritage values. The SWQMF acknowledges gaps in ecological knowledge about: winter habitat in the delta (though said to later have been addressed), riparian vegetation and aquatic mammals in the delta, access to tributaries, Richardson Lake connectivity (in the Athabasca Delta), Big Egg Lake connectivity (perched basins), and dissolved oxygen in some parts of the Athabasca River. Thus, not only are there concerns about the future achievability of the current limits, but it is unknown if the current limits adequately protect the ecological world heritage values in the PAD right now.

Projections of Climate Change and Development Impacts to Access by Indigenous People

As shown in Figure 6-11, summer flows in the Athabasca River could decrease by up to 21% in the future due to climate change. In this case, flow rates below the Aboriginal Extreme Flow (AXF), set at 500 m^3/s, could be seen in some late summer weeks. In addition, if fall flows decline by up to 10%, flow rates could reach or fall below the AXF in the fall. In addition, given winter low flow withdrawal restrictions, some operators store river water in surface reservoirs during higher flow periods for use during low flow periods (Imperial Oil, 2017). However, this restriction may prompt additional removal of surface water from the Athabasca River during the fall season, which could impact the AXF during the critical fall hunting period, as shown in Figure 6-11 (See Section 5.9.1 for explanation of AXF) (Carver and Maclean, 2016).

The SWQMF considers access by Indigenous people through the Aboriginal Navigation Index (ANI). While the general limits in SWQMF mitigate effects to Indigenous access, the ANI application in the SWQMF does not mitigate impacts on access by Indigenous people. There are two problems.

1) Not Mitigating

The ANI is calculated after the fall season is over as a mean fall-season value based on an average of weekly flows throughout the fall. Given that the calculation occurs after the impacts have occurred, it is not possible to mitigate them. In addition, even if the ANI threshold was crossed, the resulting management action is investigation, not mitigation.

2) Not Addressing Cumulative Effects and Incremental Impacts

The ANI is based on the contribution of the oil sands water withdrawals. As along as their contribution to lower water levels remains small, the ANI threshold is not crossed. Most cumulative effects occur as a result of many small contributions, often from different sources. As a result, to mitigate the effects, even small contributions may need to be mitigated so that the overall result of all those small mitigations adds up to sufficient mitigation. Even small withdrawals of water may need to apply mitigations so that overall impacts are reduced.

The second issue with this approach is that it assumes that a small increase in an already large problem is insignificant. Under this assumption, if water levels are already very low due to a dry season, any small addition to this problem as a result of water withdrawals is considered to be insignificant in comparison to the already great impact of the low water that year. However, this assumption does not reflect the significance of actual impacts from changes in navigation, for example, relating to Indigenous access to harvesting areas in the fall. Access in the fall is of critical importance to Indigenous peoples because it is a key time for harvesting. If they can’t travel the Athabasca River and access harvesting areas in the PAD, they can’t harvest wildlife and then their freezers are emptier all winter long and costs of store bought food are large. Small changes in water levels (e.g. that last cm of water that allows clearance of a motor) can shift navigation from being possible to impossible, and prevent that extra week of harvesting. A one week difference may seem small, but if it was a key week for waterfowl harvest, for example, it could be very costly socially, culturally and economically.

In summary, while the general limits in SWQMF mitigate effects to Indigenous access, there is no assessment and mitigation to ensure the mitigation is adequate for Indigenous access in the PAD.

6.4.3 Groundwater Quality and Quantity in the Athabasca River Basin

It is important to note existing conventional mining and thermal in-situ oil sands facilities utilize groundwater for production and there appears to be no available data on the actual volumes of groundwater being withdrawn, along with the impact this may be having on the recharge of the Athabasca River system. It is unclear what effect additional conventional mining and in-situ projects may have on groundwater resources in the Athabasca River basin. Although unlikely, significant use of groundwater resources by in-situ oil sands facilities may have an effect on the recharge of the Athabasca River. Gibson et al. (2016), who investigated the partitioning of streamflow sources in the Athabasca River and its tributaries, note groundwater accounts for 39 to 50% of the annual streamflow in the Steepbank River, Muskeg River, and Firebag River. As such, additional developments utilizing groundwater on these tributary rivers may have an impact on the surface water flows of the Athabasca

River in the future. Additional information regarding current and potential groundwater withdrawals by oil sands facilities in the Athabasca River basin is needed in the future to further assess the potential effect from additional in-situ oil sands facilities.

With regard to groundwater quality, the Government of Alberta reports “no significant trends in key indicators have been recorded since initial sampling in 1975” for the Northern Alberta Oil Sands area (NAOS), however they note “there is poor to fair knowledge of groundwater quality in the surficial sands and buried channels within the NAOS area, as well as the basal McMurray Formation” (Government of Alberta, 2012b, p. 20). For the SAOS, knowledge of “groundwater quality conditions in the various key aquifers beneath the SAOS area is limited both from a temporal and spatial perspective” (Government of Alberta, 2012b, p. 21). From this assessment, it is clear that much more information is required in order to obtain an accurate picture of groundwater quality conditions in the NAOS and SAOS. More targeted and localized scientific studies may be required in the future in order to obtain additional information on groundwater quality to assess impacts from point sources. In summary, given the limited information about the current status, the future withdrawals from reasonably foreseeable development, and the impacts of climate change, the future trend is considered unknown.

The municipal, agricultural, and industrial use of groundwater in the province of Alberta is mainly governed by the provincial *Water Act* (through the issuance of water allocation licenses) and industrial activities that may impact groundwater are assessed as part of Alberta’s *Environmental Protection and Enhancement Act* (Government of Alberta, 2012b). As part of any industrial approval application, key policies and legislation reviewed include the Alberta Tier 1 and Tier 2 Soil and Groundwater Remediation Guidelines (AEP, 2016; AESRD, 2014), the Water Conservation and Allocation Guideline for Oilfield Injection (AENV, 2006), and the Alberta Environment Guide to Groundwater Authorization (AENV, 2011).

Historically, groundwater conditions have been monitored in the lower Athabasca region for the last 20 to 30 years through site-specific monitoring programs at oil sands facilities (Government of Alberta, 2012b). The Alberta government’s Groundwater Observation Well Network (GOWN) monitored regional groundwater conditions from the 1970s to the 1990s, however the program was put on hiatus until 2009, when the Groundwater Management Framework was established. In 2012, the Government of Alberta issued their Groundwater Management Framework for the Northern Athabasca Oil Sands area (NAOS - north of Fort McMurray) and began the development process for the Southern Athabasca Oil Sands area (SAOS - south of Fort McMurray) as part of the Lower Athabasca Regional Plan (LARP) (Government of Alberta, 2012b). The NAOS encompasses 18,000 km^2 north of Fort McMurray and the SAOS area encompasses 35,215 km^2 south of Fort McMurray, as shown below in Figure 6-12. With the exception of 2015, since 2012 groundwater monitoring has been conducted each year in the NAOS and SAOS.

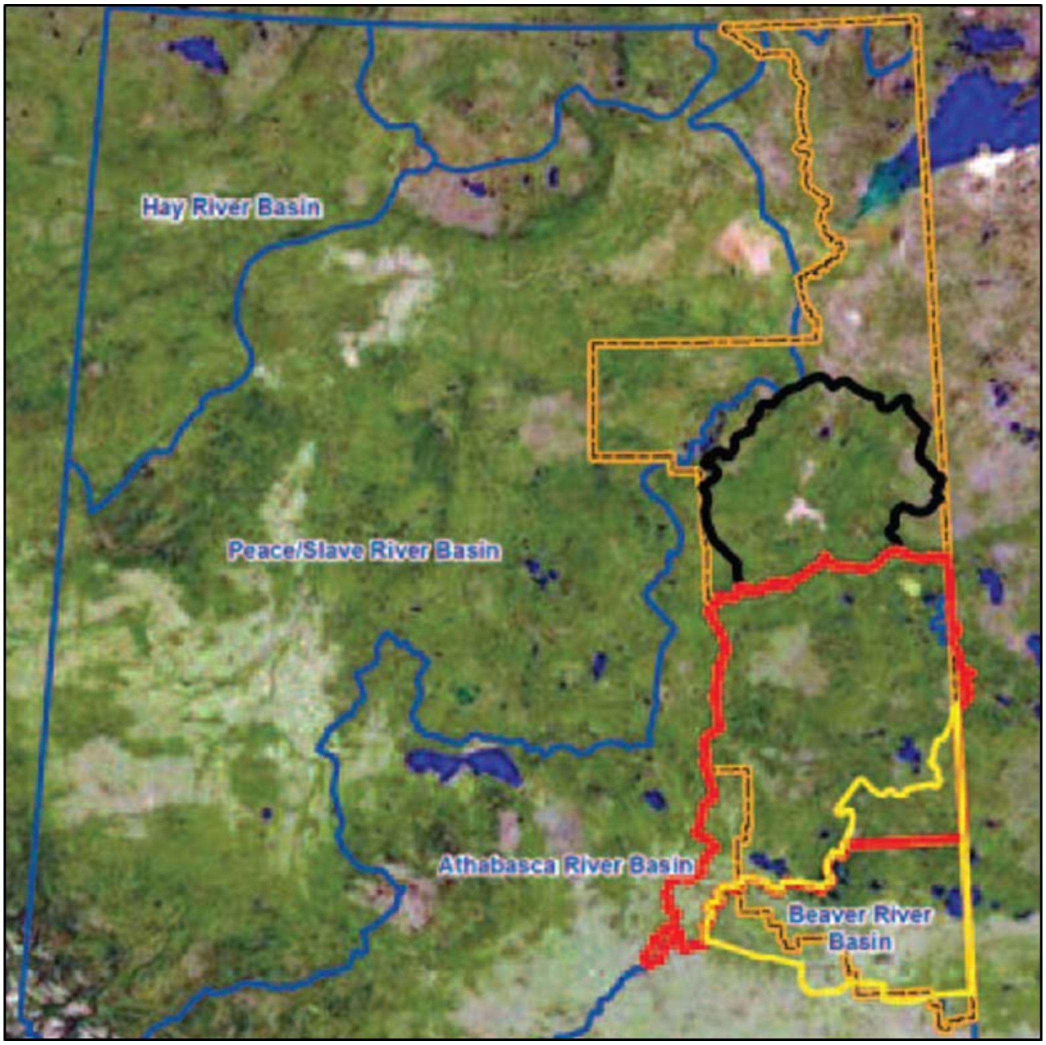


Figure 6-12: Map of the Groundwater Management Areas (Notes: NAOS shown in black and SAOS shown in red) (from Government of Alberta, 2012b)

As part of the Groundwater Management Framework, the Government of Alberta developed interim groundwater quality triggers in the NAOS and the SAOS. As they note “knowledge of the region’s groundwater resources is incomplete and continues to develop…The interim regional triggers will be compared to measurements taken at monitoring wells identified as representative of regional quality (i.e., not to compliance wells on industrial sites)” (Government of Alberta, 2012b, p. 26).

With regard to groundwater quantity, the available drawdown estimated in the various aquifers in the lower Athabasca region was assessed as substantial (Government of Alberta, 2012b). Further, for the NAOS “initial high-level estimates of groundwater volumes and recharge in the Lower Athabasca Region suggest a significant and sufficient volume to accommodate the current level of development and water use. However, additional data is required from future monitoring and assessment initiatives to refine these estimates and help facilitate future determination of sustainable yields for the regional aquifers in the NAOS area” (Government of Alberta, 2012b, p. 20). In addition, the Government of Alberta notes “at the current time, there are no interim regional (groundwater) quantity triggers. In their absence, a guideline [described below] exists for the in-situ industry with respect to the amount of water that can be safely used in support of bitumen recovery or injection for enhanced oil recovery" (Government of Alberta, 2012b, p. 26).

The Water Conservation and Allocation Guideline for Oilfield Injection (AENV, 2006), mentioned in the quote above, states "an applicant that proposes to use non-saline groundwater for underground (oilfield) injection will be restricted to a maximum of one-half of the long-term yield of a given aquifer in the immediate vicinity of the water source well. This will be accomplished by limiting drawdown in the production aquifer, as measured in the observation well at a distance of 150 m from the production well, to 35% during the first year of operation and no more than 50% over the life of the project" (p. 27). However, as described above, the cumulative effects of following this guideline are unknown.

6.4.4 Air Quality

As noted in Section 5.7, both science and ITK have indicated a downward air quality trend resulting from poorer air quality at certain times in the year. Further, Section 5.7.1 outlines the potential for long-range atmospheric transport of contaminants, such as metals and PAHs, from the oil sands region to the PAD, ranging anywhere from 50 km to 100 km from the source (Willis et al., 2018; Cooke et al., 2017; Landis et al., 2017; Manzano et al., 2017; Manzano et al. 2016; Kirk et al., 2014; Landis et al. 2012). Further, ECCC's air quality model for air deposition impacts resulting from oil sands development (August 2013 through July 2014 model simulations) predicted critical load exceedances within the WBNP for: (a) terrestrial ecosystems, along the south-western border, (b) aquatic ecosystems with respect to sulphur deposition, in the park's south and south-western portions, and (c) aquatic ecosystems in throughout much of the park (Makar et all, 2018).

Given these findings, the fact the proposed Teck Frontier project is located within 30 km of the south border of the WBNP indicates a potential increased risk to the air quality of WBNP. However, the current downward air quality trend is relatively weak and the Teck Frontier project is currently being reviewed through the environmental assessment process and mitigation measures are not known for this project. Thus, the future status of the air quality trend for the WBNP world heritage values is unknown.

Currently, some of the management tools in place include: JOSM monitoring, environmental approvals for individual projects, and a number of federal and provincial frameworks described below. Federally, air quality targets are set and managed through the *Canadian Environmental Protection Act* and work of the Canadian Council of Ministers of the Environment (2014a), among other tools. The federal, provincial, and territorial governments are working collaboratively to improve air quality through the implementation of the Air Quality Management System (AQMS). Under the AQMS, each province and territory is delineated into one or more air zones. These air zones provide focal points for stakeholders and governments to work together in order to improve air quality and maintain air pollutant concentrations below established Canadian Ambient Air Quality Standards (CAAQS).

Air zones provide guidance for assigning priority to those areas where air quality is approaching or exceeding the CAAQS or where populations and the environment are most at risk. As a result, the Alberta government published the Lower Athabasca Region Air Zone Canadian Ambient Air Quality Standards Response Government of Alberta Action Plan (September 2017).

(http://aep.alberta.ca/air/management-frameworks/canadian-ambient-air-quality-standards/documents/LowerAthabascaCAAQS-ActionPlan-Sep2017.pdf).

In Alberta, the Air Quality Management Framework for the Lower Peace Region has not been completed. An Air Quality Management framework is available for the Lower Athabasca Region. This Framework includes the area immediately outside WBNP (i.e. Fort Chipewyan), but not WBNP World Heritage Site (Government of Alberta, 2012c). It is unknown if mitigation for Fort Chipewyan would be adequate for WBNP World Heritage Site.

Air quality in the Lower Athabasca Region is monitored by the Wood Buffalo Environmental Association (WBEA) through contracts with the Environmental Monitoring and Science Division (EMSD) of the Government of Alberta. The 23 WBEA air monitoring stations include continuous and intermittent monitoring at facility fence line, community, and background locations for the following contaminants, which may be naturally present and/or associated with regional developments, include carbon monoxide (CO), hydrogen sulphide (H_2S), total reduced sulfur (TRS), ammonia (NH_3), nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen oxides (NOx), ozone (O_3), particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), total hydrocarbons (THC), and methane/non-methane hydrocarbons (CH_4/NMHC). However, it is important to note the Lower Athabasca Region Air Quality Management Framework assesses regional ambient quality using only Sulfur Dioxide (SO_2) and Oxides of Nitrogen (NOx) and there is only a single monitoring station within the PAD region at Fort Chipewyan. The air quality rating is calculated as the Air Quality Health Index (AQHI). Lower Athabasca Region's Air Quality Management Framework does not include important elements, such as odours, flaring, CO_2 and particulate matter that can degrade the world heritage values of the park.

Environment and Climate Change Canada began monitoring air quality in WBNP in 2014 through its Canadian Air and Precipitation Monitoring Network (CAPMoN). The Canadian Air and Precipitation Monitoring Network (CAPMoN) is designed to study the regional patterns and trends of atmospheric pollutants such as acid rain, smog, particulate matter and mercury, in both air and precipitation. The WBNP CAPMoN site was installed in collaboration with Parks Canada to address data gaps in air quality and atmospheric deposition in Western Canada. It is located in an area of WBNP free from local pollution sources and monitors ozone, air and precipitation chemistry in real time. Data from the CAPMoN site will be used to evaluate and validate air quality modelling outputs and satellite measurements. Further, the site will provide a baseline for air quality and atmospheric deposition in the WBNP region and for assessment of individual and cumulative impacts on the WBNP.

6.4.5 Athabasca River Water Quality

As outlined in Chapter 5 of this report, the Athabasca River has experienced an increasing trend in concentrations of magnesium, sodium, dissolved aluminum, total selenium, dissolved iron, and dissolved arsenic, as well as PAHs and PACs (Glozier et al., 2018). Elevated PAC concentrations retaining an oil sands chemical signature were found in the lower reaches of the Athabasca River near the southeastern tip of the WBNP and the Richardson, Quatre Fourches, and Birch Rivers (tributary EMP sites) also showed slightly elevated PAC levels in comparison to background values (Glozier et al., 2018). The documented increase in contaminant levels in the Athabasca River, in conjunction with the potential for increased contaminant levels from reasonably foreseeable oil sands facilities, could affect water quality in the Athabasca River and the PAD in the future.

Further, as noted in Section 5.5.1, dissolved nutrient and metals concentrations increase in the PAD rivers as flow volumes decrease, including phosphorus (TP), dissolved iron, major ions, nutrients, TSS, and turbidity. Presumably, as flow volumes in the Athabasca River are further reduced due to climate change and increased withdrawals from reasonably foreseeable oil sands facilities, concentrations of nutrients and metals concentrations will increase. Thus, based on the potential for increased concentrations of metals, nutrients, and PAHs and PACs in the Athabasca River from reasonably foreseeable projects, combined with the potential for increases in nutrients and metals due to decreasing water flows on the Athabasca River due to climate change, the projected future trend for the desired outcome for water quality in the PAD is negative.

Currently, some of the management tools in place include: JOSM/RAMP monitoring, water licences and environmental approvals for individual projects and the LAR Surface Water Quality Management Framework.

The Regional Aquatics Monitoring Program (RAMP), initiated in 1997, reports on surface water quality in the upstream river basin systems within the Lower Athabasca Region. Notably, there are minimal sampling locations within the PAD beyond Fort Chipewyan.

In addition, the LAR Surface Water Quality Management Framework for the Athabasca River is in effect. Spatially, the framework excludes WBNP World Heritage Site and PAD within it and therefore while mitigating effects on the PAD, it is not designed to ensure that effects are fully mitigated in the context of the cumulative effects being experienced by the PAD. It also excludes certain oil sands-related contaminants (naphthenic acids and polycyclic aromatic hydrocarbons and compounds) and does not require biological measurements such as fish counts, health assessments and bioaccumulation of toxic substances in key species for WBNP.

The lack of monitoring within the PAD and WBNP has led independent researchers and First Nations to undertake community-based monitoring and research programs in an attempt to understand current ambient conditions in surface water quality (see Chapter 5). There is no indication that regulators or companies are using community-based monitoring information to inform decision-making.

6.4.6 Fire suppression

Increases to temperature and decreases in precipitation predicted for the region (see Section 6.3.2) could result in increased fire risk. The management response to this increased risk is important for WBNP's future landscape. The *Parks Canada Wildland Fire Management Directive* (Parks Canada, 2017a) provides fire management guidance, which:

- ensures public and staff safety and the protection of natural and cultural resources by reducing wildfire risk and maintaining an effective fire management capacity;
- maintains and restores EI of park/site ecosystems;

- contributes to the restoration of cultural landscapes and integrates Indigenous Knowledge (IK), including cultural practices in the management of fire;
- demonstrates a commitment to the "PARKS" principles outlined in *Promising Pathways Guide*;
- facilitates unique visitor experiences and learning opportunities

Park fire management plans are used to clarify how these goals are met in an individual park. WBNP does not have an approved fire management plan. Therefore, while fire in WBNP is currently managed such that the long term ecological process is maintained, the park wild fire plan should be finalized to ensure this direction continues. In the absence of a final plan, the trend is assumed to be worsening due to climate change.

6.4.7 Increased Linear Corridor Density and Habitat Changes Surrounding the WBNP

Low impact seismic practices, restoration and land use planning are all mechanisms used to decrease the impact of linear corridor density and habitat loss around WBNP. However even with this mitigation, the reasonably foreseeable developments identified in Section 6.2 are expected to further contribute to this pathway of effect. It is not known if climate change will be a significant contributor to this pathway of effect. The future trend is therefore predicted to be worsening.

As mentioned, a variety of management tools are already in place to manage this effect, including: project assessments, low seismic practices and restoration. In addition, a variety of tools focused on the cumulative nature of effects could be used to manage this pathway of effect, including forest management agreements, species specific plans, and land use plans and associated frameworks.

The Lower Peace Regional Plan has not been completed. There is also no land use plan in this area of the Northwest Territories. As a result, there is an opportunity to address linear corridor density and habitat loss in the development of any future plans.

The Lower Athabasca Regional Plan has been completed and indicates that a biodiversity management framework will be developed including biodiversity indicators and addressing caribou habitat. Alberta has also indicated that a landscape management plan will be developed to manage linear footprint and land disturbance (Alberta Government, 2014).

The Ronald Lake Bison Herd is particularly important, given it is the only disease-free herd to include range in the park. Existing development in their range is already extensive and the proposed Teck Frontier project plans to add to the disturbance, risks are higher for this herd than the others.

6.4.8 Disease Management and Hunting Outside WBNP

The reasonably foreseeable development identified in Section 6.2 could facilitate access for hunting (legal or illegal), for example for the Ronald Lake Bison Herd. However, this contribution to the pathway of effect is likely small. It is unknown if climate change will significantly contribute to this pathway of effect. Likely the more significant impacts on this pathway of effect are not climate change and development, but rather government decisions with respect to disease management. As the current status of bison is unknown and the contributions of proposed development and climate change are small or unknown, the future trend is considered unknown.

Wood Bison are protected under the *Species at Risk Act*. The *Recovery Strategy for the Wood Bison* (ECCC, 2016) has not been finalized. Alberta and Northwest Territories Regulations are intended to protect the healthy herds and the risk of disease transmission to cattle, but there is currently no protection for the Wabasca herd which is presumed disease free and protection for the Ronald Lake Bison Herd does not cover the full herd range.

6.4.9 Hydrological Changes in Karst/Whooping Crane Nesting Area

Changes in hydrology could affect both the karst and the Whooping Crane nesting area. Forestry is the only reasonably foreseeable project that could contribute to this pathway of effect, in combination with climate change effects on hydrology. The hydrology of this habitat is not understood sufficiently to make a prediction about the impacts of climate change and these proposed developments. As a result, the future trend for the related desired outcomes is considered unknown.

Whooping cranes are protected under the *Species at Risk Act.* Critical habitat for the Whooping Crane has been identified in WBNP and protected through identification in the Canada Gazette. The *Whooping Crane Recovery Strategy* indicated that further studies were needed to identify critical habitat beyond WBNP and they would be completed by 2013 (Environment Canada, 2007). Critical habitat has not yet been identified and protected outside of WBNP. Project environmental assessments and forest management agreements are other tools that may be important to manage hydrological changes in the future.

6.4.10 Short-Term Exposures to Contaminants in Local Migratory Habitat

Two proposed developments identified in Section 6.2 will add further tailings ponds area. However, closure and capping of tailings ponds is expected to occur as will over the next 30 years. The trend will depend on the relative speeds of restoration versus expansion, which is unknown at this time.

There is no coordinated approach to mitigating the contamination of migratory waterfowl to oil sands development. However, there is a coordinated Oil Sands Bird Monitoring Plan (St. Clair et al., 2014) for monitoring and project level assessments are used to identify mitigations and an Oil Sands Bird Technical Team whose work includes research on acute and chronic effects on birds that have come into contact with process affected waters.

6.4.11 Changes to Habitat and Food Availability in Local Migratory Habitat

While many of the proposed projects in Section 6.2 are smaller, the reasonably foreseeable developments are expected to continue to impact habitat for migratory waterfowl. Furthermore, the potential success of the restoration of wetland habitat has currently not been demonstrated (Gosselin et al., 2010). The effects of climate change on this pathway of effect are not known. As a result of the reasonably foreseeable developments expected, this pathway of effect is predicted to continue to worsen.

As discussed in Section 6.4.7, a variety of cumulative effects management tools could be used to manage this pathway of effect, including forest management agreements, species specific plans, and land use plans and associated frameworks.

6.4.12 Invasive Species

As a primary pathway of effect, the mechanism for introducing invasive species is not understood. Given that it is not clear to what degree invasive species can enter the salt plains, the future trend remains unknown. For the Great Plains Boreal Grasslands, invasive species would be a negative trend, although the extent of the effect is unknown.

6.4.13 Changes in Local Migration Routes

Not enough is known about what is causing the changes in local migration routes to know whether proposed future development or climate change will contribute to the effect. However, given the already substantial effect, the trend is assumed to continue to worsen in the future without further understanding and intervention.

6.5 SUMMARY

After identifying the reasonably foreseeable development and the projected climate change for the next 30 years, each primary pathway of effect identified in Chapter 4 and 5 was evaluated to predict the future trend. These trends in combination with their current status were then used in Table 6-9 to predict the future trend for each desired outcome. For context to this analysis, the cumulative effects tools being used to manage the pathways of effects were described. The existence of such a broad suite of cumulative effects and other environmental effects management tools is evidence of the evolving sophistication of management of cumulative effects. Only a decade ago, this breadth of tools was not available.

Key observations from the analysis in this chapter are as follows:

- With the PAD and migratory waterfowl desired outcomes already not being met and predicted negative trends, the predicted trends of these desired outcomes are negative.
- With the exception of Whooping Crane, future trends for other desired outcomes were not possible to predict.
- Many tools with the potential to effectively manage cumulative effects have not been completed or were developed without analysis to ensure they were protective of the WBNP world heritage values. While all tools that are in place contribute to the protection of WBNP, if they were not developed with consideration of the world heritage values, it is unknown whether they will adequately protect the world heritage values in the context of the cumulative effects on the world heritage values.

Chapter 7 identifies recommendations to address these issues.

Table 6-9: Projected Cumulative Effects Trends on Desired Outcomes for the WBNP

Desired Outcomes	Does weight of evidence indicate outcome is currently being achieved?[2]	What does the weight of evidence indicate with respect valid linkage or pathway of effect between the desired outcome and key stressors? What is the likely current direction of the trend from each stressor?[3]				What is the likely future trend direction resulting from all stressors?
		Climate Change (e.g. low rain or snowfall)	Change in Surface Water Quantity (e.g. dams, water removal)	Change in GW and Surface Water Quality (e.g. metals or HC pollution)	Other Impacts	
1. Great concentrations of viable, healthy populations of migratory waterfowl species continue to use WBNP seasonally.	NO	YES ↘	YES ↘	YES ↘	Local Migratory Habitat ↘	↘
2. Adequate quantity and quality habitat, unimpaired by contamination, is available for migratory waterfowl to fulfil all key life cycle stages while present in WBNP.	NO	YES ↘	YES ↘	YES ↘		↘
3. Indigenous groups are able to maintain traditional harvest of waterfowl species and practice their way of life with confidence in healthy, sustainable and accessible populations of waterfowl	NO	YES ↘	YES ↘	YES ↘		↘
4. Flow regimes and water quality into the PAD maintain the ecological function of the ecosystem	NO	YES ↘	YES ↘	Unknown YES↘	Air Quality ↘	↘

[2] Determined based on chapters 4 & 5 and described in narrative rationale in chapter 6 prior to this table
[3] ↗= positive or improving effect on desired outcomes, →= neutral effect ..., ↘= declining or negative effect…, assumes overall anticipated trend from present (2017) to 2050 unless otherwise stated.

Desired Outcomes	Does weight of evidence indicate outcome is currently being achieved?[2]	What does the weight of evidence indicate with respect valid linkage or pathway of effect between the desired outcome and key stressors? What is the likely current direction of the trend from each stressor?[3]				What is the likely future trend direction resulting from all stressors?
		Climate Change (e.g. low rain or snowfall)	Change in Surface Water Quantity (e.g. dams, water removal)	Change in GW and Surface Water Quality (e.g. metals or HC pollution)	Other Impacts	
5. Flow regimes and water quality in the PAD sustains vegetation communities and healthy and abundant populations of key ecological and cultural species including waterfowl, muskrat, fish, bison and wolves.	NO	YES ↘	Unknown	YES ↘		↘
6. Indigenous groups have access to the PAD and are confident enough in the health of the PAD to maintain traditional use and way of life through hunting, fishing, gathering, and cultural activities.	NO	Unknown	YES ↘	YES ↘	Air Quality ↘	↘
7. The salt plains remain aesthetically, ecologically and geologically unique in Canada, providing habitat for salt tolerant plants, grazing bison and nesting / staging waterfowl.	YES	Unknown	Unknown	Unknown		Unknown
8. Gypsum karst topography in WBNP remains intact and functioning within natural parameters.	YES	YES	YES	Unknown		Unknown
9. The karst landforms in the park continue to provide some of the finest examples of collapse and pond sinkholes in the world.	YES	YES	YES	Unknown		Unknown

Desired Outcomes	Does weight of evidence indicate outcome is currently being achieved?[2]	What does the weight of evidence indicate with respect valid linkage or pathway of effect between the desired outcome and key stressors? What is the likely current direction of the trend from each stressor?[3]				What is the likely future trend direction resulting from all stressors?
		Climate Change (e.g. low rain or snowfall)	Change in Surface Water Quantity (e.g. dams, water removal)	Change in GW and Surface Water Quality (e.g. metals or HC pollution)	Other Impacts	
10. All species and community representatives of the Great Plains-Boreal grassland are present and functioning.	YES	YES ↘	YES - locally↘	NO	Fire Suppression ↘ Invasive Species ↘	↘
11. These grasslands continue to provide important grazing and calving areas for wood bison.	NO	YES ↗	YES ↘	NO	Invasive Species ↘	Unknown
12. The predator-prey relationship between wolves and wood bison that spend time in the park remains intact and within natural ranges of variation	Unknown	Unknown	YES locally ↘	NO	External development ↘ Disease management ↘	Unknown
13. Populations of bison and wolves remain viable, evolve as naturally as possible and support Indigenous traditional use and ways of life.	NO	Unknown	YES - locally↘	NO		Unknown
14. Habitat continues to support recovery strategy goals for Whooping Crane breeding pairs and demonstrates resilience to climate change impacts.	YES	NO	YES	NO		Unknown

Desired Outcomes	Does weight of evidence indicate outcome is currently being achieved?[2]	What does the weight of evidence indicate with respect valid linkage or pathway of effect between the desired outcome and key stressors? What is the likely current direction of the trend from each stressor?[3]				What is the likely future trend direction resulting from all stressors?
		Climate Change (e.g. low rain or snowfall)	Change in Surface Water Quantity (e.g. dams, water removal)	Change in GW and Surface Water Quality (e.g. metals or HC pollution)	Other Impacts	
15. Whooping crane population reaches recovery strategy goal.	NO	NO	NO	NO	Local Migratory Habitat ↘	↗
16. Recovery and down listing from endangered status.	NO	NO	NO	NO		↗

7.0 CHAPTER 7: RECOMMENDATIONS

Chapters 4 and 5 discussed the pathways of effects (stories of change), current status and trends of aspects of the world heritage values of WBNP. Chapter 6 first described reasonably foreseeable developments in the WBNP region and projected climate change impacts. Based on this, Chapter 6 then projected likely future cumulative effects trends. This final chapter of the SEA makes recommendations in response to the findings about pathways of effects and desired outcomes.

7.1 INTRODUCTION

In order to understand and implement the recommendations in this chapter, the precautionary principle, adaptive management, partnership with Indigenous peoples and robust collaboration are essential and introduced briefly.

7.1.1 Precautionary Approach

The precautionary approach recognizes "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." (ECCC, 2017). The precautionary approach is applied when there is 1) a lack of full scientific certainty and 2) a risk of serious or irreversible harm.

> ***"If we don't save what we have, pretty soon we won't have anything."***
> ***(NWT Métis, 2018)***

Lack of full certainty

Lack of full certainty is often evident when baseline information is lacking and there are gaps in understanding. The RMM recommendations recognized the need for baseline information. For example, recommendations 3, 7, 6, 8, 9, 10, 16, 17 all focus on gathering more information or undertaking analysis. Similarly, in this chapter there are a number of gaps identified in information. The PAD is a very complex ecosystem. The hydrological ecosystem processes alone are multi-dimensional and in addition to these, fire, predation and other processes are at work. The complexity of developments around the park also adds to the uncertainty. Chapters 4 and 5 demonstrate that there are some emerging lines of consensus and clarity about some impact pathways; however, given the level of complexity in this system there will continue to be some level of uncertainty in determining cause and effect contributions from various activities in the region and their consequent impacts on ecosystem receptors in the receiving WBNP environment.

Risk of serious or irreversible harm

Chapters 4 and 5 document important changes that have been observed within WBNP, and in the PAD in particular. Chapter 6 identifies that at least some of these changes will continue to increase without changes to the management of cumulative effects on the world heritage values of WBNP. Ecologists and Indigenous knowledge holders have already implied that some impacts may already be irreversible given the large amount of change they have seen. For example, Remmer et al. (2018) found that a single ice-jam flooding event in 2014 was insufficient to mitigate the ongoing declining water availability for more than a season. While the ecological changes may still be reversible, the scale of intervention needed to reverse them may be increase the more time passes.

When determining the seriousness of the risk, one must consider the ecological impacts, as well as the context of those impacts and the values associated with them. In other words, the consequences of effects cannot be reversed are higher or lower depending on the values associated with them. In the case of this SEA for WBNP, the risk must be examined in the context of value of the place to Indigenous people, international designations, and the national park designation.

For the Indigenous people of the WBNP region, particularly those using the main water ways and the PAD as well as downstream areas, there are many risks to their current health, culture and ways of life. Furthermore, those who can no longer travel to their traditional areas can no longer pass on their ways of life and stories to future generations. The risk increases that this loss will be irreversible as those who used these areas when they were accessible and healthier grow older.

You can tell kids, but it's so much better to show them where we pick because they will remember then. If it's too shallow, you can't go out with family and friends.

Quote context: *This is very true! That is why a lot of times we say in meetings that when we tell you stuff some don't really believe it as you don't actually see it (while in a meeting room). I tell my grandkids a lot of stuff when we go camping. "That is good papa." My grandson said "I want to try to be like you, you showed me all that I want to be like you." I. If you want to learn I will open the book (on the land).*
Source: *Sloan Whiteknife*
About Sloan Whiteknife: *I am George Sloan Whiteknife. I was born and raised in the bush. Ever since then I've always been in the bush. I was taught from my dad to trap and to hunting moose, geese etc. I was always with him and he always used to tell me things. I learned quite a bit from my dad in my past life, and my uncles. I went out with all my relations. We need water. When I say something has to be done, I mean we need more water.*

As a world heritage site, Wood Buffalo National Park is recognized for its outstanding universal value. Furthermore, the designation of two Ramsar wetlands within the park's boundaries also encourage the maintenance and restoration of wetlands where possible. If serious and/or irreversible harm occurred to components of such international designations, the world would face an impoverishment of this international heritage treasure.

Canadian national parks, like Wood Buffalo National Park, are dedicated to the "people of Canada for their benefit, education and enjoyment, …and the parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations" (*Canada National Parks Act* s.4(1)). Therefore, if serious and/or irreversible harm was caused to the ecological integrity of Wood Buffalo, Indigenous peoples of the area, and all Canadians, including future generations, will be impacted.

Conclusion

Given the high risk to the health, culture, way of life of Indigenous peoples, the world heritage values, and the ecological integrity of the national park, as well as the possibility of irreversible impacts, the governments at all levels, Indigenous communities and industry should apply the precautionary principle.

7.1.2 Adaptive Management Approach

An adaptive management approach is imperative given that there is a considerable need to act in WBNP, even without full understanding and information. The process of adaptive management is "seen as an evolving process that includes learning (the accumulation of understanding over time) and adaptation (the adjustment of management over time)" (Williams & Brown, 2014).

Adaptive management is most effectively applied in ecosystems:

- that are dynamic and have been influenced by changing environmental variables and management actions;
- where environmental change is only partially predictable and often appears as random;
- where management intervention influence the system's behaviour, directly or indirectly; and
- where traditional management processes are limited by uncertainty in the system behaviour and the lack of knowledge over how management will influence the system.

These characteristics are all present within the PAD.

Adaptive management (Figure 7-1) works to implement and monitor management approaches with the intention of reducing uncertainty over time, and to enable changes in management to be made in based on new information and teachings (Williams & Brown, 2014). Adaptive management is often illustrated by a loop where the formulation of a problem flows "through decision-making, implementation, evaluation, and feedback into problem formulation" (Williams & Brown, 2014).

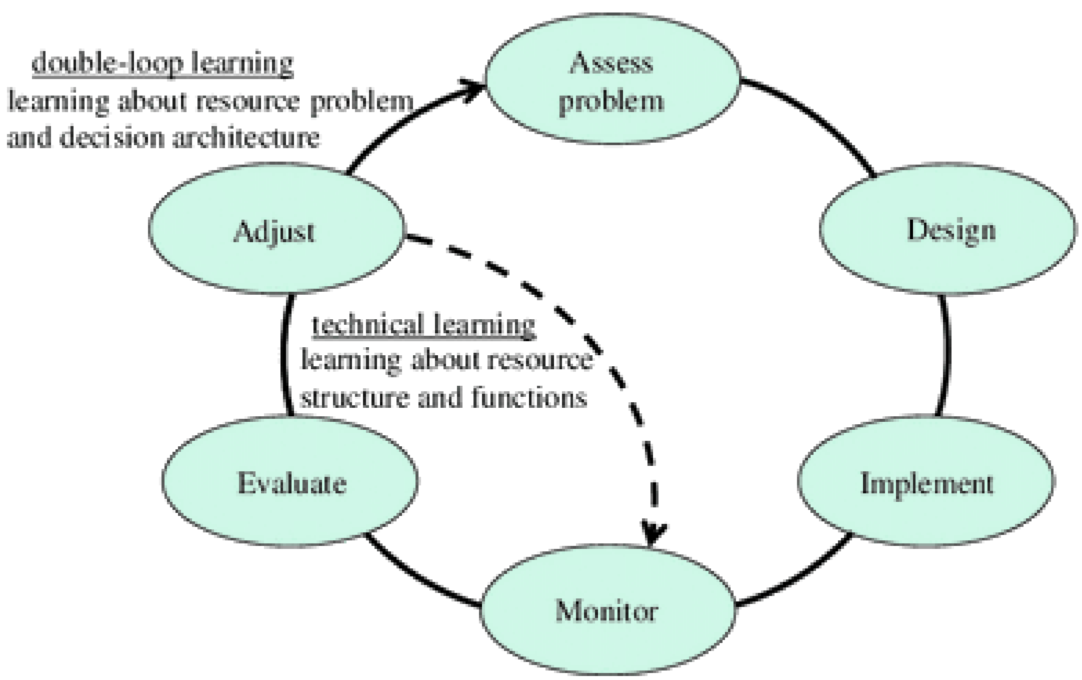


Figure 7-1: Adaptive Management Cycle (Source: Williams & Brown, 2014)

It will be important to apply the adaptive management approach along with the precautionary approach described above as they work in tandem.

7.1.3 Partnership with Indigenous peoples

As the ones whose grocery store, kitchen, school, photo album and culture are most affected by the recommendations of this SEA, Indigenous peoples need to be full partners in the identification, implementation and adaptive management of future management approaches within WBNP. Indigenous peoples experience impacts most directly due to their intrinsic connection to the land. As such, ITK is critical to the advancement of adaptive management solutions. This SEA has attempted to illustrate the complementarity, importance and necessity of inclusion of ITK alongside western science in analysis and decision making.

RMM Recommendations 1, 13, and 14 have recognized the importance of partnerships with Indigenous people. In addition, the mandate letter for the Minister responsible for Parks Canada and Environment and Climate Change Canada calls for a "renewed, nation-to-nation relationship with Indigenous Peoples, based on recognition of rights, respect, co-operation, and partnership".

7.1.4 Robust collaboration

This SEA does not include a comprehensive analysis of the legal, policy, administrative and governance framework that is in place to protect the world heritage values of WBNP. However, two observations can be made as a result of the SEA process.

First, the existence of already observed effects on the world heritage values described in Chapter 5 means to some degree that the past and present framework for anticipating cumulative effects has not succeeded. While some of the effects observed are more recent, and perhaps one could argue that a response is in progress, other effects have clearly occurred over a longer time scale. Whatever the situation, the fact that effects have been observed indicates additional mitigation is required.

Second, the SEA found that there are multiple legal, policy, administrative and governance components involved in the framework. In the development of the SEA, discussions were held with and/or comments were received from more than 11 Indigenous groups, two provinces, a territory, federal government departments and stakeholder groups. This represents the breadth of groups with a role in protecting the world heritage values of WBNP. In addition, all these groups referred to numerous legal, policy, administrative and governance tools that were relevant to the protection of the world heritage values of WBNP. The extent of the groups and tools considered indicates that collaboration will be foundational to the implementation of recommendations from the SEA to protect the world heritage values of WBNP.

Third, many of the pathways of effects cross jurisdictional boundaries. For example, water flows into the park, wildlife move in and out of the park, migratory waterfowl fly through the park etc. The nature of jurisdictional responsibilities is that a jurisdiction focuses on fulfilling their responsibilities. Yet in order to protect the world heritage values of WBNP it will be necessary for all to look beyond their jurisdictional responsibilities.

While it is true that collaboration has the power to bring positive and improved results, there are also risks that collaborative processes lead to inaction and the lowest common denominator, among other problems. In order for collaboration to result in restoration of and reduced risk to the world heritage values of WBNP, robust collaboration will require careful design and commitment to results by all those involved.

7.2 Urgency

Since the world heritage designation in 1983, there have been improvements to the Great Plains Boreal Grasslands as fire has been restored to more natural levels on the landscape, to bison as wolf control effects are reduced, and to Whooping Crane populations. However, the status of some of the desired outcomes demonstrates that restoration has not occurred for all desired outcomes and the trends for many are negative. As a result, further action and restoration is urgently needed.

The call for action and action now, was repeated throughout the course of the development of this SEA. Ecological monitoring and ITK have shown that with improved flooding, for example, ecosystems will rebound. However, if the current direction continues, other undesirable permanent shifts are possible. The urgency for Indigenous people to maintain their culture and ways of life cannot be understated. One way Indigenous people transfer knowledge and skills to the next generation is on the land, in the context of carrying out traditional activities. When Indigenous people cannot do this, they risk losing their culture and connections to the land. The longer the time that traditional way of life cannot be carried out due to lack of access, limited resources and/or diminished quality of resources, the higher the risk that the chain of transmission will be permanently broken.

We are here to show/tell you we need action. We are the reasons why. That is why we have our stories.

Quote context: *We are telling you are stories good heartedly. I know the land. The elders know the land all their lives. That is why we call them our scientists. My quote is to explain why they are here. The years' experience they have. This is their true experiences and what they go through. It is the truth today and what they want for the future generations.*
Source: *Terri Marten*
About Terri Marten: *I was born and raised out in the PAD. I was out there until I was 7 or 8. Then I was in the convent until 16. Then my parents took me out for a year in the bush at 16 or 17. Then I stayed around town with families here. I have always stayed in Chip, in and out from different areas of the PAD.*

7.3 SEA Recommendations

The SEA recommendations were developed to address the findings for desired outcomes, pathways of effects and the SEA in general. Where desired outcomes were not being met, in some cases there is a need for more information to understand the causes for the effects being observed. In other cases, the causes are understood well enough and restoration is needed. Similarly, there is not enough information about some pathways of effects and recommendations are made to investigate. In other cases, there is need to address the cumulative effect tool to adequately mitigate the pathway of effect. Finally, some recommendations were developed as a result of the general learning from the development of the SEA.

The future risk to the desired outcomes identified in Table 6-9 will be significantly reduced with the implementation of these recommendations and the recommendations of the RMM. Given that specific

RMM recommendations are intended to protect and restore the world heritage values, it is appropriate to consider the recommendations of the SEA in this context. Recommendations from the SEA, which are more detailed than the RMM recommendations, were therefore grouped under the same headings as the RMM recommendations. Each of these headings identify lead jurisdiction(s) responsible for developing and implementing the Action Plan. The intent is to provide SEA recommendations to these jurisdictional leads for consideration in the development and implementation of the Action Plan. In recognition of the constraints to this SEA (see Section 1.5.1), it is expected that additional analysis will be needed during the Action Plan development and implementation to confirm the appropriateness of these recommendations and, where appropriate, further develop them.

It should be noted that some of these recommendations have been made before, committed to and are even embodied in legal requirements. Yet, they have not been acted upon or completed. Understanding the urgency of the situation must motivate all those involved to act now.

RMM Recommendations 1, 13 and 14 represent a foundational approach to implementation and, therefore, are not repeated here. RMM Recommendation 2 and 12 relate to capacity required to implement all other recommendations. Completion of this SEA fulfills RMM Recommendation 8 and the 2015 World Heritage Centre decision. The other RMM recommendations are listed below followed by additional recommendations arising from the SEA.

7.3.1 Environmental Flows / Hydrology

Chapter 4 and 5 describe how the desired outcomes related to the PAD and the consequential impacts on migratory waterfowl, Great Plains Boreal Grasslands, and wolf-bison relationship are not being achieved. As a result, action/restoration is required to achieve the desired outcomes (Recommendations 1, 2 and 4). Pathways of effects related to the flows on the Peace River and Athabasca River were found to have expected declining trends in the future due to climate change and reasonably foreseeable development and therefore these pathways of effects need additional information gathering (Recommendations 3, 5 and 6). The following recommendations are made for consideration by the Environmental Flows/Hydrology Working Group.

1) Implement cross-jurisdictional (including Indigenous governments) cooperation in order to achieve the world heritage desired outcomes for the PAD and the national park by:
    - Recognizing the fact that water releases are complex hydrological events with potential negative consequences, consult with communities upstream and downstream of the PAD to ensure intervention risks are understood and acceptable.
    - Providing major water releases from the Bennett Dam at appropriate opportunities during the early freshet to encourage ice-jam events capable of flooding the PAD's perched basins
    - Investigating and implementing strategies to promote favourable flooding conditions on the Peace River, involving reducing water flow in late fall to promote lower and thicker ice cover freeze up, as well as increasing water flow during spring freshet and summer open water season.
    - Reviewing the relative success of past attempts to restore flood conditions in the PAD, including the following releases of water from the Bennett dam to inform above work:

    - In the spring of 1996, approximately 500 m^3/s was released for approximately a week to augment hydrometeorological conditions favourable to ice jam formation (a large spring snowpack, high ice cover strength, and intense spring snowmelt). The augmented release increased the ice-jam flooding near the PAD and increased flood elevations in the PAD by 20 cm (Maclean, 2018).
    - In July of 1996, approximately 5,000 m^3/s was released for approximately seven weeks due to of a structural fault (sinkhole) in the dam, resulting in an emergency spill to draw down the reservoir by 3 metres while repairs took place. The spill resulted in the contribution of additional water to the delta through an extended period of flow reversals on delta channels (Maclean, 2018). However, following this spill, water levels were again reduced on the Peace River and water flowing from Lake Athabasca toward the Slave River resulted in the degradation of the winter road and open water on the Rivière des Rochers, causing vehicle damage and loss of life.

2) Consider options for strategically placed water management/control structures within the PAD, recognizing flow regulation, water withdrawals, and projected climate change impacts on available water resources and implement using an adaptive management approach, including:

    - Reviewing past attempts to control outflow on the PAD, conducting modelling analyses of interventions in Recommendation 1 and climate change, identifying appropriate feasible objectives and evaluating implications of any options for the downstream.
    - Developing options for constructing ice dams, improvement to or additional rockfill weirs, inflatable/gated weirs, and/or retentive/flexible flow barriers at strategic points within the PAD to restore water levels in the PAD in the short term and long term.
        - As noted by MCFN (2007), a control dam on the Quatre Fourches River at Dog Camp would immediately raise water levels in the Delta, and greatly improve water levels in both Lake Claire and Lake Mamawi.
    - Establishing a monitoring system in the PAD to measure ice conditions (thickness and quality), water levels, advise on water release measures, and to verify the effectiveness of physical interventions measures (flow releases and flow barriers) on an ongoing basis.
    - Developing a PAD water management group to monitor the success of implementing water release/control measures.

3) Work with Alberta's Climate Change office and federal climate change specialists to determine more precise climate change model projections for the Athabasca and Peace River basins

4) Update the water flow framework for the Athabasca River (the Surface Water Quantity Management Framework or SWQMF) to incorporate all three world heritage desired outcomes for the PAD, including:

    - Completing the work required to address gaps in knowledge related to impacts to the PAD identified in SQWMF.
    - Including a mechanism that provides mitigation for navigation and access by Indigenous people.

5) Install additional monitoring capability at the hydrological stations on the Athabasca River below the Fort McMurray oil sands area, including:
   - Investigating options for the Embarras, Old Fort and/or 27th Baseline stations
   - Investigating the ability to measure water depths to provide data for navigational studies on the Athabasca River.
   - Assessing water quality in terms of flow rates (AECOM, 2010)
   - Estimating sediment and nutrient loads to the PAD

6) Install a hydrometric monitoring station on the Peace River at the 5th meridian.

7) Develop a hydrologic and hydraulic model of the watershed for the Peace, Athabasca, Lake Athabasca and PAD system that could be used to understand the cumulative impacts of upstream developments and activities and assess restoration options.

8) Conduct a water balance of the entire lower Athabasca River basin or, alternately, Fort McMurray downstream to the PAD, and Peace River basin considering:
   - Weekly surface water demand (m^3/s) for oil sands facilities from the mainstem Athabasca River
   - Weekly surface water withdrawals from tributary rivers of the Athabasca River (i.e., not the main stem as measured at the Fort McMurray station)
   - Municipal and other non-industrial water withdrawals
   - Projected weekly start up surface water demand for the three new conventional mine projects coming on line (mainstem AR and tributary)
   - Weekly groundwater demand for in-situ oil sands facilities
   - Projected groundwater demand for reasonably foreseeable in-situ projects coming on line
   - Annual volume of surface water being diverted by conventional and in-situ oil sands facilities from rain/snow and muskeg/peat water
   - Weekly peak demand for surface water for the oil sands (mainstem and tributary)
   - Weekly low flow surface water demand during the winter (if any)
   - Annual volume of in-situ process water being injected into deep formations (and the depth of injection)
   - Groundwater discharge rate into the Athabasca River downstream of the oil sands
   - Water volumes entering the PAD from the Athabasca River
   - Annual estimate of total volume of surface water being removed by conventional oil sands facilities
   - Annual estimate of total volume of groundwater being removed by in-situ oil sands facilities

9) In order to determine the difference between climate variability and anthropogenic effects on the Athabasca River over the past fifty years, investigate the naturalized flows (flow conditions that would have existed without the effect of industrial, agricultural, and municipal water withdrawals) below the Fort McMurray hydrometric station.

7.3.2 Environmental Assessment

One objective of this SEA was to inform project environmental assessments. Project environmental assessments are forward looking with an opportunity to prevent future impacts rather than fix them afterwards. The following recommendations support the fulfillment of this objective.

10) Submit this SEA to the Joint Review Panel for the Teck Frontier Oil Sands Mine Project for consideration.

11) Revise the *Guidelines for the Preparation of an Environmental Impact Statement* for the Amisk Hydroelectric Project to include a requirement to evaluate the effects on the Outstanding Universal Values of WBNP and the effects the project would have on the ability to restore the PAD.

12) Refer projects under the *Canadian Environmental Assessment Act, 2012* (or subsequent legislation) and *Mackenzie Valley Resource Management Act* for environmental assessment when they might have significant adverse environmental effects on the World Heritage Values of WBNP world heritage site and evaluate those potential impacts as part of the assessment.

13) Include an analysis of the impacts of projects within WBNP on the World Heritage Values of WBNP proportionate to the risk of the project to the World Heritage Values.

14) Build on the experience of this SEA by including ITK related to WBNP in project assessments.

7.3.3 Tailings Ponds Risk Assessment

RMM recommendation 6 requested a systematic risk assessment of the tailings ponds of the Alberta Oil Sands region with a focus on risks to the PAD. Chapter 4 and 5 describe how the desired outcomes related to the PAD are not being achieved. The pathway of effect related to the water quality on the Athabasca River was found to have a declining trend and a declining/stable trend in the PAD. As a result, additional work is recommended to reduce the unknowns and understand if the tailings ponds are contributing to the trends in water quality from the Athabasca River. Recommendations related to the tailings pond risk assessment below are for consideration by Alberta in leading this aspect of the Action Plan.

15) The evaluation of the risk of the tailings ponds on the PAD and OUV objectives (as described in Chapter 5) should include an evaluation of the probability and consequence of catastrophic failure as well as risks from seepage, VOCs, GHG emissions and bird impacts.

16) Ensure active involvement of relevant Indigenous groups in the risk assessment process so that Indigenous views and perspectives are represented and taken into account to support trust in the restoration of resource quality.

17) Ensure that the risk assessment captures the cumulative impact of both existing and future tailings ponds facilities within the Athabasca River basin.

18) Establish a governance structure and terms of reference for this assessment to be conducted at arm's length from government and industry. The model, terms of reference and findings from the review of the Mount Polley tailings breach in British Columbia may be a helpful guide in this regard.

7.3.4 Conservation Area Connectivity

There are a mix of desired outcomes for wolf-bison predator prey relationship, karst, Whooping Crane and PAD water quality being achieved and not being achieved. However, each includes pathways of effects that are on the border of WBNP. The increased linear corridor density and habitat changes and surface water quality pathways of effects were both found to be expecting additional pressures from climate change and reasonably foreseeable development. The karst hydrology and Whooping Crane changes in nesting habitat and food availability pathways were both found to lack information required to project future impacts. RMM recommendations 10 and 11 relate to creating a buffer around WBNP. More important than a buffer around WBNP, is the ability to situate WBNP as a protected area in an ecologically connected landscape. A suite of different tools could be used achieve this goal, but in order to select the right tools for the right location to achieve the desired outcomes, a systematic analysis must be conducted as outlined in RMM recommendation 11. By systematically evaluating the relevant desired outcomes and pathways of effects for specific locations, the appropriate tools can be selected. Forest management agreements are highlighted as one of those potential tools needing examination. Recommendations below are for consideration by Alberta and Northwest Territories in leading this aspect of the Action Plan.

19) When conducting the systematic assessment of options required by RMM recommendation 11, consider:

- Protection of Whooping Crane habitat and supporting hydrology beyond the WBNP boundary
- Protection of hydrology supporting karst within WBNP
- Habitat protection for bison herds ranging beyond the WBNP boundary
- Implications for changes to other species that may affect the wolf-bison relationship such as deer, moose and caribou
- Opportunities to reduce the risk to water quality

20) A number of the forest management agreements bordering WBNP are held by Indigenous groups. These agreements present opportunities for management to address the issues identified in SEA recommendation 18 either through long term conservation forest management agreements, protected areas that permit timber harvesting (permitted in some IUCN category VI parks), Indigenous protected and conserved areas or other effective area-based conservation measures.

7.3.5 Wildlife and Habitat Conservation

There are a mix of desired outcomes for wolf-bison predator prey relationship and Whooping Crane that are being achieved and not being achieved. The following recommendations support the desired outcomes for Whooping Crane and the wolf- bison relationship, respond to the information gaps identified and address pathways of effect related to habitat and hunting/disease management. Note that additional recommendations related to bison and Whooping Crane can be found in Section 7.3.4. Recommendations below are for consideration by multiple jurisdictions in leading this aspect of the Action Plan.

21) Analyze bison population data in light of the end of wolf control to better understand the population's natural range of variability.

22) Complete the identification and protection of Whooping Crane critical habitat to meet desired outcomes.

23) Implement additional measures to protect the Wabasca Bison herd and the entire Ronald Lake Bison Herd range from non-Indigenous hunting.

24) While maintaining or restoring the ecological integrity of WBNP, minimize the risk of disease and parasite transmission to or from cattle. Proactively consider implementing management actions that support the wood bison recovery goal of the local population levels being sufficient "to sustain traditional Aboriginal harvesting activities, consistent with existing Aboriginal and Treaty rights of Aboriginal peoples of Canada"

7.3.6 Water Quality

The RMM recommendations did not explicitly include actions related to water quality. Yet, this SEA has shown that there are increasing risks to water quality and the desired outcome is already not being achieved. Identification of actions to mitigate impacts on water quality is particularly difficult as a result of the gaps in understanding, whether because no data have been collected or because monitoring does not show there are concerns, yet issues continue to be identified in the PAD. Following the precautionary approach, action should be taken before water quality effects in the PAD become too difficult or impossible to reverse.

25) Consider implementing a water quality improvement plan for each watershed draining into the PAD using inspiration from similar plans from other places with sensitive receiving waters from multiple drainages.

7.3.7 Monitoring and Science

Recommendations below are for consideration by Environment Canada and Parks Canada in leading this aspect of the Action Plan in collaboration with others.

While the lack of understanding of the karst and salt plains is likely not an issue given the current threats, monitoring programs can be designed for these values with limited additional effort. For example, satellite monitoring could include measurements of the extent of the salt plains. If the Pine Point Mine moves to production, additional research into the hydrology of the region would help to ensure that the information is available during the environmental assessment to ensure desired outcomes for the karst and salt plains are achieved.

26) Opportunistically include monitoring and research on karst and salt plains in other research and monitoring programs.

27) If Pine Point Mine becomes closer to an application for full mine operation, conduct research on hydrological connectivity between the mine site and the karst and Whooping Crane habitat.

Lack of analysis and information are obstacles to achieving the desired outcomes for migratory waterfowl. As a result, recommendations related to these outcomes focus on understanding the situation better.

28) Analyze breeding waterfowl data for the PAD to better define the quantitative objectives breeding bird populations in the PAD and to better understand the relationship between breeding waterfowl population trends in the PAD and elsewhere in North America.

29) Develop a multi-partner project to understand changes in waterfowl migration around WBNP. A key element of this project should be a more detailed exploration of ITK about changes in waterfowl migration. During the SEA discussions, Indigenous land users discussed in much greater detail the changes they had seen by species and differences in spring and fall migration patterns etc. It wasn't possible to explore all this detail in the SEA, but it would be helpful in the context of this project.

30) Establish an approach to monitoring and understanding waterfowl migration numbers and routes.

Chapter 6 predicted that climate change may contribute to the pathway of effect related to fire in the Great Plains Boreal Grasslands in the future. Although the desired outcome is currently being achieved, the WBNP fire management plan is a key tool to maintain habitat across the park in the context of a changing climate.

31) Complete the WBNP fire management plan including consideration of climate change.

ITK was integral to the completion of this SEA and will be important to achieve the desired outcomes and implement the Action Plan, yet multiple Indigenous groups indicated they may have to systematically gather Action Plan related ITK.

32) Support ITK studies that can feed into the Action Plan implementation. A robust monitoring program will be essential as the Action Plan is implemented.

Based on the experience of this SEA, the following recommendations would support all monitoring for all desired outcomes.

33) Implement approaches to monitoring for all monitoring recommendations that integrate ITK and science and engage local land users, including Community Based Monitoring programs. The Peace-Athabasca Delta Ecological Monitoring Program provides an example of the approach that could be used.

34) Ensure monitoring information and hydrological data is provided by regulatory and industry bodies in a transparent and easily accessible format.

35) Ensure data collected by researchers on world heritage values is shared in a manner that it can benefit broader ongoing work.

36) Use integrated monitoring approaches, particularly in the PAD, to support understanding in this very complex ecosystem. For example, monitor sediment, ground water, fish, water, snow, wildlife and air in an interconnected manner. This approach can help with understanding the linkages between biota and the dynamic abiotic processes that are characteristic of the PAD.

37) Develop and implement objectives to maintain/restore traditional resources (such as bison, muskrat, moose, migratory waterfowl, fish and traditional plants) and biodiversity in the PAD.

Invasive species were found to be a pathway of effect on the desired outcomes for the wolf-bison relationship and Great Plains boreal-grasslands. However, there is still not a lot known about the pathway of effect. As a result, the recommendation focuses on restoration and action, while learning to address gaps.

38) Develop and implement adaptive management approaches for managing invasive species (such as thistle) using science and ITK.

The SEA has shown there are increasing risks to water quality and the desired outcome is already not being achieved. There are also gaps in information related to water quality and air quality which these recommendations are aimed at addressing.

39) Develop and implement site specific guidelines for water and sediment quality in the Athabasca and Peace Rivers and Athabasca River estuary in Lake Athabasca, including:

- Referring to CCME 2003 for published approaches;
- Providing a better information about water quality concerns, particularly for parameters which are associated with the commonly occurring highly suspended sediments, such as total metals, total petroleum hydrocarbons (TPH) including F1-F2 fractions and nutrients.

40) Implement a large-scale monitoring program for PACs and PAHs in the PAD, including:

- Expanding the scope of the current JOSM PAH water monitoring program to snow sampling, spring runoff sampling, and an expanded water sampling within PAD water bodies and tributary rivers;
- Implement an air quality monitoring program for PAHs and RCSs in Fort Chipewyan;

- Distinguishing between petrogenic vs. pyrogenic PAHs in PAD.

41) Update and expand the Surface Water Quality Management Framework for the Lower Athabasca Region to include monitoring stations in the Peace Athabasca Delta, a more comprehensive selection of oil sands related contaminants and guidelines or thresholds relevant to the desired outcomes for the PAD.

42) Implement a fish monitoring program for western Lake Athabasca and the PAD.

43) Develop life-cycle assessment (LCA) for major pollutants such as Hg including global sources when applicable.

44) Initiate a study of natural sources of pollutants originating from bitumen deposits through which the Athabasca River and its tributaries are incised, or other sources responsible for loading of PAD sediments

    a) Propose measures how to manage natural pollution from bitumen and groundwater in order to manage cumulative effects on the PAD.

    b) Quantify contribution of tributaries to the mass balance of contaminants of potential concern (COPC'-s) that influence water quality in PAD.

    c) Assess Birch Mountain contribution to PAD pollution from its natural Black Shale deposits and propose measures to control it.

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