Lower Athabasca Region

Status of Management Response for
Environmental Management Frameworks, as of December 2021

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Comments or questions regarding the content of this document may be directed to:
Alberta Environment and Parks
Lands Planning Branch Lands Division
AEP.Planning@gov.ab.ca

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Executive Summary

Air Quality

This report communicates the status of the Government of Alberta's management response to air quality trigger crossings for Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2) in the Lower Athabasca Region since 2012. This fulfills commitments made to Albertans in the Lower Athabasca Region Air Quality Management Framework for Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2). The report is intended for engaged stakeholders and those involved in the implementation of the Air Quality Management Framework but is available to the public.

In 2020, 23 air monitoring stations measuring nitrogen dioxide (NO_2) and 27 stations measuring sulphur dioxide (SO_2) were considered.

The following is a summary of some key findings and the management response to date.

- No limits were exceeded for air quality indicators.
- The following triggers were crossed in 2020:

For SO_2:

- Barge Landing, Buffalo Viewpoint, Fort McKay–Bertha Ganter, Fort McKay South, Fort McMurray-Patricia McInnes, Wapasu and Waskow ohci Pimatisiwin stations crossed the 99th percentile ambient air quality Level 2 trigger.
- Christina Lake, Lower Camp and Mildred Lake stations crossed the 99th percentile ambient air quality trigger for Level 3, and
- Mannix station crossed the Level 4 99th percentile ambient air quality trigger
- No stations crossed a trigger or exceeded a limit for annual average ambient concentrations

For NO_2:

- No stations crossed a trigger for annual average ambient concentrations
- Barge Landing, Buffalo Viewpoint, Fort Hills and Fort McKay-Bertha Ganter crossed the 99th percentile ambient air quality Level 2 trigger

The ongoing investigation focuses on the Level 3 and Level 4 SO_2 trigger crossings. The following activities are underway to better understand potential sources of NO_2 and SO_2 in the Lower Athabasca Region:

- The Alberta Energy Regulator (AER) has undertaken an air dispersion modelling project for SO_2 source attribution at Mannix, Lower Camp, and Mildred Lake stations.
- AER is planning for surveillance activities and engagement with operators at source facilities to assess and take action on trigger crossing events at Mannix, Mildred Lake, and Lower Camp stations.

Management actions have been identified and initiated at the Christina Lake SAGD operation, including planned project improvements aimed at sulphur recovery and implementation of an acid deposition monitoring program.

Surface Water Quality

This report communicates the status of the Government of Alberta's management response to seven water quality indicators crossing a trigger in 2020. This fulfills commitments made to Albertans in the *Lower Athabasca Region: Surface Water Quality Management Framework for the Lower Athabasca River* (SWQMF). The report is intended for engaged stakeholders and those involved in the implementation of the framework but is available to the public.

The following is a summary of some key findings and the management response to date:

- No indicators have exceeded a limit.
- Based on water quality monitored at the 'Old Fort' station during 2020, trigger crossings included seven mean indicators (Lithium D, Uranium D, Arsenic D, Potassium (K+), Total Dissolved Phosphorus (TDP), Total Nitrogen (TN), Uranium T) and

two peak triggers (Arsenic D, Uranium D). Trigger crossings were identified in the Status of the Ambient Condition for water quality report (Laceby et al., 2022).

- A new investigation was initiated for dissolved arsenic based on a preliminary assessment.
- After preliminary assessment, the management response for the indicator 'Total Dissolved Phosphorus (TDP)' was closed.
- Current investigations include the following parameters: chloride, dissolved iron, dissolved lithium, total nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite, potassium, sulphate, total and dissolved uranium, dissolved selenium, dissolved barium, and dissolved arsenic.

Key planned investigative actions are as follows:

- Supplement investigative analyses with relevant regulatory, Oil Sands Monitoring, and watershed stewardship program water quality data
- Explore seasonal patterns and refine trend analysis
- Where undesirable trends exist, collate, compare, and summarize existing department- and community-led management plans and available land use activity information to identify potential source areas, prepare to engage stakeholders, and support the development of mitigation measures.
- Consider findings from the recently completed 1-D surface water quality model for the Lower Athabasca River.

Management actions underway focus on improving the water quality monitoring network and are summarized below:

- AEP to encourage the monitoring of parameters currently under investigation in relevant water quality monitoring programs conducted by third parties
- AEP to enhance geographical resolution of provincial water quality monitoring programs by expanding monitored parameters and locations.

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Part 1: Air Quality

1.0 Introduction to Air Quality

Under the *Lower Athabasca Regional Plan* (Government of Alberta, 2012), a management response is initiated when the Minister of Environment and Parks determines that an indicator or limit, as identified in the Lower Athabasca Region Air Quality Management Framework (AEP, 2012), has been crossed or exceeded.

Alberta Environment and Parks (AEP) is the lead coordinator in undertaking the management response and works with other government branches and regulators (e.g. Alberta Energy Regulator) and external parties, as required, to identify and implement a management response.

Presently, nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) are reported annually under the Lower Athabasca Region Air Quality Management Framework using data collected at monitoring stations shown in Figure 1.

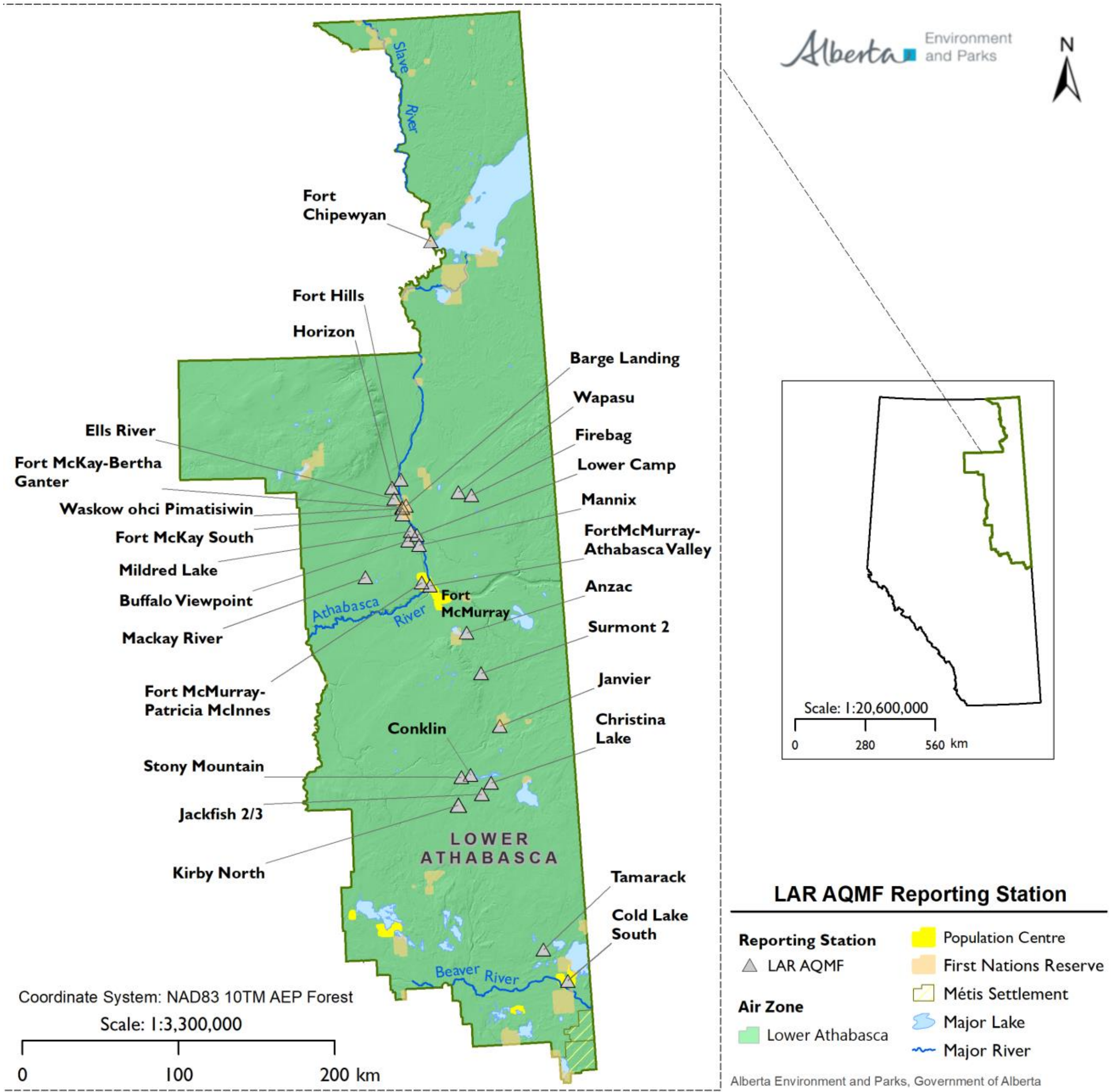

Figure 1. Map of continuous monitoring station used in the assessment

A management response was initiated for the Lower Athabasca Region after triggers were crossed for sulphur dioxide (SO_2). As each annual report on conditions becomes available, the management response is re-evaluated and updated based on new information. This current report provides an update on the management response since the last status report in December 2020 (AEP, 2021).

The management response is a seven-step process that is undertaken, in full or in part, when an ambient air quality trigger is crossed or a limit is exceeded. A full description of the management system can be found in the Lower Athabasca Region Air Quality Management Framework (AEP, 2012)

The management response for air quality considers a variety of factors including but not limited to the type and location of the monitoring station, averaging time (i.e. hourly, 24-hour or annual) and the ambient air quality trigger or limit that was exceeded. In addition, the management response can also include investigation into the cause of an exceedance, notification of the identified sources and affected First Nations, Métis communities and stakeholders, and the identification of management actions to prevent reoccurrence.

The LAR AQMF and all previous status of ambient air quality and status of management response reports can be found on the Environment and Parks website (www.alberta.ca/lower-athabasca-regional-planning.aspx), as well as on Open Government (https://open.alberta.ca/publications)

1.1 Evolving Context for Air Management in Alberta

This report considers data and analysis available at the time of writing, and aligns with annual reporting as per the LAR AQMF. New and more stringent Canadian Ambient Air Quality Standards (CAAQS) have come into effect as of 2020 and air management in the Lower Athabasca Region will be in response to these new and more stringent standards moving forward. It is expected that higher management levels for the region will result.

Alberta will be developing a provincial management plan in response to new CAAQS management levels and will incorporate the AQMF management response reporting.

Reporting under the Air Quality Management Framework is being integrated with the provincial CAAQS reporting structure. The Status of Air Quality in Alberta: Air Zones Report 2018-2020 represents the first integrated status of conditions report, including metrics reported under the AQMF as well as the most recent CAAQS analysis. The first integrated management report will be released within two years of the Air Zones 2018-2020 report, replacing this regional status of management response report.

2.0 Summary of Ambient Levels Assigned for Air Quality

2.1 Verification and Preliminary Assessment

Alberta Environment and Parks conducts the annual assessment of ambient air quality data gathered from continuous ambient air monitoring stations in the Lower Athabasca Region. Data are downloaded from Alberta's ambient air data warehouse and checked for accuracy and completeness. Once these data have been verified, the air quality metrics are used to assess ambient conditions relative to triggers and limits in the Lower Athabasca Region Air Quality Management Framework.

In 2020, 23 air monitoring stations measuring nitrogen dioxide (NO_2) and 27 stations measuring sulphur dioxide (SO_2) were considered, which includes the new addition of the Kirby North air monitoring station. In 2020, Fort Chipewyan station for NO_2, and Horizon and Surmont stations for both NO_2 and SO_2 did not fulfill the data completeness criteria and are not included in this report.

More information on the methodology, procedures, verification and preliminary assessments are reported in the Status of Air Quality in Alberta: Air Zones Report 2018-2020 (Brown, C., 2022).

2.2 Minister's Determination

The Minister's Determination confirmed that no annual average limits were exceeded for any air quality indicators for January 1 to December 31, 2020, in the Lower Athabasca Region, or since the implementation of the framework. However, crossings of air quality triggers occurred at several monitoring stations, resulting in the assignment of air quality levels summarized in Table 1 and Table 2, and detailed in the Status of Air Quality in Alberta: Air Zones Report 2018-2020 (Brown, C., 2022). Averages for hourly and annual data for NO_2 and SO_2 from 2016 - 2020 are also presented in Appendix A.

TABLE 1. AMBIENT LEVELS ASSIGNED TO AIR QUALITY MONITORING STATIONS IN THE LOWER ATHABASCA REGION FOR 2016-2020 BASED ON NO_2 TRIGGERS AND LIMITS ESTABLISHED IN THE FRAMEWORK

Station Names	Nitrogen Dioxide									
	Annual Average					99th Percentile				
	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
Anzac	1	1	1	1	1	1	1	1	1	1
Barge Landing			NA	2	1			NA	2	2
Buffalo Viewpoint		NA	1	1	1		NA	1	2	2
Christina Lake			NA	1	1			NA	1	1
Cold Lake South	1	1	1	1	1	1	1	1	1	1
Conklin		1	1	1	1		1	1	1	1
Ells River					NA					NA
Firebag	1	1	1	1	1	1	1	1	1	1
Fort Chipewyan	1	1	1	1	NA	1	1	1	1	NA
Fort Hills			2	2	1			2	2	2
Fort McKay-Bertha Ganter	1	1	1	1	1	1	2	2	2	2
Fort McKay South	1	1	1	1	1	1	2	2	2	1
Fort McMurray-Athabasca Valley	1	1	1	1	1	1	2	1	2	1
Fort McMurray-Patricia McInnes	1	1	1	1	1	1	1	1	1	1
Horizon	1	1	1	2	NA	1	2	2	2	NA
Jackfish 2/3			NA	1	1			NA	1	1
Janvier		1	1	1	1		1	1	1	1
Kirby North					1					1
Lower Camp										
MacKay River	1	1	1	1	1	1	1	1	1	1
Mannix										
Mildred Lake										
Muskeg River	2	2	2			2	2	2		
Stony Mountain	1	1	1	1	1	1	1	1	1	1
Surmont	NA	1	1	NA	NA	NA	1	1	NA	NA
Surmont 2				1	1				1	1
Tamarack	1	1	1	1	1	1	1	1	1	1
Wapasu	1	1	1	1	1	1	1	1	1	1
Waskow ohci Pimatisiwin										

: Parameter was not measured at this location and period.

NA : Station did not fulfil the criteria of 75 percent data completeness

TABLE 2. AMBIENT LEVELS ASSIGNED TO AIR QUALITY MONITORING STATIONS IN THE LOWER ATHABASCA REGION FOR 2016-2020 BASED ON SO_2 TRIGGERS AND LIMITS ESTABLISHED IN THE FRAMEWORK

Station Names	Sulphur Dioxide									
	Annual Average					99th Percentile				
	2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
Anzac	1	1	1	1	1	1	1	1	1	1
Barge Landing			NA	1	1			NA	1	2
Buffalo Viewpoint	1	1	1	1	1	2	2	2	1	2
Christina Lake			NA	1	1			NA	2	3
Cold Lake South	1	1	1	1	1	1	1	1	1	1
Conklin		1	1	1	1		1	1	1	1
Ells River					NA					NA
Firebag	1	1	1	1	1	1	2	1	1	1
Fort Chipewyan	1	1	1	1	1	1	1	1	1	1
Fort Hills			1	1	1			1	1	1
Fort McKay-Bertha Ganter	1	1	1	1	1	2	2	1	1	2
Fort McKay South	1	1	1	1	1	2	2	1	1	2
Fort McMurray-Athabasca Valley	1	1	1	1	1	1	1	1	1	1
Fort McMurray-Patricia McInnes	1	1	1	1	1	1	1	1	1	2
Horizon	1	1	1	1	NA	1	1	1	1	NA
Jackfish 2/3			NA	1	1			NA	1	1
Janvier		1	1	1	1		1	1	1	1
Kirby North					1					1
Lower Camp	1	1	1	1	1	4	4	3	3	3
MacKay River	1	1	1	1	1	1	1	1	1	1
Mannix	1	1	1	1	1	3	3	2	2	4
Mildred Lake	1	1	1	1	1	3	3	2	2	3
Muskeg River	1	1	1			2	2	2		
Stony Mountain	1	1	1	1	1	1	1	1	1	1
Surmont	NA	1	1	NA	NA	NA	1	1	NA	NA
Surmont 2				NA	1				NA	1
Tamarack	1	1	1	1	1	1	1	1	1	1
Wapasu	1	1	1	1	1	1	2	1	1	2
Waskow ohci Pimatisiwin		NA	1	1	1		NA	1	1	2

: Parameter was not measured at this location and period.

NA : Station did not fulfil the criteria of 75 percent data completeness

3.0 Status of Management Response for Air Quality

The management response is a set of steps taken, in full or in part, when an ambient trigger is crossed or limit is exceeded. The management response will support the management intent associated with each trigger crossing or limit exceedance (Table 3 and Table 4). A full description of the management system is found in the Lower Athabasca Region Air Quality Management Framework (AEP, 2012). The status of the management response is reported on a regular basis and may be supported by supplemental technical reports. This section of the report provides an update on the investigation and actions being advanced as part of the management response.

TABLE 3: DESCRIPTION AND MANAGEMENT INTENT FOR AVERAGE OF ANNUAL DATA FOR NO_2 AND SO_2 AMBIENT AIR QUALITY

Level	Description	Management Intent
4	Ambient air quality exceeding the air quality limit	Improve ambient air quality to below the limit
	Limit	
3	Ambient air quality below but approaching the air quality limits	Proactively maintain air quality below the limit
	Trigger into Level 3	
2	Ambient air quality below air quality limits	Improve knowledge and understanding, and plan
	Trigger into Level 2	
1	Ambient air quality well below air quality limits	Maintain air quality through standard regulatory and non-regulatory approaches

TABLE 4. DESCRIPTION AND MANAGEMENT INTENT FOR UPPER RANGE OF HOURLY DATA NO_2 AND SO_2 AMBIENT AIR QUALITY

Level	Description	Management Intent
4	Peak ambient air quality concentrations are likely exceeding the hourly objective	Reduce probability that hourly objectives are exceeded during peak events
	Trigger into Level 4	
3	Peak ambient air quality concentrations may be approaching or exceeding the hourly objective	Maintain air quality to reduce probability that objectives are exceeded during peak events
	Trigger into Level 3	
2	Peak ambient air quality concentrations below hourly objective	Improve knowledge and understanding, and plan
	Trigger into Level 2	
1	Peak ambient air quality concentrations are well below hourly objective	Maintain air quality through standard regulatory and non-regulatory approaches

3.1 Investigation

The purpose of investigation is to determine the likely factors influencing the performance of an indicator and inform decisions about management actions. Adequate understanding of the various possible influences on indicators under investigation is required prior to moving to the identification of management objectives and management actions to support them. Without adequate information, management actions are unlikely to achieve significant improvements to ambient air quality. The scale of the investigation depends on the management level as well as the complexity of the issue identified. Support from the public, Indigenous communities and organizations, industry, non-governmental groups, government at multiple levels, and regulatory agencies may all be important for understanding regional issues and to explore options to address ambient air quality issues.

Analysis of ambient concentrations, trends, and the identification of potential emission sources leading to elevated ambient concentrations are ongoing. A summary of the completed, ongoing and proposed activities is provided in Table 5 and detailed in the sections below.

TABLE 5. STATUS OF COMPLETED, PROPOSED, AND ONGOING INVESTIGATIONS AS OF DECEMBER 2021

Investigation Task	Lead	Status	Notes
Assess and improve monitoring network	AEP	Complete	An air monitoring network assessment for the Oil Sands Area was completed in 2015 and used to inform the Oil Sands Monitoring plan. No further work is required at this time.
Cross-validation of trend assessment tools	AEP	Complete	Trend analysis and comparison of tools is described as part of the 2020 management response and in Nunifu et al. 2019. No further work is required at this time.
Review of studies that use satellite SO_2 and NO_2 data in the LAR	AEP	Complete	Information and results from these studies will be used to inform current and future investigations.
Investigation of elevated SO_2 levels at Lower Camp station	AER	Ongoing	Investigations into elevated SO_2 levels and determination of approach for management is underway. More information provided in Section 3.1.1 of this report.
Air dispersion modelling for source attribution in Athabasca Oil Sands Area.	AER	Underway	Air dispersion modelling project being conducted for Mannix, Mildred Lake, and Lower Camp stations. Details provided in Section 3.1.1 of this report.
Targeted surveillance and operator engagement	AER	Planned	Described in Section 3.1.1 of this report.
Investigation of elevated SO_2 levels at Christina Lake station	AER	Ongoing	Described in Section 3.1.1 of this report.

3.1.1 Investigation Summary

Building on the investigation activities completed in 2020 and in previous years, the following investigations are ongoing or planned to support the understanding of conditions and trends for NO_2 and SO_2 concentrations in the LAR.

Investigations into elevated SO_2 levels at Lower Camp station

A series of studies and analysis have been completed since 2015 to investigate and identify the sources of repeated elevated SO_2 levels at Lower Camp station. Industrial point sources are the major contributors of SO_2 in the Region (ECCC and AEP 2016); however determination of key contributors (i.e., which facility operators) and the influence of other variables (e.g., meteorology, topography, cumulative effects, etc.) make understanding and managing SO_2 emissions at this station a challenge. In response, AEP and the Alberta Energy Regulator (AER) formed a task team in 2021 to determine investigative priorities and identify effective approaches and actions for SO_2 management going forward. Subsequently, AER has undertaken a modelling project to understand major emissions sources and key contributors at several stations in the region, including the Lower Camp station. This project and preliminary results are described below.

As information regarding exceedance events at Lower Camp evolves, investigative priorities shift. As such, investigations proposed in prior year's management responses (i.e., effects of industry flaring, emissions from petroleum coke deposits, and ground-level monitoring) are no longer priority for allocation of resources. Investigation needs will be re-evaluated as required and information and results from previous studies at Lower Camp will continue to be used to inform investigation and development of mitigative actions.

Air dispersion modelling for source attribution

AER has undertaken a comprehensive modelling project to determine the major source(s) and/or contributors of SO_2 at key air monitoring stations in the Oil Sands Area, including Mannix, Lower Camp, and Mildred Lake stations. The goal of this study is to model reported SO_2 emissions from 2020 from point source emitters in the region while considering meteorological and topographic conditions. Preliminary assessment suggest that one stack source in particular seems to be the main contributor to Level 3 and Level 4 trigger crossings at the three stations of interest. Work is underway to refine results and prepare presentation and reporting materials. It is expected that these results will guide where to focus further efforts and actions towards reducing SO_2 emissions and reduce trigger crossings at key air monitoring stations in the region. As well, AEP and AER are working closely to share information, results, and determine control actions that can be implemented to reduce emissions levels and improve air quality.

Targeted Surveillance and Operator Engagement

Increases in SO_2 exceedance episodes from 2019 and prior years were observed at Lower Camp, Mannix, and Mildred Lake stations. AEP has conducted a preliminary analysis of emissions data to understand frequency, magnitude, direction, and characteristics of SO_2 exceedances at these stations (Appendix B). In addition, it is expected that AER's modelling project will inform where to direct efforts and actions towards emissions reductions. In 2022, AER will oversee annual and site specific targeted surveillance activities based on results and recommendations from the modelling work. Engagement with operators is also planned for 2022 to review and assess the events leading to trigger crossings at the key stations identified and to ensure that suitable progress towards emissions management is made.

Investigation of elevated SO_2 levels at Christina Lake

The Christina Lake ambient air monitoring station, a compliance monitoring station of the Cenovus Steam-Assisted Gravity Drainage (SAGD) Operations Project, crossed the Level 3 trigger for the upper range of hourly data for SO_2 for the first time in 2020, and was approaching the Level 4 trigger. A review of emissions was conducted to understand and identify SO_2 sources that may be related to the increase in SO_2 emissions from 2019 to 2020.

Preliminary analysis of emissions data conducted by AEP suggests that emissions are originating from the northwest, are consistent with stack sources (per $H_2S:SO_2$ ratio), and trigger crossings occur throughout the year (Appendix B). This is consistent with emissions characteristics from prior years; however, more frequent SO_2 exceedance episodes were observed in 2020 compared to 2018 and 2019. Further, several new SO_2 emission sources were identified nearby the ambient air station, including three new butane bullets and offload stations, three flare stacks, and two steam generators. These sources may have been a factor in the elevated SO_2 levels observed in 2020.

Concurrent to preliminary investigations, Cenovus has applied for approval to implement a number of changes to the Christina Lake SAGD project aimed at reducing SO_2 emissions and increasing sulphur recovery. A gradual reduction in emissions is anticipated as projects are completed (further described in Section 3.3).

3.2 Identification of Management Actions

Air quality management in the Lower Athabasca Region requires a proactive and future focused approach. Since industrial point sources have been identified as major contributors of SO_2 in the Region, AER is playing an active role in the development and implementation of air quality management initiatives. AEP is committed to working with AER to initiate a proactive management plan and will collaborate to improve the effectiveness of management response actions. As well, support from the public, Indigenous communities and organizations, industry, non-governmental groups, government at multiple levels, and regulatory agencies are all important for meaningful and effective implementation of air quality management in the LAR.

Management actions are actionable items or initiatives implemented in response to trigger crossings or limit exceedances. Management actions support, rather than replace existing policies and regulations and may include actions that range from policy or regulatory initiatives to voluntary actions and/or educational campaigns for raising awareness and understanding surrounding air quality. Consideration must be given to the management intent associated with each trigger crossing or limit exceeded. When a station crosses a Level 4 trigger, is approaching a Level 4 trigger, or has crossed a Level 3 trigger for several years in a row, management actions and efforts must be directed towards reducing emissions and improving air quality.

A list of management actions that have been proposed or are currently being implemented is provided in Table 6. It is important to recognize that some management actions can take a number of years to initiate and the impact of implementing certain actions may take several additional years to be realized. For example, management of industrial sources is a sensitive and complex issues that requires cross-regulatory considerations. Collaboration and support of all stakeholders is key to the success of proactive management actions.

Investigation, studies, and engagement with stakeholders will continue to inform and establish necessary mitigative actions as required.

TABLE 6. MANAGEMENT ACTIONS IDENTIFIED FOR IMPLEMENTATION IN THE LOWER ATHABASCA REGION

Action	Lead	Description	Status
Cenovus Christina Lake Project Improvements	AER and Cenovus	In response to a Level 3 trigger crossings in 2020, Cenovus has applied for a number of project improvements at the Christina Lake SAGD operation aimed at reducing SO_2 emissions, which include adding equipment and infrastructure for additional sulphur recovery capability and for reducing produced gas volumes (the primary source of sulphur) received at the central processing facility. The sulphur recovery performance of the Christina Lake project will gradually improve as modifications are implemented. All modifications and construction projects are anticipated to be completed by December 31, 2023. As per correspondence from AER, once complete the operation would achieve 90% sulphur recovery and have a substantial reduction in SO_2 emissions rates (to approximate 2 tonnes/day, down from upwards of 7 tonnes/day).	Underway
	AER, Cenovus, and WBEA	In response to elevated SO_2 levels at Christina Lake air monitoring station, Cenovus was required to develop an acid deposition monitoring program to measure aerial acid deposition effects on aquatic and terrestrial ecosystems. This program has been authorized to proceed and will be implemented through Wood Buffalo Environmental Association's (WBEA) Terrestrial Environmental Effects Monitoring Program.	Underway

4.0 Next Steps for Air Quality

Several stations in the Lower Athabasca Region have crossed Level 3 and Level 4 triggers for hourly SO_2 thresholds and will remain under investigation. In collaboration with AER, the next steps in the Management Response will focus on advancing investigation activities, monitoring, and oversight of the implementation of management actions. AEP is committed to supporting AER in air quality management initiatives and taking a proactive approach towards the protection and improvement of air quality in the Lower Athabasca Region now and in the future.

Additionally, a review of the Lower Athabasca Regional Plan is due for initiation prior to September 2022. As part of this process, the Air Quality Management Framework for the Lower Athabasca Region will be reviewed. The intention is to align the LAR Air Quality Management Framework with the new Canadian Ambient Air Quality Standards (CAAQS) following the review. As well, reporting under the Air Quality Management Framework is being integrated with the provincial CAAQS reporting structure. The first integrated provincial management response plan, which will include AQMF management response reporting and a response to new CAAQS management levels will be released within two years of the Air Zones 2018-2020 report, replacing this regional status of management response report.

AEP is committed to working with stakeholders and Indigenous communities and organizations to inform the investigation, assist in improving the current environmental management system, and identifying management actions that may be necessary to address point and non-point source emissions. Progress updates on the ongoing investigative work and management actions outlined in this report will be communicated to the public in subsequent Management Response reports.

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Air Quality Glossary

Air Quality	The composition of air, with respect to quantities of substances therein, and/or a measure of the health-related and visual characteristics of the air used most frequently in connection with standards against which the contribution of the particular source can be compared.
Air Quality Objective	A numerical concentration, value or narrative statement which is intended to provide protection of the environment and human health to the extent that is technically and economically feasible, and is socially and politically acceptable.
Airshed organization	Regional partnership associations that include government, industry, environmental groups and the public. These partnerships are responsible for air quality monitoring and, in some cases, air quality management for a specific region of Alberta. Alberta presently has nine local airshed organizations.
Air Zone	Air zones are geographic areas identified through the national Air Quality Management System to facilitate effective air quality management at a local scale. In Alberta, the air zones align with the regional Land-use Framework boundaries.
Alberta's Ambient Air Quality Data Warehouse	Alberta's central repository for ambient air quality data collected in the province, made available online to the public. Currently known as the air data warehouse.
Ambient Air	Outside air - any portion of the atmosphere not confined by walls and a roof to which the public has access.
Canadian Ambient Air Quality Standards (CAAQS)	Ambient air quality standards applied across Canada that are designed to provide a uniform measure of protection for human health and the environment.
Fine Particulate Matter	Fine particulate matter refers to airborne solid or liquid particles that are 2.5 microns or less in diameter. It is either emitted directly (primary PM) or formed in the atmosphere from precursor emissions (secondary PM). Important precursors of secondary PM are nitrogen oxides, sulphur dioxide, ammonia, and volatile organic compounds. The chemical composition of particles can vary widely and depends on location, time of year, and weather.
Indicators	Measurement of substances that give us information about the condition of the environment through comparison to defined triggers and limits.
Limits	Thresholds at which the risk of adverse effects on health or environmental quality is becoming unacceptable.
Metric	A procedure for processing ambient air quality monitoring data to determine a value which can be compared to the trigger and limit values. These procedures specify the averaging periods and statistics applied to the data.
Nitrogen Dioxide (NO_2)	Toxic pungent reddish-brown gas formed by the reaction of atmospheric ozone with the nitric oxide produced from combustion.

Nitrogen Oxides (Oxides of Nitrogen, NO_x)	A general term pertaining to compounds of NO, NO_2, and other oxides of nitrogen. Nitrogen oxides are created during combustion processes and are major contributors to smog formation and acid deposition.
Ozone (O_3)	Ozone is a chemical whose effect on the environment is either beneficial or detrimental depending on where it occurs. Stratospheric ozone (the layer of the earth's atmosphere above the troposphere, extending to about 50km above the earth's surface) protects us from the sun's UV light, but tropospheric ozone (the lowest region of the atmosphere, extending from the earth's surface to a height of about 6-10km), can be toxic. Ozone is a highly reactive, colourless gas that is normally present in the troposphere as a result of naturally occurring photochemical and meteorological processes. It has a sharp, clean odour that can often be detected around running electric motors, after lightning storms, and around new mown hay.
Primary pollutants	Primary pollutants are those, which are emitted directly from sources (e.g., sulphur dioxide emitted from a combustion process). Secondary pollutants are atmospheric contaminants, which form due to the reaction or transformation of primary pollutants and other atmospheric compounds in the atmosphere (e.g., ground-level ozone is formed through photochemical reactions of nitrogen dioxide and volatile organic compounds in the atmosphere).
Secondary pollutants	Secondary pollutants are atmospheric contaminants, which form due to the reaction or transformation of primary pollutants and other atmospheric compounds in the atmosphere (e.g., ground-level ozone is formed through photochemical reactions of nitrogen dioxide and volatile organic compounds in the atmosphere).
Source (of Emissions)	There are many sources of emissions, but these have generally been grouped into two categories: emissions from point and non-point sources. A **point source** is a stationary location or fixed facility from which substances are discharged; e.g., a smokestack. A **non-point source** is a pollution source that is not recognized to have a single point of origin. Common non-point emission sources are agriculture, forestry, urban, mining, construction, and city streets.
Sulphur Dioxide (SO_2)	A colourless gas that is formed primarily by the combustion of fossil fuels containing sulphur. Sour gas processing plants, oil sands processing plants and coal-fired power generating plants are major sources of SO_2.
Transboundary (Transport)	The long-range movement of emissions and substances across political or pre-determined spatial borders. Transboundary pollution refers to substances that originate in one jurisdiction, but have adverse effects in another area/jurisdiction at such a distance that it is not generally possible to distinguish the contribution of individual emission sources or groups of sources.
Triggers	Set in advance of limits as early warning signals for evaluation, adjustment and innovation on an ongoing basis.

Appendix A - Air Quality Conditions of Last Five Years

A1. Nitrogen Dioxide

Annual Average of NO_2 Concentrations

In 2020, the annual average concentrations of NO_2 within the Lower Athabasca Region remained at management Level 1 at all stations (**Error! Reference source not found.**). No specific investigations are warranted at this time.

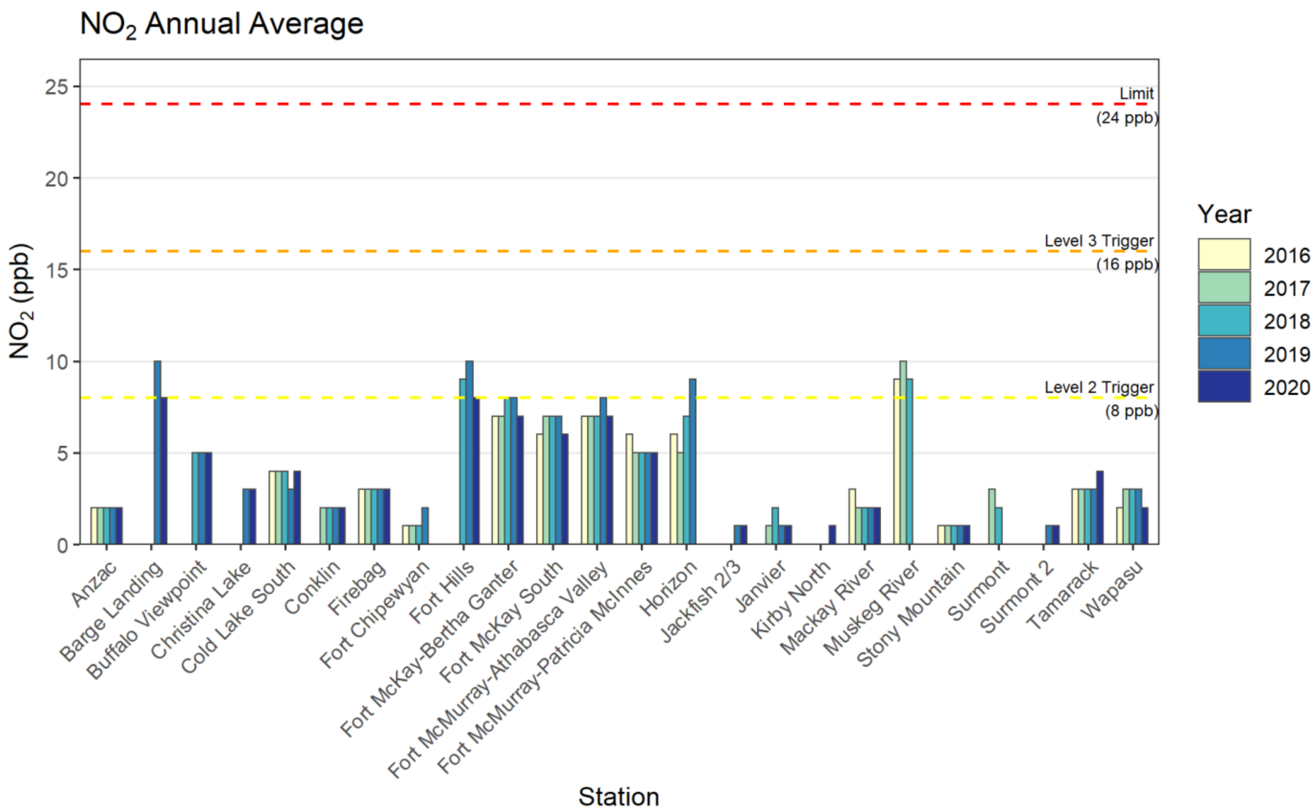

Figure A1. Annual average of hourly data for nitrogen dioxide for 2016-2020 in the Lower Athabasca Region

Upper Range of Hourly NO_2 Concentrations

The upper range of hourly ambient concentrations of NO_2 crossed the Level 2 trigger at Barge Landing, Buffalo Viewpoint, Fort Hills, and Fort McKay Bertha Ganter in 2020, which is consistent with previous years (**Error! Reference source not found.**). The upper range of hourly NO_2 was reduced (to Level 1) at Fort McKay South and Fort McMurray – Athabasca Valley in 2020.

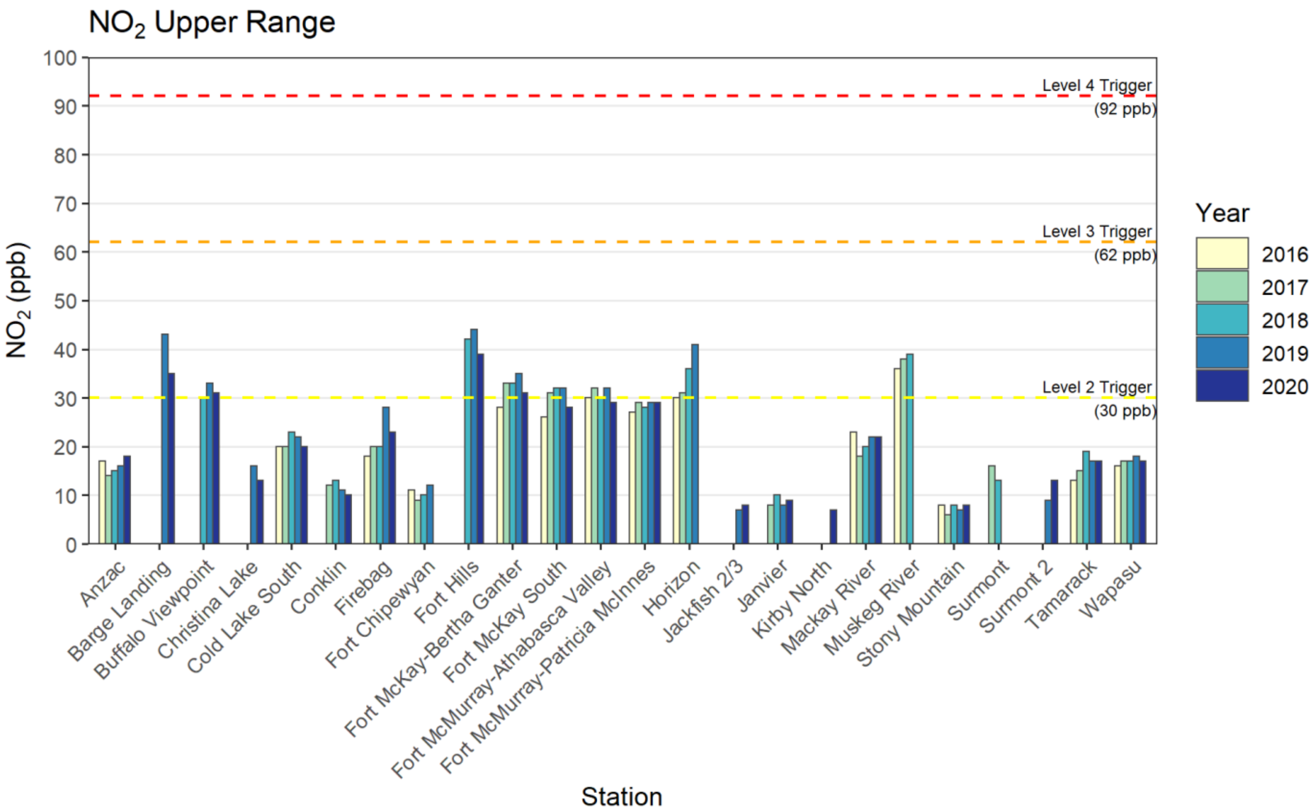

Figure A2. Upper range of hourly emissions for nitrogen dioxide from 2016 - 2020 in the Lower Athabasca Region

A2. Sulphur Dioxide

Annual Average of SO_2 Concentrations

In 2020, the annual average ambient concentrations of SO_2 at all air monitoring stations remained at management Level 1 at all stations (**Error! Reference source not found.**). No investigations assessing annual average SO_2 concentrations are required at this time.

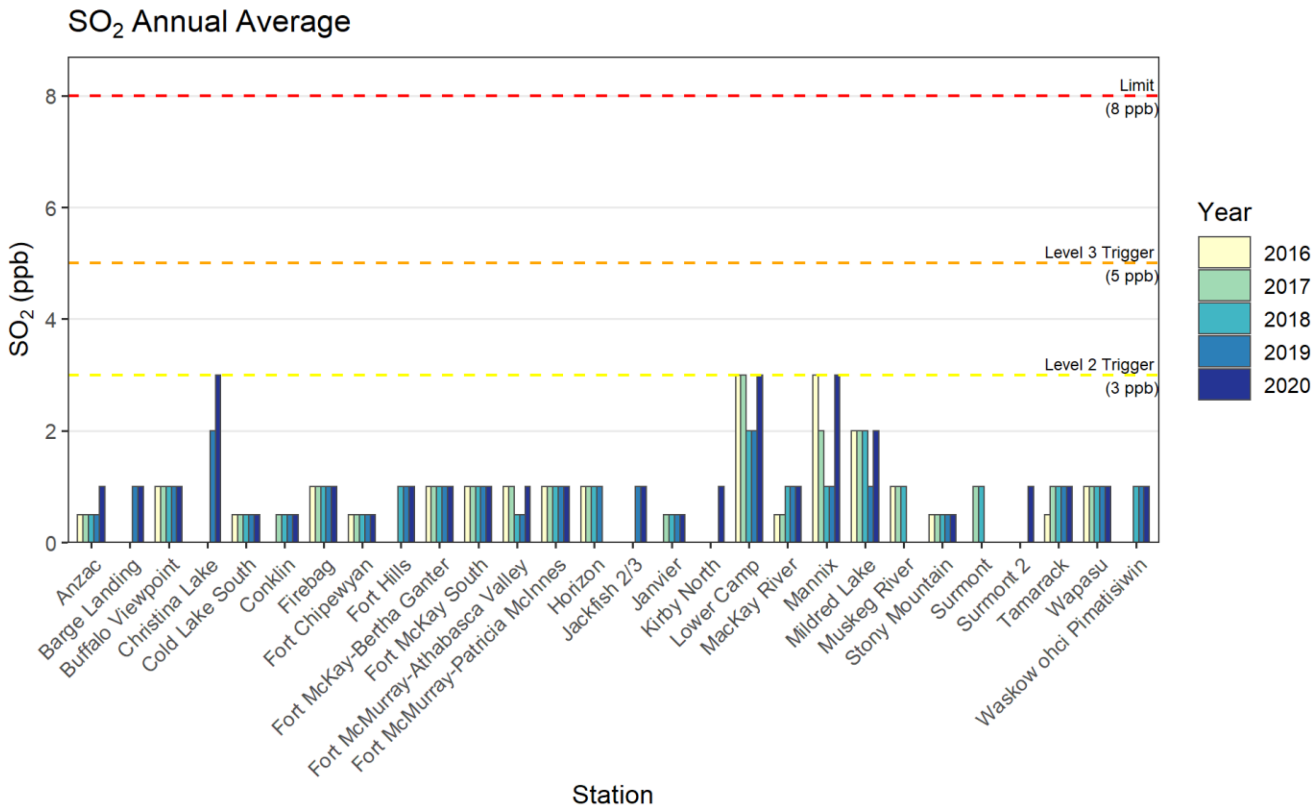

Figure A3. Annual average of the hourly data for Sulphur Dioxide for 2016-2020 in Lower Athabasca Region*.

*Sites with annual averages that round to zero are shown as 0.5 ppb to distinguish them from sites that did not meet completeness requirements.

Upper Range of Hourly SO_2 Concentrations

In 2020, eleven stations crossed Level 2, Level 3, or Level 4 triggers. Barge Landing, Buffalo Viewpoint, Fort McKay-Bertha, Fort McKay South, and Fort McMurray – Patricia McInnes, Wapasu, and Waskow ohci Pimatisiwin all crossed Level 2 triggers, which is an increase in the upper range of hourly SO_2 emissions from last year.

Lower Camp station remained at management Level 3, consistent with 2018 and 2019, however, upper range of hourly emissions were higher than observed in 2019.

The upper range for ambient concentrations of SO_2 crossed the trigger for Level 3 at Cristina Lake and Mildred Lake stations for the first time in recent years, whereas Mannix crossed the Level 4 trigger, which is a significant increase in emissions from recent years (**Error! Reference source not found.**).

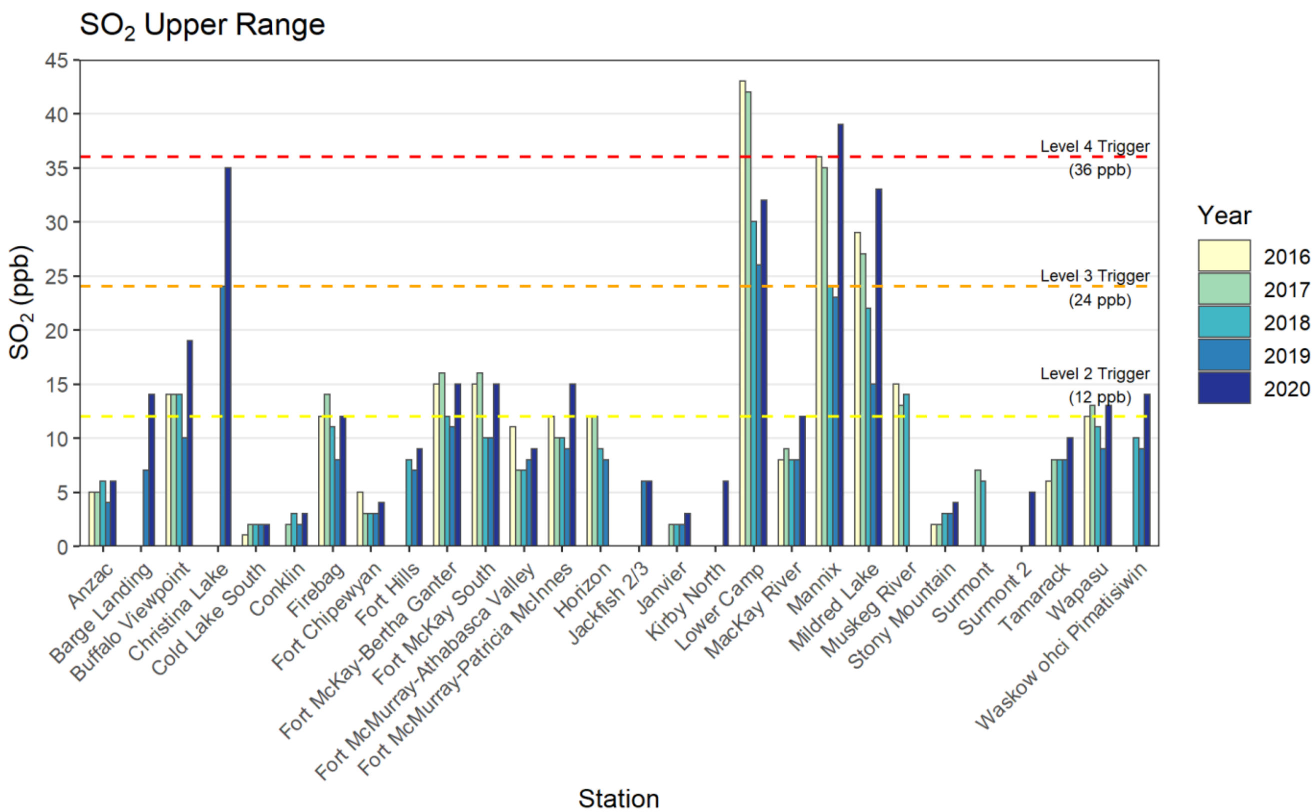

Figure A4. Upper Range of the 99th percentile hourly data for Sulphur Dioxide for 2015-2019 in Lower Athabasca Region

Appendix B – Alberta Environment and Parks Investigations into SO_2 Exceedances

In 2021, AEP conducted a preliminary analysis of ambient data at Mannix, Mildred Lake, Christina Lake, and Lower Camp stations where Level 3 or Level 4 trigger crossings were observed, to understand key characteristics of SO_2 episodes at these stations (unpublished, AEP, 2021). Details on analysis methods and results from previous years' analysis at Lower Camp station are provided in the 2019 LAR Status of Management Response Report (AEP, 2020). Preliminary results are provided below.

B1. Mannix Station

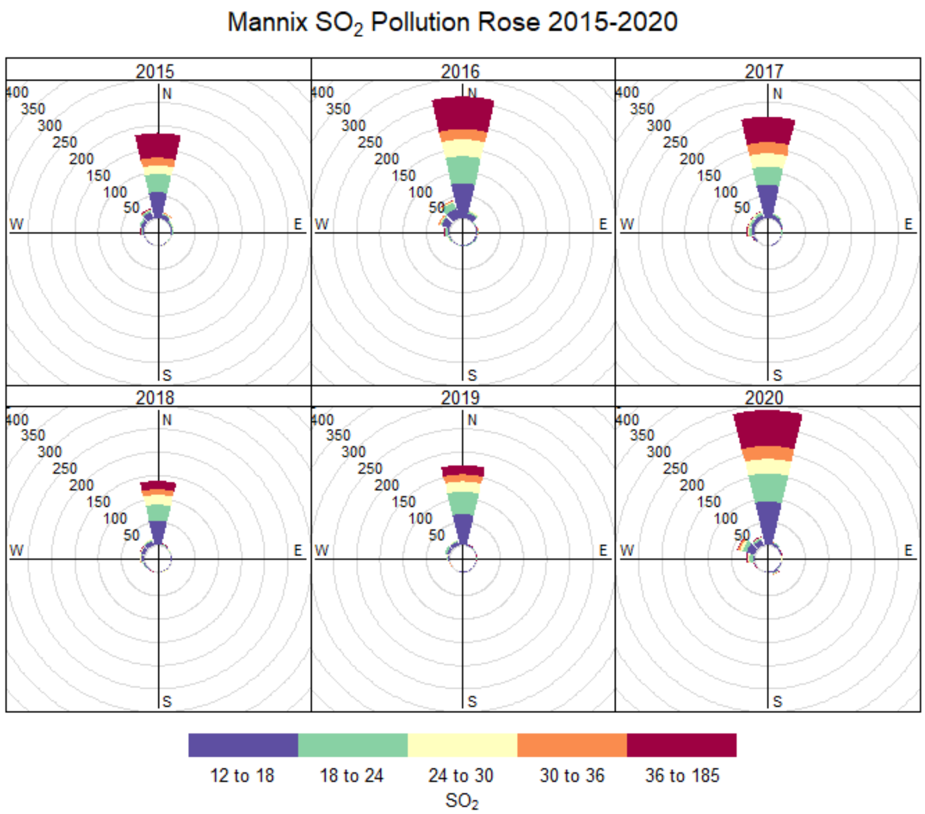

Figure A5. Pollution roses for Mannix station from 2015-2020 identifying count of all hourly episodes where SO_2 > 12 ppb show that the majority of elevated SO_2 emissions originate from the north.

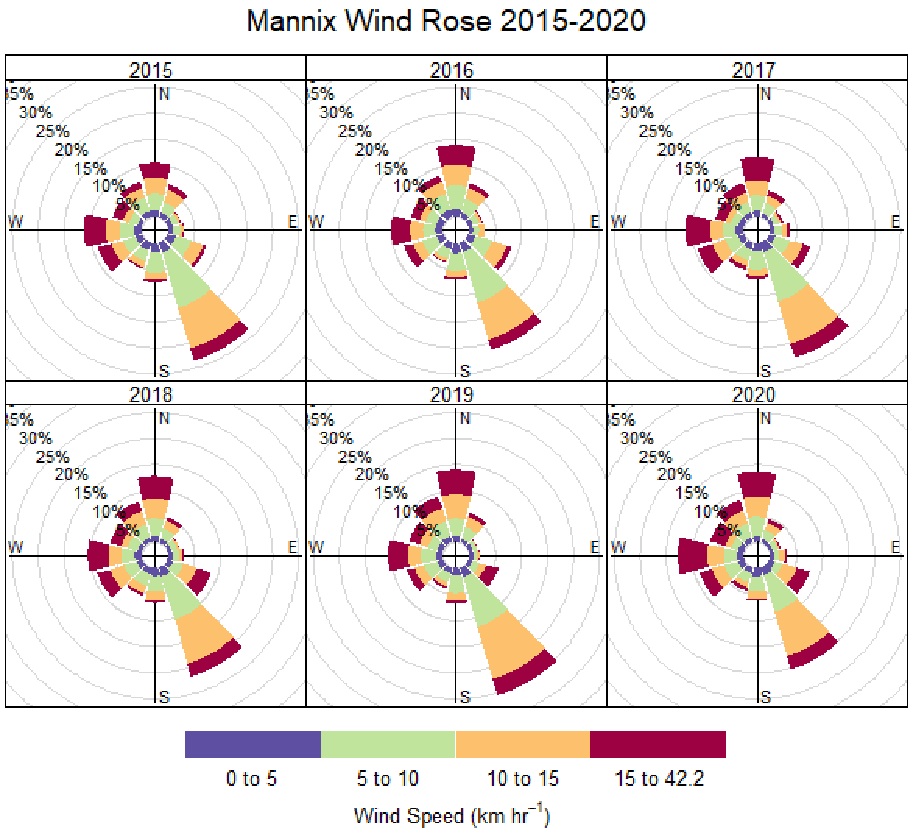

Figure A6. Wind roses for Mannix station from 2015-2020 showing frequency of wind speed by direction. Results show that the wind rose for 2020 was consistent with other years.

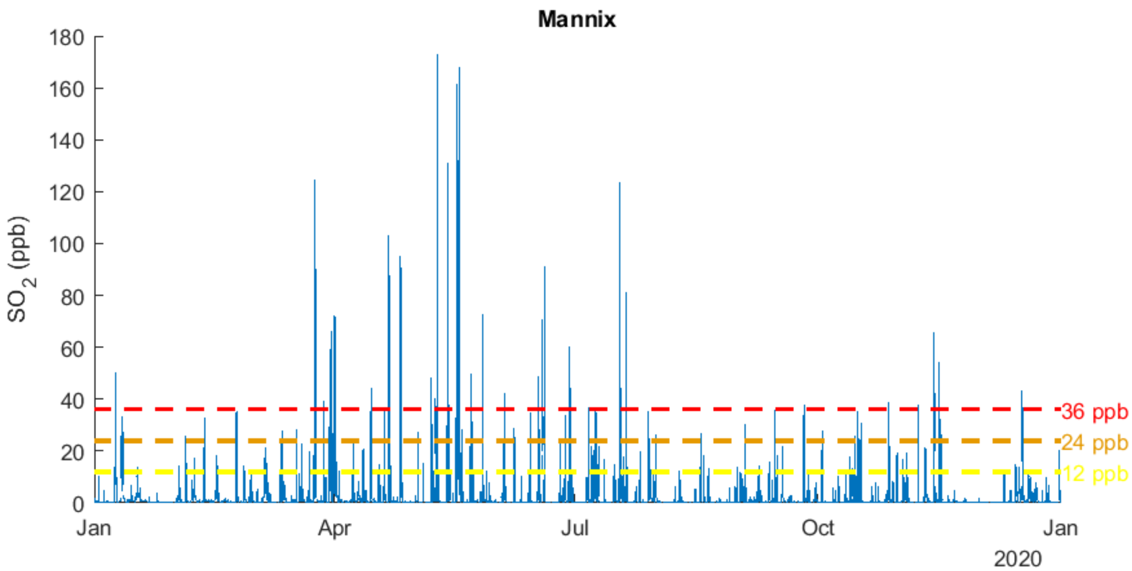

Figure A7. SO_2 episode analysis for Mannix station shows most episodes occurred in the spring, and may be linked to operational challenges experienced during the COVID Public Health Emergency.

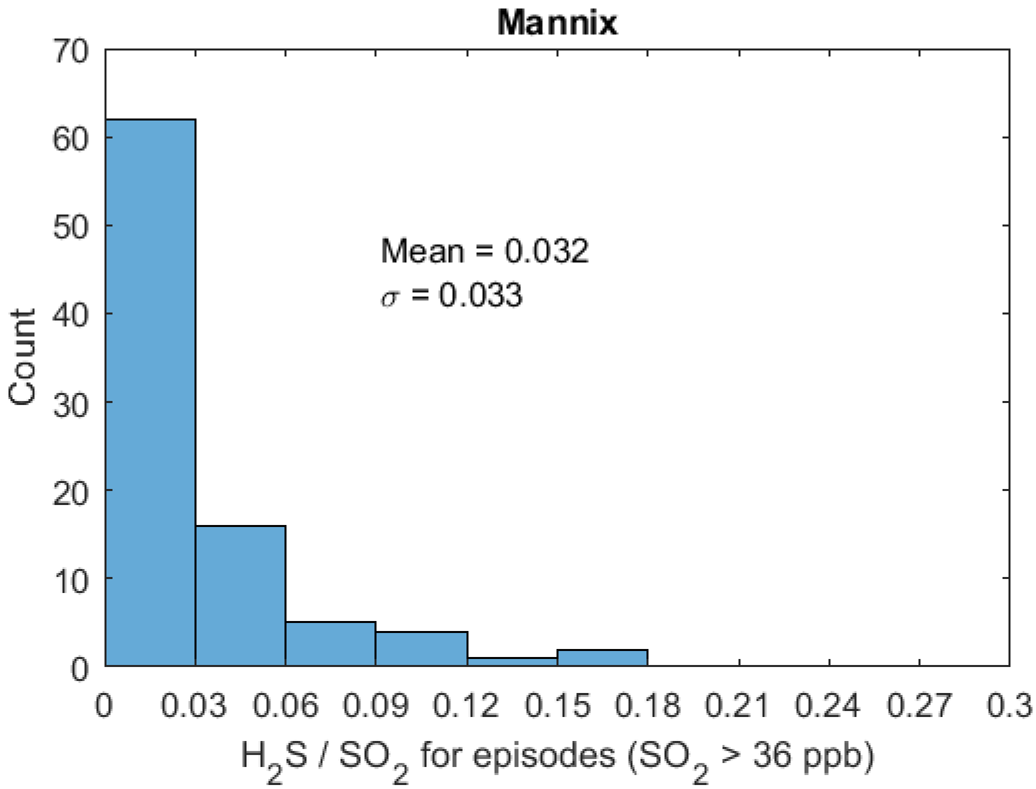

Figure A8. Histograms showing relationship between H_2S and SO_2 at Mannix station for hourly average data, for peak SO_2 episodes (> 36 ppb) in 2020. SO_2 episodes with low H_2S/SO_2 fractions suggest stack sources of SO_2.

B2. Mildred Lake Station

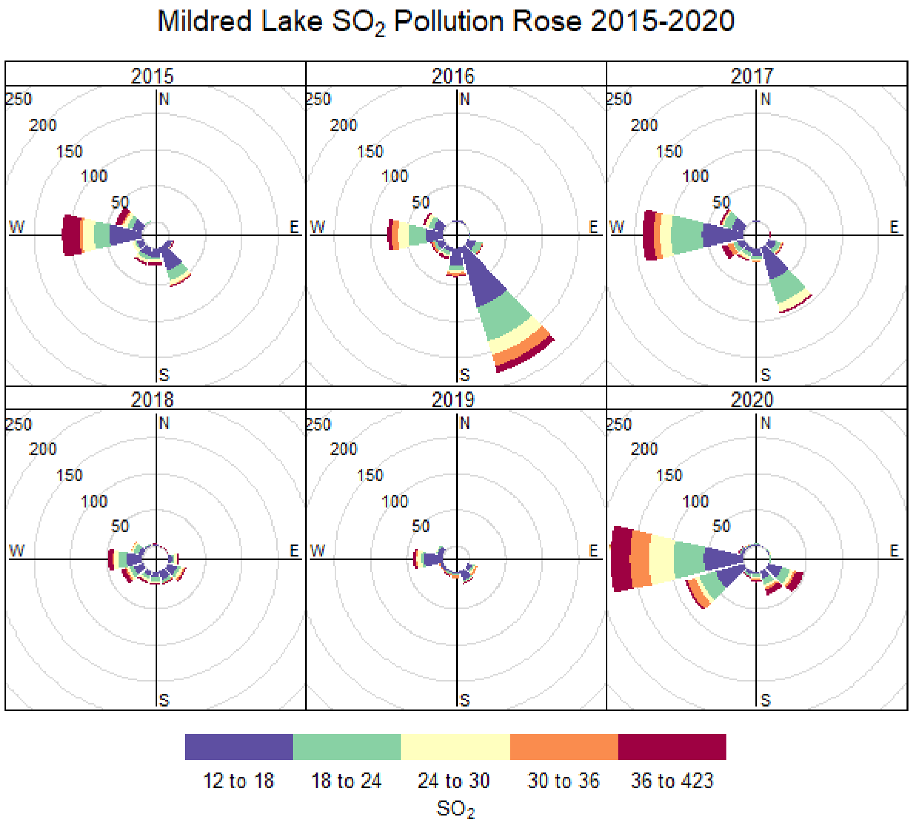

Figure A9. Pollution roses for Mildred Lake station from 2015-2020 identifying count of all hourly episodes where SO_2 > 12 ppb. Results show elevated SO_2 emissions originating from the west, with a small portion from the southeast. Elevated SO_2 levels in 2020 are much more frequent than observed in 2018 and 2019.

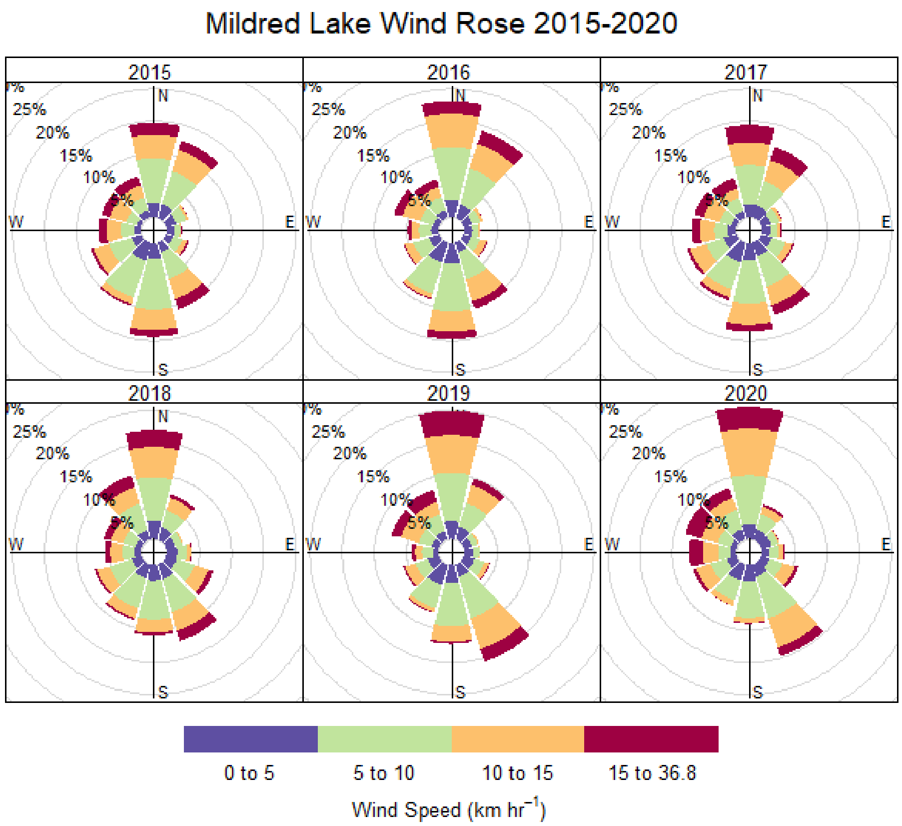

Figure A10. Wind roses for Mildred Lake station from 2015-2020 showing frequency of wind speed by direction. Results show that the wind rose for 2020 was similar to other years.

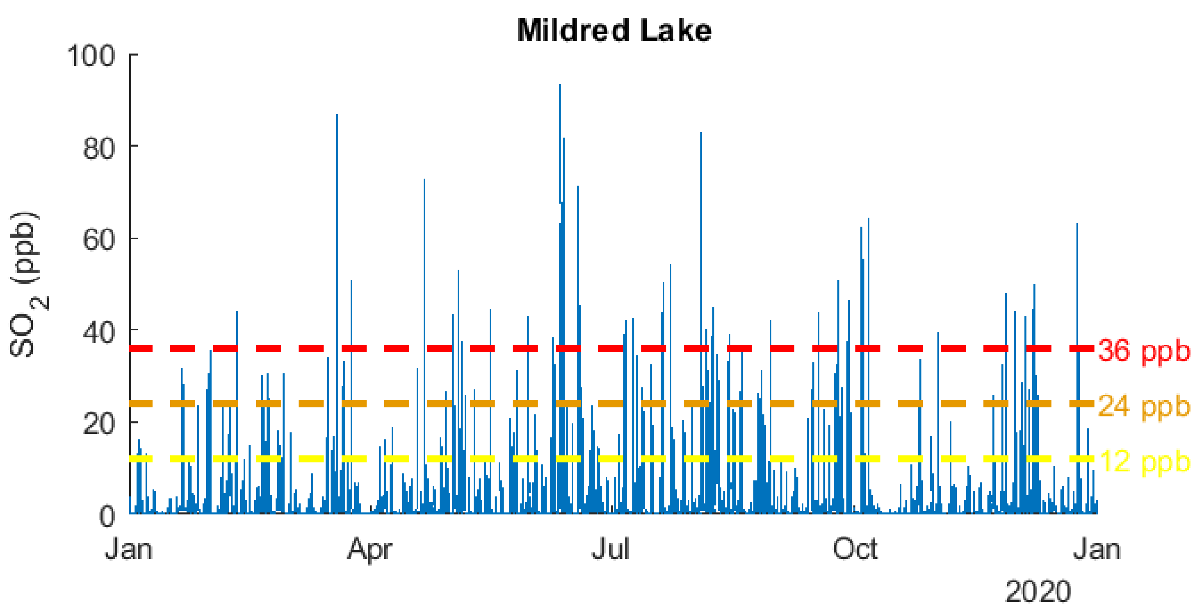

Figure A11. SO_2 episode analysis for Mildred Lake station shows that episodes were observed throughout the year.

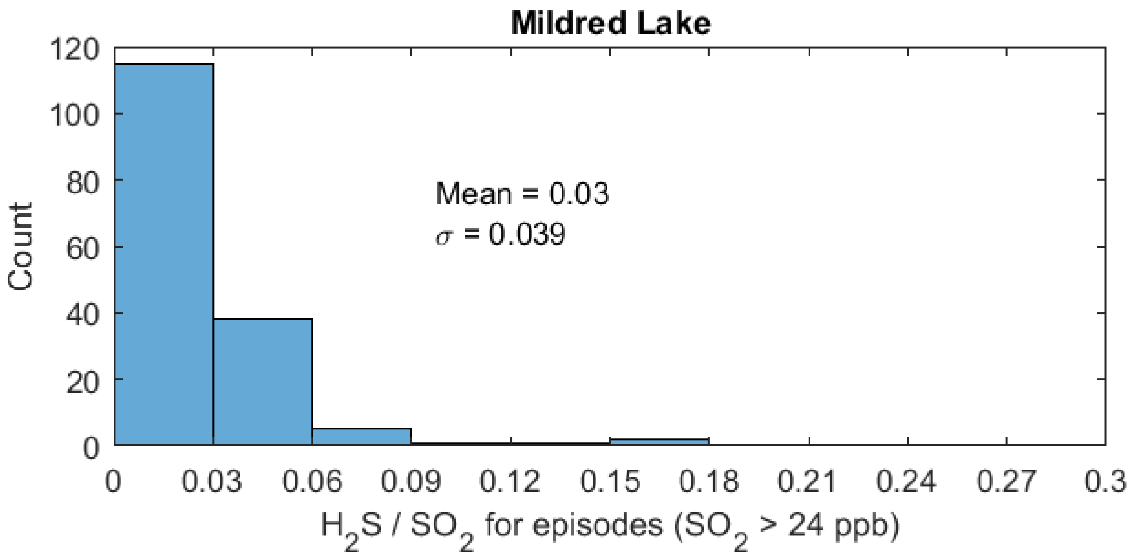

Figure A12. Histograms showing relationship between H_2S and SO_2 at Mildred Lake station for hourly average data for peak SO_2 episodes (> 24 ppb) in 2020. SO_2 episodes with low H_2S/SO_2 fractions suggest stack sources of SO_2.

B3. Christina Lake Station

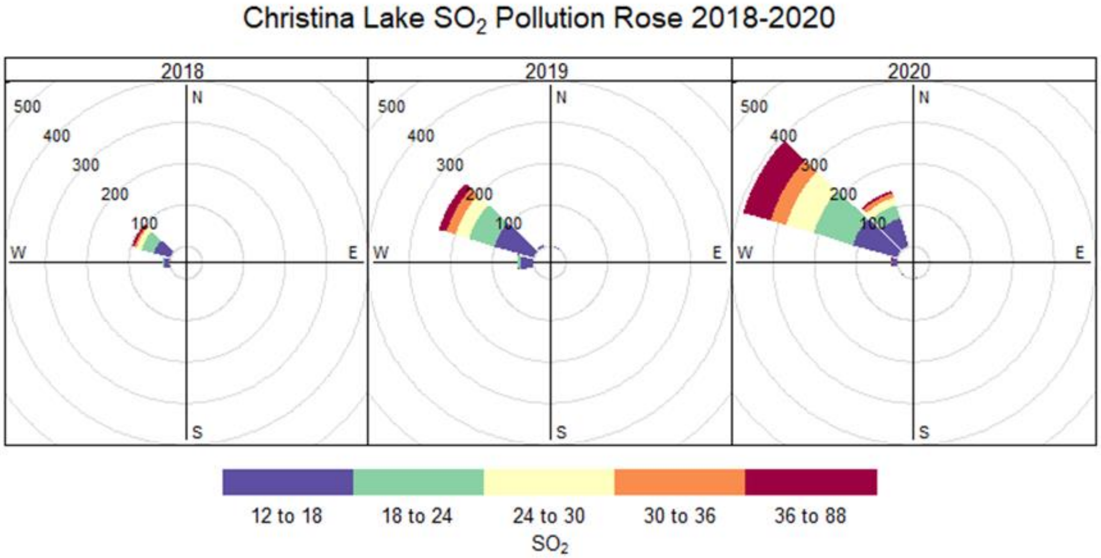

Figure A13. Pollution roses for Christina Lake station from 2018-2020 identifying count of all hourly episodes where SO_2 > 12 ppb show that the majority of elevated SO_2 emissions originate with winds from the north west, which is consistent with previous years. Episodes of SO_2 were more frequent in 2020 compared to previous years.

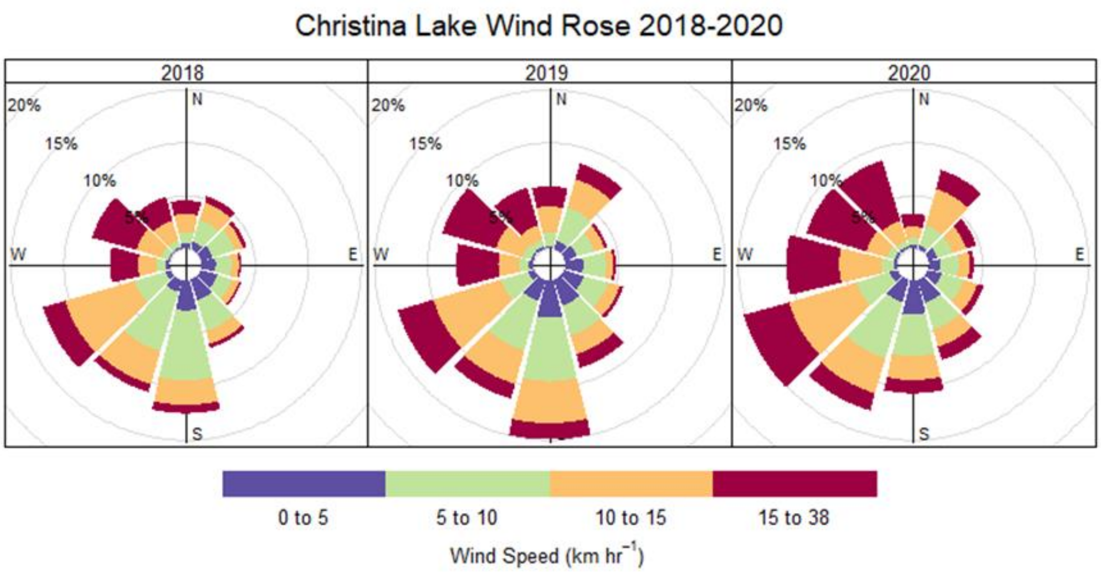

Figure A14. Wind roses for Christina Lake station from 2018-2020 showing frequency of wind speed by direction. Results show that winds are variable at Christina Lake station and readings in 2020 were consistent with other years.

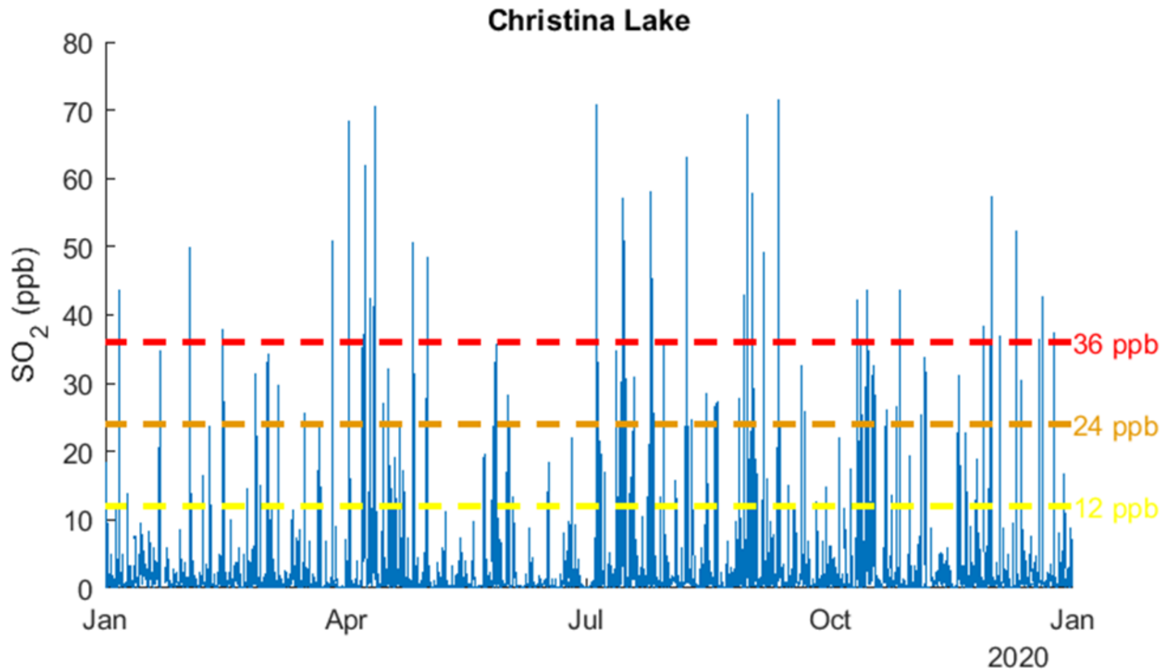

Figure A15. SO_2 episode analysis for Christina Lake station shows that episodes were observed throughout the year.

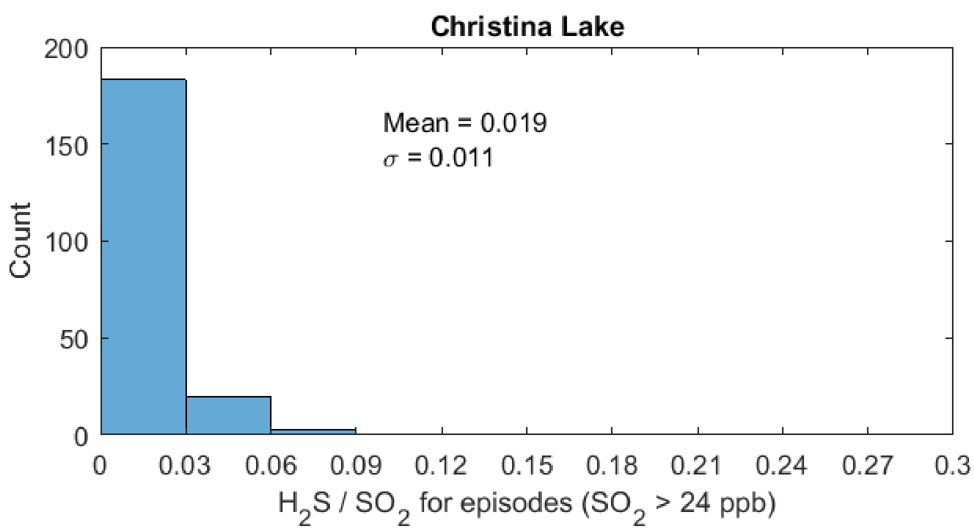

Figure A16. Histograms showing relationship between H_2S and SO_2 at Christina Lake station for hourly average data for peak SO_2 episodes (> 24 ppb) in 2020. SO_2 episodes with low H_2S/SO_2 fractions suggest stack sources of SO_2.

B4. Lower Camp Station

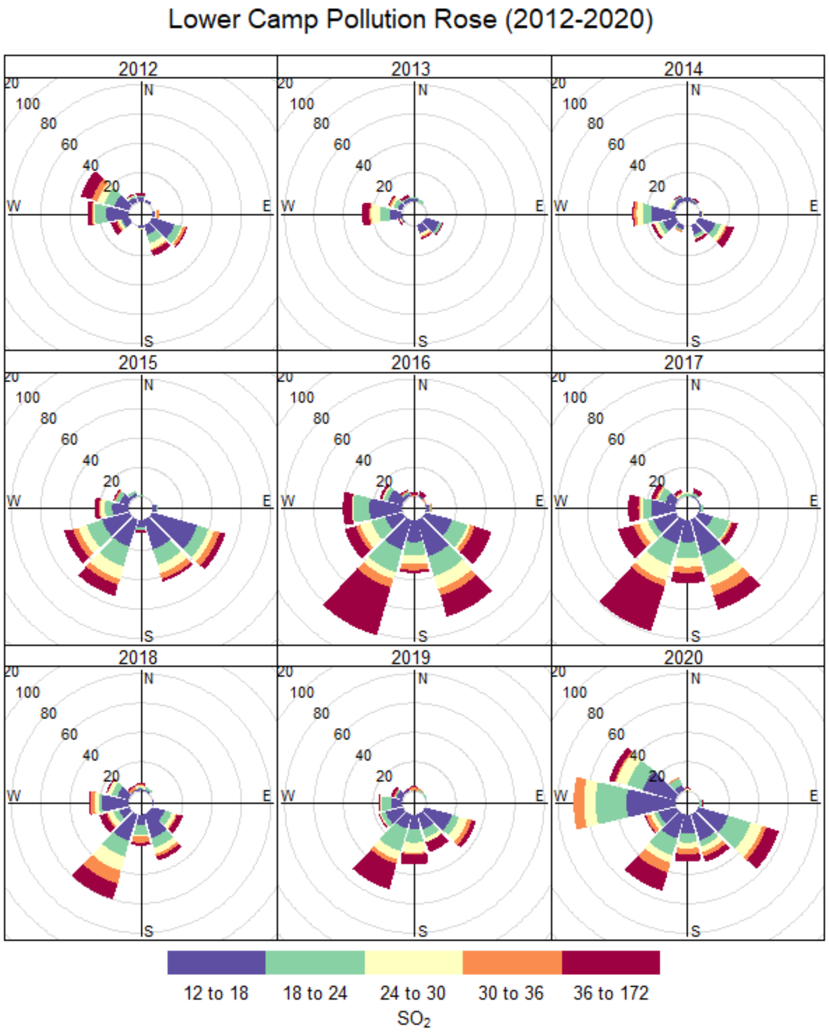

Figure A17. Pollution roses for Lower Camp station from 2012-2020 identifying count of all hourly episodes where SO_2 > 12 ppb showing elevated SO_2 emissions originating from the south west and consistent with prior years.

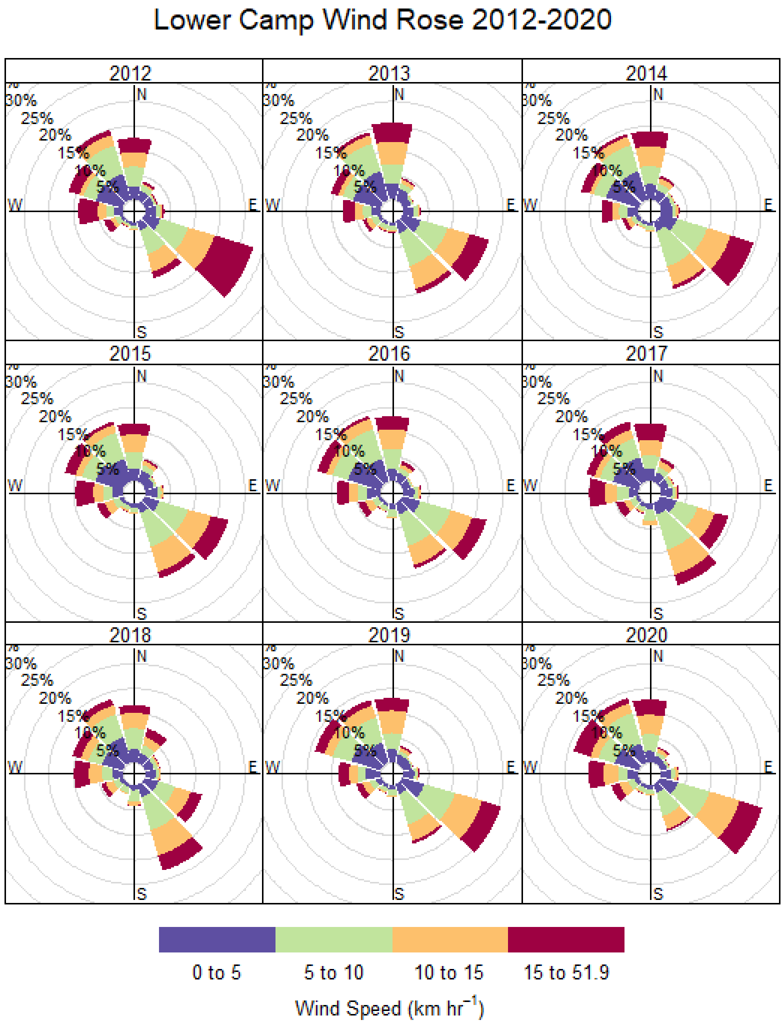

Figure A18. Wind roses for Lower Camp station from 2012-2020 showing frequency of wind speed by direction. Results show that the wind rose for 2020 was consistent with other years.

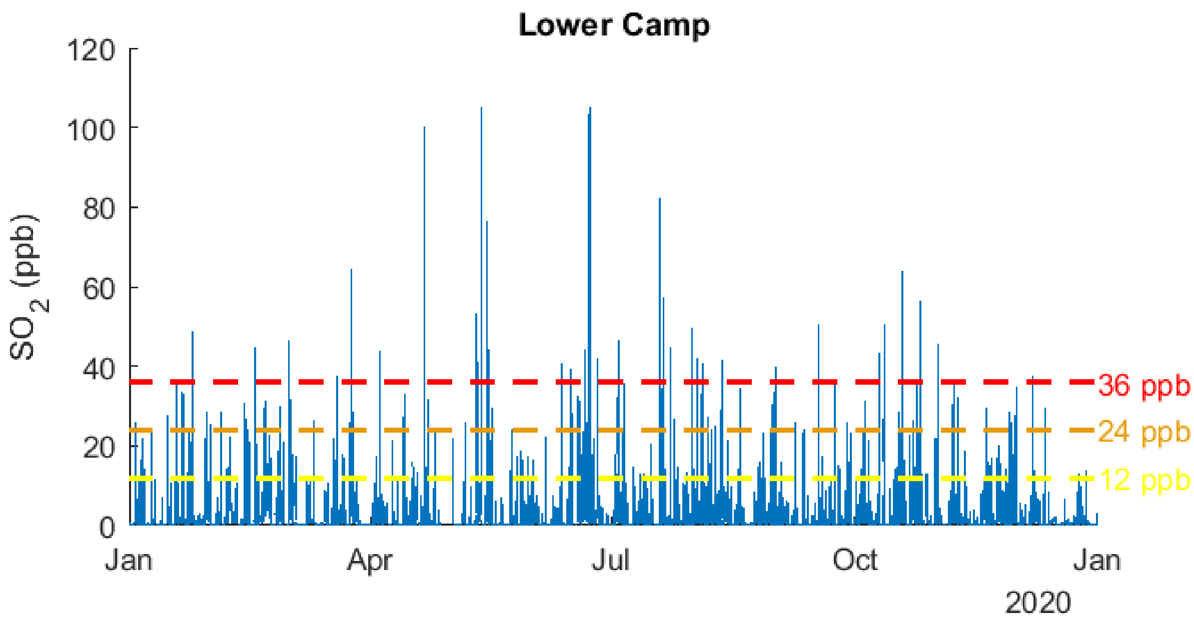

Figure A19. SO_2 episode analysis for Lower Camp station shows that episodes were observed throughout the year, which is consistent with timing of episodes in previous years (see 2019 Status of Management Response Report).

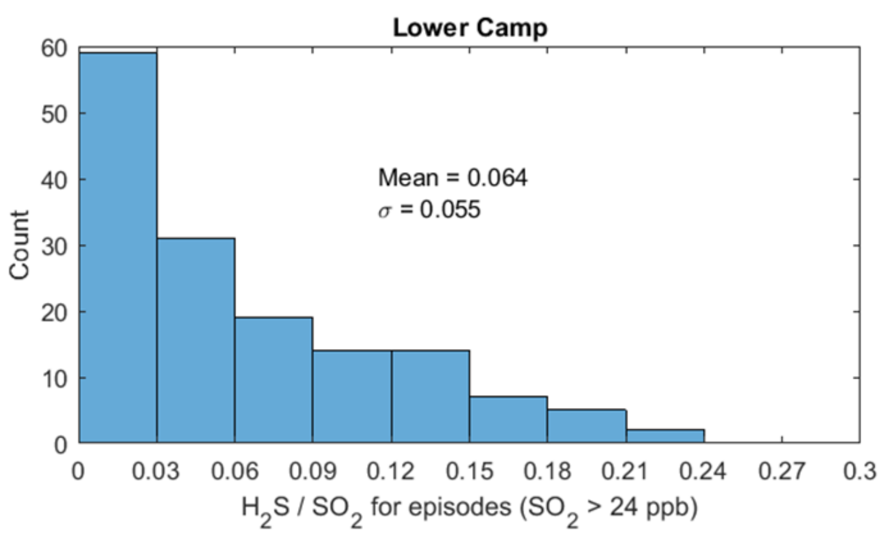

Figure A20. Histograms showing relationship between H_2S and SO_2 at Lower Camp station for hourly average data for peak SO_2 episodes (> 24 ppb) in 2020. SO_2 episodes with low H_2S/SO_2 fractions suggest stack sources of SO_2, whereas episodes with higher H_2S/SO_2 fractions suggest ground level SO_2 sources.

Part 2: Surface Water Quality

5.0 Introduction to Surface Water Quality

Under the *Lower Athabasca Regional Plan* (GoA, 2012), a management response is initiated when the Minister of Environment and Parks determines a trigger or limit as identified in the Lower Athabasca Region Surface Water Quality Management Framework (AEP, 2012) has been exceeded. As identified in the Framework, management responses may also be undertaken for indicators that exceed relevant surface water quality guidelines, or if undesirable trends are developing in the region. A full list of Framework indicators can be found in Appendix C - Surface Water Quality Indicators for the SWQMF. The triggers and limits apply to two stations in the region, from which pooled data comprises the historical dataset. These stations are Old Fort and Devil's Elbow, and collectively referred to herein as 'Old Fort' (Figure). Devil's Elbow data is used only where measurements are unavailable from Old Fort. Additional stations within the Athabasca basin beyond the 'Old Fort' stations are used to support investigations.

Alberta Environment and Parks (AEP) is the lead coordinator of the management response, and works with other government branches and regulators (e.g. Alberta Energy Regulator) and external parties, as required, to identify and implement a management response.

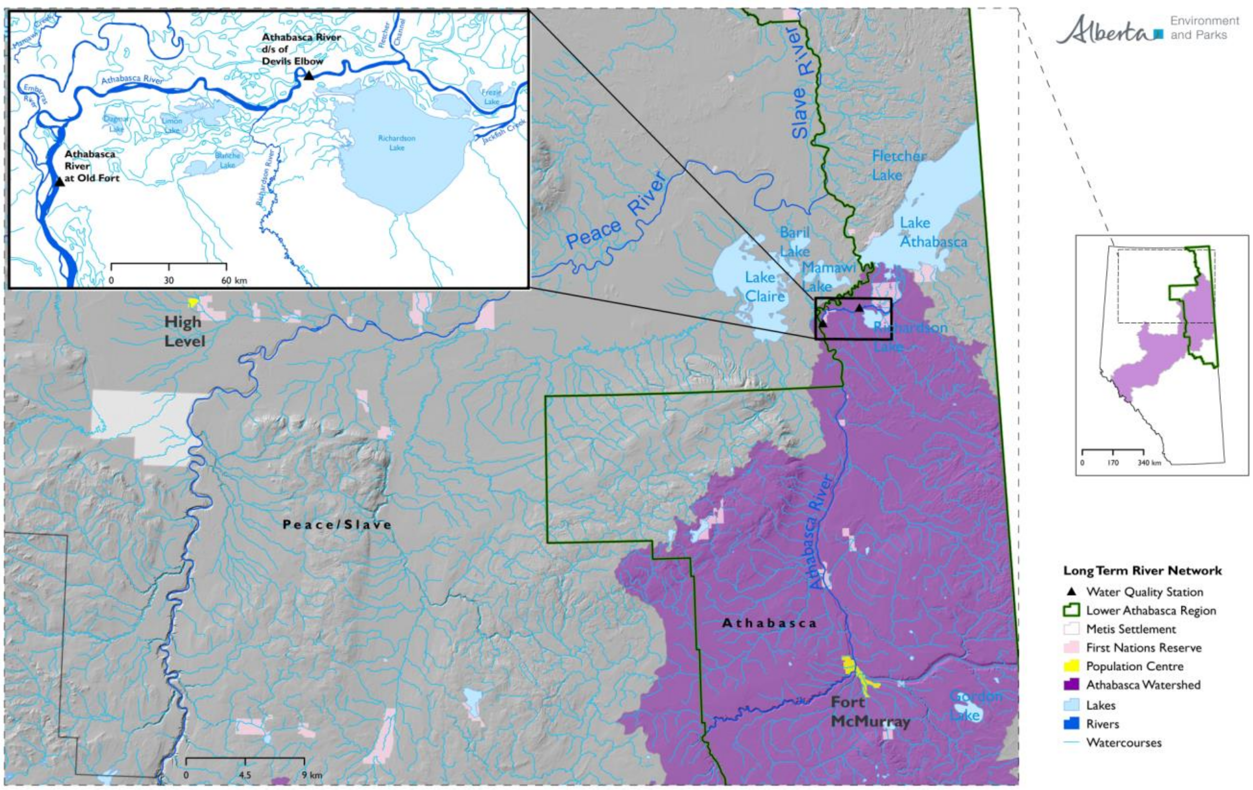

Figure 2. Map of surface water quality monitoring stations used in the assessment

A management response was initiated for the Lower Athabasca Region after triggers were crossed in 2020 for dissolved lithium, dissolved uranium, dissolved arsenic, potassium, total dissolved phosphorus, and total uranium (Laceby *et al*, 2022). As each annual report on conditions becomes available, the management response is re-evaluated and updated based on new information.

This report provides an update on the management response since the last status report in press (AEP, 2021). This is the eighth status report produced since the Framework came into effect in August 2012

A full description of the management response process can be found in the Framework. Initial steps include preliminary assessment and an investigation to determine the need for management actions. These steps are taken, in full or in part, when a surface water quality trigger is crossed or limit is exceeded.

Part of the management response is determining the need for management action. The management response for surface water quality may consider a variety of factors including: the number and location of monitoring stations (beyond 'Old Fort') where undesirable water quality occurs, the potential impact on the aquatic environment or water uses, and any additional influences or sources that lead to a deterioration. As the status of condition report becomes available, the management response is re-evaluated and updated based on new information.

Definitions:

Parameter: Chemical, physical, or biological characteristics of water that are measured as part of monitoring for water quality.

Indicator: Values derived from metrics that provide insight into the status of water quality when compared to triggers and limits.

Triggers: Thresholds set in advance of limits as early warning signals for evaluation, adjustment, and innovation on an ongoing basis. Indicators are compared to triggers to determine if a trigger crossing has occurred.

Limits: Thresholds at which the risk of adverse effects on health or environmental quality is becoming unacceptable. Indicators are compared to limits to determine if a limit exceedance has occurred.

The LAR SWQMF and all previous status of ambient surface water quality and status of management response reports can be found on the Environment and Parks website (www.alberta.ca/lower-athabasca-regional-planning.aspx), as well as on Open Government: (https://open.alberta.ca/publications).

6.0 Summary of Trigger Crossings and Limit Exceedances

6.1 Minister's Determination

The Minister's Determination for 2020 confirmed that monitoring at 'Old Fort' detected trigger crossings for Lithium D, Uranium D, Arsenic D, Potassium (K+), Total Dissolved Phosphorus (TDP), Total Nitrogen (TN), and Uranium T in the Lower Athabasca Region (Table 7). Trigger crossings from previous assessment periods are summarized in Appendix D.

TABLE 7. THRESHOLD EXCEEDANCES FOR SURFACE WATER QUALITY IN THE LOWER ATHABASCA REGION FOR 2020 BASED ON TRIGGERS AND LIMITS ESTABLISHED IN THE FRAMEWORK.

Indicator	Station	Trigger Crossing	Limit Exceedance
Lithium D	'Old Fort'	Mean	NA
Uranium D	'Old Fort'	Mean, Peak	NA
Arsenic D	'Old Fort'	Mean, Peak	NA
Potassium (K+)	'Old Fort'	Mean	NA
Total Dissolved Phosphorus (TDP)	'Old Fort'	Mean	NA
Total Nitrogen (TN)	'Old Fort'	Mean	NA
Uranium T	'Old Fort'	Mean	NA

7.0 Preliminary Assessment for Surface Water Quality

Once trigger crossings are identified, decisions must be made as to whether or not the exceedance warrants investigation. To this end, a preliminary assessment is performed to determine whether exceedances represent changing ambient conditions (trends) over time.

Rare events or natural circumstances that cause water quality indicators to cross a trigger do not always result in a trend. Some approaches used to assess the environmental significance of an exceedance include comparing annual and historical data sets, trend assessments, and evaluating the influence of flow.

Preliminary assessments consisted of either one or two trend analyses, performed on un-adjusted and flow-adjusted data, respectively. They confirmed if undesirable trends in water quality are present at 'Old Fort'.

Flow was accounted for using flow-adjustment. Parameter concentrations and flow estimates were compared. If a predictable relationship existed, concentrations were adjusted to account for flow. If not then flow-adjustments were not used.

Trend tests start assuming that no significant trend in water quality exists. We reject this assumption if a significant trend is shown. Where possible, we repeat these tests after flow-adjustment. Flow-adjustment can expose trends obscured by flow, or show if a trend is explained by it. If a trend was revealed or not explained by flow-adjustment an investigation resulted. If a flow-adjustment model was unreliable, unadjusted trends were used to make this determination.

If a preliminary assessment identifies changing ambient conditions the parameter is assigned a management level of 2, initiating an investigation into the cause. If the preliminary assessment does not identify changing ambient conditions, a management level of 1 is assigned and no investigation results.

The parameters listed in Table 8 are already under investigation. Follow-up on these indicator exceedances are reported in Section 8.1. Results of the detailed analyses for all parameters under investigation are reported in Appendix E.

TABLE 8. PARAMETERS WITH INDICATOR EXCEEDANCES ALREADY UNDER INVESTIGATION.

Indicator	Parameter	Trend direction	Significance
Lithium D	Dissolved lithium	Increasing	Significant
Potassium (K+)	Potassium	Increasing	Significant
Total Nitrogen (TN)	Total nitrogen	Increasing	Significant
Uranium D	Dissolved uranium	Increasing	Significant
Uranium T	Total uranium	Increasing	Significant

Trend directions and significance for un-adjusted parameters not already under investigation are listed in Table 9. Table 10 indicates that the flow-adjustment models for these parameters did not meet criteria for use in flow-adjusted trend assessment.

The indicator Arsenic D has been assigned a Management Level of 2 and an investigation into the associated parameter (dissolved arsenic) has been initiated. The indicator Total Dissolved Phosphorus (TDP) has been assigned a Management Level of 1 (details of analysis provided in Appendix E.1) and as a result, its management response has been closed.

TABLE 9. TREND DIRECTION AND SIGNIFICANCE OF PARAMETERS NOT ALREADY UNDER INVESTIGATION

Indicator	Parameter	Trend Direction	Significance
Arsenic D	Dissolved arsenic	Increasing	Significant
Total Dissolved Phosphorus (TDP)	Total dissolved phosphorus	Decreasing	Not significant

TABLE 10. TREND DIRECTION AND SIGNIFICANCE OF FLOW-ADJUSTED PARAMETERS NOT ALREADY UNDER INVESTIGATION. NA INDICATES THAT FLOW-ADJUSTMENT MODELS DID NOT MEET CRITERIA FOR USE.

Indicator	Parameter	Trend Direction	Significance
Arsenic D	Dissolved arsenic	NA	NA
Total Dissolved Phosphorus (TDP)	Total dissolved phosphorus	NA	NA

8.0 Status of Management Response for Surface Water Quality

The management response is a set of steps taken, in full or in part, when an ambient trigger is crossed or limit is exceeded. The management response will support the management intent associated with each level (Table 11). Levels are set through evaluation of parameters once a threshold has been exceeded; limit exceedances move parameters directly to investigation, whereas trigger crossings are evaluated through preliminary assessment prior to setting a level. A full description of the management system can be found in the Framework. The status of management response is reported on a regular basis and may be supported by supplemental technical reports.

This section of the report provides an update on the investigation phase of the management response.

TABLE 11. SURFACE WATER QUALITY LEVELS – DESCRIPTION AND MANAGEMENT INTENT

Level	Description	Management Intent
3	Exceedance of water quality limits	Improve water quality to below limits.
	Limit Exceedance	
2	Crossing of water quality triggers	Proactively maintain water quality below limits. Improve knowledge and understanding of trends.
	Trigger Crossing	
1	Mean and peak water quality conditions at or better than historical water quality conditions.	Apply standard regulatory and non-regulatory approached to manage water quality.

8.1 Investigation

The purpose of an investigation is to determine the factors influencing water quality. Source attribution informs decisions about management actions. The scale of the investigation depends on the management level and the complexity of the issue. Investigations consider monitoring stations beyond 'Old Fort'. Where undesirable trends are developing, understanding where they occur, their impacts to the aquatic environment or water uses, as well as their natural or human-caused origins is necessary.

The parameters under investigation are listed in Table 12. These correspond to the indicators set at Management Level 2. They are known to exhibit increasing trends after flow-adjustment, or had increasing trends in un-adjusted data where flow-correction models did not meet criteria for use. Table 12 includes the newly initiated investigation into dissolved arsenic, started as a result of the preliminary assessment of 2020 data.

AEP is currently interpreting trends in dissolved arsenic. However, the maximum value for dissolved arsenic (0.78 µg/L) observed in 2020 was well below the Alberta environmental quality guideline for total arsenic (5 µg/L). Further, an update to the basin scale trend analyses presented in the 2018 data year report (AEP, 2020) is underway that will include dissolved arsenic.

The basin scale update will involve seasonal Kendall trend analysis performed at nineteen sites spanning the Athabasca Basin using updated datasets for each parameter under investigation as of 2020. These sites include monitoring stations on the main stem and tributaries of the Athabasca River. The update will help to attribute source areas contributing to trends in each parameter and explore the seasonality of trends in concentration. Coincident land use activity, seasonality, and the location of trends will help to refine options for mitigating undesirable water quality trends at their source.

TABLE 12. MANAGEMENT LEVELS FOR INDICATORS AND MANAGEMENT INTENT FOR THE ASSOCIATED PARAMETERS.

Indicator	Parameter	Management Level	Management Intent
Arsenic D	Dissolved arsenic	Level 2	Under investigation
Barium D	Dissolved barium	Level 2	Under investigation
Chloride (Cl-)	Chloride	Level 2	Under investigation
Iron D	Dissolved iron	Level 2	Under investigation
Lithium D	Dissolved lithium	Level 2	Under investigation
Total Nitrogen (TN)	Total nitrogen	Level 2	Under investigation
Total Nitrogen (TN)	Nitrate plus nitrite	Level 2	Under investigation
Total Nitrogen (TN)	Total Kjeldahl nitrogen (TKN)	Level 2	Under investigation
Potassium (K+)	Potassium	Level 2	Under investigation
Selenium D	Dissolved selenium	Level 2	Under investigation
Sulphate (SO4 2-)	Sulphate	Level 2	Under investigation
Uranium D	Dissolved uranium	Level 2	Under investigation
Uranium T	Total uranium	Level 2	Under investigation

Parameter investigations to date show:

- Source areas for exceedances occur both upstream of, and within the Lower Athabasca Region (LAR)
- Geographical gaps in monitoring preclude differentiating some source areas relating to municipal and provincial jurisdictions.
- The geographical extent of trends are parameter specific but overlap in many areas. For example, many parameters under investigation have positive trends at ‘Old Fort’ but only some do at Old Entrance (near Jasper).
- Supplementary and/or continued monitoring data may provide the additional resolution between:
  - The Clearwater River Basin and the Oil Sands Region
  - The Athabasca River Basin upstream of the Athabasca town site and the:
    - McLeod River
    - Municipalities of Hinton and Whitecourt

8.2 Proposed and Ongoing Investigation Activities

A key component of ongoing investigations is related to understanding and determining source attribution of spatial and temporal trends throughout the Athabasca River Basin. Knowledge of source areas and seasonality of trends helps to narrow the range of possible influences. Understanding influences on water quality will inform where and when to focus mitigation efforts and helps to identify effective management actions. Ongoing investigation activities are as follows:

Procure and integrate available and relevant water quality data
Description: Itemize, compile, and integrate supplementary data and analyses from available sources, including the provincial Long Term River Network and Tributary Monitoring programs and others. This may also include third party data submitted to the department or published research findings. This information may inform source-tracking or the development of mitigation strategies.

Status: Ongoing

Progress update: The logistics of integrating Oil Sands water quality monitoring data with provincial monitoring program data are underway. The electronic capture and storage of municipal and industrial effluent data from third parties, reported to Alberta Environment and Parks, has been identified as a priority. Opportunities to capture and store 3rd party data associated with the continued development and roll out of the Digital Regulatory Assurance System (DRAS) with respect to the *Environmental Protection and Enhancement Act* approvals and renewals are being explored. Expansion of digitized historical third party regulatory and water quality information datasets is also being explored.

Explore and interpret seasonal patterns in water quality trends
Description: Seasonal trend analyses are conducted to identify the recurring time intervals in which undesirable trends develop. If an effect is known to be season-specific, then activities with known coincident impacts can be identified, evaluated, and prioritized. Seasonal trend analysis identifies the locations and timing of effects which, in turn, determine geographical areas of interest; by parameter and season.

Status: Ongoing

Progress update: Seasonal trend analyses were completed and presented as part of previous management response report (AEP, 2020). Seasonal trend analysis for 2020 and 2019 data is currently under investigation and near completion, which includes an expanded list of parameters. Next, areas of interest will be identified from the results of the trend analysis to evaluate contributing impacts and activities. Additional work currently underway on seasonal trend analysis includes streamlining the analytical process and determination of most suitable seasonal definition.

Summarize existing land use activity information within potential source-areas
Description: Under the *Water Act* and *Environmental Protection and Enhancement Act*, activities are land use categories that are used to group events on the land that are similar in nature, and usually relate to planned hydrological changes and emissions to the environment. Information about these land surface alterations and discharges is collected and assessed during the application and renewal processes and these records have the potential to inform the prevalence and timing that activities occur within specific geographic area over time.

Status: Ongoing

Progress update: Currently, framework investigations are evaluating the seasonal timing and geographic location of trends in water quality throughout the Athabasca Basin. Trends will identify specific geographical areas of interest where summary land use information will be compiled and evaluated.

Identify existing department- and community-led management plans that may impact water quality and update relevant partners on investigative progress.
Description: The *Water for Life* Strategy supports planning on several scales, including provincial (Alberta Water Council), watershed (Watershed Planning and Advisory Councils), and local scales (watershed stewardship groups). Municipalities also develop municipal and project specific plans that may impact water quality. In combination, land use activity and geographic information on water quality trends may be used to identify opportunities to work collaboratively to mitigate area-specific, undesirable trends in water quality.

Status: Ongoing

Progress update: AEP is continuing to work with partners in watershed stewardship to advance *Water for Life* goals. AEP is currently compiling information about watershed management plans and partners that exist within the Athabasca Basin. This information will inform engagement on water quality issues. If existing plans have identified potential options to mitigate area specific water quality issues, this will help guide engagement and coordination with local stakeholders in the development of mitigation efforts. If relevant plans are not available, this information will help inform the prioritization of planning efforts. Specifically, engagement sessions regarding investigative results and progress on water quality management is currently underway. Results and updates were also shared during a public webinar held in April 2020.

Development of a surface water quality model for the Lower Athabasca River

Description: A 1-D river model is being developed using the Mike Hydro River software. The model covers the mainstem Athabasca River from Fort McMurray to the Old Fort monitoring station and can be used to predict hydraulics, sediment transport, and metal transport. The model is intended to inform ongoing management responses under the Lower Athabasca Surface Water Quality Management Framework and support future framework amendments.

Status: Model development is complete, although further refinement could occur in the future. Planning and analysis of future scenarios is underway.

Progress update: The model has been calibrated and validated for eight metals (i.e. cadmium, chromium, lead, iron, selenium, lithium, silver, and uranium). Preliminary findings show the importance of smaller tributaries for metals loadings into the Lower Athabasca River and the influence of sediment bed quality on the concentration of metals in the water column.

8.2 Identification of Management Actions

Management actions support, rather than replace existing policies and regulations. Management actions may range from policy or regulatory initiatives to reduce point and nonpoint inputs, to voluntary actions, to raising awareness and understanding surrounding surface water quality. Knowledge improvement actions may also be considered, including gathering baseline information, improving scientific understanding, knowledge, and learning from other jurisdictions.

It is important to recognize that some management actions can take a number of years to initiate and the impact of implementing certain actions may take several additional years to be realized.

Collaboration of all stakeholders and Indigenous communities and organizations is key to the success of proactive management actions. Ongoing investigation and studies will continue to inform and establish necessary and appropriate mitigative actions. Future management response reports will provide updates on the progress towards investigation and management actions developed as a result.

Below is a list of the management actions identified in this and priors year's reports and progress to-date.

Encourage the monitoring of parameters under investigation conducted by third party water quality monitoring programs.
Description: Monitoring programs conducted through approval and compliance processes provide data that link water quality and specific land use activities, in specific areas. Those not linked to undesirable trends in water quality can refine the prioritization of mitigation efforts elsewhere.

Status: Ongoing

Progress Update: Relevant parameters have been included in some monitoring programs supporting approvals or renewals of existing approvals within the Lower Athabasca Region. An opportunity to improve efficiency exists in the electronic capture and aggregation of third party monitoring data submitted to the province.

Enhance geographical resolution in provincial water quality monitoring programs
Description: Within the Athabasca River Basin, the provincial water quality monitoring programs consist of regular monitoring at predetermined sites along the main stem and tributaries. Enhancements to monitoring at more sites will enable upstream source-tracking of contaminants and would improve the capability of provincial water quality monitoring program data to inform mitigation efforts.

Status: Ongoing

Progress Update: Within the Athabasca basin, the Tributary Monitoring Network has expanded its parameter lists to include dissolved metals. Depending on location, this has initiated or expanded the collection of provincial water quality monitoring programs within Athabasca tributaries to enhance current and future upstream source-tracking and the capability of provincial water quality monitoring program data to inform mitigation efforts.

9.0 Next Steps for Surface Water Quality

AEP will continue to oversee the implementation of the management actions, while continuing preliminary assessment and investigative work. AEP will update the seasonal Kendall trend analysis within the Athabasca basin to include the most recent data and all parameters currently under investigation. This information, along with findings from the surface water quality model, will be used to prioritize areas for further management action. Within these areas, land use information and community or government led plans will be leveraged to identify opportunities to work in partnership to mitigate area-specific undesirable trends in water quality. AEP will work with specific stakeholders and Indigenous communities and organizations, as appropriate, to inform the investigation, mitigation, and assist in improving the current environmental management system and identifying management actions necessary to address influences on surface water quality.

Additionally, a review of the Lower Athabasca Regional Plan is due for initiation prior to September 2022. As part of this process, the Surface Water Quality Management Framework for the Lower Athabasca Region will be reviewed.

AEP is committed to working with stakeholders and Indigenous communities and organizations to inform investigations, develop mitigative strategies and management actions to improve surface water quality, and involve in the renewal of the surface water quality management framework. AEP is planning public engagement sessions to communicate findings, connect with stakeholders, and seek local knowledge. Progress updates on the work outlined in this report will be communicated to the public in subsequent Status of the Management Response Reports and webinars.

Surface Water Quality References

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Surface Water Quality Glossary

Contaminant/Pollutant	A substance in a concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment
Ecosystem Health	A healthy aquatic ecosystem is an aquatic environment that sustains its ecological structure, processes, functions, and resilience within its range of natural variability.
Indicator	Values derived from metrics that provide insight into the status of water quality when compared to triggers and limits.
Limits	Thresholds at which the risk of adverse effects on health or environmental quality is becoming unacceptable. Indicators are compared to limits to determine if a limit exceedance has occurred.
Non-point Source Pollutant	Pollution that enters a water body from diffuse or undefined sources and is usually carried by runoff.
Parameter	Chemical, biological or physical characteristics of water that are measured as part of monitoring for water quality.
Point Source Pollution	Pollution that originates from an identifiable cause or location, such as a sewage treatment plant.
Substance	From the framework, a 'substance' is defined as: i) Any matter that: a. Is capable of becoming dispersed in the environment, or b. Is capable of being transformed in the environment into matter referred to in a., ii) Any sound, vibration, heat, radiation or other form of energy, and iii) Any combination of things referred to in i) and ii).
Toxicity	The adverse effect on the growth, reproduction, or survival of an organism.
Triggers	Numerical thresholds set in advance of limits as early warning signals for evaluation and proactive management.
Wastewater	The liquid waste generated through various industrial and municipal processes.
Water Uses	For the purpose of the framework these include: protection of aquatic life, drinking water, recreation and aesthetics, agricultural, and industrial.

Appendix C - Surface Water Quality Indicators for the SWQMF

TABLE A1. LIST OF PRIMARY INDICATORS FOR LOWER ATHABASCA REGION SURFACE WATER QUALITY MANAGEMENT FRAMEWORK FOR THE LOWER ATHABASCA RIVER.

Indicators		
Aluminum D	Iron D	Sulphate (SO_4^{2})
Aluminum T	Iron T	Thallium D
Antimony D	Lead D	Thallium T
Antimony T	Lead T	Thorium D
Arsenic D	Lithium D	Thorium T
Arsenic T	Lithium T	Titanium D
Barium D	Magnesium (Mg+)	Titanium T
Barium T	Manganese D	Total Ammonia (NH_3+4-N)
Beryllium T	Manganese T	Total Dissolved Phosphorus (TDP)
Bismuth T	Mercury T	Total Nitrogen (TN)
Boron D	Molybdenum D	Total Phosphorus (TP)
Boron T	Molybdenum T	Uranium D
Cadmium D	Nickel D	Uranium T
Cadmium T	Nickel T	Vanadium D
Calcium (Ca^{2+})	Nitrate (NO_3-N)	Vanadium T
Chloride (Cl-)	Potassium (K+)	Zinc D
Chromium D	Selenium D	Zinc T
Chromium T	Selenium T	
Cobalt D	Silver T	
Cobalt T	Sodium (Na+)	
Copper D	Strontium D	
Copper T	Strontium T	

Appendix D - History of Exceedances

TABLE A2. HISTORY OF MEAN (M) AND PEAK (P) TRIGGER CROSSINGS FOR WHICH THERE IS A CURRENT MANAGEMENT RESPONSE.

Parameter	2012	2013	2014	2015	2016	2017	2018	2019	2020
Aluminum (dissolved)		P							
Arsenic D									M/P
Barium (dissolved)								M	
Chloride									
Cobalt (dissolved)			P		P			P	
Iron (dissolved)		M							
Lithium (dissolved)	P				M/P	M/P			M
Lithium (total)		P							
Nitrogen (total)	M	M							M
Nitrogen NO3+NO2									
Nitrogen Total Kjeldahl (TKN)									
Potassium			M			M	M	M	M
Selenium (dissolved)								M	
Strontium (dissolved)				M					
Sulphate			M	M	P				
Total Dissolved Phosphorus (TDP)									M
Uranium (dissolved)	M/P	M/P	P	M/P	M/P	M/P	M/P	M/P	M/P
Uranium (total)								M	M

Appendix E - Preliminary Assessment Technical Information

E1. Trend Assessments

This section provides trend assessments related to preliminary assessments for parameters relating to indicators that crossed triggers in the 2020 data year and were not already under investigation. Trend assessments relating to parameters under investigation prior to this report can be found in Section E2.

Arsenic D (dissolved arsenic)

There was no limit set for dissolved arsenic in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2020, three occurrences were above the peak trigger, which was set at 0.7 µg/L. The maximum value was 0.78 µg/L, which equals 111.4% of the peak trigger value. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The trend analysis for dissolved arsenic showed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A21). Changes in flow-concentration relationships over time prevented the development of an adjustment model for dissolved arsenic. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and an investigation into this parameter has been initiated.

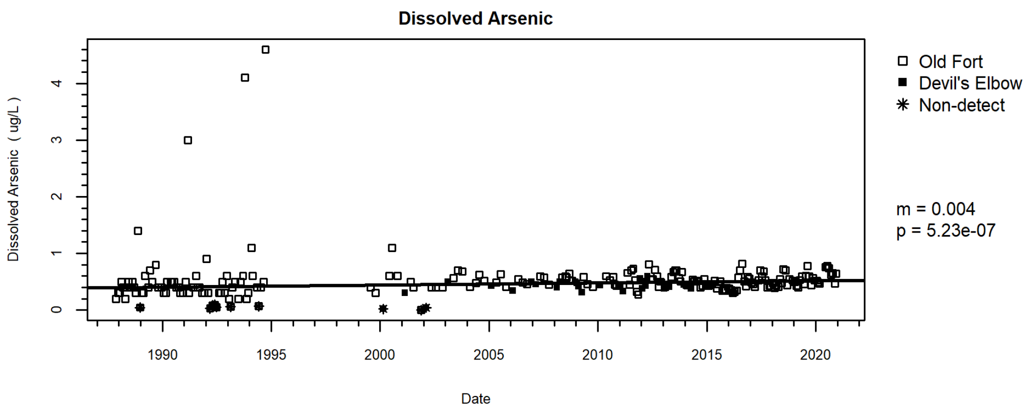

Figure A21. Dissolved arsenic concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Total Dissolved Phosphorus (TDP)

There was no limit set for total dissolved phosphorus in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2020, no occurrences were above the peak trigger, which was set at 0.032 mg/L. The maximum value was 0.025 mg/L, which equals 78.1% of the peak trigger value. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The February 2020 sample had a censored value with an unusually high detection limit of about 100 times higher than normal. This was due to complications (i.e. matrix interference) in the measurement. However, trend analysis methods used are robust and this censored measurement was unlikely to influence the outcome of the trend analysis.

The trend analysis for total dissolved phosphorus revealed a decreasing trend in un-adjusted concentration that was not statistically significant at 'Old Fort' (Figure A22). Changes in flow-concentration relationships over time prevented the development of an adjustment model for total dissolved phosphorus. Thus, no significant trend in total dissolved phosphorus was observed and standard regulatory practices will resume for the management of this parameter.

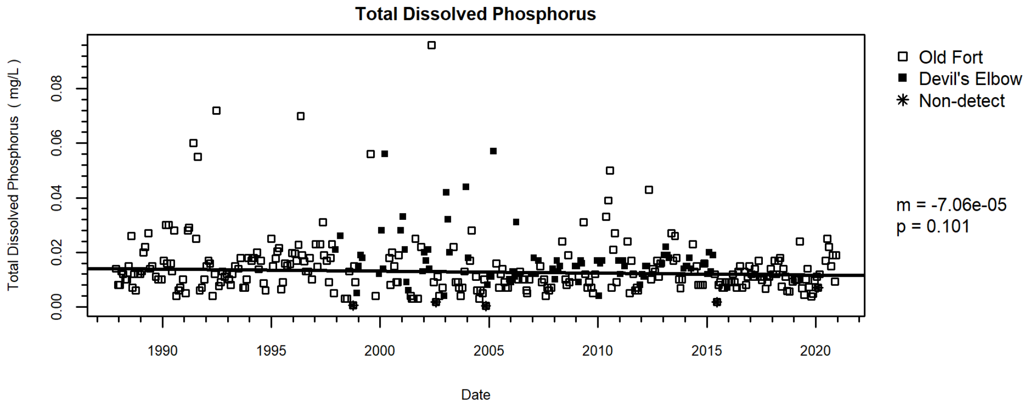

Figure A22. Total dissolved phosphorus concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Due to the pivotal influence of phosphorus on the eutrophication of freshwater, the scope of the preliminary assessment was supplemented with exploratory analysis of trends in the Athabasca River and its tributaries throughout the basin (Figure A23). Note that this analysis was limited to rivers and streams and included no analysis of lentic systems or stream flow and interpreting these results to infer trends in individual lakes and wetlands is not recommended.

This analysis showed only one statistically significant trend ($\alpha = 0.05$) near the mouth of the Muskeg River, and likely trends (p-values in the range of 0.2 - 0.45) upstream in the Muskeg River Basin, with the exception of Jackpine Creek. Dissolved phosphorus trends in the Muskeg River basin are largely a localized issue and will be followed up on via standard regulatory practices at this time.

Concentrations throughout the majority of the Athabasca basin appeared to be in decline, but these trends carry very little statistical certainty (e.g. p-values > 0.45). These preliminary trend analysis results for total dissolved phosphorus seem consistent with recent assessments made downstream in the Peace - Athabasca Delta (Glozier *et al.* 2018). More broadly, while patterns in the trend directions are encouraging, implementation of best phosphorus management practices should continue where possible.

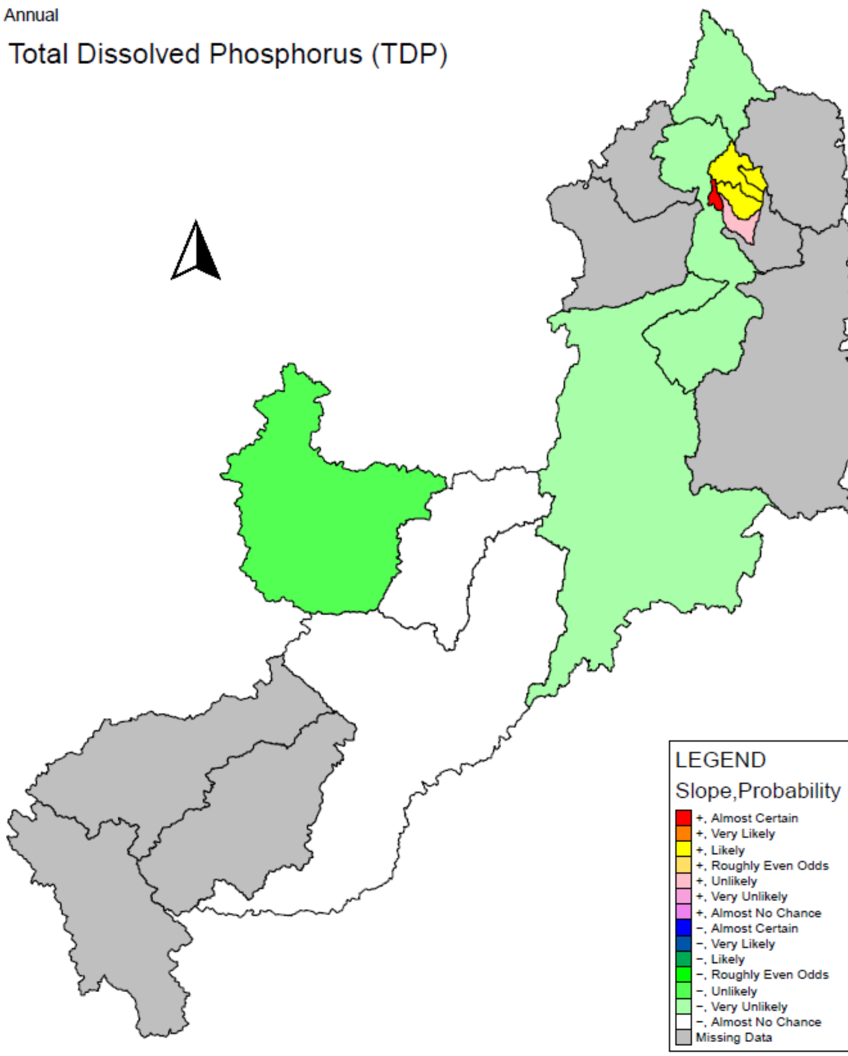

Figure A23. Preliminary results of time series trend direction and significance for total dissolved phosphorus concentrations in the Athabasca River Basin main stem and tributaries. Trends reflect analyses of un-adjusted concentration data. Trend direction and significance were assessed via the seasonal Kendall analyses as implemented in the EnvStats R package (Millard 2013). Polygon areas correspond to those as identified in AEP (2020).

E2 Investigation Technical Information

This section provides trend assessments for parameters currently under investigation, including those relating to indicators that crossed triggers in the 2020 data year. Trend assessments relating to preliminary assessments can be found in Section E1.

Dissolved barium

There was no limit set for dissolved barium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2020, no occurrences were above the peak trigger, which was set at 73.7 µg/L. The maximum value was 68.2 µg/L, which equals 92.5% of the peak trigger value. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The trend analysis for dissolved barium showed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A24). Changes in flow-concentration relationships over time prevented the development of an adjustment model for dissolved barium. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and investigation into this parameter will continue.

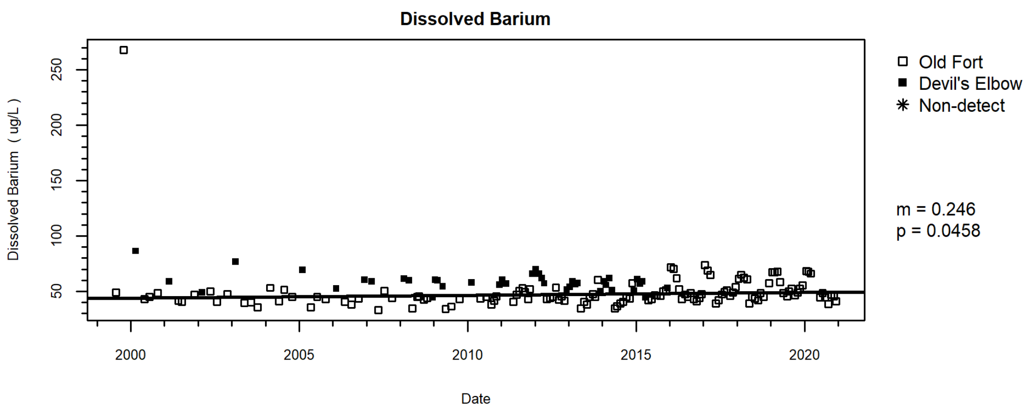

Figure A24. Dissolved barium concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and Mann-Kendall p value (p).

Chloride

The framework limit for chloride was set at 100 mg/L and the peak trigger was set at 45 mg/L. In 2020, no occurrences were above the limit and no occurrences were above the peak trigger. The maximum value observed in 2020 was 23 mg/L which equals 51.1% of the peak trigger and 23% of the limit values. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The trend analysis for chloride revealed a decreasing trend in un-adjusted concentration at 'Old Fort' (Figure A25). In contrast, flow-adjustment revealed a significant increasing trend. Thus, chloride will continue to be investigated.

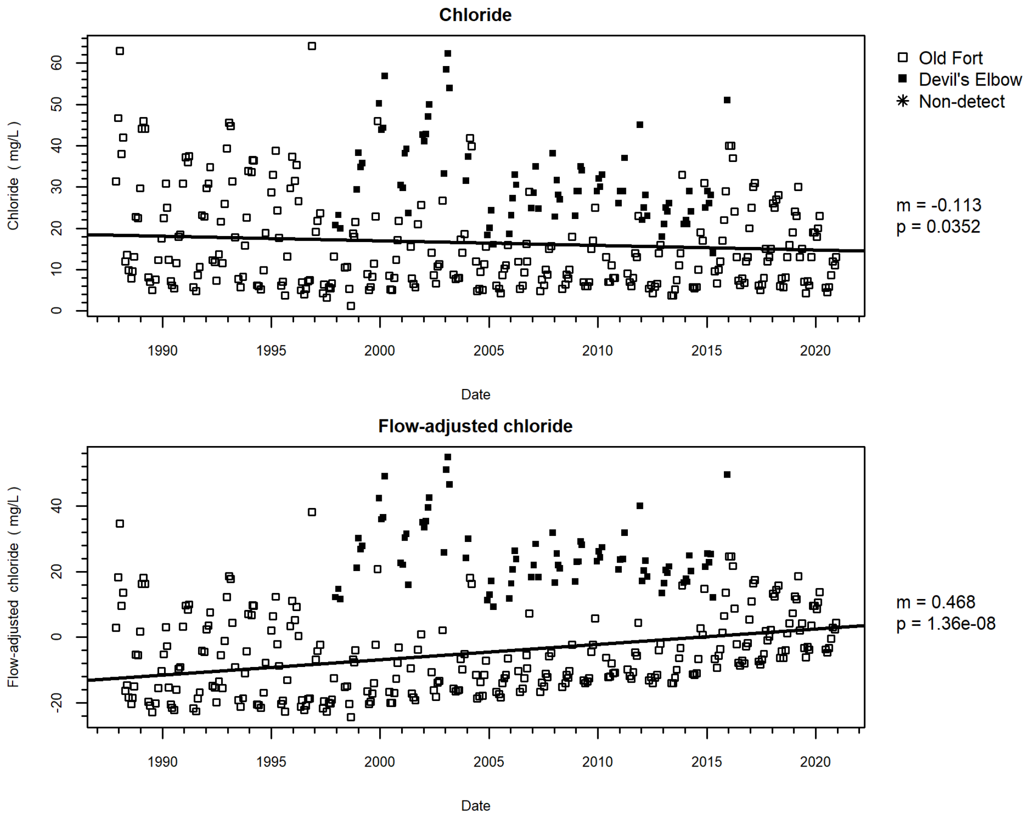

Figure A25. Chloride concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and Mann-Kendall p values (p).

Dissolved iron

There was no limit set for dissolved iron in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2020, no occurrences were above the peak trigger, which was set at 372 µg/L. The maximum value was 341 µg/L, which equals 91.7% of the peak trigger value. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The trend analysis for dissolved iron revealed a decreasing trend in un-adjusted concentration that was not statistically significant at 'Old Fort' (Figure A26). In contrast, flow-adjustment revealed a significant increasing trend. Thus, dissolved iron will continue to be investigated.

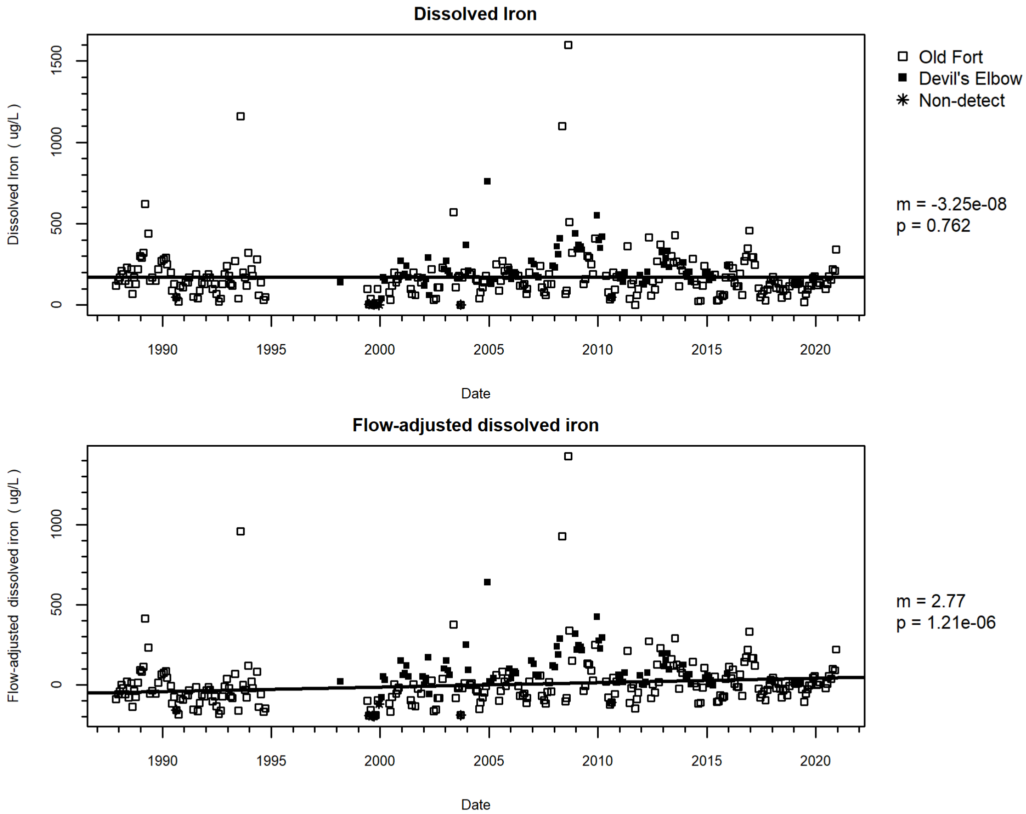

Figure A26. Dissolved iron concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and censored Mann-Kendall p values (p).

Dissolved lithium

There was no limit set for dissolved lithium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2020, two occurrences were above the peak trigger, which was set at 9 µg/L. The maximum value was 9.87 µg/L, which equals 109.7% of the peak trigger value. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The trend analysis for dissolved lithium showed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A27). Changes in flow-concentration relationships over time prevented the development of an adjustment model for dissolved lithium. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and investigation into this parameter will continue.

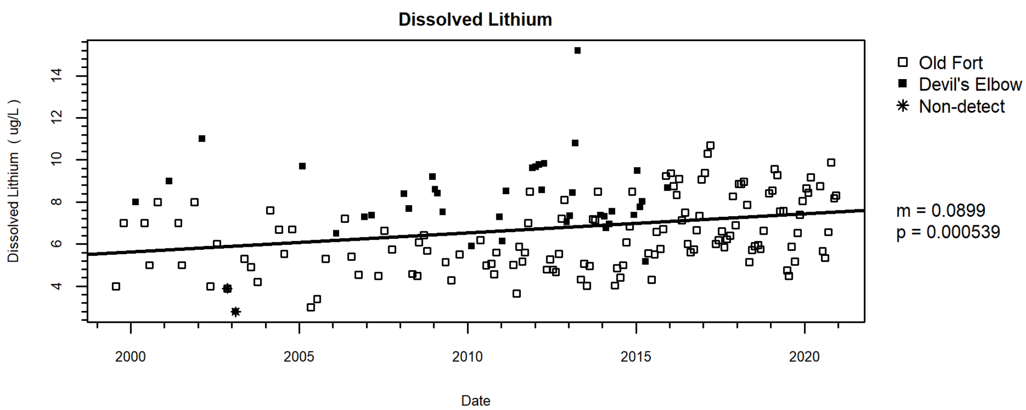

Figure A27 Dissolved lithium concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Nitrate plus nitrite

There were no limits or triggers set for nitrate plus nitrite in the Lower Athabasca Regional Surface Water Quality Management Framework. However, triggers are in place for nitrate specifically. AEP examined trend results and historical records of nitrate, nitrite, and nitrate plus nitrite and determined that, due to its more extensive historical dataset, nitrate plus nitrate would prove more useful in the continued investigation of total nitrogen, of which it is a component (AEP 2020).

The 2020 maximum value of nitrate plus nitrite was 0.24 mg/L. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). Trend analysis for nitrate plus nitrite showed an increasing trend in un-adjusted concentration at ‘Old Fort’ (Figure A28). The trend was also significant when adjusted for flow.

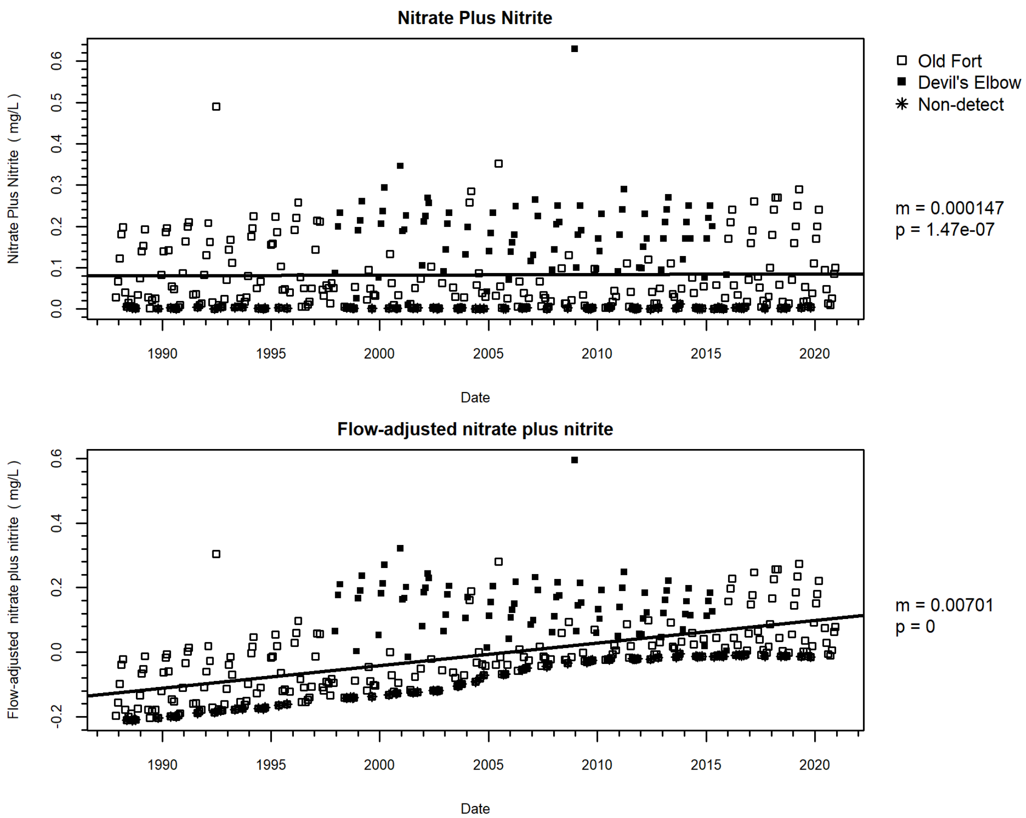

Figure A28. Nitrate plus nitrite concentrations at ‘Old Fort’ over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and censored Mann-Kendall p values (p). **Figure A8:**

Total Kjeldahl nitrogen

There were no limits or triggers set for total Kjeldahl nitrogen in the Lower Athabasca Regional Surface Water Quality Management Framework. AEP provided justification for how total Kjeldahl nitrogen would prove useful in the continued investigation of total nitrogen, of which it is a component (AEP 2020).

The 2020 maximum value was 1.5 mg/L. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). At 'Old Fort', the trend analysis for total Kjeldahl nitrogen showed an increasing trend in un-adjusted concentration that was not statistically significant, but showed a significant decreasing trend in flow-adjusted values (Figure A29).

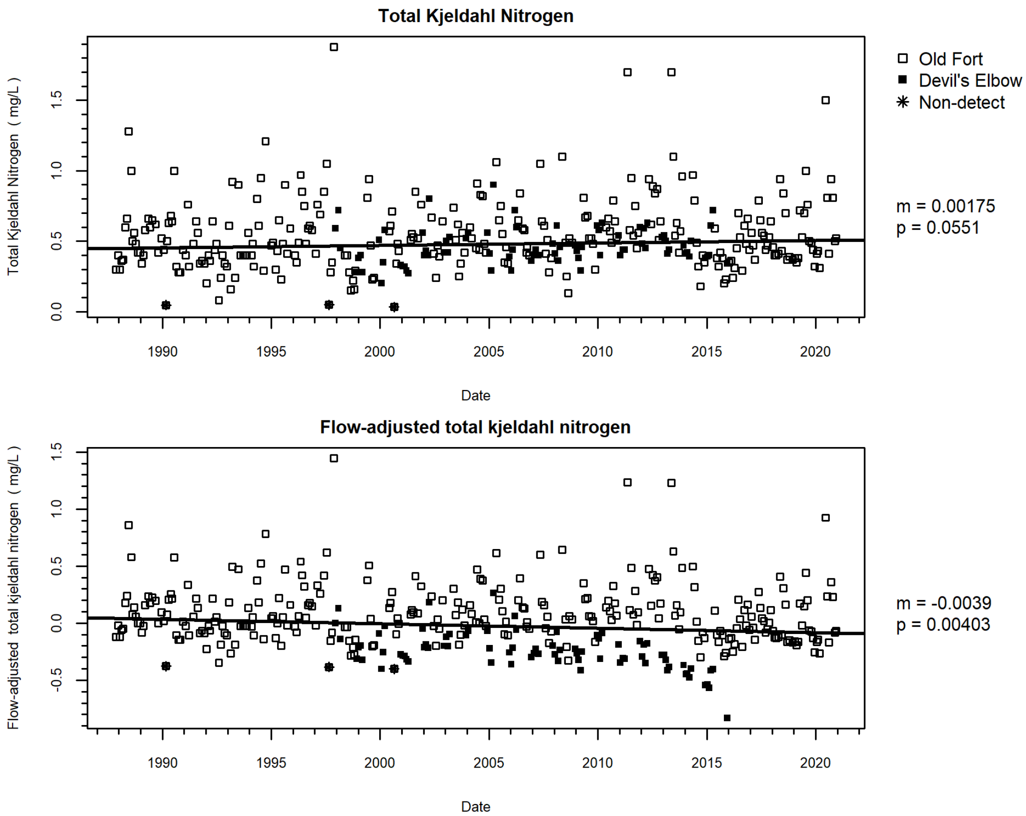

Figure A29. Total Kjeldahl nitrogen concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and censored Mann-Kendall p values (p).

Total nitrogen

There was no limit set for total nitrogen in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2020, one occurrence was above the peak trigger, which was set at 1.041 mg/L. This maximum value was 1.6 mg/L, which equals 153.7% of the peak trigger value. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The trend analysis for total nitrogen showed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A30). Changes in flow-concentration relationships over time prevented the development of an adjustment model for total nitrogen. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and investigation into this parameter will continue.

Total nitrogen comprises the sum total of total Kjeldahl nitrogen (TKN), nitrate, and nitrite. The bulk of total nitrogen by weight is made up of TKN, likely in the form of organic particulates. On a flow adjusted-basis, TKN appears to be in decline at 'Old Fort' whereas dissolved fractions (nitrate plus nitrate) appear to be increasing. This changing composition of total nitrogen at 'Old Fort' suggests potential changes in nitrogen cycling within the Athabasca River. Neither parameter is assumed to be conservative in that dissolved fractions may be consumed by primary producers or converted to N_2 and TKN can oxidize to form dissolved fractions. Therefore, investigations into source areas and seasonality of both components are relevant to investigations.

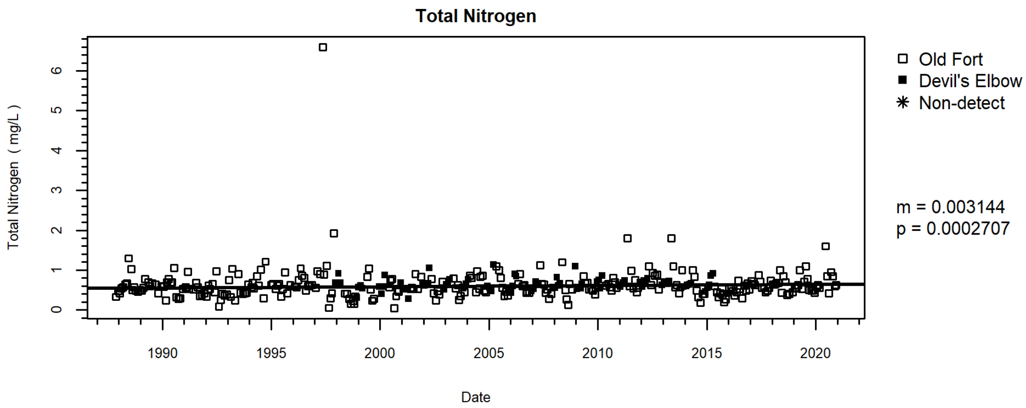

Figure A30. Total nitrogen concentrations at 'Old Fort' over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and Mann-Kendall p value (p).

Sulphate

The framework limit for sulphate was set at 500 mg/L and the peak trigger was set at 41.4 mg/L. In 2020, no occurrences were above the limit and no occurrences were above the peak trigger. The maximum value observed in 2020 was 35 mg/L which equals 84.5% of the peak trigger and 7% of the limit values. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The trend analysis for sulphate showed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A31). The trend was also significant when adjusted for flow. Thus, sulphate will continue to be investigated.

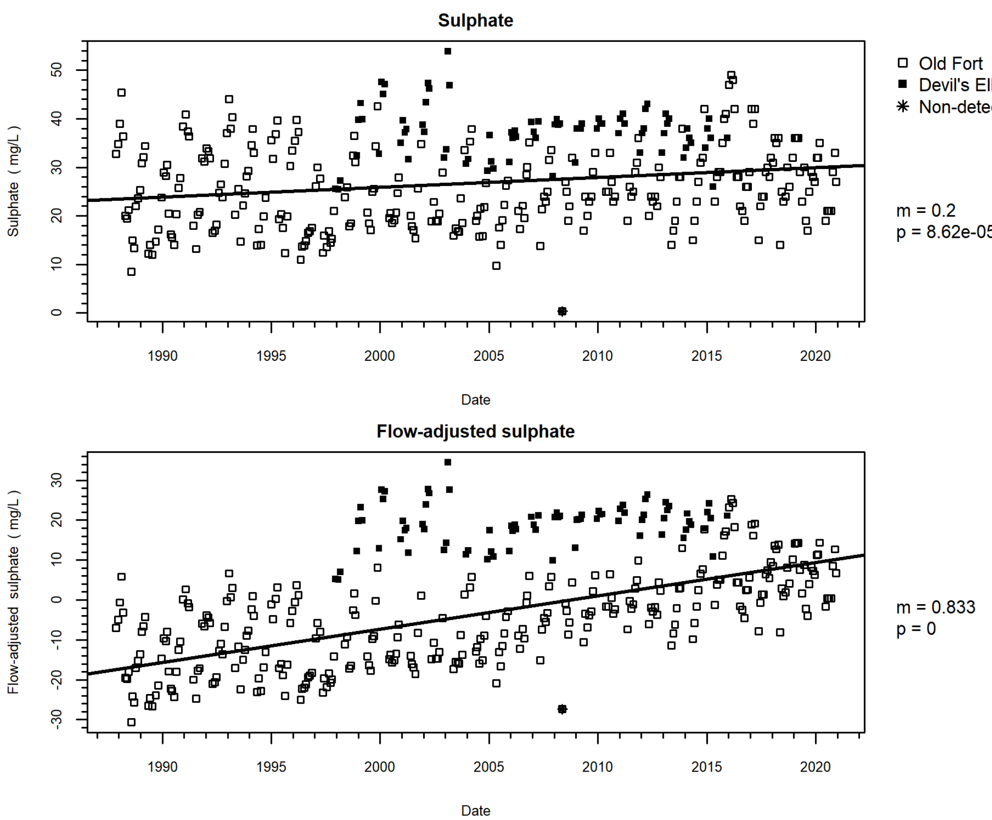

Figure A31. Sulphate concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and censored Mann-Kendall p values (p).

Potassium

There was no limit set for potassium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2020, no occurrences were above the peak trigger, which was set at 2.1 mg/L. The maximum value was 2 mg/L, which equals 95.2% of the peak trigger value. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The trend analysis for potassium showed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A32). The trend was also significant when adjusted for flow. Thus, potassium will continue to be investigated.

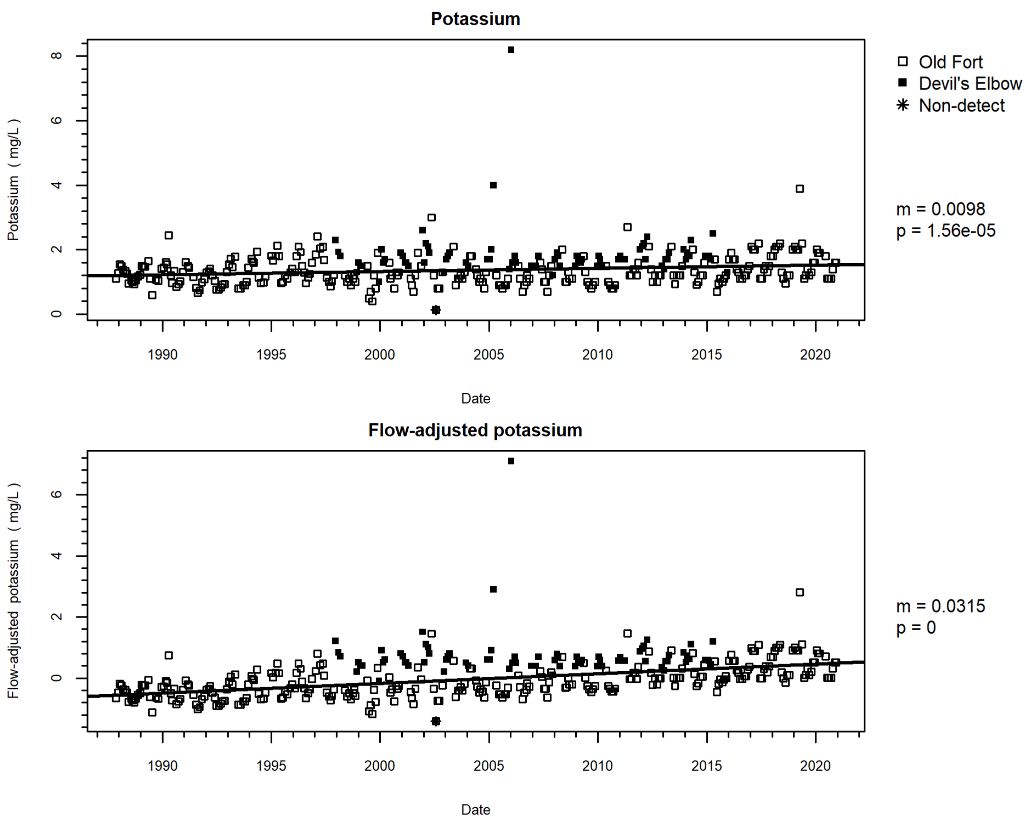

Figure A32. Potassium concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and censored Mann-Kendall p values (p).

Dissolved selenium

There was no limit set for dissolved selenium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2020, no occurrences were above the peak trigger, which was set at 0.409 µg/L. The maximum value was 0.3 µg/L, which equals 73.3% of the peak trigger value. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019). The trend analysis for dissolved selenium showed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A33). The trend was also significant when adjusted for flow. Thus, dissolved selenium will continue to be investigated.

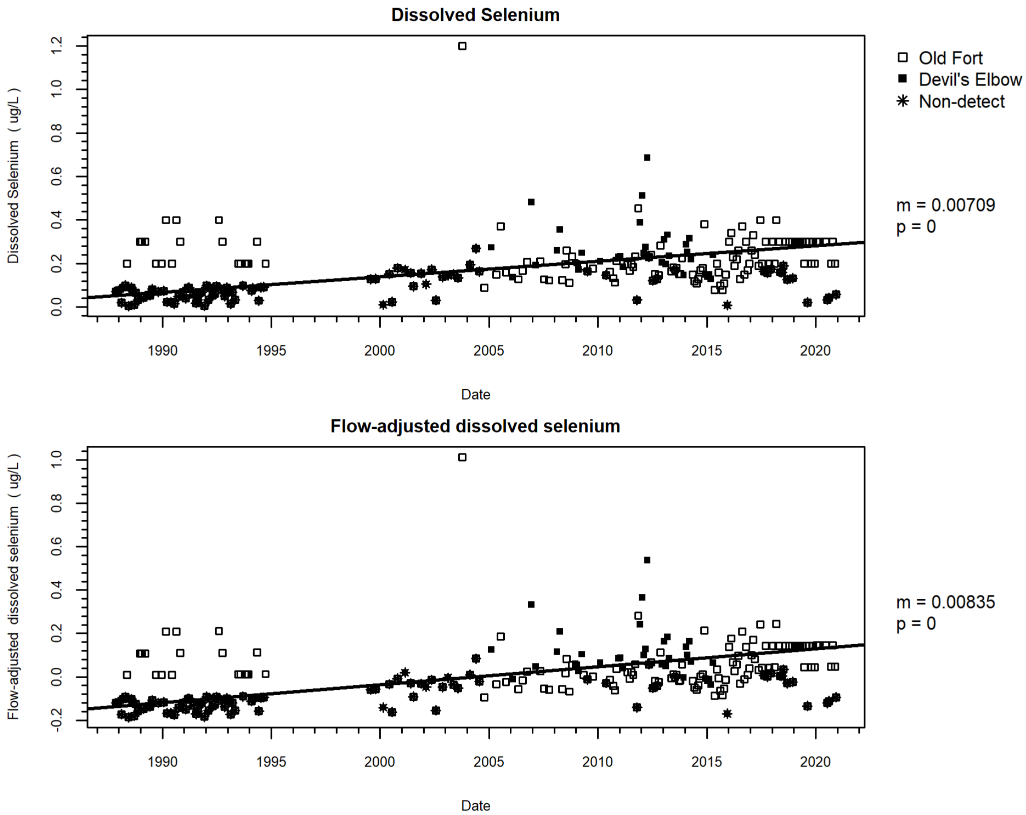

Figure A33. Dissolved selenium concentrations at 'Old Fort' over time. Trends in un-adjusted (top) and flow-adjusted (bottom) concentrations are represented by the Akritas-Thiel Sen line, their slopes (m), and censored Mann-Kendall p values (p).

Dissolved uranium

There is no limit set for dissolved uranium in the Lower Athabasca Regional Surface Water Quality Management Framework. In 2020, 8 occurrences were above the peak trigger, which is set at 0.381 µg/L. The maximum value was 0.508 µg/L, which equals 133.3% of the peak trigger value. In 2020, 1 measurements exceeded the range of historical values (before 2010), and two exceeded observed values during the interim (2010-2019).The trend analysis for dissolved uranium revealed an increasing trend in un-adjusted concentration at 'Old Fort' (Figure A34). Changes in flow-concentration relationships over time prevented the development of an adjustment model for dissolved uranium. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and investigation into this parameter will continue.

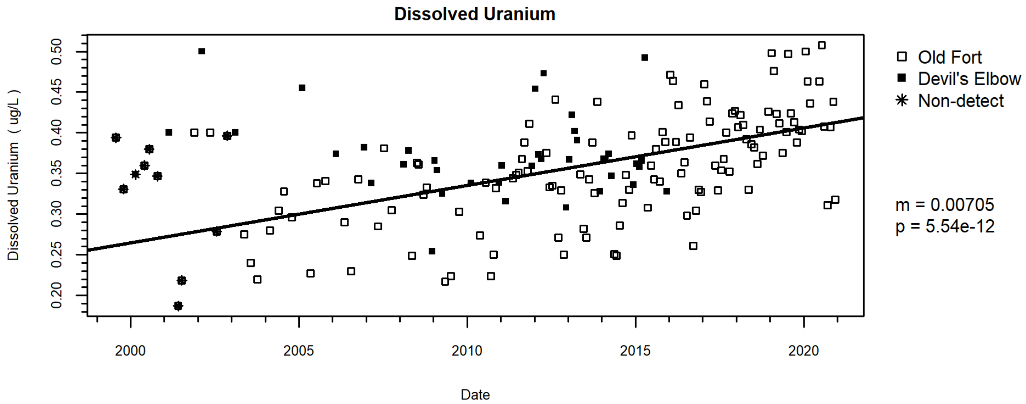

Figure A34. Dissolved uranium concentrations at ‘Old Fort’ over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).

Total uranium

The framework limit for total uranium is set at 10 µg/L and the peak trigger is set at 0.7 µg/L. In 2020, 0 occurrences were above the limit and 2 occurrences were above the peak trigger. The maximum value observed in 2020 was 1.03 µg/L, which equals 147.1% of the peak trigger and 10.3% of the limit values. The 2020 measurements ranged within historical values (before 2010) and those observed during the interim (2010-2019).The trend analysis for total uranium revealed an increasing trend in un-adjusted concentration at ‘Old Fort’ (Figure A35). Changes in flow-concentration relationships over time prevented the development of an adjustment model for total uranium. Therefore, flow is unable to explain the trend observed. Consideration of other factors is needed and investigation into this parameter will continue.

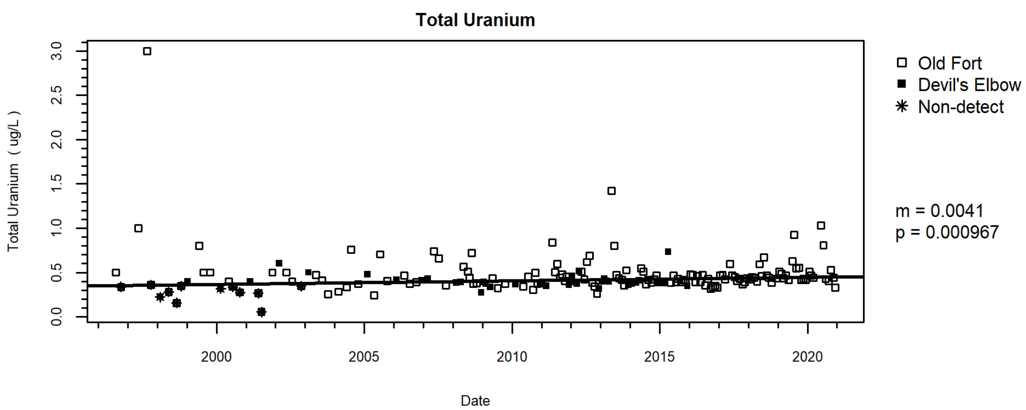

Figure A35. Total uranium concentrations at ‘Old Fort’ over time. The trend in un-adjusted concentrations are represented by the Akritas-Thiel Sen line, its slope (m), and censored Mann-Kendall p value (p).