FORT HILLS ENERGY CORPORATION
FORT HILLS OIL SANDS PROJECT

MCCLELLAND LAKE WETLAND COMPLEX OPERATIONAL PLAN OBJECTIVE 5

December 2021

Operated by SUNCOR ENERGY

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McClelland Lake Wetland Complex Operational Plan

Executive Summary / Introduction / Supporting Attachments

Objective 1 – Define Baseline Conditions

Objective 2 – Define Functionality

Objective 3 – Assess Potential Impacts of Mine Development

Objective 4 – Establish Necessary Design Features and Contingency Mitigation Measures

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6. OBJECTIVE 5: DEVELOP AN EFFECTS MONITORING PROGRAM

6.1. Introduction

The effects monitoring program is designed to detect Fort Hills Oil Sands Project (Fort Hills Project) effects in the non-mined portion of the McClelland Lake Wetland Complex (MLWC). The effects monitoring program builds upon Objective 1 (Section 2), in which pre-mining baseline conditions for the MLWC were characterized, and Objective 2 (Section 3), in which indicators were defined. Furthermore, the effects monitoring program is informed by the assessment of potential mine impacts described under Objective 3 (Section 4), and the design features and contingency mitigation plans associated with Objective 4 (Section 5). The response framework associated with the effects monitoring program is described under Objective 6 (Section 7). The effects monitoring program is designed to meet *Water Act* Approval No. 151636-01-00, as amended, Conditions 3.13 (c), (d) and (e). The effects monitoring program was designed in consultation with the Sustainability Committee (SC) and will be refined as needed based on continued data collection.

6.1.1. Background and Sustainability Committee Input

As discussed in Objective 2, Section 3.3.1, to support the knowledge gathering and shared work of the Aboriginal Advisory Group (AAG) and Technical Advisory Group (TAG), the SC organized a series of workshops on the indicators, starting in 2019. During these workshops, the AAG and TAG co-created a list of indicators and methods that could be used to monitor the function and biodiversity of the non-mined portion of the MLWC using the Two Roads Approach. Linking these two ways of knowing provides a more robust, integrated monitoring system to assess environmental changes to the non-mined portion of the MLWC that may result from the Fort Hills Project, and the socio-cultural responses to these environmental changes. Joint workshops were held to develop recommendations on indicators and methods. A summary was prepared and reviewed and validated by the participants. Indicators and methods were developed and documented for nine environmental and socio-cultural and economic values identified for the MLWC:

- Wildlife and aquatic resources
- Vegetation (communities and plants)
- Surface and groundwater levels and flows and/or ice conditions
- Surface and groundwater quality (including sediment)
- Biodiversity
- Harvesting and subsistence use
- Indigenous culture and habitation
- Education and learning
- Health and wellness

As discussed in Objective 2 (Section 3.3.1), the linkages between the environmental and socio-cultural functions highlight the interrelated nature of ecological and socio-cultural elements in the MLWC.

It is recognized that the members of the AAG and TAG of the SC have tremendous knowledge about the MLWC and the environmental and socio-cultural impacts associated with oil sands development.

They also have valuable insight and experience with a range of indicators that can be used to monitor environmental and social change caused by specific project impacts. While all of the indicators are individually important, knowledge holders emphasized that it is the sum or holistic sense of all of these indicators throughout the seasons that is important for assessing the integrity and health of a site. Linking two ways of knowing – ITK and science – provides a robust, integrated monitoring system to assess environmental changes that may result from the Fort Hills Project and the socio-cultural responses to these environmental changes.

Figure 6.1-1 illustrates how the monitoring program components relate to the wetland functions and create a holistic program encircling all wetland functions. Over the past 16 years of engagement with the SC and the supporting Advisory Groups, the monitoring programs have been developed collaboratively, with the SC and supporting groups providing input on the programs (e.g., types of monitoring and monitoring locations) and occasionally participating in some field programs with the Fort Hills Project team. FHEC is committed to ongoing engagement with the SC to solicit input and adapt the monitoring program design, if warranted, to improve the monitoring program and inform management responses.

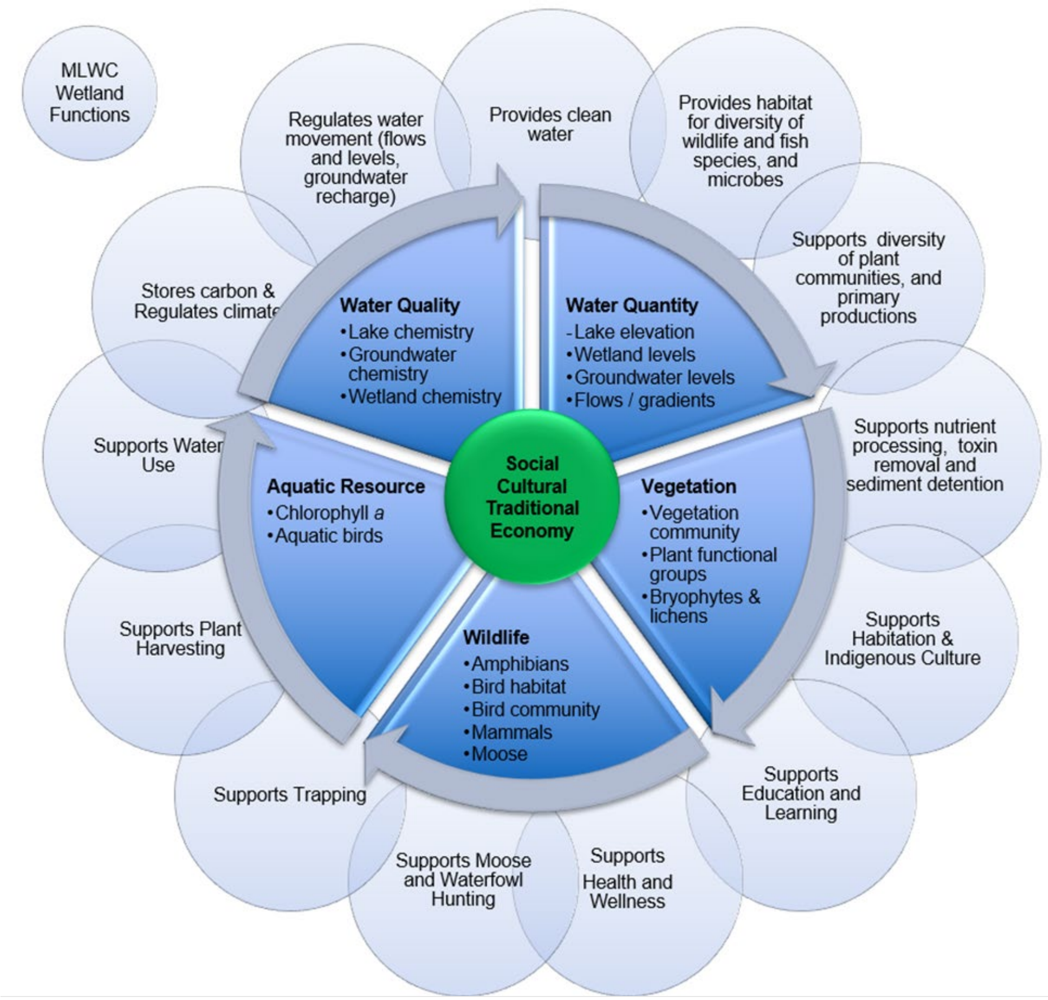

Figure 6.1-1: Illustration of Monitoring Program Encircled by the Environmental and Socio-Cultural Functions of McClelland Lake Wetland Complex

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6.2. Monitoring Program Overview

Key drivers, physical receptors (potential stressors), and biological receptors (potential responses) were identified under Objective 2 to characterize Project-scale factors with the potential to affect wetland functionality. A subset of the physical, biological and Indigenous community receptors initially considered for the OP was selected for inclusion as primary effects indicators or environmental, social, cultural, and traditional economic values and land use indicators (ESCT indicators) under Objective 2; these have been carried forward to the effects monitoring program under Objective 5.

For the MLWC, potential stressors to the ecosystem that were identified as primary effects indicators under Objective 2 include changes to groundwater levels, surface water levels, groundwater quality, and surface water quality in the wetland. Changes to water levels and water quality in the wetland may, in turn, affect surface water levels and surface water quality in McClelland Lake. If they persist, changes in the physical environment may bring about changes in the biological environment. For example, as described under Objective 1, string and flark plant community characteristics are related to wetland water quality (Vitt and House 2020). Thus, a change in wetland water quality may bring about a change in plant community composition. Similarly, a change in lake water quality may bring about a response in chlorophyll *a* concentrations, signalling a change in primary productivity.

Indigenous communities may also be affected by changes in the physical and biological environments of the non-mined portion of the MLWC. The interrelated nature of the ecological and socio-cultural elements in the MLWC link the bio-physical, bio-cultural and socio-cultural aspects of indicators in the MLWC. The ESCT indicators included to assess values at MLWC, based on recommendations from the SC, include aspects of environmental indicators, such as:

- wildlife and aquatic resources
- vegetation
- surface and groundwater levels, flows and/or ice conditions
- surface and groundwater quality
- biodiversity

and socio-cultural indicators such as:

- harvesting and subsistence use
- indigenous culture and habitation
- education and learning
- health and wellness

The ESCT indicators are discussed further in Section 6.3.6.

Potential impacts to indicators in the non-mined portion of the MLWC were explored under Objective 3 (Section 4). Specifically, an integrated groundwater/surface water model and a separate water quality model were developed to evaluate scenarios of (i) no development within the MLWC watershed; (ii) development with no implementation of water management design features; and (iii) development with implementation of the selected water management design features. Model results were used to inform water management design features under Objective 4 (Section 5), which include operational water management and closure drainage facilities. The purpose of the effects monitoring program described in

Objective 5 is to detect changes in the non-mined portion of the MLWC, and to determine whether changes constitute effects associated with the Fort Hills Project. Specifically, the effects monitoring program is designed to address the following key questions:

1. Is the Fort Hills Project affecting primary effects indicator metrics in the non-mined portion of the MLWC?
2. Is the Fort Hills Project affecting ESCT indicators in the non-mined portion of the MLWC?

To address these key questions, types of monitoring, proposed sampling locations, and methods specific to each monitoring component are described in detail in Sections 6.2.1 to 6.3.6.

6.2.1. Types of Monitoring

Both status information (to provide a snapshot of current conditions in an area) and trend information (to detect and track longer-term changes through time) are needed to characterize conditions in a long-term effects monitoring program (Ciborowski et al. 2012). For the MLWC effects monitoring program, monitoring is proposed at permanent sampling locations (whose placement was guided by the system understanding summarized in Objectives 1, 2 and 3) within the MLWC and two reference sites (i.e., Audet Lake Wetland Complex [ALWC] and Gipsy Gordon Wetland Complex [GGWC]). Three spatially defined monitoring types are proposed: early warning monitoring, integrated wetland monitoring, and lake monitoring.

6.2.1.1. Early Warning Monitoring

The purpose of early warning monitoring is to identify effects to groundwater level, surface water hydrology, and water quality before changes occur within the patterned fen. Early warning monitoring is proposed:

- in the mined portion of the MLWC
- in both mined and non-mined areas of groundwater aquifers supporting the MLWC
- near the cutoff wall
- near groundwater/surface water injection locations
- along dominant groundwater flowpaths

Early warning monitoring locations are shown in Figure 6.2-1. Early warning monitoring locations outside the cutoff wall will provide early warning of effects as mining advances towards the non-mined portion of the MLWC; many of these monitoring locations will ultimately be lost. Early warning monitoring locations inside the cutoff wall will provide early warning of effects to the non-mined portion of the MLWC once the cutoff wall is in place; they occur spatially between the cutoff wall and the patterned portion of the fen and are expected to be retained for the duration of the effects monitoring program.

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6.2.1.2. Integrated Wetland Monitoring

The purposes of integrated wetland monitoring are to: (i) identify effects within the non-mined portion of the MLWC beyond the early warning monitoring network; (ii) spatially integrate groundwater level, surface water hydrology, water quality, and vegetation data where applicable; and (iii) explore long-term trends as datasets allow. In addition, expansion of the existing vegetation plot network to include the grid sampling locations established by Vitt and House (2020) is included as a component of integrated wetland monitoring to provide a snapshot of the status of vegetation, surface water quality, and water table characteristics (i.e., local water table measurements in relation to the ground/vegetation level) during years when permanent vegetation plots are not surveyed. Integrated wetland monitoring is proposed for locations within the non-mined portion of the MLWC and the reference sites, as described in Section 6.2.2.2.

6.2.1.3. Lake Monitoring

The purpose of lake monitoring is to identify changes to surface water hydrology, surface water quality, and aquatic resources that may result from mining activities. Lake monitoring will occur within McClelland Lake, and at the reference sites within Audet Lake (associated with the Audet Lake Wetland Complex) and Birch Lake (associated with the Gipsy Gordon Wetland Complex).

6.2.2. Proposed Monitoring Locations

6.2.2.1. McClelland Lake Wetland Complex

The MLWC effects monitoring program is designed to use as many established monitoring locations as possible to build upon existing datasets. In addition, new monitoring locations are proposed for some components to complement existing monitoring infrastructure and provide spatial integration of key monitoring components.

6.2.2.1.1. Early Warning Monitoring

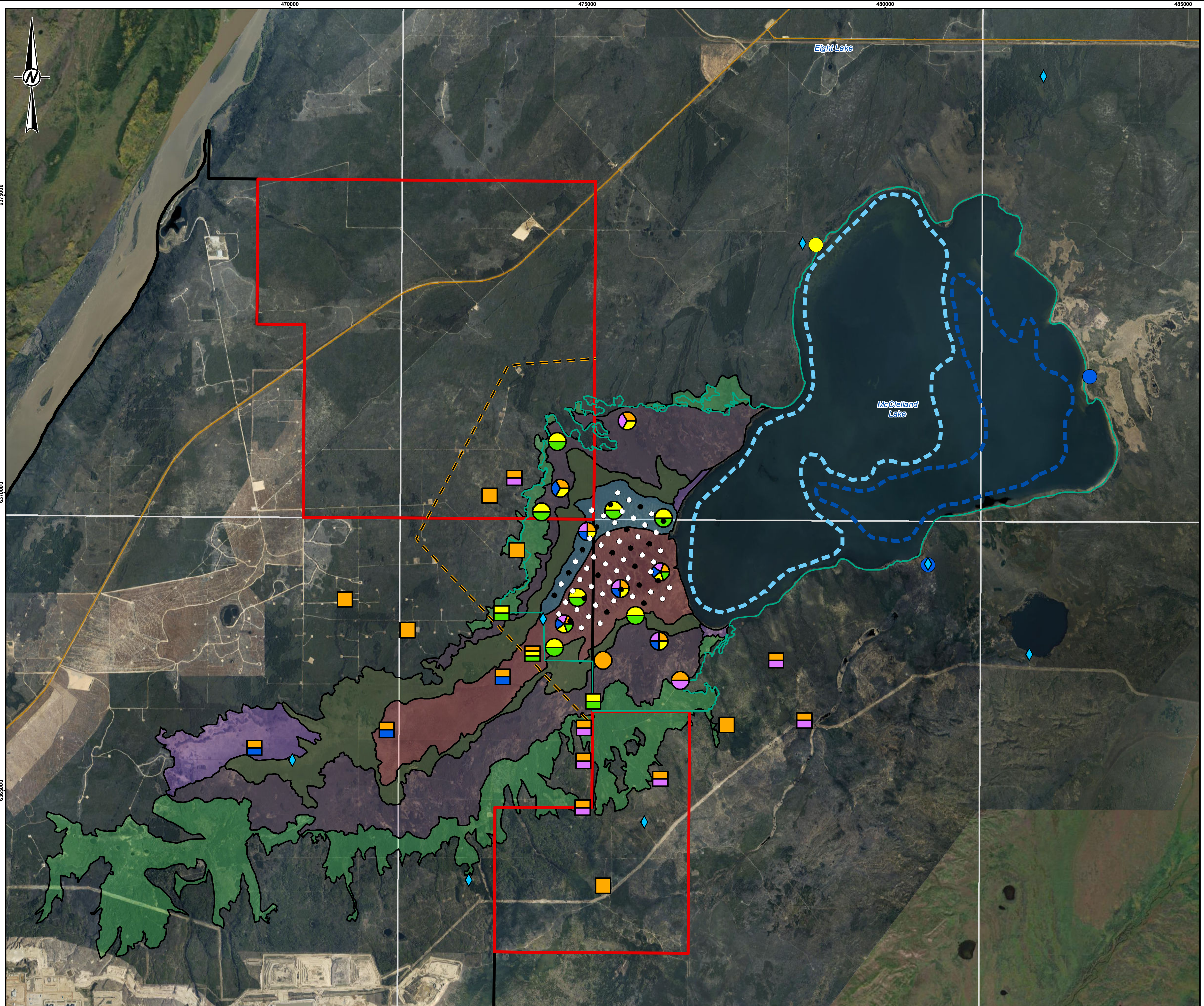
For early warning monitoring, 19 groundwater well locations were selected in the uplands and parts of the MLWC that will be lost as the mine advances (Figure 6.2-1; Table 6.2-1). At seven of these locations, groundwater level monitoring is spatially integrated with groundwater quality monitoring; at six of these locations, groundwater levels are monitored; at three of these locations, groundwater level monitoring is spatially integrated with surface water hydrology monitoring; at two of these locations, surface water quality monitoring is spatially integrated with vegetation monitoring, and at one of these locations, groundwater level monitoring is spatially integrated with surface water quality and vegetation monitoring (Figure 6.2-1; Table 6.2-1).

Table 6.2-1: Proposed Number of Locations within the McClelland Lake Wetland Complex for Each Monitoring Component

Monitoring Component	Proposed Number of Locations
Early Warning Monitoring	
Groundwater level Surface water hydrology Groundwater quality Surface water quality Vegetation	19 locations: • 7 locations for groundwater levels and groundwater quality • 6 locations for groundwater levels only • 3 locations for groundwater levels and surface water hydrology • 2 locations for surface water quality and vegetation • 1 location for groundwater levels, surface water quality, and vegetation[(a)]
Integrated Wetland Monitoring	
Climate	8 existing climate stations
Groundwater level Surface water hydrology Groundwater quality Surface water quality Vegetation	16 locations: • 7 locations for surface water quality and vegetation[(a)] • 3 integrated locations for groundwater levels, surface water hydrology, groundwater quality, and surface water quality • 2 fully integrated locations for groundwater levels, surface water hydrology, groundwater quality, surface water quality, and vegetation • 1 location for groundwater levels, surface water hydrology, and surface water quality • 1 location for groundwater levels, groundwater quality, and surface water quality • 1 location for groundwater levels and groundwater quality • 1 location for groundwater levels only
Integrated Wetland Monitoring – Grid	
Groundwater level	Not applicable
Groundwater quality	Not applicable
Surface water hydrology (water table)	Inclusion of full (64 locations) or partial (20 locations) grid for each survey event; details discussed in Objective 6
Surface water quality	
Vegetation	
Lake Monitoring	
Groundwater level	Not applicable
Groundwater quality	Not applicable
Surface water hydrology	2 existing locations for surface water hydrology on shore
Surface water quality and aquatic resources	3 locations: • 2 composite samples + depth profiles[(b)] within lake for surface water quality and aquatic resources • 1 surface water quality sample from shore, near the boat launch
Vegetation	Not applicable

(a) In total, there are 12 existing vegetation locations associated with 18 existing vegetation monitoring sites (six wooded fen sites, six string sites and six flark sites; string and flark sites are paired at the same general location) (Table 6.2-2). For the six locations within the patterned fen, each vegetation monitoring location includes one string site and one flark site for a total of six wooded fen sites, six string sites and six flark sites.

(b) Two composite samples from three to five representative locations within each portion of the lake (i.e., one composite sample from the shallow area and one composite sample from deep area) for water quality indicators, depth profile of field-measured parameters within the water column at the deepest location, one depth-integrated composite sample for chlorophyll *a* at each location.



LEGEND

- CUTOFF WALL
- LOCAL ROAD
- EXTENSION AREAS AS PROPOSED IN THE INTEGRATED PLAN AMENDMENT APPLICATION
- APPROVED PROJECT AREA
- NON-MINED PORTION OF MLWC

EARLY WARNING MONITORING

- GROUNDWATER LEVEL
- GROUNDWATER QUALITY
- SURFACE WATER HYDROLOGY
- SURFACE WATER QUALITY
- VEGETATION

INTEGRATED WETLAND MONITORING

- GROUNDWATER LEVEL
- GROUNDWATER QUALITY
- SURFACE WATER HYDROLOGY
- SURFACE WATER QUALITY
- VEGETATION
- CLIMATE STATION

INTEGRATED WETLAND MONITORING – GRID

- FULL SURVEY GRID PLOT
- PARTIAL SURVEY GRID PLOT

LAKE MONITORING

- SURFACE WATER HYDROLOGY
- SURFACE WATER QUALITY - SHORE
- SURFACE WATER QUALITY AND AQUATIC RESOURCES – DEEP
- SURFACE WATER QUALITY AND AQUATIC RESOURCES – SHALLOW

ECOHYDROLOGY ZONES

- 1
- 2
- 3
- 4
- 5
- 6

0 2 4

1:65,000 KILOMETRES

NOTE(S)

1. MLWC - McCLELLAND LAKE WETLAND COMPLEX
2. ECOHYDROLOGY ZONES ARE DEFINED IN OBJECTIVE 1, SECTION 2.4.3

REFERENCE(S)

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PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

TITLE
PROPOSED MONITORING LOCATIONS

FORT HILLS
Operated by Suncor Energy

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DESIGNED	KS
PREPARED	LB
REVIEWED	ZG
APPROVED	JH

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6.2.2.1.2. Integrated Wetland Monitoring

Sixteen locations are included for integrated wetland monitoring (Figure 6.2-1; Table 6.2-1). Seven integrated wetland monitoring locations include surface water quality and vegetation monitoring. Three integrated locations include groundwater levels, surface water hydrology, groundwater quality, and surface water quality. Two locations are fully integrated with groundwater levels, surface water hydrology, groundwater and surface water quality, and vegetation. Four additional locations include different combinations of groundwater levels, surface water hydrology, groundwater and surface water quality, and vegetation. Eight climate stations are included to complement the surface water hydrology dataset.

Because different monitoring components vary at different spatial scales, it is not necessary to include groundwater level, surface water hydrology and groundwater quality at every integrated vegetation and surface water quality monitoring location. Plant community composition is closely tied to water quality characteristics, and the two components appear to vary spatially in the same way (Objective 1; Section 2); thus, these two components are closely linked spatially in the effects monitoring program.

For the grid-based wetland monitoring component of integrated wetland monitoring, either the full grid (64 locations; Figure 6.2-1) or a partial grid (20 locations; Figure 6.2-1) will be surveyed for water table (i.e., local water table measurements in relation to the ground/vegetation level), surface water quality, and vegetation characteristics. Survey intensity (i.e., whether the full grid or partial grid is surveyed) will be based on the monitoring tier as described under Objective 6 (Section 7). For the full grid, 21 locations are within Ecohydrology Zone (EHZ) 1 and 43 locations are within EHZ 2 (Figure 6.2-1). For the partial grid, 8 locations are within EHZ 1 and 12 locations are within EHZ 2 (Figure 6.2-1); five of the locations to be included in the survey of the partial grid were selected because of their potential to show early signs of change (Vitt 2021, pers. comm.). At each grid location, separate plots will be surveyed in string and flark fen types.

6.2.2.1.3. Lake Monitoring

For lake monitoring, two surface water hydrology monitoring locations on the shore of McClelland Lake are included in the effects monitoring program (Figure 6.2-1; Table 6.2-1). For surface water quality and aquatic resources sampling within the lake, two composite samples will be collected from representative areas within the shallow portion and deep portion of McClelland Lake. These shallow and deep portions of the lake were identified using bathymetry data and are shown on Figure 6.2-1. In addition, surface water quality parameters will be sampled from shore at one location near the boat launch.

6.2.2.2. Reference Sites

Monitoring at the reference sites will follow the same principle of spatial integration of water quality and hydrology components with the vegetation component, and will incorporate surface water hydrology and surface water quality monitoring near permanent vegetation plots in addition to lake and climate monitoring. Temporal and spatial gaps currently exist in the reference site monitoring datasets. To achieve a balanced design that would complement the monitoring programs currently underway at the MLWC, the monitoring components shown in Table 6.2-2 will be included in reference site monitoring programs.

Surface water hydrology data have been collected from Audet Lake from 2017 to 2020 (Figure 2.5-15 in Objective 1, Section 2.5.5.1.), but surface water hydrology data have not yet been collected from the ALWC, Birch Lake, or the GGWC. To fill these gaps, surface water hydrology data will be collected from one new wetland location at each of ALWC and GGWC, and from one new location at Birch Lake (Table 6.2-2).

Table 6.2-2: Proposed Monitoring Locations within the Audet Lake Wetland Complex and Gipsy Gordon Wetland Complex for Each Monitoring Component

Monitoring Component	Proposed Number of Locations	
	Audet Lake Wetland Complex	Gipsy Gordon Wetland Complex
Integrated Wetland Monitoring		
Climate	One existing location	One existing location
Surface water hydrology	One new location	One new location
Surface water quality	Eighteen locations spatially integrated with vegetation sites	Eighteen locations spatially integrated with vegetation sites
Vegetation	Eighteen sites: • Six existing string fen sites • Six new flark fen sites paired with existing string sites • Six existing wooded fen sites	Eighteen sites: • Six existing string fen sites • Six existing flark fen sites • Six existing wooded fen sites
Lake Monitoring		
Surface water hydrology	One existing location	One proposed location
Surface water quality and aquatic resources	One composite sample + depth profile[(a)] within lake	One composite sample + depth profile[(a)] within lake
Vegetation	Not applicable	Not applicable

(a) One composite sample from three to five representative locations within the lake (including shallow and deep areas) for integrated water quality indicators; depth profile of field-measured parameters within water column at the deepest location; one depth-integrated composite sample for chlorophyll *a* at each location.

Water quality data were collected from the ALWC from 2010 to 2019, and from Audet Lake in 2010 and from 2013 to 2019. At the ALWC, only one of the four water quality sampling locations (i.e., ALE-2-SW) in the wetland occurs within the Audet Lake watershed boundary shown on Figure 2.5-35 in Objective 1 (Section 2.5.6.3.). Similarly, three of the 12 vegetation plots occur outside of this boundary (Figure 2.5-43 in Objective 1, Section 2.5.9.3). Following a more thorough assessment of the location of this watershed boundary using detailed topographic information derived from Light Detection and Ranging (LiDAR) prior to the next survey event at the ALWC, relocation of water quality and vegetation monitoring locations to within the ALWC watershed boundary will be considered. Flark sites have not yet been established for vegetation monitoring at the ALWC. To fill data gaps, additional monitoring locations will be established to bring the total to 18 integrated vegetation and water quality monitoring locations at the ALWC, with six each in string, flark, and wooded fen types (Table 6.2-2).

Spatial integration of water quality and vegetation sampling locations was partially taken into consideration at the GGWC, with the five established water quality sampling locations situated relatively close to four of the 18 vegetation plots (i.e., GF3, GS3, GT3, GT4). As for the ALWC, additional water quality monitoring locations will be sampled near the 18 established vegetation monitoring locations, with six each in string, flark, and wooded fen types (Table 6.2-2). Existing water quality and vegetation monitoring locations at the GGWC are shown on Figures 2.5-36 and 2.5-44 in Objective 1.

To meet the requirements of a before-after-control-impact (BACI) design, data will be collected from control (i.e., ALWC and GGWC) and impact (i.e., MLWC) sites during the same time period. Therefore, the new components included in Table 6.2-2 will be added to the monitoring programs as soon as possible, and collection of pre-mining baseline data will occur at all three sites every year until development commences within the MLWC watershed, or until an adequate pre-mining baseline dataset is established.

6.2.3. Overview of Analytical Approach

Analytical approach will vary by discipline. Analytical approaches to be implemented by more than one discipline are outlined in this section, and additional, discipline-specific details and information on other analyses are included for each discipline in Section 6.3. Overall, the analytical approach will include calculation of summary statistics (e.g., mean, median, standard deviation) and normal ranges to evaluate whether data fall within the MRV as characterized for each component under Objective 1 (Section 2). In addition, temporal trends, BACI analyses, and other analyses relevant to each component will be used.

Normal ranges are used by some disciplines (e.g., water quality, aquatic resources, and vegetation) to identify the MRV and bounds within which future observations are expected to occur. For these disciplines, normal ranges were calculated to describe “normal” conditions based on pre-mining baseline data from the MLWC and reference plot data from the ALWC and GGWC, as described in Objective 1, Section 2.5.1. As monitoring progresses beyond the pre-mining baseline data collection stage, observations will be compared to the normal range to evaluate whether change is occurring. Normal ranges will be re-calculated as additional pre-mining baseline and reference site data are collected; therefore, they should not be considered static.

For all components, trends in the dataset may indicate that change is underway before a trigger is reached (triggers are discussed in detail under Objective 6 in Section 7). Trends may be assessed visually, and trend analysis will be completed using the Mann-Kendall test to evaluate whether datasets have a statistically significant monotonic increasing or decreasing trend, as applicable to each component. The Mann-Kendall test does not require data to have a normal distribution, and a two-sided hypothesis can be used to test for increasing or decreasing trends. The Mann-Kendall test analyzes the sign of the difference between later-measured data and earlier-measured data, and each later-measured value is compared to all values measured earlier.

Where applicable, a BACI experimental design (Underwood 1992) will also be implemented. This design can be used to assess short- and long-term effects at the MLWC compared to at least one reference site; this analysis does not require reference sites to have identical characteristics (Underwood 1994). Prior to statistical analysis, the residuals of the BACI linear model will be assessed for normality and homogeneity of variances. Should these assumptions not be met, the response variable will be transformed, or the test will be conducted on the ranks of the response variable.

In addition, multivariate analysis such as canonical correspondence analysis will be completed to relate plant community patterns to surface water level and/or surface water quality metrics. More information describing multivariate ordination techniques is provided in Section 6.3.5.4.

6.3. Methods

6.3.1. Hydrogeology

Groundwater levels in the non-mined portion of the MLWC vary naturally, and are expected to vary due to proposed activities at the Fort Hills Project; however, based on the mitigation system design, it is expected that effects to groundwater within the non-mined portion of the MLWC will be minimized. The hydrogeology monitoring program is designed to collect information on groundwater levels within the aquifers that provide groundwater input to and groundwater pressure support for the surface water levels within the fen. This program will collect data to generate MRVs for pre-mining baseline conditions in the groundwater aquifers and the peat within the fen. The MRV for pre-mining baseline conditions will then be used to assess whether changes to groundwater level are occurring in the monitoring network after the start of mining activities at the Fort Hills Project within the MLWC watershed.

6.3.1.1. Sampling Locations

The groundwater level monitoring locations were selected based on the following considerations:

- dominant groundwater flowpaths based on current site knowledge
- spatial coverage within the fen, including locations on both the mined- and non-mined sides of the cutoff wall
- location of the design features (cutoff wall and injection wells)
- spatial coverage in the North Outwash Plain (NOP) between the injection wells and the fen and in the Fort Hills Upland Complex (FHUC) near the fen, including consideration of the groundwater discharge zones in the FHUC
- use of existing wells, and well pairs across the peat-sand interface, where possible
- co-location with water quality sampling and surface water hydrology monitoring locations

Specifically, locations within the fen were selected to generate a transect along the length of the non-mined portion of the MLWC from the cutoff wall to McClelland Lake, and a second transect perpendicular to the first, stretching from the NOP to the FHUC. Monitoring locations within the fen include spatial integration of groundwater level, surface water level, groundwater quality and surface water quality where applicable. Early warning locations for groundwater levels were chosen to provide coverage of the groundwater conditions at the edges and outer areas of the MLWC, within the NOP sand aquifer upgradient of the MLWC, and within the FHUC aquifers upgradient of the MLWC, including assessment of dominant flow paths and hydrogeologic features. Monitoring locations were also identified within the mined portion of the MLWC to provide early warning during mine advance.

The early warning groundwater network consists of 17 locations with a total of 20 monitoring points, as detailed in Table 6.3-1.

Table 6.3-1: Early Warning Locations for Groundwater Level Monitoring

Upper Sand Wells			Peat Wells			VWP or Well	Ecohydrology Zone/Area
Well Name	**Top of Screen [m bgs]**	**Bottom of Screen [m bgs]**	**Well Name**	**Top of Screen [m bgs]**	**Bottom of Screen [m bgs]**		
GT07-092B	9.3	10.8	GT07-092C	4.9	7.9	Well	2
GT07-091B	7.0	8.5	GT07-091C	2.7	5.7	Well	2
MLWC2-P560[(a)]	5.4	5.6	MLWC4-P250	0.8	1.0	Well	2
GT07-090B	4.0	5.5	GT07-090C	1.2	2.8	Well	3
FH17-WR438-SN1[(b)] and -SN2[(b)]	27 and 12, respectively	31 and 15, respectively	N/A	N/A	N/A	Well	6
FH17-WR428-SN1	19.0	25.0	N/A	N/A	N/A	Well	NOP
PW-08-02	15.6	21.8	N/A	N/A	N/A	Well	NOP
FH19-ES614-SN1	12.5	15.5	N/A	N/A	N/A	Well	NOP
FH20-WR633-SN1	27.7	30.7	N/A	N/A	N/A	Well	NOP
MW08-12	30.0	33.1	N/A	N/A	N/A	Well	NOP
FH18-ES436-DR1[(b)]	31.5	39.9	N/A	N/A	N/A	Well	FHUC
GT07-101A[(b)]	34.2	37.2	N/A	N/A	N/A	Well	FHUC
FH20-WR672-SN1[(b)]	35.1	38.1	N/A	N/A	N/A	Well	FHUC
FH19-ES696-SN1[(b)]	7.4 and 32.5		N/A	N/A	N/A	VWP	FHUC
FH18-ES427-SN1[(c)]	22.6	25.6	N/A	N/A	N/A	Well	FHUC
FH20-WR677-SN2[(b)] and -SN3[(c)]	33.0 and 10.7, respectively	36.0 and 13.7, respectively	N/A	N/A	N/A	Well	FHUC
FH17-WR414-SN1[(b)] and -SN2[(c)]	44.7 and 17.7, respectively	47.8 and 20.7, respectively	N/A	N/A	N/A	Well	FHUC

(a) Note that this location is near the cutoff wall.
(b) Wells completed in AQ4.
(c) Well completed in AQ3.
Note: Wells not otherwise noted are completed in the upper portion of the surface sands unit.
FHUC = Fort Hills Upland Complex; m bgs = metres below ground surface; N/A = not applicable (well not available in this horizon at this location); NOP = North Outwash Plain; VWP = vibrating wire piezometer.

For integrated wetland monitoring, groundwater monitoring locations within the fen were selected. A total of nine locations with a total of 18 monitoring points are proposed, including installation of five additional peat wells. A breakdown of the monitoring points, with new required well installations noted, is provided in Table 6.3-2.

Peat wells in both networks may be replaced with a new installation if they are “floating” wells and move vertically as the fen swells and decompresses. Floating wells can result in inaccurate groundwater elevations being reported for the well. This is because groundwater elevations are measured and calculated relative to the top of well casing, which in a floating well does not represent a static elevation. The need to replace peat wells will be assessed as part of the initiation of monitoring and instrumentation.

Table 6.3-2: Integrated Wetland Monitoring Groundwater Level Locations

Upper Sand Wells			Peat Wells			VWP or Well	Ecohydrology Zone
Well Name	Top of Screen [m bgs]	Bottom of Screen [m bgs]	Well Name	Top of Screen [m bgs]	Bottom of Screen [m bgs]		
FH17-WR418-SN2	13.4	16.4	To be installed	N/A	N/A	Well	1
GT07-093B	4.1	4.9	GT07-093C	1.2	2.7	Well	2
MLWC1-P530	5.1	5.3	MLWC1-P460	4.4	4.6	Well	2
FH17-WR416-SN1	8.9	12.0	To be installed	N/A	N/A	Well	2
FH18-ES415-SN1 VVWPB	8.9		FH18-ES415-SN1 VWPC	2.1		VWP	5
FH19-ES619-SN1 VWPB	10		FH19-ES619-SN1 VWPC	4.5		VWP	5
FH17-WR420-SN1	7.6	9.1	To be installed	N/A	N/A	Well	5
MLWC4-P360	3.4	3.6	To be installed	N/A	N/A	Well	5
FH20-WR666-SN3	7.0	10.0	To be installed	N/A	N/A	Well	5

Note: Upper sand wells are targeting the upper portion of the surface sand unit
m bgs = metres below ground surface; N/A = no specific depth because the well is not yet installed; VWP = vibrating wire piezometer.

6.3.1.2. Data Collection

Groundwater wells will be equipped with a pressure transducer to record water levels. Two barometric loggers will be installed at the site to record barometric pressure for compensation of water levels. Dataloggers will record data at a minimum of every 12 hours and will be synchronized to record levels at the same time across the monitoring network.

Field measurements will occur approximately once every six months and will include manual depth to water measurements and pressure transducer downloading at all locations, including downloading of the barometric pressure transducers onsite.

The following activities will be undertaken at each well during field visits:

- documenting of well condition, including measurement of top of casing to ground surface and total well depth as potential indicators of well movement or damage, and photos of any well damage
- measuring water level from top of casing and confirming manual measurement in the field
- measuring depth to bottom of well from top of casing and confirming measurement in the field
- downloading of pressure transducer and checking data and transducer condition (damage, battery level, hanging equipment condition)
- leaving well in secure condition (i.e., locked)

6.3.1.3. Quality Assurance and Quality Control

Data quality assurance and quality control (QA/QC) will generally follow industry-standard procedures, including:

- using specific operating procedures and standard field forms for collection of data and recording field conditions
- assessing pressure transducer data for instrument drift
- checking manual depth to groundwater measurements during field visit (i.e., multiple measurements collected at the same visit)
- checking consistency between measured depth to groundwater, pressure transducer hanging depth and pressure transducer readings during every field visit

Groundwater level data will also be checked to identify data gaps and changes to transducer hanging depth over time. Data will be annotated to ensure periods of water level changes due to purging and water quality sampling are clearly identified in the data record, to ensure that data used for assessment of pre-mining baseline conditions are not affected by sampling procedures. Similarly, when new wells are drilled next to existing wells, data assessment will be conducted to ensure any effects from drilling are removed from the pre-mining baseline assessment dataset.

Depth to well bottom measurements will be checked to identify whether wells have collected silt or may be damaged; this will be noted, and the well will be identified for redevelopment/purging if recommended. Well condition will also be checked after the field event, including photographs and measurements of top of casing to ground surface; wells that are damaged or appear to have moved relative to ground surface will be annotated, and further work on the well will be conducted to investigate the issue and repair or replace the well as required.

6.3.1.4. Analytical Approach

Manual water levels measured during each monitoring event will be used to correct pressure transducer data and calculate groundwater elevations. Each dataset will be reviewed, and any required basic corrections will be completed and annotated. If required, adjustment for pressure transducer drift will be applied to the data. Comparison of manual measurements to recorded data will be undertaken, and data identified as affected by sampling methods, well installations, or other factors will be removed from the baseline assessment dataset. The raw data will be kept as an original record, and the annotated dataset will be clearly identified.

After annotation and culling of raw data, barometric pressure compensation will be applied to the data to produce a final dataset for assessment.

For assessment of changes in groundwater level, data from peat/sand well pairs will be used to calculate the vertical gradients in the pair. These data will be used to generate the measured range in vertical gradients for a well pair over the pre-mining baseline data collection period. For locations with a single well, groundwater elevations at the well will be used to generate a measured range to describe pre-mining baseline conditions. Groundwater level data will be used to detect change in individual monitoring wells (groundwater elevations), or in monitoring well pairs (vertical gradient).

6.3.2. Surface Water Hydrology

Surface water in the non-mined portion of the MLWC may vary both naturally and due to Fort Hills Project activities. The surface water hydrology monitoring component is intended to target the key stressors related to wetland moisture regime, water level and hydrological connectivity within the MLWC. The objective of the surface water hydrology monitoring component is to determine if key drivers, such as development within the McClelland Lake watershed, may impact water level or hydrological connectivity in a manner that changes the moisture regime in the non-mined portion of the MLWC.

Water levels in the MLWC fluctuate throughout the year and between years. Typically, peak seasonal water levels are observed following spring snowmelt and then decrease as water is lost to outflow, infiltration, or evaporation/ evapotranspiration. The degree of saturation and persistence of ponding throughout the snow-free season are important determinants of moisture regime and wetland function.

The MLWC is hydrologically connected to other parts of the watershed (e.g., FHUC and NOP or other wetlands) through both surface and groundwater pathways. The presence, absence, and pattern of these connections influence the local moisture regime of the MLWC.

The climate regime (i.e., precipitation, temperature, and other variables), is one of the main drivers determining the hydrology and influencing the ecological conditions in the McClelland Lake watershed. Hence, characterizing and quantifying the climate regime is crucial to the understanding of the watershed characteristics and hydrologic processes in the watershed. Specifically, estimating the statistical indicators for the most relevant climate variables is important.

Although climate variables are not directly used as indicators, climate data are important complementary information to understand surface water hydrology drivers and stressors for the watershed. The following climate variables will be measured as part of this monitoring program:

- Precipitation (total precipitation, rainfall, and snowfall) is the main input in the watershed water balance and influences the amount of runoff in the watershed.
- Air temperature influences the quantity of accumulated snow, the timing of snow melt, and the evapotranspiration or evaporation processes from the watershed.
- Solar radiation, relative humidity, and wind speed also influence snow melt, evapotranspiration, and evaporation.
- Wind direction plays an important role in snow redistribution patterns within the watershed and energy available for evaporation or evapotranspiration.

Characterizing the climate regime at a given location requires a long-term (i.e., sometimes extending up to several decades) continuous record of data; however, complete long-term climate data for all climate variables seldom exist at a specific location. The standard approach to derive and characterize climate data at a specific location with limited data consists of establishing a regional relationship, based on available shorter-term recorded data that include sufficient spatial and temporal variation at several stations, and use of this relationships to transfer data to the study site (e.g., transfer data from Fort McMurray A station to McClelland Lake watershed).The regional transfer approach has been applied many times in hydrological studies completed for the oil sands region in general, and for the McClelland Lake watershed in particular.

6.3.2.1. Sampling Locations

Inflows and outflows at McClelland Lake are currently measured following industry-standard guidelines. Water levels have been recorded at the outlet of McClelland Lake since 1997, and within the fen to the southwest of McClelland Lake and the unnamed lake south of McClelland Lake since 2018.

Additional water level measurements at nine locations within the fen (Figure 6.2-1) are recommended to capture the variation of water level across the fen and the effects of planned mitigation during operation of the Fort Hills Project. Overall, nine monitoring locations within the fen (three for early warning monitoring and six for integrated wetland monitoring) plus two existing flow monitoring locations associated with McClelland Lake are proposed for inclusion in the effects monitoring program, for a total of 11 surface water hydrology monitoring locations.

Existing climate monitoring stations within the McClelland Lake watershed include a climate station installed as part of the Regional Aquatics Monitoring Program (RAMP) that has been in operation since 2002, and seven stations installed by Suncor in 2018 throughout the watershed to improve the understanding of spatial and temporal variation of climate variables.

In addition, quasi-direct measurements of evapotranspiration rates using eddy-covariance towers were completed at two locations within the watershed. The towers also include equipment for measuring net radiation, relative humidity, air temperature, and wind velocity, at the same location to allow a direct comparison between these quasi-direct measurements and standard theoretical models.

Lake water levels have been measured at the ALWC reference site since 2018. Monitoring at Audet Lake will continue and monitoring at Birch Lake will be added to the effects monitoring program. In addition, monitoring of wetland water levels at the ALWC and GGWC will be included as a component of the effects monitoring program. Climate data have been collected from the ALWC since 2018, and from the Gordon Lake Lookout station since 2010. The monitoring stations within the McClelland Lake watershed and at the ALWC and GGWC reference sites are expected to be maintained during the operation and closure of the Fort Hills Project.

6.3.2.2. Data Collection

Continuous monitoring stations for water levels and flows will each be equipped with a pressure transducer to measure water level, and a datalogger to record the data. The surface water monitoring stations will be tied to groundwater monitoring location. If the locations of the groundwater monitoring wells change, surface water monitoring locations may also be adjusted.

Field measurements will occur approximately once every two months, and will consist of water level (i.e., at all locations) and flow (i.e., for South Creek discharges to McClelland Lake) measurements, and datalogger download. The velocity-area method will be used to measure discharge in the field (i.e., the discharge from South Creek to McClelland Lake). A minimum of 20 measurements within “panels” will be made in each cross-section. Discharge in panels will be summed to calculate total discharge through the channel.

Stage will be manually measured in the field with an engineer’s level, and water elevation will be referenced to benchmarks. Benchmark elevation, water level, and pressure transducer elevation will be tracked through time to assess channel and station stability. Water level will be logged every 15 minutes with OTT HydroMet pressure transducers. The existing stage-discharge relationships (SDR) will be updated using manual flow and level measurements. Continuous discharge will then be derived using the SDR. The SDR will be refined as additional flow measurements and water level surveys become available.

The following activities will be undertaken at the water level and flow monitoring stations during each field visit:

- documenting of station condition, including depth of ice, vegetation, large woody debris, and beaver activity near the station
- surveying of water level at the logger relative to established station benchmarks
- measuring discharge
- checking stage and discharge measurements against the existing rating curve for each station
- downloading dataloggers and checking data
- checking that loggers are in working order and performing maintenance if required
- marking benchmarks clearly

Data collection from the climate stations currently operated within the McClelland Lake watershed and at the ALWC reference site will continue during operation of the Fort Hills Project and implementation of the effects monitoring program. Operation of the Gordon Lake Lookout station, which is not owned by FHEC, is expected to continue for the same time period; however, if the station is decommissioned, other options will be evaluated to continue monitoring climate near the GGWC. Most climate stations operate year-round; however, rainfall and evapotranspiration instruments operate only from April to October at some stations. All stations are equipped with telemetry, and data are stored in a database in near-real time.

In addition to local monitoring stations, climate data are also collected from several regional monitoring stations, which could be used to establish regional relationships and to fill any data gaps at the local stations.

6.3.2.3. Quality Assurance and Quality Control

Data QA/QC will generally follow industry-standard and ISO 9001:2015 procedures, including:

- using specific operating procedures for taking measurements and rating the quality of individual discharge measurements
- verifying the calibration curves for pressure transducers
- checking consistency between water level surveys and pressure transducer readings during each field visit
- replacing the pressure transducers with calibrated sensors where required
- checking manual measurements against stage-discharge rating curves
- revising the rating curves because of changes in channel geometry, beaver dams, obstructions, or roughness
- comparing hydrographs calculated from continuous water level measurements and the rating curve with manual measurements on the same plot to check for consistency

- comparing to hydrographs calculated for different stations in the same region to identify anomalies and verify similarity in the timing and magnitude of runoff responses

Hydrometric data will also be checked to identify data gaps and compare the data graphically over the period of record with data from adjacent stations to check that the data are suitable for their intended use in verifying the hydrological model results and calculating summary statistics.

The QA/QC of climate data collected for the study site is important as a few weeks of missing or faulty data in one year are sufficient to compromise the usefulness of data collected for the rest of the year, and could limit the ability to derive and characterize climate statistics. Therefore, timely QA/QC of recorded data will help to identify and correct any data issues.

Data QA/QC will generally follow industry-standard and ISO 9001:2015 procedures, including:

- documentation of field activities, including maintenance of site visit records, data processing, station characteristics, and station history
- recording of field data on standardized data sheets or tablets
- entering data and importing of discrete measurements and time series into a database
- screening of measurement results against a series of tests, including threshold, temporal, internal, and spatial consistency tests

The climate stations will be visited during each surface water quantity sampling event to observe the physical condition of the station and perform routine maintenance such as leveling, tightening shoring, and removing debris from the tipping bucket rain gauges (TBRG). Climate instruments will be calibrated according to the manufacturer's recommendations.

Recorded climate data used for this study will be further checked to identify and fill data gaps using near-by regional data. Data will be compared graphically over the period of record with data from other climate stations to assist with identifying outliers and visually check for errors and potential bias in the record.

The QA/QC procedures for data entry will include a 100% re-check on all hardcopy and electronic data collected to verify accurate transcription from field collected data sheets and digital formats.

6.3.2.4. Analytical Approach

Manually collected data from water level surveys completed during each visit will be used to correct water level time series data collected using data pressure transducers. Each water level elevation survey will consist of two sets of measurements relative to two to three established benchmarks at each station, with an acceptable level of difference of less than 0.004 m between the two sets. If the difference in water level elevation surveyed from two or three benchmarks is more than 0.004 m, the survey will be repeated until the difference is within the acceptable range.

Water level records will be reviewed, and basic corrections will be made in the water level database. Manual water level surveys completed during each field visit will be used to verify and correct datalogger water levels. The water level time series data recorded by the dataloggers may be adjusted to account for sensor drift or fouling, if required. If the datalogger was found above the water level (e.g., if the stream runs dry), the water level data for that period would be deleted, since the data recorded by datalogger will be erroneous.

The previously developed SDR curves will be updated using open-water manual discharge and water level measurements, and stage shifts applied where needed. Stage shifts will be applied to the SDR curve to account for scour and backwater conditions observed in the field; these are usually applied if manual measurements deviate by at least 5% from the stage-discharge relationship. The final step in data analysis will be to correct and finalize the discharge time series data.

Analysis for climate data will include:

- correction for wind effect on precipitation that could result in under-catch for unshielded TBRGs
- in the short-term, extending the data compilation of this study with a more detailed analysis of correlations between local and more regional precipitation records
- analysis of other climate parameters, including snow depth survey data, evapotranspiration, net radiation, air temperature, and wind data measured at existing climate stations
- in the long-term, complete analysis using additional monitoring data as data become available on a regular basis to update the reference local climate statistics

Data analysis will be carried out for each month of the year, for individual significant storm and snowfall events, and for particularly wet and dry periods. Additional regional stations will be included to characterize spatial variability and to develop reliable relationships that can be used to transfer long-term recorded data from the regional stations to the local stations.

The water level, flow and climate time series data will be used to calculate weekly, monthly, and annual flow statistics. The data will also be used to determine range of variation and trends, compare the results to the pre-mining baseline conditions, and assess changes in water level due to the Fort Hills Project.

6.3.3. Water Quality

Surface and groundwater quality in the non-mined portion of the MLWC may be affected by the mine development and operations (assessment of potential impacts of mine development is detailed under Objective 3). Key water quality drivers considered for this monitoring program include changes in water quality due to land disturbance, changes in surface and groundwater levels, construction of the cutoff wall, and installation and operation of injection wells. The effects monitoring program has been designed to detect water quality changes in the non-mined portion of the MLWC and determine whether these changes are a result of activities associated with the Fort Hills Project. Alterations in water quality due to mine activities may affect wetland plant community characteristics. The surface and groundwater quality component of the effects monitoring program consists of monitoring water quality in the MLWC and comparing values to triggers defined in Objective 6.

6.3.3.1. Sampling Locations

The proposed water quality sampling locations are intended to provide sufficient spatial coverage within the fen to characterize effects to surface water quality and are integrated with surface water hydrology, groundwater levels, and vegetation monitoring to understand interdisciplinary linkages.

For early warning monitoring, groundwater quality samples will be collected from seven locations integrated with groundwater level monitoring and surface water quality samples will be collected from three locations integrated with vegetation monitoring (Figure 6.2-1). The intent of these early warning monitoring locations is to identify changes to surface water and groundwater quality associated with mining activities before changes occur in the patterned fen.

For integrated wetland monitoring, groundwater and surface water quality samples will be collected from 16 locations integrated with groundwater level, surface water hydrology, and/or vegetation monitoring locations (Figure 6.2-1).

For grid-based wetland monitoring, surface water quality samples will be collected from either the full or partial grid during each sampling event, in coordination with vegetation monitoring (Section 6.3.5); more details on monitoring frequency are provided under Objective 6 (Section 7). Groundwater quality samples will not be collected for grid-based wetland monitoring.

For lake monitoring, two composite samples will be collected from three to five representative locations within the lake for water chemistry (one from the shallow area and one from deep area; Figure 6.2-1), depth profiles of field-measured parameters within water column at the deepest location, and one depth-integrated composite sample for chlorophyll *a* at each location. In addition, one water quality sample will be collected from the shore of McClelland Lake (Figure 6.2-1).

In addition to water quality monitoring at the MLWC, surface water quality monitoring will occur at ALWC and GGWC. At the two reference sites, surface water quality samples will be collected from the fen area at monitoring stations co-located with vegetation monitoring locations, as well as from Audet Lake and Birch Lake (Table 6.2-2).

6.3.3.2. Data Collection

Surface water quality monitoring will consist of in-situ water quality measurements and sample collection for laboratory analysis at each established monitoring location. Wetland water quality samples will be collected from pooled water or shallow wells installed at each monitoring location, groundwater samples will be collected from selected groundwater wells completed in peat and/or sand, and lake water quality samples will be collected from discrete locations within the lake area.

During planning, collection, and transport of water quality samples, established sampling techniques and procedures will be followed, as per provincial and federal protocols (AENV 2006; RAMP 2009; CCME 2011). These procedures are summarized by FHEC in the *Standard Operating Procedures for Field Sampling* (FHEC 2015). For field measurements, handheld water quality meters will be calibrated and operated according to the manufacturer instructions.

Surface water quality samples in the wetland will be collected from pooled water (if present) or shallow wells using groundwater sampling procedures. Prior to sample collection, each monitoring well will be purged using a low-flow groundwater sampling protocol to remove stagnant water so that near-surface samples are representative of fen water conditions.

Groundwater quality samples in the wetland will be collected using low-flow groundwater sampling protocols. At each sampling well, the initial depth of water will be measured using an electric water level meter. Prior to sample collection, each monitoring well will be purged at a constant rate (less than 1 litre per minute [L/min]) and drawdown will be recorded to ensure it does not exceed 0.1 m. During purging, field measurements of water quality parameters (temperature, pH, and specific conductivity) will be collected on each tube length volume until the measurements are stable over at least three consecutive readings. Purging and field measurements will continue until stabilization is reached or a maximum of five tube volumes. Purged non-saline water will be disposed on site. Once the parameters have stabilized, samples will be collected for analysis. Water quality samples will be prepared in the field (e.g., field filtered, preserved) as per laboratory instructions.

Lake sampling will consist of two composite water quality samples collected from three to five representative locations within the lake (i.e., one from the shallow area and one from the deep area). Lake bathymetry data confirmed by depth measurements in the field will be used to confirm the shallow and deep areas of the lake. Within each area, sampling locations will be separated spatially by a minimum of 200 m (Figure 6.2-1). At each location, water depth and field water quality measurements will be recorded, and water quality samples will be collected from mid-depth using a boat. A PVC Kemmerer sampler will be used to collect discrete water samples at the required depth. A depth profile of field-measured parameters within the water column will be recorded at the deepest location within the lake, and one depth-integrated composite sample for chlorophyll *a* will be collected at each location.

Field in-situ water quality measurements will be recorded at each sampling location and water quality samples will be submitted to accredited laboratories for the following analytical tests (primary effect indicators):

- In-situ wetland and lake water quality measurements:
  - pH
  - specific conductivity[1]
- Wetland and groundwater quality samples for laboratory analysis:
  - electrical conductivity
  - alkalinity
  - total dissolved solids
  - base cations (dissolved calcium, magnesium, potassium, and sodium)
- Lake water quality samples for laboratory analysis:
  - electrical conductivity
  - alkalinity
  - base cations (dissolved calcium, magnesium, potassium, and sodium)
  - chlorophyll *a*

Selection of these analytical parameters is discussed in detail under Objective 2 (Section 3). Additional parameters may be collected as complementary data (as detailed in Objective 2) as needed based on the assessment of results and as part of the response framework described under Objective 6 (Section 7).

6.3.3.3. Quality Assurance and Quality Control

The QA/QC practices determine data integrity and are relevant to all phases of the monitoring program from sample collection to data analysis and reporting. Quality assurance encompasses management and technical practices designed to verify that the data generated are of consistent high quality. Field data

[1] Temperature compensated electric conductivity (corresponding to 25°C)

will be recorded on standardized field data sheets or tablets, according to established field record-keeping procedures. Data management and data review processes will use standardized data manipulation/summary tools, filling of data and project information according to established protocols to provide an organized, secure, and consistent system of data storage.

Quality control includes the procedures used to measure and evaluate data quality. Appropriate methods will be used during planning, collection, and transport of water quality samples. The QC samples collected as part of the water quality program will consist of field duplicate samples, field blank and trip blank samples. Field duplicate samples will be used to check within-site variation and the precision of field sampling methods and laboratory analysis. Field blank samples will be used to detect potential sample contamination during sample collection, handling, shipping, and analysis. Trip blank samples will be used to detect any widespread contamination resulting from the containers, preservatives, or field conditions during transport and storage. The number of QC samples collected will be at least 10% of the total number of samples submitted for analysis. The QC samples will be collected throughout the field sampling program and analyzed for the same suite of parameters as the test samples.

6.3.3.4. Analytical Approach

Data analyses of surface and groundwater quality data will generally follow the analytical approach described in Section 6.2.3. Water quality changes will be assessed by comparison to the normal ranges defined from the pre-mining baseline dataset at the MLWC, and regional normal ranges based on data collected from the ALWC and GGWC. Normal ranges were calculated for each water quality indicator within each EHZ (methods and results are detailed under Objective 1). Spatial differences will be assessed using the BACI statistical design and data will be analyzed using both a BACI model and comparisons to normal ranges as described in Section 6.2.3, separated by fen type. Normal ranges will be calculated using “before” data from the MLWC and reference sites, and “after” data from the reference sites. When sufficient temporal data have been collected, the Mann-Kendall test will be used to assess temporal trends in water quality.

Water quality data collected for early warning monitoring will be used to detect changes in water quality due to injection wells and the cut-off wall. Water quality data collected for integrated wetland monitoring will be used to define long term trends and compare pre-mining baseline data to the construction and operation period for the Fort Hills Project. Water quality data collected at the lake will also be compared to guidelines for the protection of aquatic life and wildlife health. Changes in water quality will also be assessed through temporal trends and comparison among sampling locations. Water quality results that fall outside the normal range will be addressed following the response framework described under Objective 6 (Section 7).

6.3.4. Aquatic Resources

Primary productivity in McClelland Lake may be affected by mine development and operations (assessment of potential impacts of mine development is detailed under Objective 3). Key drivers considered for this monitoring program include changes in water quality and surface water levels. The effects monitoring program has been designed to detect changes in chlorophyll *a* concentration in McClelland Lake and evaluate whether these changes are a result of activities associated with the Fort Hills Project. The aquatic resources component of the effects monitoring program consists of monitoring chlorophyll *a* concentration in McClelland Lake, Audet Lake and Birch Lake, comparing values to normal ranges, assessing spatial differences among lakes using a BACI model, assessing trophic status, and identifying temporal trends.

6.3.4.1. Sampling Locations

Chlorophyll *a* samples will be collected from McClelland Lake, Audet Lake and Birch Lake in conjunction with surface water quality samples, as detailed in Section 6.3.3.1, and will include three to five surface water quality locations.

6.3.4.2. Data Collection

A depth-integrated water sample will be collected for chlorophyll *a* analyses from the euphotic zone at each sampling location. The depth of the euphotic zone will be estimated as two times the Secchi depth. A PVC Kemmerer sampler will be used to collect discrete water samples starting at the surface, and at 1 m depth intervals through the euphotic zone. If the total water column depth is less than the euphotic zone depth, water samples will be collected at 1 m depth intervals to approximately 1 m above the lake bottom. Equal volumes of the water from each depth will be combined into the bucket to create a depth-integrated composite sample. Samples will be processed and submitted for laboratory analysis.

6.3.4.3. Quality Assurance and Quality Control

The QA/QC practices determine data integrity and are relevant to all phases of the monitoring program from sample collection to data analysis and reporting. Quality assurance encompasses management and technical practices designed to verify that the data generated are of consistent quality. Field data will be recorded on standardized field data sheets or tablets, according to established field record-keeping procedures. Data management and data review processes will use standardized data manipulation/summary tools. Data and project information will be stored according to established protocols to provide an organized, secure, and consistent system of data storage.

Quality control includes the procedures used to measure and evaluate data quality. Appropriate methods will be followed during planning, collection, and transport of water quality samples. The QC samples will consist of duplicate samples used to check within-site variation and the precision of field sampling methods and laboratory analysis. The number of QC samples collected will be at least 10% of the total number of samples submitted for analysis.

At a randomly selected station, two water samples (i.e., field duplicates) will be collected, filtered, and analyzed separately for QC purposes.

6.3.4.4. Analytical Approach

Chlorophyll *a* concentrations in McClelland Lake will be compared to the MRV for chlorophyll *a* in McClelland Lake developed from pre-mining baseline data that describe “normal” conditions using methods described in Objective 1, Section 2, to assess whether concentrations fall outside of the normal range. Spatial differences in chlorophyll *a* concentration between McClelland Lake and reference lakes over time will also be assessed using a BACI model as described in Section 6.2.3.

Additionally, trophic status will be assessed for McClelland Lake and reference lakes based on chlorophyll *a* concentration and supporting information (e.g., total phosphorus). When sufficient temporal data have been collected, the Mann-Kendall test will be used to assess temporal trends in chlorophyll *a* concentrations.

Spatial and temporal trends in chlorophyll *a* concentration will be examined annually using time series plots. Concentrations in McClelland Lake, Audet Lake, and Birch Lake will be compared to trophic classification categories. Total phosphorus concentrations, and other supporting data will be referenced in support of the trophic classification.

6.3.5. Vegetation

Plant community characteristics in the non-mined portion of the MLWC may be affected by mine development and operations. Specifically, changes in surface water hydrology or water quality may affect plant community characteristics through changes in moisture regime and wetland water chemistry. The vegetation component of the effects monitoring program will include vegetation surveys at permanent wetland monitoring locations from which vegetation data have been collected since 2008. Surface water quality data will also be collected from the permanent vegetation monitoring locations, which will allow for interpretation of vegetation results in consideration of surface water quality characteristics. In addition, vegetation data will be collected from grid-based plots to add spatial coverage beyond the permanent vegetation monitoring locations and characterize the plant community in relation to water quality characteristics between sampling events at the permanent vegetation monitoring locations. To complement MLWC vegetation data from permanent vegetation monitoring locations, vegetation data will also be collected from the ALWC and the GGWC. If changes in the plant community are documented, a mitigation response may be triggered, as described under Objective 6 (Section 7).

6.3.5.1. Sampling Locations

For permanent vegetation monitoring locations, vegetation data will be collected from 12 existing locations at the MLWC (Figure 6.2-1; Table 6.2-1 and Table 6.3-3). Each of the six existing permanent vegetation monitoring locations in the patterned portion of the fen includes one string site and one flark site, while each of the six existing permanent vegetation locations in the wooded portion of the fen includes one wooded fen site, for a total of 18 sites.

For grid-based monitoring, vegetation data will be collected from either the full grid established by Vitt and House (2020) (64 locations) or a partial grid (20 locations; Figure 6.2-1); monitoring frequency and full vs. partial grid sampling is discussed under Objective 6 (Section 7). For the full grid, 21 locations are within EHZ 1 and 43 locations are within EHZ 2 (Figure 6.2-1). For the partial grid, eight locations are within EHZ 1 and 12 locations are within EHZ 2 (Figure 6.2-1); five of the locations to be included in the survey of the partial grid were selected because of their potential to show early signs of change (Vitt 2021, pers. comm.). At each grid location, separate plots will be surveyed in string and flark fen types.

Vegetation data will also be collected from permanent vegetation monitoring sites at the ALWC and GGWC reference sites. As outlined in Table 6.2-2, eighteen permanent vegetation sites will be surveyed at each reference site in string, flark, and wooded fen types. The eighteen vegetation sites were previously established at the GGWC, while flark sites need to be added at the ALWC to complement previously established string and wooded fen site types. Methods will follow those described for permanent vegetation monitoring locations in Section 6.3.5.4.1.

Table 6.3-3: Permanent Vegetation Monitoring Locations

Location Identifier	Site Identifier	Plot Identifier	Fen Type
X1	X1S	X1S-A	String
		X1S-C	
	X1F	X1F-A	Flark
		X1F-C	
W2	W2S	W2S-A	String
		W2S-C	
	W2F	W2F-A	Flark
		W2F-C	
S3	S3S	S3S-A	String
		S3S-C	
	S3	S3F-A	Flark
		S3F-B	
S6	S6S	S6S-A	String
		S6S-B	
	S6F	S6F-A	Flark
		S6F-C	
S7	S7S	S7S-A	String
		S7S-B	
	S7F	S7F-A	Flark
		S7F-C	
T1	T1S	T1S-A	String
		T1S-B	
	T1F	T1F-A	Flark
		T1F-C	
S4	S4	S4-A	Wooded
		S4-C	
T2	T2	T2-A	Wooded
		T2-C	
S5	S5	S5-A	Wooded
		S5-C	
T3	T3	T3-B	Wooded
		T3-C	
O1	O1	O1-A	Wooded
		O1-C	
R4	R4	R4-A	Wooded
		R4-B	

6.3.5.2. Data Collection

6.3.5.2.1. Permanent Vegetation Monitoring Locations

Permanent vegetation monitoring locations are organized at three spatial scales: subplot, plot, and site. Ten ground subplots and three shrub subplots comprise each plot, and two spatially proximate plots comprise each site.

Percent cover of all woody species (excluding prostrate shrubs) occurring within the shrub layer (i.e., less than 3.0 m tall) will be recorded within the 4 m x 4 m (16 m^2) shrub subplot, including overhanging foliage of shrubs not rooted in the plot and for tree species less than 3.0 m in height. Percent cover of vascular plant species (including prostrate shrubs) will be recorded within each 1 m x 1 m (1 m^2) ground subplot. Percent cover values will be recorded for all terrestrial bryophyte and lichen species within the same ground subplot. Percent cover will be estimated to the nearest 5% for species occupying 10% or more of the plot, or to the nearest 1% for species occupying less than 10% of the plot. For species occupying less than 1% of the plot, cover will be assigned as 0.5%. Individual species cover cannot exceed 100%; however, cumulative cover for all species can exceed 100% due to foliage overlap. In cases where species cannot be identified in the field, specimens will be collected from outside the ground subplot, if possible, for identification in the office or herbarium.

6.3.5.2.2. Grid-Based Vegetation Plots

Grid-based wetland monitoring locations are distributed evenly throughout the non-mined patterned portion of the MLWC. Two plots comprise each location, one in each of the string and flark components of the fen. Within each grid-based vegetation plot, vegetation characteristics and surface water characteristics will be measured or documented.

Vegetation Characteristics

Abundance of trees (tamarack) will be determined by counting the number of individuals (living and dead) occurring on the associated string for a distance of 10 m.

Abundance of all plant species (including woody species, vascular plant species, and non-vascular plant species) will be estimated from within a 2 m diameter circular plot. Estimates of percent cover will be recorded to the nearest 5% and will be recorded as 0.5% if trace amounts are present. Individual species cover cannot exceed 100%; however, cumulative cover for all species can exceed 100% due to foliage overlap. In cases where species cannot be identified in the field, specimens will be collected from outside the ground subplot, if possible, for identification in the office or herbarium.

Surface Water Characteristics

Water samples will be collected from each grid-based vegetation plot, and the water quality parameters identified in Section 6.3.3.2 will be analyzed. Depth to water table (i.e., distance of ground surface above or below the water surface) will be measured at each plot using a ruler; measurements will be taken from the moss or bare peat surface, whichever is highest. Measurements will be taken at two locations beside each plot (i.e., one plot in each of the string and flark fen types) and the two measurements will be averaged together for that plot.

6.3.5.3. Quality Assurance and Quality Control

At the beginning of each day, surveyors will perform and record a calibration of cover estimates; known calibration charts will be examined, surveyors will together estimate cover of one quadrat and compare their estimate to the chart, then surveyors will individually estimate cover in one quadrat and compare estimates to each other and the chart (U.S. EPA 2019). Vegetation data will be collected digitally in the field, using data forms with species look-up tables to help reduce data entry errors. The species look-up tables will follow scientific and common names used by Alberta Conservation Information Management System (ACIMS) (ACIMS 2018). All data forms will be reviewed for completeness and accuracy prior to leaving a plot, and screenshots of data forms will be taken upon completion of each site. Screenshots will be automatically uploaded to the cloud, serving as a backup to ensure the original data remain available. Data forms will also be checked at the end of each field day and traded between crew leads to check for errors, omissions, and inconsistencies among surveyors. Data forms will be downloaded daily.

Upon completion of the field program, data checks will be implemented to search for outlying values or incorrectly entered species names. At permanent vegetation plots, species lists will be compared in the field to those from previous years to check that species are not misidentified and cover incorrectly assigned to a morphologically similar species, and that species with relatively low cover values are not unintentionally omitted by the surveyor. Bryophyte collections will be made, and specimens will be identified by a taxonomic expert to help reduce some of the species identification issues noted in the vegetation dataset under Objective 1 (Section 2).

6.3.5.4. Analytical Approach

6.3.5.4.1. Permanent Vegetation Monitoring Locations

The analytical approach for permanent vegetation monitoring locations will follow a BACI experimental design, and data will be analyzed using both a BACI model and normal ranges as described in Section 6.2.3, separately by fen type. Normal ranges will be calculated using “before” data from the MLWC and reference sites, and “after” data from the reference sites.

Plant Community Assessment

Plant community composition can be evaluated using multivariate analytical techniques that simultaneously examine the responses of many variables (e.g., species in a plant community) to environmental gradients. Ordination is a type of multivariate analytical tool that provides a graphical means of assessing patterns in relationships between plant species and the underlying environmental gradients that may be influencing these patterns. Plots that are most similar to each other are grouped closer together on ordination axes, while those that are less similar appear farther apart. Non-metric multidimensional scaling is an ordination technique that is particularly well-suited to non-normally distributed ecological data (e.g., plant community data) (McCune and Grace 2002), and it may be used to visualize relationships among plant communities at the plot level and/or site level. Trace species occurrences will be removed from plant community assessments because species present with low cover can be overlooked during vegetation surveys, leading to erroneous interpretation of results from the same plot over multiple years (Vittoz and Guisan 2007).

Additional analyses may be carried out to evaluate plot-level and site-level differences in plant community composition to complement ordination results. These additional analyses may include canonical correspondence analysis or constrained correspondence analysis combined with a multiple regression to identify relationships between plant community characteristics and surface water level or water quality metrics, or permutational multivariate analysis of variance (PERMANOVA), a non-parametric multivariate test, to test for differences between groups. In addition, basic descriptive statistics and changes in ratios of vegetation groups over time will be used to identify changes in plant community composition and possible trends. Plant community composition will be evaluated using PC-ORD software (McCune and Mefford 2018) or R software (R Core Team 2020).

Four plant indicator groups were identified based on known species habitat preferences and EHZ fidelity (Vitt and House 2020); the indicator groups are defined as string indicators, moderate-rich fen water chemistry indicators, extreme-rich fen water chemistry indicators, and nutrient eutrophication indicators (discussed in more detail under Objective 1, Section 2). Percent cover for each indicator group for each plot will be determined by summing average cover values for each species within an indicator group. Normal ranges will be calculated for each indicator group.

6.3.5.4.2. Grid-Based Vegetation Plots

Similar analytical approaches to those described above for the permanent vegetation plots will be followed for the grid-based vegetation plots for measured plot attributes (i.e., vegetation characteristics and surface water characteristics). However, unlike the permanent vegetation plots, which follow a BACI experimental design and consider reference site data, data from grid-based vegetation plots will be compared to normal ranges calculated using data from only the MLWC grid-based vegetation plots.

6.3.6. Environmental, Social, Cultural, and Traditional Economic Values and Land Use

The SC, with the support of the AAG and TAG, is working to develop a methodology for monitoring and assessing ESCT indicators (a list of ESCT indicators is included in Table 6.3-4). Work to define methodologies and logistics for these indicators continues at the SC. At the time of writing, the approach has not been determined, and the AAG is developing a set of questions for use in a Community Observation Log or in land user interviews. FHEC is committed to continue to support this work to define methodologies and logistics, and to work with the SC to implement.

Table 6.3-4: Environmental, Social, Cultural, and Traditional Economic Values and Land Use Indicators

Category	Indicator
Ice	Ice thickness on the lake – thickness in time and space, trends and variability
	Timing of ice – date of ice on/off
Water use	Access to and use of clean water in the fen, wetland and McClelland Lake, including ice/snow
Aquatic resources	Waterfowl – abundance, health and behaviour
Vegetation health and usability	Changes in single plant species; focus on plants important to Indigenous communities at gathering locations; health is defined as contaminants and good nutritional and medicinal components for evaluation; usability (protocol and preference)
Plant harvesting (consumption, medicinal, ceremonial plants)	Accessibility to harvest sites and change in harvest effort
Wildlife health	Moose, beaver and muskrat health, abundance and usability

Table 6.3-4: Environmental, Social, Cultural, and Traditional Economic Values and Land Use Indicators

Category	Indicator
Hunting	Harvest effort; change in usability of hunted products; community observation logs of eggs; quality and taste of meat/eggs; usability of fur, feathers and other parts of wildlife; seasonal changes in moose hunting or waterfowl hunting; increased conflict and competition use with non-Indigenous users; change in purpose of hunting; use of traditional practices related to hunting (before harvest, after kill, preparing meat, sharing meat); use of traditional names and language specific to hunting
Trapping	Harvest effort; usability of fur and other parts of furbearers; use of traditional practices related to trapping; use of traditional names and language specific to trapping
Indigenous culture and habitation	Maintain culture; maintain and access important gathering places, ceremonial sites, sacred sites, and historic sites; sense of place
Education and learning	Transfer of Indigenous knowledge
Health and wellness	Ability to practice and enjoy, food security, spiritual well being

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ABBREVIATIONS, ACRONYMS, AND UNITS

Abbreviations and Acronyms

Abbreviation/Acronym	Definition
AAG	Aboriginal Advisory Group
ACIMS	Alberta Conservation Information Management System
AENV	Alberta Environment
ALWC	Audet Lake Wetland Complex
BACI	Before-after-control-impact
CCME	Canadian Council of Ministers of the Environment
e.g.,	for example
EHZ	Ecohydrology Zone
ESCT indicator	environmental, social, cultural, and traditional economic values and land use indicator
Fort Hills Project	Fort Hills Oil Sands Project
FHEC	Fort Hills Energy Corporation
FHUC	Fort Hills Upland Complex
GGWC	Gipsy Gordon Wetland Complex
i.e.,	that is
ITK	Indigenous Traditional Knowledge
LiDAR	Light Detection and Ranging
MLWC	McClelland Lake Wetland Complex
MRV	Measured range of variability
NOP	North Outwash Plains
OP	Operational Plan
QA/QC	quality assurance and quality control
RAMP	Regional Aquatics Monitoring Program
SC	Sustainability Committee
SDR	stage-discharge relationships
TAG	Technical Advisory Group
TBRG	tipping bucket rain gauges
VWP	vibrating wire piezometer

Units

Unit	Definition
%	percent
<	less than
L/min	litres per minute
m	metre
m bgs	metres below ground surface
m^2	square metre