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Acid Deposition Monitoring Program Expansion Committee
Meeting Minutes
Wednesday, December 15, 2021
9:00 a.m. – 12:00 p.m.
LICA Boardroom and via Microsoft Teams

Present:	Heather Harms Desiree Parenteau Brent McGarry Clarence Makowecki Wally Qiu Jennifer O'Brien Leo Paquin Fin MacDermid Andrea Woods Sean Mercer (Arrived 10:04 a.m.) Lindsay Hollands (Left at 11:01 AM)
Observers and Guests:	
Staff and Contractors:	Kristina Morris, LICA Executive Director Michael Bisaga, Manager, Environmental Monitoring Programs Lily Lin, LICA Data & Reporting Specialist Eveline Hartog, LICA Administrative Professional
Regrets:	Larry Turchenek Colin Cooke Salim Abboud Amanda Avery-Bibo

1.0 CALL TO ORDER

Heather Harms Committee Chairperson, called the meeting to order at 9:03 a.m.

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Initials

1.1 Territorial Acknowledgement

1.2 Introductions

1.3 Vision, Mission and Values

1.4 Roll Call

1.5 Approval of Agenda

1.5.1 December 15, 2021

#1 Moved by Desiree Parenteau AND CARRIED that the December 15, 2021, Agenda be approved.

1.6 Approval of the Minutes

1.6.1 December 2, 2021

#2 Moved by Jennifer O'Brien AND CARRIED that the December 2, 2021, minutes be approved as presented.

2.0. ONGOING BUSINESS

2.1.1 Surface Water Acidification Next Steps

The Manager of Environmental Monitoring Programs informed the Committee that he was not able to secure Julian Aherne from Trent University to present last week. However, he indicated that that Mr. Aherne would be able to do a presentation on surface water acidification to the Committee in mid-January 2022.

2.1.2 Monitoring Plan Table of Contents

The Manager of Environmental Monitoring Programs shared a slide presentation with the Committee detailing the strategy for expanding the acidification monitoring plan for the Cold Lake area. He indicated that at this point the plan is an evolving strategy, and the Committee will adjust things as we move forward. Some elements of the strategy are already in place and LICA will build on existing components to implement a holistic and regional approach to acid deposition monitoring.

The key points to the plan presentation were as noted:

1. Lakeland Industry and Community Association
   - A brief history of LICA and the LICA region was given.

2. Acid Deposition Monitoring Program Expansion Committee
   - A review of the composition of the Committee was given along with an overview of the purpose of the ad-hoc committee

-The Committee will be responsible for developing Phase 1: to develop a plan (now a strategy) to meet the needs of the new regional regulatory compliance acid deposition monitoring and reporting requirements; Phase 2: address the implementation of Phase 1; Phase 3:to address further enhancement of the program to implement a complete regional approach to acid deposition monitoring and reporting.

3. Regulatory Context
- AER recently issued an operating approval in the LICA region and this approval has requirements to develop an acid deposition monitoring program and must include monitoring of air, soil, water and must include a report schedule for all monitoring activities conducted.
- The addition of when regulatory conditions were issued will be noted in the plan document

4. Acid Deposition Management Framework (ADMF)
- The acid deposition framework and assessment group
- Part of the reason for extending the deadline for creation of LICA's plan is that the current acid deposition framework was under review and as the framework changes, LICA will adaptively manage LICA's monitoring plan and strategy to address changes in the ADMF.

5. Potential Acid Input and Critical Loads
- Discussion on critical loads, target loads, and monitoring loads which helps to inform where LICA will do its surveillance
- A section concerning adapting LICA's monitoring plan to the new provincial framework will be added but ultimately it will not really change the monitoring LICA currently conducts

6. Acid Deposition Monitoring
- Our existing program can detect deposition but there is no holistic approach to the deposition monitoring
- LICA will collect data that using methods that align with WBEA, so data across the entire oilsands region is comparable

6.1 Wet Deposition
- Strategy proposes to collect weekly precipitation samples at additional locations in the Cold Lake region (specific locations not yet identified)

6.2 Dry Deposition
- Adding monitoring sites in the Cold Lake region, especially in areas where facilities have been added or expanded since the implementation of LICA's existing passive monitoring network. Existing passive monitoring stations will be enhanced with the capability to monitor for acidifying substances; new stations will be added in the areas where there is an increased level of industrial development and predicted higher deposition velocities.
- To align with WBEA, LICA will monitor NH3 and HNO3 monthly
- The Committee noted that stack emissions have risen and there is modelling to support a recent EPEA application for increased sulfur limits; this modelling may help inform the location of monitoring activities

- Additionally, passive deposition sampling will be achieved through ion exchange resin technology.

7. Soil Monitoring
- The acid deposition monitoring strategy does not recommend any changes to LICA's already-established soil monitoring program; the addition of passive monitoring at existing soil monitoring sites will help establish a relationship between deposition velocities and any potential responses in sensitive soils.
- Forest health monitoring is not currently part of the proposed monitoring strategy, but this may be something that LICA will want to consider in Phase 3
- The Committee suggested that some soil monitoring could be done closer to emission sources. It was further suggested that a development of a network of short-term soil monitoring sites (for 2-3 years) may be a way to identify sites that are potentially being acidified closer to emissions sources

8. Surface Water
- The Manager of Environmental Monitoring Programs indicated that Cold Lake lacks a robust surface water monitoring program except for ALMS and industrial in-field monitoring on selected lakes in LICA region
- Most lakes in the region are well buffered and not acid sensitive. However, through Environmental Impact Assessments and other studies, 4 lakes have been identified as being moderately sensitive to acid input: Unnamed Lake 599, Unnamed Lake UN-5, Caribou Lake, and Underwood Lake
- The acid deposition monitoring strategy recommends updating the acid sensitivity rating on these lakes; these lakes would form the initial surface water monitoring component of the strategy.
- The Committee recommended that the strategy look for the most sensitive lakes with the smallest catchment located closer to facilities since petroleum facilities are usually located in areas with smaller lakes
- It was added that two of the four lakes mentioned above do meet these criteria
- The Committee further recommended that additional lakes could be added to the monitoring strategy once more background information about regional lake sensitivity is known.

9. Mitigation Response
- It is out of LICA's scope to implement mitigation and management strategies when exceedances of critical loads are identified
- The Committee noted that industry and regulators will respond to the information and data collected by LICA's network. It is important to develop LICA's acid deposition strategy and monitoring plan with regulatory compliance in mind; some monitoring sites should be located in the areas of highest predicted deposition.

10. Summary
- Wet Deposition: add 1 more monitoring site
- Passive Monitoring: establish enhancement of existing networks with additional monitoring
- Ion Exchange: recommend that ion is co-deployed with existing soil acidification sites
- Soil Monitoring: add two new sites
- Surface Water Monitoring: update acid sensitivity rating for four identified lakes

2.1.3 Collective Review: Major Components of Phase One Monitoring Plan Recommendations

The Manager of Environmental Monitoring Programs will update the presented draft plan document and have it available on Teams Chat for live edits by Thursday, November 16. It was requested of the Committee to review the plan and have their suggestions submitted by December 23.

2.1.4 Discuss Feedback Timing

The Manager of Environmental Monitoring Programs presented the proposed strategy to AEP who is also working on the new acid deposition monitoring framework. The Committee chair wondered if it would be possible to push out submission date by a month and it was felt that the end of January 2022 would be reasonable since it would give the Committee time to review and give feedback on the proposed strategy. In addition, the extra month will give the Committee the time to get feedback from AEP and get information on water deposition from Julian Aherne. The AER cannot commit to a decision on this immediately but would be receptive to receiving this request.

The Committee agreed to honor the feedback deadline of December 23rd, in the event that a deadline extension is not granted.

#3 Moved by Heather Harms AND CARRIED that Cenovus submit a deadline extension request of January 31, 2022, to the AER for completion of the plan.

The Manager of Environmental Monitoring Programs indicated that OSM budgeting needs to be added to the proposed plan. Part of the budget for next year is to allocate $200,000 to begin the deposition program.

3.0 ACTION LIST

3.1 Follow-up On Action List

3.1.1 Action List for December 2, 2021

The Committee reviewed the action list from the December 2, 2021, meeting, noting that all items have been completed.

4.0 UPCOMING MEETING DATES

4.1 Board Meeting – December 16, 2021

4.2 Next ADMPEC Meeting

The next ADMPEC meeting will be determined in early January to coincide with availability of presenter Julian Aherne. A doodle poll will be forthcoming to the Committee.

5.0 ADJOURNMENT

Meeting adjourned at 11:28 a.m.

#4 Moved by Desiree Parenteau AND CARRIED that the meeting be adjourned.

Approved on: _____
Date

_____
Signature

_____
Initials

Proposed Table of Contents
ADMPEC Monitoring Plan

Acid Deposition Monitoring Strategy for the LICA Region

Lakeland Industry and Community Association

Acid Deposition Monitoring Program Expansion Committee

Prepared by:

Michael Bisaga

December 15, 2021

1. Lakeland Industry and Community Association

In response to the expansion of oil and gas production in the region, the Lakeland Industry and Community Association (LICA) was formed in October 2000 as a not-for-profit association, registered under the Alberta Societies Act.

Today, LICA is:

- a Synergy Group that facilitates all stakeholders' voices when addressing issues concerning the environment in the Cold Lake region,
- the Watershed Planning and Advisory Council (WPAC) for the Beaver River Watershed, and;
- an Airshed Zone monitoring air quality and deposition throughout the LICA region.

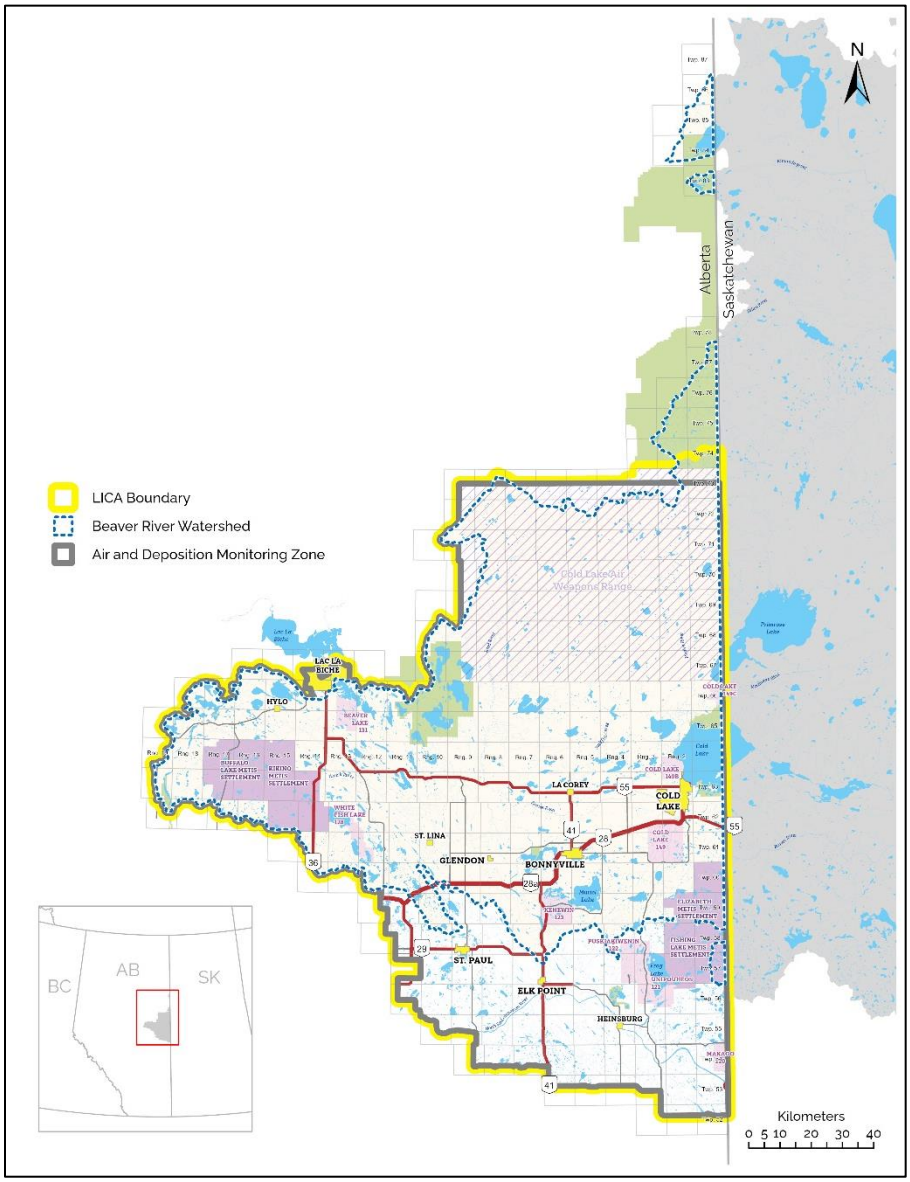

Figure 1: The LICA Region

2. Acid Deposition Monitoring Program Expansion Committee

LICA's Acid Deposition Monitoring Program Expansion Committee (ADMPEC) was formed to assist in the development and oversight of the expansion of LICA's Acid Deposition Monitoring Program. The expansion of the Program will be completed in phases:

- Phase One of the expansion will address development of an acid deposition monitoring plan to meet the needs of new regional regulatory compliance acid deposition monitoring and reporting requirements.
- Phase Two will address implementation of the Phase One.
- Phase Three will have a broader scope than Phase One and Two and address further enhancement of the program to implement a complete regional approach to acid deposition monitoring and reporting.

The ADMPEC is an ad-hoc committee of LICA and is supported by representation from industry, government, indigenous communities and the public. A multi-stakeholder committee composition allows for diverse insight, expertise, and support for the development of recommendations for acid deposition monitoring. This document presents a strategy for building on the existing LICA monitoring program and expanding the acid deposition monitoring program in the Cold Lake region (Phase One).

The image below (USEPA, 2021) illustrates the pathway for acid deposition in our environment: (1) Emissions of sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) are released into the air, where (2) the pollutants are transformed into acidic particles. (3) These acid particles then fall to the earth as wet and dry deposition (dust, rain, snow, etc.) and (4) may cause harmful effects on soil, forests, streams, and lakes. LICA's acid deposition monitoring plan will be multi-media; it will address direct deposition monitoring as well as potential acidification effects on soils and surface water.

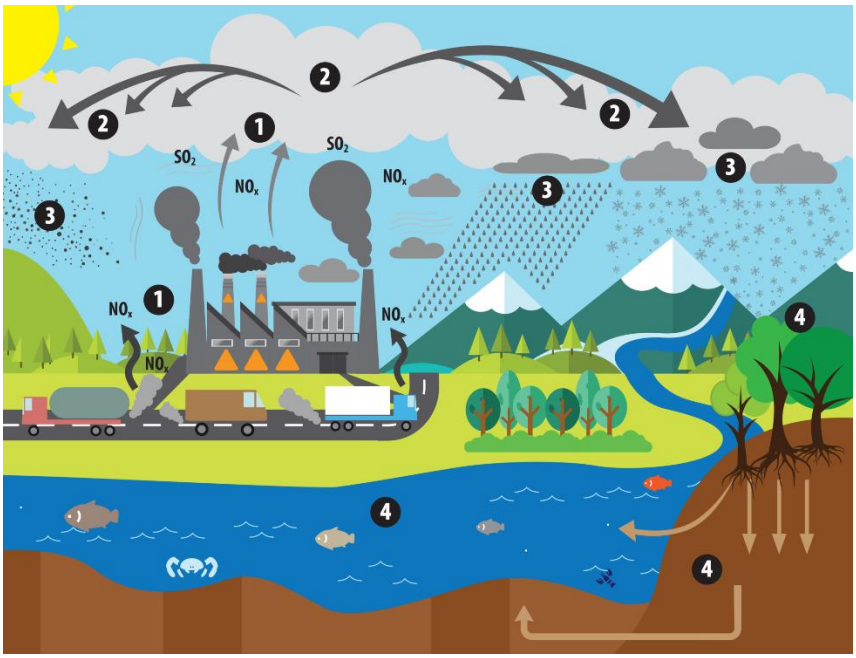

Figure 2: Pathway for acid deposition in our environment

3. Regulatory Context and Oil Sands Monitoring Program

In 2019, the Alberta Energy Regulator issued an operating approval to and oil sand facility in the LICA region; the approval has requirements to develop an acid deposition monitoring program (referred to in the previous section as the *'new regional regulatory compliance acid deposition monitoring and reporting requirements'*). The acid deposition monitoring program mush include the following at a minimum:

(a) for air:
  (i) a plan to monitor dry and wet deposition;
(b) for soil:
  (i) identification of soils that are sensitive to acid deposition and will likely receive aerial deposition inputs;
  (ii) a plan to monitor soil quality at locations representative of the soils identified in (b) (i);
  (iii) a description of how soil quality data collected under this program will be used to determine potential acidification effects under periods of increased sulphur dioxide emissions;
(c) for water:
  (i) a summary of existing water quality data collected to date and analysis of the results;
  (ii) a plan to monitor water quality for water bodies which will likely receive aerial deposition inputs;
  (iii) identification of local water bodies that are sensitive to acidification;
  (iv) a description of how water quality data collected under this program will be used to determine potential acidification effects under periods of increased sulphur dioxide emissions;
  (v) a plan to develop triggers for further enhanced surface water quality monitoring to determine impacts of aerial deposition inputs;
(d) reporting schedule for monitoring activities conducted for (a) through (c)

Since February 2012, the governments of Canada and Alberta have worked as partners to implement and jointly manage the Oil Sands Environmental Monitoring (OSM) Program. The program strives to improve characterization of the condition of the environment and enhance understanding of the cumulative effects related to oil sands development in the oil sands area of Alberta. Building on existing monitoring, where possible, the approach to program implementation is adaptive to ensure the program is responsive to existing knowledge, emerging priorities, and input from Indigenous peoples and key stakeholders. LICA's existing regional air and deposition monitoring efforts form part of the OSM Program and it is expected that the enhanced deposition monitoring effort recommended by this strategy will also become part of the OSM Program.

4. Acid Deposition Management Framework

Alberta Environment and Sustainable Resource Development (ESRD) uses the REgional Lagrangian Acid Deposition (RELAD) model to model annual Potential Acid Input (PAI); at a provincial scale, this was last done for Alberta in 2011 using 2006 and 2020 (projected) acidifying emissions (ESRD 2014). The comparison of RELAD predicted deposition values with inferred deposition using monitoring data indicates that RELAD modelling provides a representative estimate of regional deposition patterns of acid forming pollutants. RELAD is identified as *the* acid deposition assessment model for the implementation of the Alberta Acid Deposition Management Framework (Alberta Environment, 2008). Relatedly, ESRD's Acid Deposition Assessment Group (ADAG) provides input into the ongoing evaluation of current and projected acidifying emissions and resulting acid deposition levels and effects in Alberta, including assessment of the RELAD outputs. This evaluation is required every five years under the 2004 Alberta Acid Deposition Management Framework. The 2014 report of RELAD results forms part of the 2011 acid deposition assessment; its purpose was to compile the current state of knowledge on provincial acidifying emissions, resulting acid deposition levels and effects in the province of Alberta.

At the time of creating this monitoring strategy, a new Alberta Acid Deposition Management Framework, a novel acid deposition modelling approach, and an updated acidifying emissions inventory were nearly complete; collectively, these components form the latest iteration of the outputs from the ADAG. These components were not ready for public release at the time that this strategy was created. LICA will however remain engaged in relevant policy developments and adaptively manage its approach to regional acid deposition monitoring as appropriate.

The tiered monitoring, target and critical load acid deposition management approach that was used in the 2008 ADMF is described in the sections that follow. It is being replaced with a new management approach that will provide an early warning of potential areas "at risk" to long-term acidification. The new approach also provides guidance to manage and reduce, where necessary, acidifying emissions adversely affecting the identified areas. While LICA's strategy for monitoring acid deposition in the Cold Lake region is based on the guidance and triggers in the 2008 ADMF, the surveillance that the proposed monitoring methods will provide can be adaptively managed to address the new requirements once the new ADMF is released.

5. Potential Acid Input and Critical Loads

The deposition of acidifying species is determined from the modelled potential acid input (PAI), which represents the sum of the deposited acidifying and neutralizing species. RELAD was run using 1980 meteorology in conjunction with emissions from 2006 and projected emissions for 2020 to determine the deposition of acidifying species[1] and PAI in each modelled grid cell (approximately 111 km by 60 km). Modelling results are presented in **Error! Reference source not found.**

[1] Acidifying species modelled include HNO_3 H_2SO_4, SO_4^{2-}, NO_3^-, SO_2 and NO_x

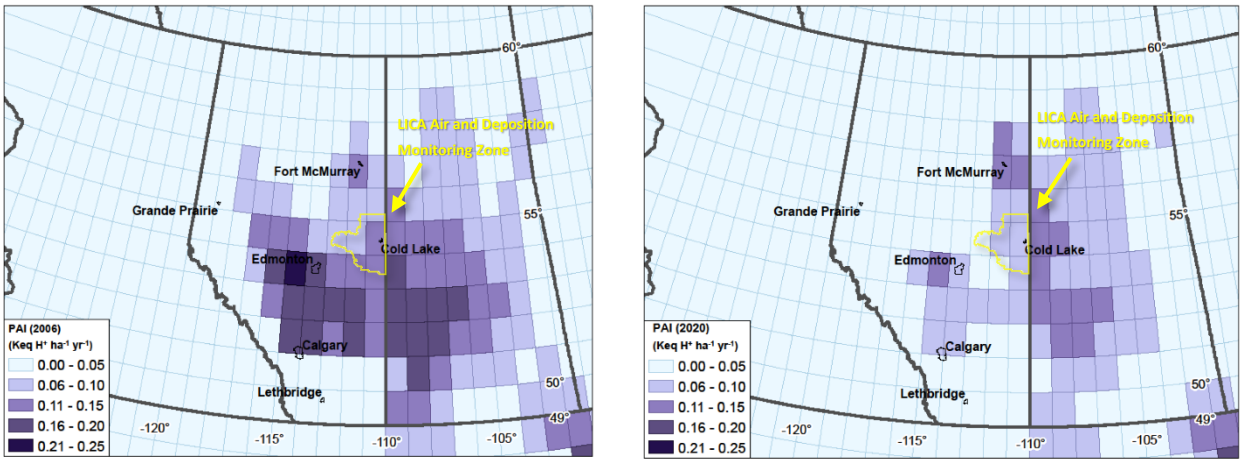

Figure 3: RELAD results for annual PAI for the years 2006 and projected 2020 (keq H^+ ha^{-1} yr^{-1}) for Alberta and Saskatchewan

The Alberta Acid Deposition Management Framework (ADMF) is based on three levels of PAI: Monitoring Load, Target Load, and Critical Load. Each level of deposition has an associated management action: increased monitoring (Monitoring Load), emissions management (Target Load), or emissions reduction (Critical Load). The RELAD model estimates acid deposition and assesses acid sensitivity of ecosystems to acidification in Alberta; in the ADMF, the ecosystem indicator is soil.

Comparison of RELAD modelled PAI to receptor sensitivity for each model grid cell is accomplished by estimation of the amount of acid deposition as a percentage of Critical, Target and Monitoring Loads.

Critical Loads for Alberta are set at 0.25, 0.50, and 1.0 keq H+ $ha^{-1}yr^{-1}$ for sensitive, moderately sensitive, and low sensitivity soils, respectively (Alberta Environment, 1999).

Target Loads for Alberta are set at 0.22, 0.45, and 0.9 keq H+ $ha^{-1}yr^{-1}$ for sensitive, medium sensitivity and low sensitivity soils, respectively (Alberta Environment, 1999). These Target Loads are established at approximately 90% of Critical Loads.

Monitoring Loads for Alberta are set at 0.17, 0.35, and 0.7 keq H+ ha^{-1} yr^{-1} for sensitive, medium sensitive and low sensitivity soils, respectively (Alberta Environment, 2008). The intent of the Monitoring Load is to allow time for collection of data on emissions, deposition and the sensitivity of receptor prior to the need to take emission management actions.

Table 1: Acid Deposition Management Framework Soil Sensitivity Ratings

RELAD Sensitivity	Monitoring Load (keq H^+/ha/yr)	Target Load (keq H^+/ha/yr)	Critical Load (keq H^+/ha/yr)
Sensitive	0.17	0.22	0.25
Medium Sensitivity	0.35	0.45	0.50
Low Sensitivity	0.70	0.90	1.00

The areas of the LICA air and deposition monitoring zone (ADMZ) nearest facilities with potentially acidifying emissions are classified as <u>medium sensitivity</u> (south of 55° N) and <u>high sensitivity</u> (north of 55° N); the critical loads are 0.50 keq and 0.25 H^+/ha/yr, respectively. The northern most facility in the

LICA region (Cenovus Foster Creek) is on the transition between these two sensitivity classes while all other facilities are in the medium sensitivity area.

Predicted 2020 emissions using RELAD show PAI in the LICA ADMZ both north and south of 55° N is 0.10 keq H+/ha/year. However, due to the difference in sensitivities as defined in the ADMF for these two adjacent areas, their predicted loading thresholds represent different percentages of critical loads:

- North of 55°N: 40% of Critical Load and below monitoring load
- South of 55°N: 20% of Critical Load and below monitoring load

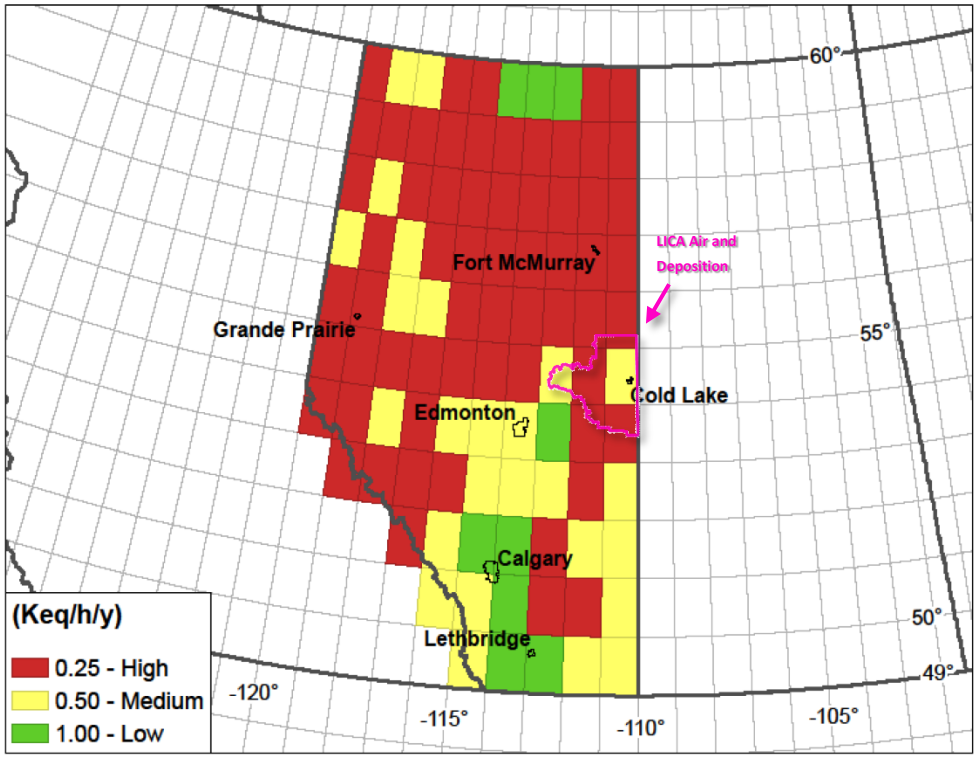

Figure 4: Alberta's soil sensitivity as defined under the Acid Deposition Management Framework (2008).

Based on RELAD modeling results, soils in the area are acid sensitive, however PAI is not predicted to increase above monitoring load levels for the two sensitivity areas within the LICA ADMZ. Relative to predicted PAI for 2006, the 2011 Acid Deposition Assessment for Alberta (ESRD 2014) showed an overall decrease in predicted PAI when using the projected 2020 emissions. This in large part is due to the predicted lowering of acidifying emissions over time, particularly sulphur dioxide. Projected emissions for 2020 did not identify acid deposition patterns over the long term that exceeded deposition criteria. However, in their assessment, ESRD notes that at the airshed level, acid deposition assessment, monitoring, and management may identify other reasons to conduct surveillance of acid deposition.

6. Acid Deposition Monitoring

Components of the existing LICA monitoring program can detect the presence and potential deposition of acidifying substances however, the Cold Lake region lacks a holistic approach to acid deposition monitoring. Typically, an acid deposition monitoring program involves monitoring direct deposition as well as ecosystem response as measured by effects on sensitive receptors. In terms of direct deposition measurements, data from LICA's passive monitoring program has been used to determine PAI and PAI gradients with mapping products (LICA 2007). Despite LICA's use of passive data to infer PAI, LICA's program does not involve some of the direct deposition measurement techniques employed by our sister monitoring organization, the Wood Buffalo Monitoring Organization (WBEA). LICA engaged WBEA staff to learn about their direct deposition monitoring methods in the Athabasca region for consideration in the expansion of LICA's acid deposition monitoring strategy. LICA stakeholders believe it is prudent to collect samples and generate data in the same way as WBEA so datasets are comparable, as much as practicably possible.

6.1. Wet Deposition

Wet deposition monitoring involves collecting rain and snow samples using precipitation samplers. LICA's field staff operate rain and snow samplers at different locations in the LICA network; while LICA has expertise and experience operating these samplers, they are not configured for acid deposition measurements (sample media, laboratory analysis, etc.). Currently, LICA operates a snow a precipitation sampler at the Tamarack monitoring station for which samples are sent to a laboratory for isotope analysis.

In the LICA region, Alberta Environment and Parks (AEP) operates a wet deposition monitoring station in Cold Lake Provincial Park; this site collects weekly samples and can provide an important link for regional historical deposition of key ions.

To supplement the AEP site, LICA proposes to collect weekly precipitation chemistry samples (for ion analysis) at an additional monitoring location in the Cold Lake region. This density of monitoring will mirror the wet deposition monitoring efforts in the southern WBEA network area which is characterized by in-situ oilsands operations, similar to the Cold Lake region. The site may be co-located with LICA's Tamarack monitoring station alongside other precipitation monitoring equipment or in the corridor between Imperial Oil's Cold Lake Operations and Cenovus' Foster Creek Facility. LICA's passive monitoring shows that this area has the potential to have higher rates of wet deposition due to the presence of acidifying substances available for scavenging by different forms of precipitation. LICA proposes to conduct wet deposition sampling using methods and standard operating procedures established by WBEA.

6.2. Dry Deposition

In the Cold Lake region, dry deposition modelling and PAI estimation can be conducted using LICA's regional passive air monitoring network. A similar approach is used the WBEA program however additional parameters and sampling methods supplement monitoring in the Athabasca region.

Passive air sampling uses a permeative or diffusive membrane, allowing for the physical uptake of gas or vapour sample over the course of a month. Chemical species monitored by passive methods in the LICA network include nitrogen dioxide (NO_2), ozone (O_3), hydrogen sulphide (H_2S) and sulphur dioxide (SO_2). WBEA additionally monitors ammonia (NH_3), nitric acid (HNO_3) due to their roles in deposition processes at all passive monitoring locations. Passive monitoring does not require power and is easily deployed to remote locations.

LICA proposes to supplement the existing passive network with NH_3 and HNO_3 monitoring (monthly). The addition of these parameters to the LICA network is a logistically- and cost-effective way to enhance LICA's ability to estimate and model dry deposition throughout the region and provide an appropriate level of surveillance. LICA also proposes to enhance the passive monitoring network with up to 5 additional stations in the corridor between Imperial Oil Cold Lake Operations and the Cenovus Foster Creek Project; this will improve LICA's ability to determine the gradient of acidifying substances (Figure 5)**Error! Reference source not found.** in the area primarily characterized by in-situ oilsands development. The network has remained unchanged in this part of LICA's ADMZ since its inception in 2003 despite the increased number of facilities and potentially acidifying emissions. LICA also proposes to co-locate passive air samplers at LICA's existing soil acidification monitoring plots.

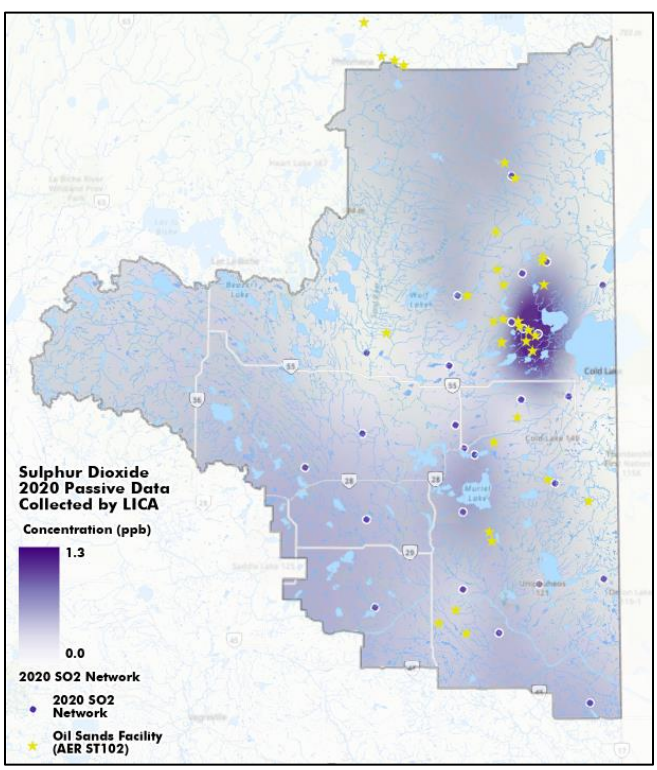

Figure 5: 2020 LICA passive monitoring network sulphur dioxide monitoring results

Another unique aspect of the WBEA network is the deployment of ion exchange resin (IER) for passive deposition sampling. Deposition using IERs is measured in forest clearings (bulk deposition) and under jack pine canopies (throughfall). Bulk deposition consists primarily of wet deposition, with a minor dry deposition component that collects onto the funnel collectors during dry periods. Throughfall deposition refers to the hydrologic flux of ions and other compounds washed from the tree canopies by precipitation or snowmelt and deposited in solution to the forest floor (Parker, 1983). Measurement of nutrient deposition in throughfall is a widely used method for estimating atmospheric deposition inputs to forest ecosystems (Bleeker et al., 2003; Thimonier, 1998). The IER technology uses a column of resin beads affixed to precipitation collectors to capture charged chemical species (ions) in precipitation water. IERs can be used to determine the deposition of ammonium (NH_4^+), nitrate (NO_3^-), sulphate (SO_4^{2-}), and calcium (Ca^+) and base cations. The major advantage of the IER method is that sample collection continues in the field without the need for repeated field trips to collect liquid samples or the need for repeated sample analyses from each collector. Deposition samples are collected seasonally. The IER columns for the summer exposures are installed in May and changed out in October. Winter exposures are from October to May. WBEA currently uses IERs at 45 sites; most are co-located with passive air sampling sites and form a key component of the forest health monitoring program. In the southern WBEA area, there are 6 existing + 2 proposed bulk IERs, and 6 existing + 2 proposed throughfall IERs.

While LICA employs a different soil sampling regime for its soil acidification monitoring plots than WBEA, the chosen soil type (sandy) and forest ecosystem (jack pine) by LICA and WBEA is similar. LICA proposes to deploy throughfall and bulk deposition IERs at LICA's 4 existing soil acidification monitoring sites. This approach will help fulfill the objective of determining potential cause-effect relationships between air pollutants, soils, and forest ecosystem health in the region. LICA also proposes to deploy two bulk deposition IERs (co-deployed with passives air samplers) in the corridor between Imperial Oil Cold Lake Operations and the Cenovus Foster Creek Project where deposition rates are expected to be higher than surrounding areas. Additionally, LICA proposes to deploy one 'upwind' and one 'downwind' bulk IER, ideally co-located with passive air monitoring stations; these sites are intended to provide some indication of the gradient of acidifying substances further afield from the sources.

6.3. Soil Monitoring

In 2010, LICA began soil acidification monitoring. From an initial screening of 8 potential monitoring sites, three long-term soil sampling plots were established: one in Moose Lake Provincial Park in 2010, another in Whitney Lakes Provincial Park in 2011, and a third on Crown Land near Tucker Lake in 2012. Soil sampling is carried out at these plots every four years in a staggered manner (one site per year). A fourth site established in the early 1980s is located near the west shore of Cold Lake; this location is operated by Alberta Environment and is complementary to the sites established by LICA (LICA 2021). The location of the three sites established by LICA were informed by a study commissioned by LICA in 2007. This preliminary or screening study of potential soil and water acidification within the LICA Area assembled information about locations and extents of sensitive soils as well as current levels of exposure to acidic deposition. This study was used to identify areas for potential monitoring sites. Major considerations and criteria for selecting sites included the following:

- Soils should be sensitive to acidic deposition, as indicated by low acid buffering capacity;
- Sites should be on similar soils and under similar native vegetation, these being generally sandy soils under jack pine stands as used in other monitoring programs;
- Landscape should be well drained and have gentle slopes; and,
- Since soil chemistry changes are slow, monitoring needs to be long-term; therefore, sites should have a high likelihood of protection from development over a long-term.

At this time, LICA is not proposing any additional *long-term* soil acidification monitoring plots within the region using its existing long-term soil monitoring protocol. As described in the previous section, existing soil monitoring plots will be enhanced with passive deposition sampling and passive air monitoring to help establish potential cause-effect relationships between air pollutants, soils, and forest ecosystem health in the region. LICA believes the 4 existing sites provide adequate surveillance of regionally acid sensitive soils from a long-term perspective. Additionally, the WBEA is establishing 2 forest health monitoring sites (of which, soil assessment is included) immediately north of LICA's northern boundary (JP-2021-4, JP-2021-15A).

While additional *long-term* soil monitoring sites remain a low priority, LICA will investigate additional *short-term* soil acidification monitoring plots to be operated in synergy with the new acid deposition monitoring activities proposed in this strategy. These sites would be located in areas of higher predicted deposition and would form a network of early warning plots for acidification effects.

For both LICA's existing long-term soil monitoring plots and the proposed network of early warning sites, the jack pine ecosystem has been identified as the most sensitive receptor. The jack pine ecosystem is characteristically dry with nutrient poor soils and has limited buffering capacity. In these ecosystems, the effects of acid deposition are expected to be observed in a cascading manner from soils to vegetation, first impacting individual organisms, then the stand, and onward to landscape level impacts. This concept is depicted in the figure below (WBEA 2020).

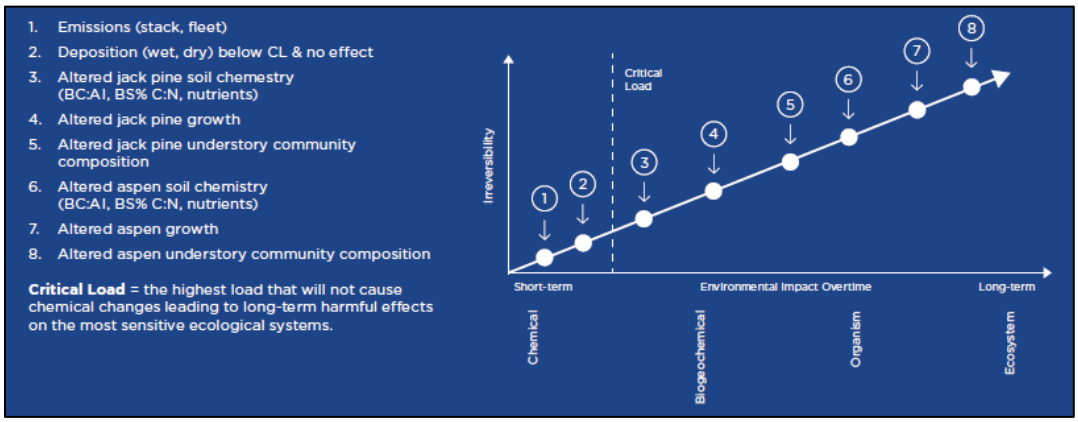

Figure 6: Cascading effect of acid deposition concept diagram (WBEA 2020)

If, through updated modelling, and supported by the proposed IER and passive monitoring activities, the total PAI (sum of wet and dry deposition PAI) exceeds 0.17 or 0.35 keq H+/ha/yr, which are the triggers for monitoring of sensitive and medium sensitivity soils respectively, LICA will reconsider establishment

of additional long-term soil monitoring sites in the region. The proposed network of early warning soil monitoring sites may also form

6.4. Surface Water

Acid deposition has the potential to alter the chemistry of surface water. The primary pollutants associated with aerial depositions include nitrogen oxides (NOx) and sulphur dioxide (SO_2), the precursors to nitric and sulphuric acid, which are the main constituents contributing to the acidification of waterbodies and watercourses. Like soil acidification monitoring, the effect of acidifying emissions on surface water is primarily determined by routinely measuring key water chemistry indicators. Like the "cascading effects" of soil acidification and it effect on forest health, it is relatively simple to monitor water quality indicators which show responses to acid inputs well before aquatic organisms.

Unlike the Athabasca Oil Sands Region, the Cold Lake area lacks a robust and coordinated surface water monitoring program. With a few exceptions, such as Alberta Lake Management Society (ALMS) and industrial in-field lake sampling programs, lake monitoring data sets in the Cold Lake area are often discontinuous and collected to support Environmental Impact Assessment applications. However, some of these data sets can been used to establish a starting point for a 'screening level' surface water monitoring program.

Work conducted by LICA (2007) and in several environmental impact assessments (EIAs) for projects in the LICA area (OSUM 2009; Cenovus 2013, IOR 2016) determined the acid sensitivity rating of lakes using the system established by Saffran and Trew (1996). The rating of acid sensitivity considers the measured alkalinity (expressed as calcium carbonate ($CaCO_3$)), calcium cation concentration, and pH. Based on the values for these three parameters, lake sensitivity to acidification was determined. Waterbodies are determined to be more susceptible to acidification (or have a high sensitivity) when measured values for alkalinity, calcium, and pH are low. In general, lakes in the LICA region were determined to have low sensitivity to acid deposition.

Table 2: Acid sensitivity ratings for lakes in the LICA area (LICA 2007)

Lake Identifier	Lake Name	Zone	Easting	Northing	Lake Surface Area (ha)	Alkalinity (mg/L)	pH	Calcium (mg/L)	Specific Conductivity (µS/cm)	Total Dissolved Solids (mg/L)	Hardness (mg/L)
LICA Study Area											
43	Ipitiak Lake	12	496692	6127900	-	67	7.5	17	136	67	-
60	Burnt Lake	12	536930	6072588	-	108	8.1	28	200	142	-
61	Unnamed Lake	12	540333	6069577	-	117	8.2	30	207	153	-
62	Unnamed Lake	12	539546	6071719	-	53	7.8	13	105	110	-
63	Unnamed Lake	12	539930	6072774	-	61	7.9	16	124	113	-
64	Unnamed Lake	12	540067	6073823	-	65	7.9	18	127	120	-
65	Unnamed Lake	12	543092	6075676	-	52	7.8	14	105	100	-
66	Unnamed Lake	12	544835	6076985	-	98	8.1	26	182	140	-
67	Unnamed Lake	12	538930	6078203	-	98	8.1	26	180	137	-
68	Unnamed Lake	12	541457	6082627	-	49	7.8	13	96	125	-
516	Sinclair Lake	12	522000	6064200	-	243	8.0	36	430	248	-
518	Marguerite Lake	12	516000	6052000	-	538	9.0	22	538	516	-
520	Leming Lake	12	532000	6050000	-	121	9.0	18	168	35	-
521	Tucker Lake	12	525300	6042700	-	212	8.1	28	400	234	-
546	Cold Lake	12	560000	6045000	-	140	8.3	31	240	155	-
547	Moore Lake	12	543043	6017650	-	340	8.7	15	686	408	-
594	McDougall Lake	12	546792	6023259	-	144	-	22	-	-	-
595	Unnamed Lake	12	541860	6020776	-	316	8.1	33	549	597	-
596	Manatokan Lake	12	503000	6035000	-	203	8.7	35	211	16	-
597	Unnamed Lake	12	522600	6078500	-	162	7.9	29	270	146	-
599	Unnamed Lake	12	529300	6074800	-	41	6.8	8	86	46	-
600	Dolly Lake	12	549700	6048200	-	244	8.5	14	-	239	-
L1	Angling Lake	12	542500	6005000	585	320	8.8	25	584	-	-
L2	Bluet Lake	12	528500	5979500	120	360	9.0	21	-	511	-
L3	Bourque Lake	12	528900	6058400	Unknown	197	8.2	37	371	221	182
L4	Ethel Lake	12	541800	6042450	490	158	8.2	33	289	179	148
L5	Fishing Lake	12	550000	5971000	Unknown	226	8.8	26	455	243	-
L6	Frog Lake	12	543000	597500	5800	386	8.8	18	877	500	-
L7	Garnier Lake	12	527500	5985000	520	364	9.0	18	-	475	-
L8	Hilda Lake	12	536600	6040900	362	428	8.8	19	893	563	280
L9	Kehewin Lake	12	506500	5990000	620	214	8.6	26	-	-	-
L10	Laurier Lake	12	532000	5967000	642	564	8.9	14	-	655	-
L11	Marie Lake	12	547000	6064900	3600	150	8.3	35	282	161	146
L12	May Lake	12	539150	6063900	Unknown	133	8.1	35	251	161	135
L13	Moose Lake	12	505000	6010000	4000	332	8.9	25	919	581	-
L14	Muriel Lake	12	520000	6000000	6410	961	9.3	5	1908	-	-
L15	Wolf Lake	12	503222	6061410	3150	159	8.5	27	-	156	-
Lakes Bordering the LICA Study Area											
45	Unnamed Lake	12	497711	6132160	-	39	7.4	10	83	41	-
46	Unnamed Lake	12	498367	6133579	-	90	8.1	21	180	119	-
47	Unnamed Lake	12	493933	6132222	-	52	7.6	13	108	76	-
48	Unnamed Lake	12	491151	6134421	-	44	7.3	11	97	45	-
49	Unnamed Lake	12	493107	6134651	-	46	7.4	11	96	45	-
132	Grist Lake	12	533788	6137575	-	117	8.5	30	222	119	-
239	Unnamed Lake	12	525364	6133813	-	108	8.3	30	208	-	-
250	Unnamed Lake	12	475613	6118973	-	67	8.7	17	135	-	-
259	Logan Lake	12	476591	6104122	-	147	9.2	33	267	-	-
536	Touchwood Lake	12	474032	6075393	-	142	8.0	31	263	148	-

Legend for Acid Sensitivity Ratings (Saffran and Trew, 1996)

Parameter	High	Moderate	Low	Least
Alkalinity	0 - 10	11 - 20	21 - 40	> 40
pH	0 - 6.5	6 .6 - 7.0	7.1 - 7.5	> 7.5
Calcium	0 - 4	5 - 8	9 - 25	> 25

There are a few exceptions to the low sensitivity ratings among the studies reviewed in the development of this strategy. Unnamed Lake UN-5 and Underwood Lake (Cenovus 2013), Caribou Lake (IOR 2016), and Unnamed Lake 599 (LICA 2007) were identified as having moderate sensitivities or were a risk of potentially exceeding a critical load. LICA recommends sampling these lakes to establish a contemporary acid sensitivity rating and revisiting the lakes as part of an ongoing lake chemistry monitoring program.

Table 3: Lakes recommended for sampling to establish contemporary acid sensitivity rating.

Water Body	Zone	Easting	Northing
Unnamed Lake 599	12U	529300	6074800
Caribou Lake	12U	508026	6104880
Underwood Lake	12U	537061	6127376
Unnamed Lake UN-5	12U	526901	6081167

LICA also recommends leveraging existing regional monitoring programs to support the ongoing and routine assessment of surface water acid sensitivity in the Cold Lake Region such as ALMS. As input to the Integrated Watershed Management Plan, in early 2022 LICA is collecting survey information from stakeholders about how different water bodies in the region are used. This information may reveal observations and other intrinsic considerations for establishment of surface water monitoring from an acid deposition perspective.

Annual analysis of wet and dry deposition will be evaluated to identify potential increases in acidifying substances. Increases above 0.17 keq H+/ha/yr (the monitoring load for sensitive soil) would trigger a monitoring response of nearby waterbodies to identify potential increases in surface water acidification. LICA will approach a monitoring response in this way because most acidic components ultimately deposited in lakes come from land runoff and drainage from the soil surface (vs. deposition of acidifying substance onto surface water bodies).

7. Mitigation Response

As defined in the ADMF, the triggers for monitoring in the LICA region are PAI values of 0.17 and 0.35 keq H+/ha/yr (sensitive and medium sensitivity respectively). The ADMF also defines target loads for the LICA region as 0.22 and 0.45 keq H+/ha/yr (sensitive and medium sensitivity respectively). If the PAI is above the target loads, mitigation will be implemented in the year following the detection of the target load exceedance and area operators will work with LICA and the AER to review monitoring data and evaluate potential mitigation options.

If annual monitoring data exceeds the target load, area operators will evaluate mitigation measures in consultation with LICA and the AER in the region. Preliminary corrective actions may include:

- Evaluation of emissions and control mechanisms
- Initiation of additional soil monitoring sites
- Initiation of additional surface water sampling
- Review of potential outlier events (upset conditions, forest fires)

8. Summary

The following table provides a high-level summary of the proposed enhancements to the LICA acid deposition monitoring program.

Table 4: Monitoring strategy summary

Monitoring	Parameters	Method	Number of Locations	Reporting Schedule	Implementation
Wet Deposition	Ions as defined by National Atmospheric Chemistry protocols (Ca^{2}+, Mg^{2}+, K+, Na+, Br-, NH4+, NO3-, Cl-, $SO_4$2-, $PO_4$3-), conductivity, and pH	Precipitation collection (Environment and Climate Change Canada)	1 existing 1 new	weekly/annually	2022
Dry Deposition	sulphur dioxide SO_2 nitrogen dioxide NO_2 ozone O_3 ammonia NH_3 nitric acid HNO_3	Passive (AEP, WBEA)	35 total *26 existing sites* *26 enhanced* *9 new enhanced*	monthly/annually	2022-23
Wet/Dry Deposition	ammonium (NH4+), nitrate (NO3-), sulphate (SO42-), and calcium (Ca+)	Ion Exchange Resin (WBEA)	4 (at soil acidification sites) 2 (in Imperial Oil – Foster Creek corridor) 2 (up/down wind)	Biannually (winter and summer)	2022-23
Soil	Indicators of Soil Acidification (soil pH, base saturation, base cation to aluminum ratio, total sulphur)	- Long-term AEP soil acidification monitoring protocol (AEP/LICA) - Short-term early warning protocol TBD	- 4 existing long-term (no new) - 4 – 8 new short-term early warning	- 4-year staggered cycle (long-term) - cycle TBD (short-term)	Existing - N/A New - As needed as per target load triggers
Surface Water	Indicators of lake sensitivity expressed as alkalinity (calcium carbonate ($CaCO_3$)), calcium cation concentration, and pH.	Whole water sample (Regional Aquatics Monitoring Program) Assessment (Saffran and Trew)	Unnamed Lake 599, Caribou Lake, Underwood Lake, Unnamed Lake UN-5	Annually	2022-23

9. Sources

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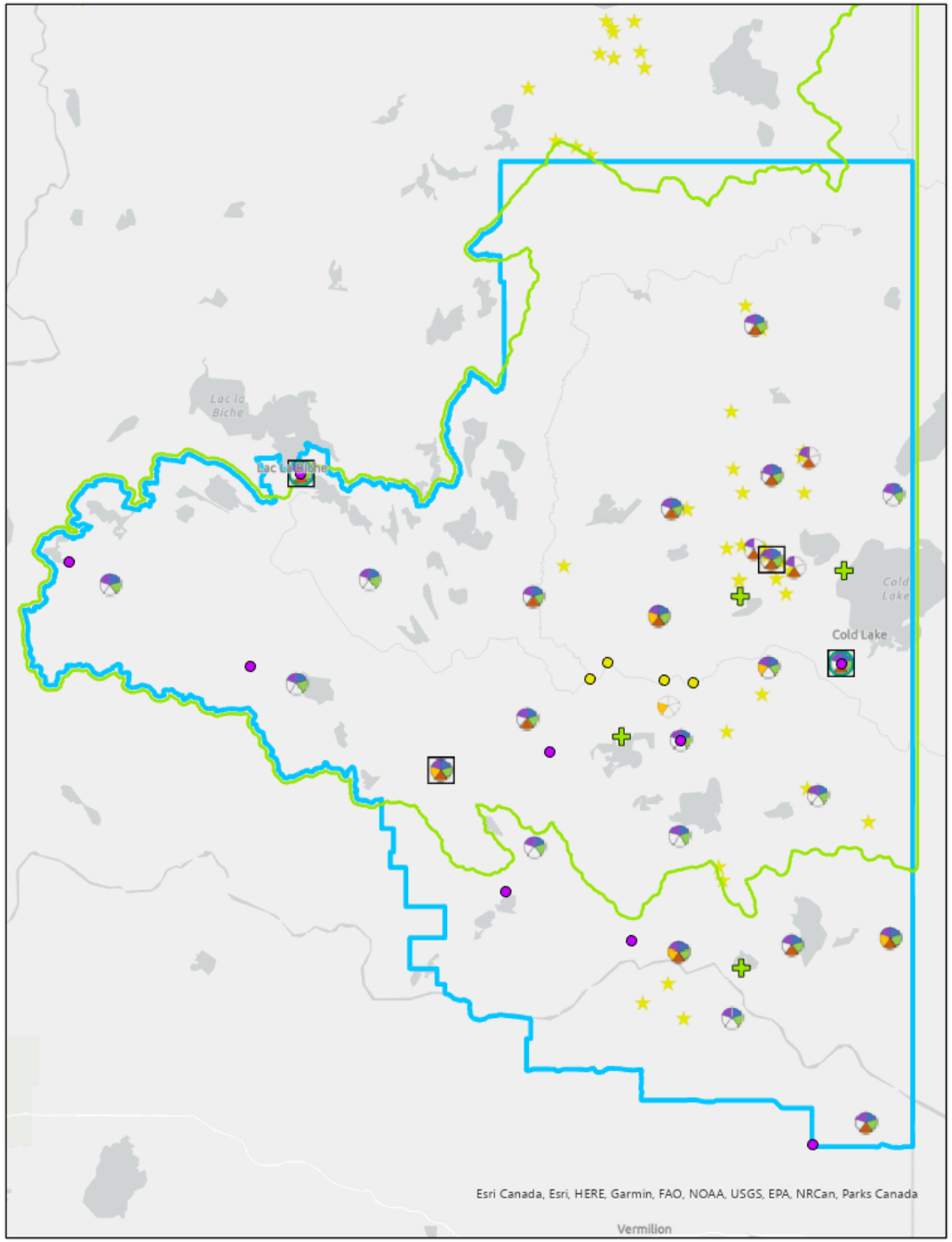
Monitoring Strategy Visualization

Monitoring	Parameters	Method	Number of Locations	Reporting Schedule	Implementation
Wet Deposition	Ions as defined by National Atmospheric Chemistry protocols (Ca^2+, Mg^2+, K+, Na+, Br-, NH4+, NO3-, Cl-, $SO_4$2-, $PO_4$3-), conductivity, and pH	Precipitation collection (Environment and Climate Change Canada)	1 existing 1 new	weekly/annually	2022
Dry Deposition	sulphur dioxide SO_2 nitrogen dioxide NO_2 ozone O_3 ammonia NH_3 nitric acid HNO_3	Passive (AEP, WBEA)	35 total 26 existing sites 26 enhanced 9 new enhanced	monthly/annually	2022-23
Wet/Dry Deposition	ammonium (NH4+), nitrate (NO3-), sulphate (SO42-), and calcium (Ca+)	Ion Exchange Resin (WBEA)	4 (at soil acidification sites) 2 (in Imperial Oil – Foster Creek corridor) 2 (up/down wind)	Biannually (winter and summer)	2022-23
Soil	Indicators of Soil Acidification (soil pH, base saturation, base cation to aluminum ratio, total sulphur)	- Long-term AEP soil acidification monitoring protocol (AEP/LICA) - Short-term early warning protocol TBD	- 4 existing long-term (no new) - 4 – 8 new short-term early warning	- 4-year staggered cycle (long-term) - cycle TBD (short-term)	Existing - N/A New - As needed as per target load triggers
Surface Water	Indicators of lake sensitivity expressed as alkalinity (calcium carbonate ($CaCO_3$)), calcium cation concentration, and pH.	Whole water sample (Regional Aquatics Monitoring Program) Assessment (Saffran and Trew)	Unnamed Lake 599, Caribou Lake, Underwood Lake, Unnamed Lake UN-5	Annually	2022-23

LICA Regional Air and Deposition Monitoring Framework

- Soil Acidification
- Beaver River Valley Meteorology
- Multi-Parameter Continuous
- Multi-Parameter Time-Integrated
- PurpleAir Sensor
- Polycyclic Aromatic Compounds Passive
- Sulphur Dioxide Passive
- Ozone Passive
- Hydrogen Sulphide Passive
- Nitrogen Dioxide Passive
- ST102_Facility_GCS_NAD83



Sensitivity Grid Cells (ADMF)

- Soil Acidification
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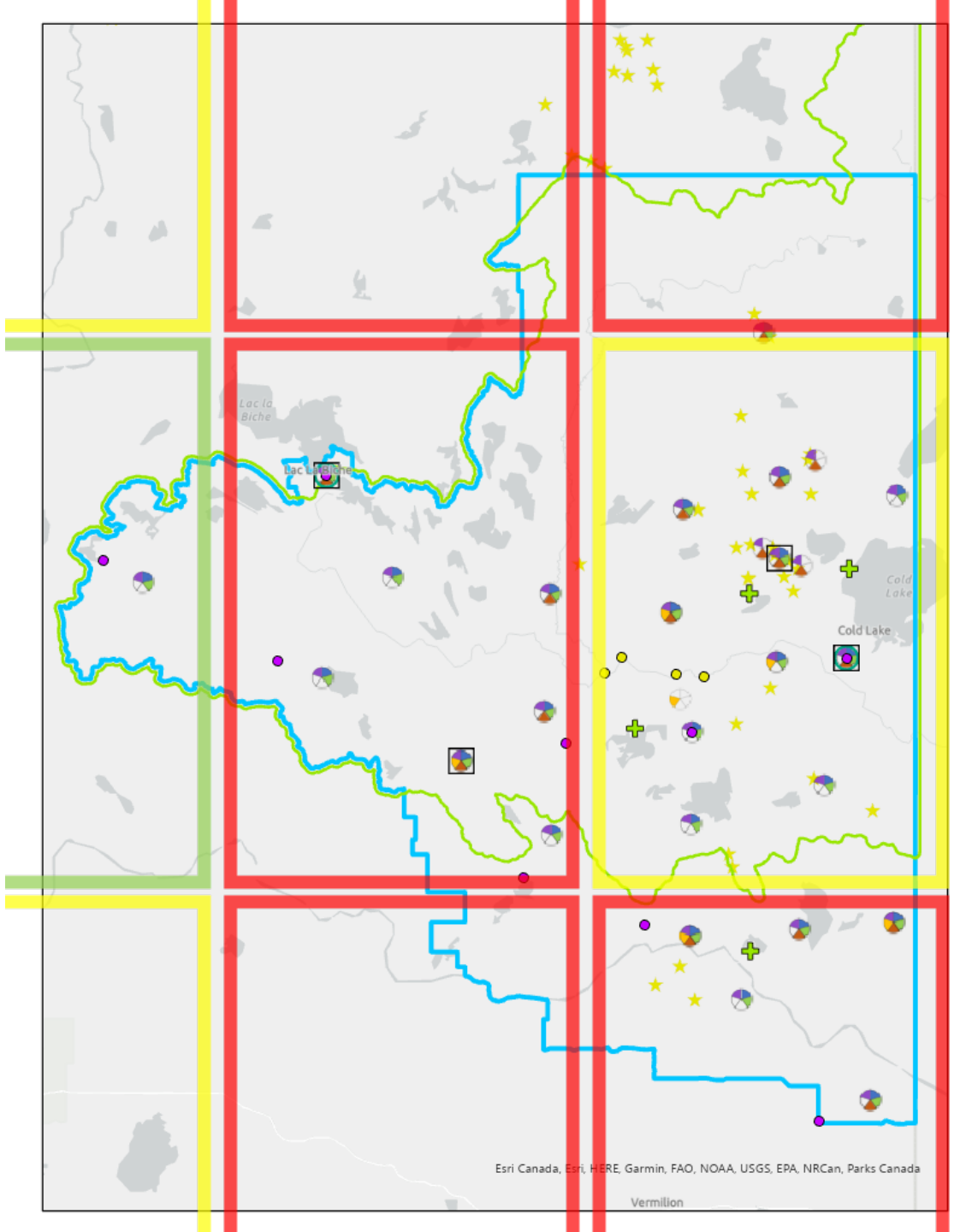
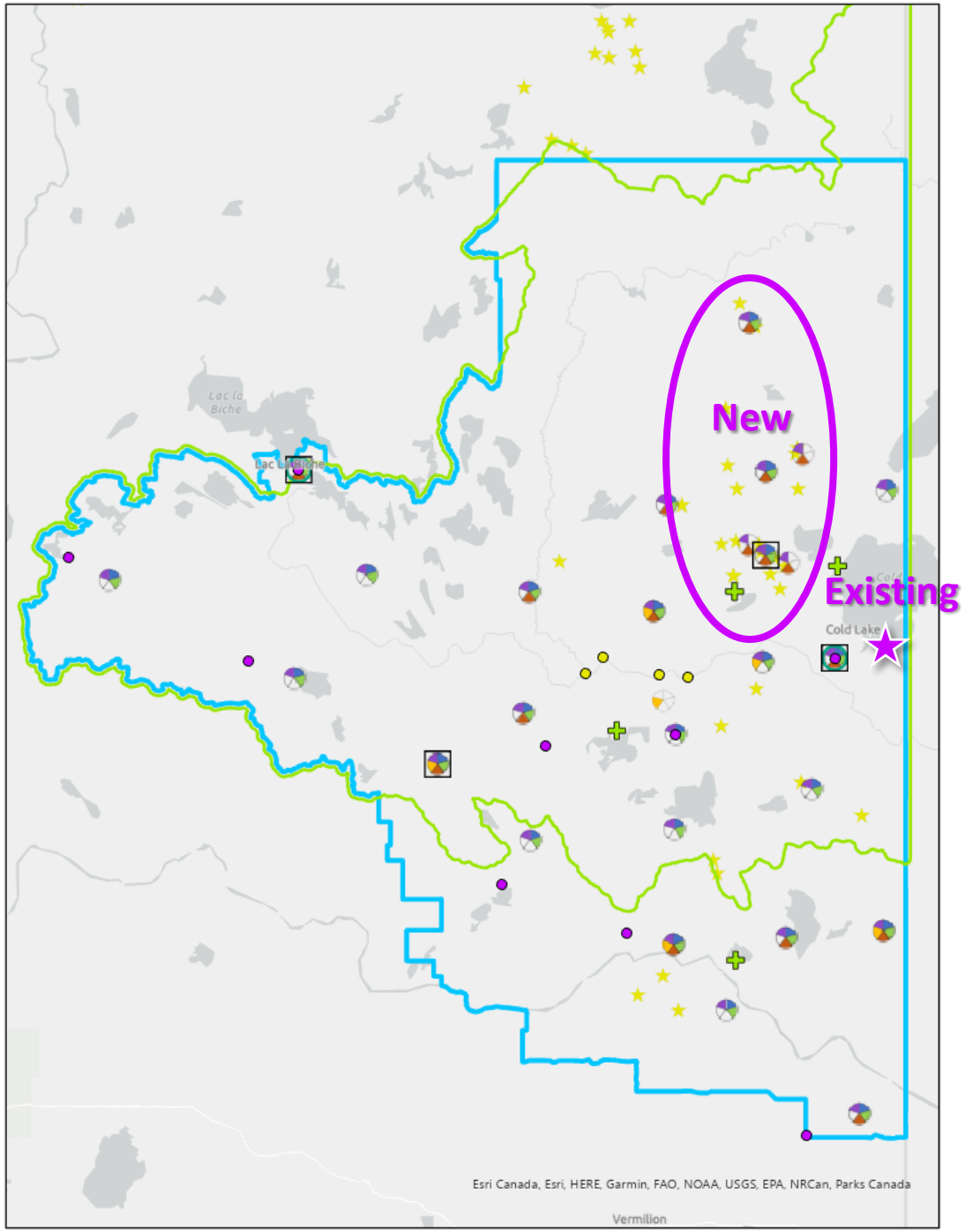


Precipitation Chemistry (Wet)

- 1 existing
- 1 new



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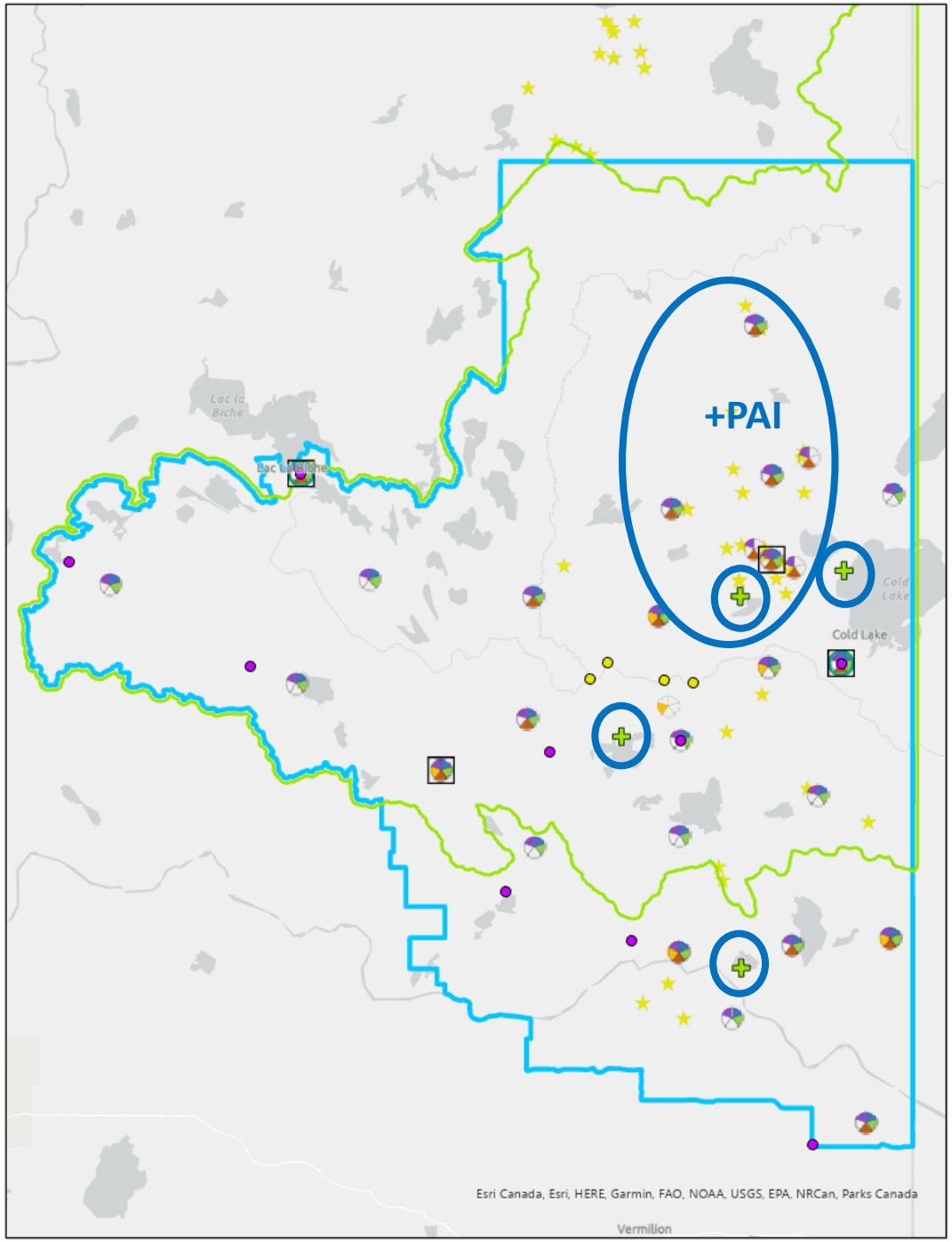
Passive Monitoring (dry)

- 35 Total
- 26 existing (+enhancements)
- 9 new enhanced

Existing + enhancements



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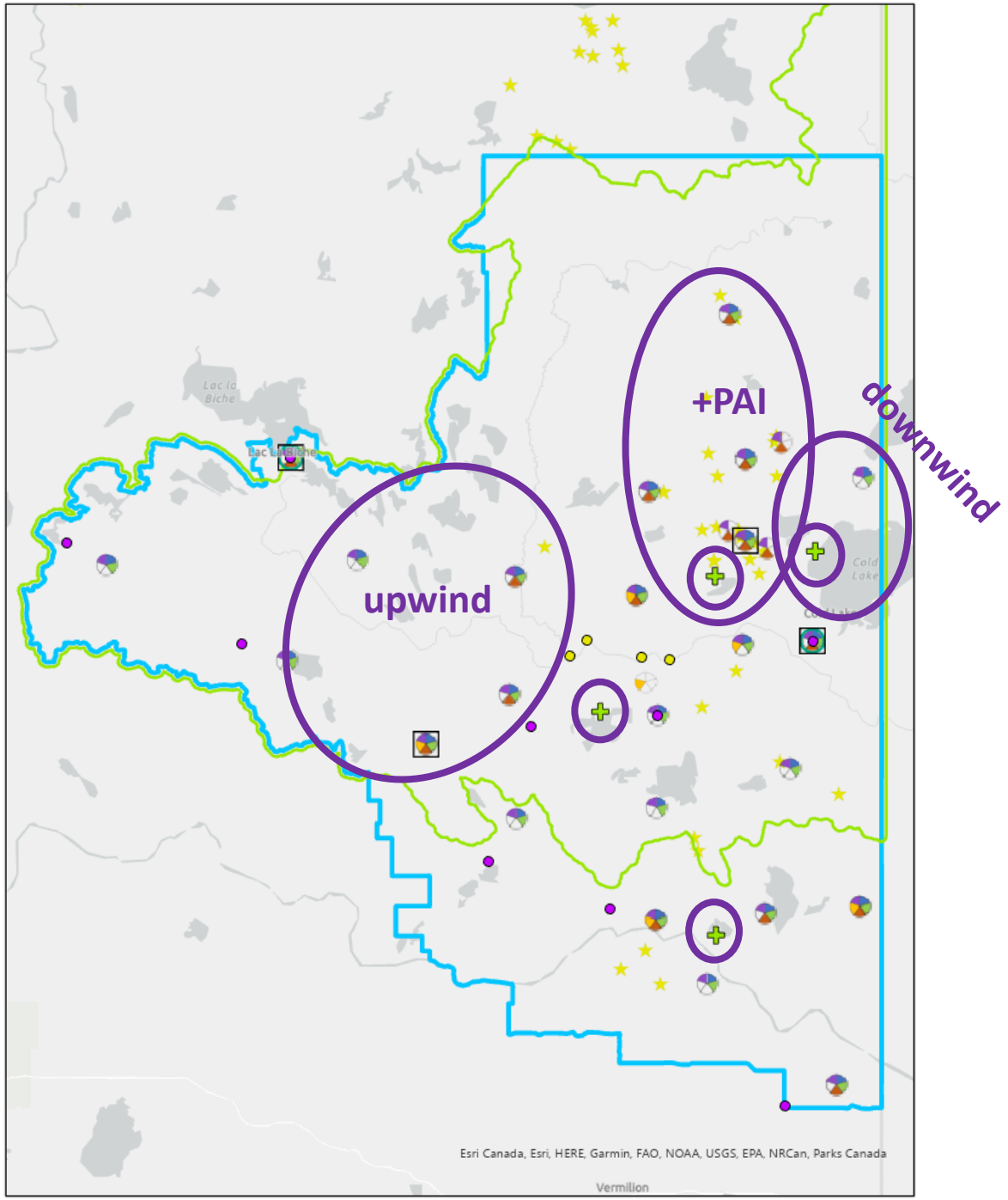
Ion Exchange Resins (wet & dry)

- co-located at soil acidification sites
- upwind and downwind of operations
- in area of increased PAI



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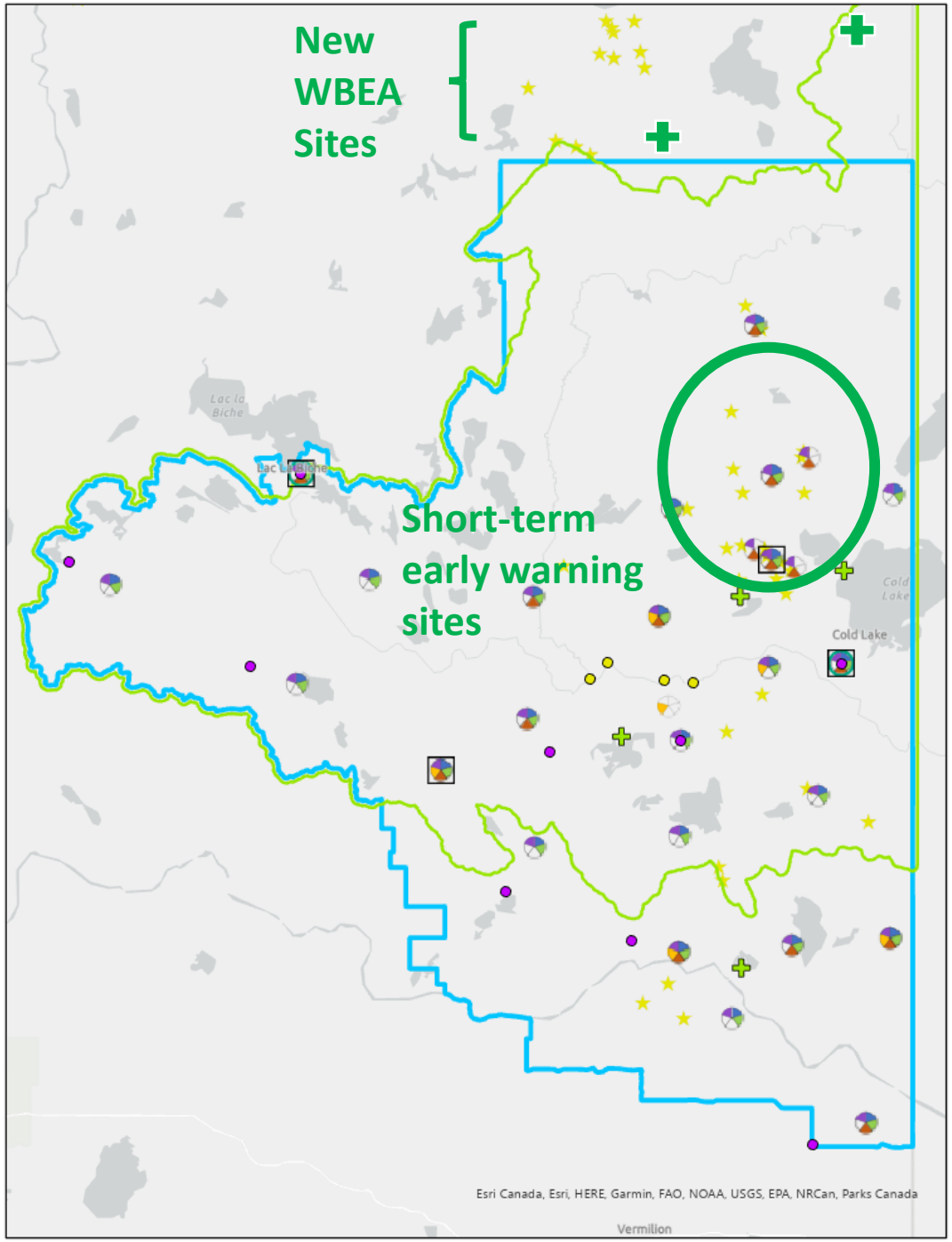
Soil Monitoring

- no new long-term sites proposed
- use new deposition monitoring data to assess future monitoring needs
- 4 – 8 short-term early warning sites in area of higher deposition



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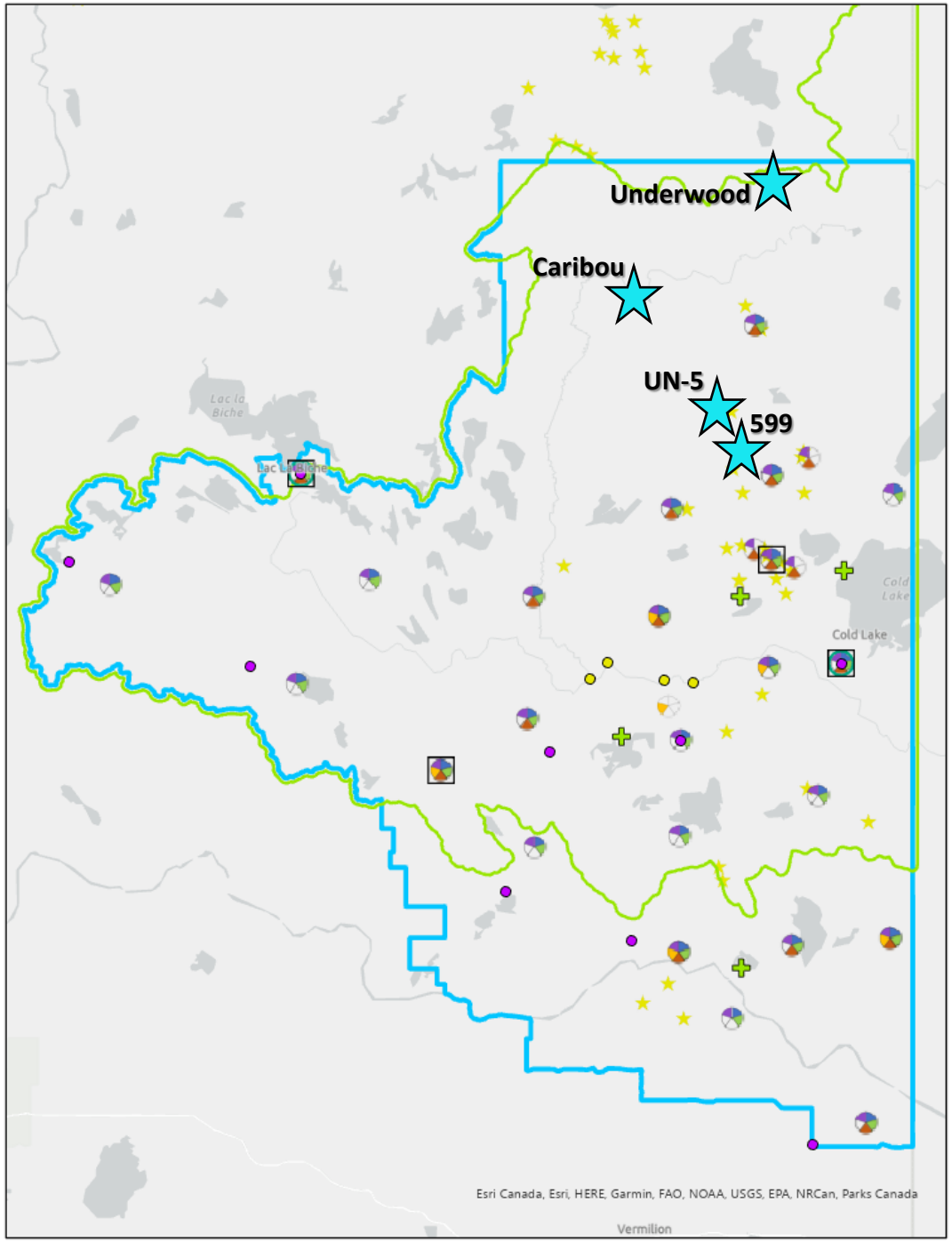
Surface Water Sampling

- **4 acid sensitive lakes identified for contemporary sensitive measurements**



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