FORT HILLS ENERGY CORPORATION
FORT HILLS OIL SANDS PROJECT

McClelland Lake Wetland Complex Operational Plan Objective 1

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McClelland Lake Wetland Complex Operational Plan

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2. OBJECTIVE 1: DEFINE BASELINE CONDITIONS

Baseline conditions are the conditions that exist before an activity takes place, and that may be used as a point of reference in the future. For the Operational Plan (OP), a distinction is drawn between pre-development baseline conditions (i.e., conditions occurring before the influence of oil sands development, defined temporally as 1960 or earlier) and pre-mining baseline conditions (i.e., conditions including existing anthropogenic disturbances and effects on the natural environment, prior to mining in the McClelland Lake Wetland Complex (MLWC) watershed, defined temporally by the timelines captured in monitoring or modelling data). Pre-development baseline conditions are informed by Indigenous Traditional Knowledge (ITK), as well as paleo-environmental data. Pre-mining baseline conditions are informed by traditional knowledge, and include MLWC monitoring program data, historical imagery, and model predictions prior to mining in the MLWC watershed.

An important aspect of characterizing baseline conditions is understanding the range of variability that has been observed or documented through time. A definition of the natural range of variability (NRV) was assembled by the SC, adapted from the Ecological Restoration Guidelines for British Columbia (BCMWLAP 2002): The NRV refers to the spectrum of ecosystem states and processes encountered over a long time period. The "natural" range of variability usually refers to the full range of ecosystem structures and processes encountered before major changes brought by non-aboriginal humans. It is also surmised from knowledge of natural disturbance regimes. The NRV is often used to describe disturbance processes, and the ecosystem variability that these disturbances create. Ecosystems are thought to be more sustainable if we manage them so that their current disturbance regime falls within the NRV. The NRV can be informed by pre-development baseline conditions (including ITK and paleo-environmental data) as well pre-mining baseline conditions (including ITK and measured/modeled data), with recognition that ITK may help inform how conditions have changed from pre-development times. For the purposes of the OP, the measured range of variability (MRV) is defined as the variability observed in the pre-mining baseline conditions for the chosen indicators. The MRV is informed by monitoring and modelling data, as well as targeted studies of paleo-ecology, paleolimnology, and conceptual models that have been developed for the MLWC watershed. Data collected to characterize the MRV are used to inform definitions of triggers and limits under Objective 6.

Understanding the baseline conditions, NRV, and MRV in the MLWC is the critical first step in the development of the OP, as it sets the stage for the completion of the other five objectives. The Fort Hills Energy Corporation (FHEC) has considered three sources of information to define baseline conditions for the MLWC: ITK, Paleo-Environmental Data, and Monitoring Data.

2.1. Indigenous Traditional Knowledge

Pre-development baseline is informed by generations of knowledge passed down to the following generations. This knowledge becomes critical for several of the Aboriginal Advisory Group (AAG) communities' participants, who were young land users living on and around the MLWC during both these baseline timespans. They received generational knowledge about, and remember being witness to, the expected function and high quality of environmental conditions before an event that brought subsequent changes to those conditions, in the region and particularly around the MLWC. Those knowledge holders have the comparative knowledge of both baseline conditions firsthand, seeing the changes observed since pre-mining baseline conditions due to cumulative effects on the MLWC.

To support development of this section and the OP in general, ITK has been included from all areas of engagement, such as, AAG and Sustainability Committee (SC) meetings, the On The Land Workshop and from all of the workshops that have included AAG members, previous Traditional Land Use (TLU) studies and ITK community reports, an Indigenous Knowledge Baseline Report developed by the Integral Ecology Group (IEG) for the SC and AAG (IEG 2021), and a McClelland Lake Wetland Complex Indicators and Methods report for the SC and AAG (Garibaldi 2021). The Indigenous Knowledge Baseline Report contains ITK provided by members, Elders, knowledge holders, land users, staff, and leadership from Fort Chipewyan Métis, Fort McKay Métis Nation, Fort McKay First Nation and Mikisew Cree First Nation. The Indigenous Knowledge Baseline Report provides a compilation of the community reports that were informed by the ITK interviews and/or TLU studies that were conducted by those four Indigenous communities and provides more extensive information on pre-development baseline conditions. The ITK interviews and TLU studies brought together individuals to respond to the AAG request to understand the biodiversity and functionality of the MLWC and surrounding area according to ITK. The information provided in the Indigenous Knowledge Baseline Report was considered during the development of Objective 1. Note that Athabasca Chipewyan First Nation (ACFN) is currently completing an ITK study, and this forthcoming information can be incorporated into future work and submissions (for exampled, future progress reports), as guided and validated by ACFN. ITK often speaks to some of the key elements of the environment that require monitoring, serving to frame and inform the scientific analysis undertaken and the resulting description of the baseline conditions presented here. Core teachings related to water quality and water quantity in the MLWC have been shared by ITK holders. The principle of connectivity – the land, the water, habitat, wildlife, harvesting, knowledge transmission, and health and wellness – is an important concept for the Indigenous Peoples who use this land, as is the importance of water quality to the functionality of the fen and broader MLWC itself, and for use and consumption by people, animals, aquatic resources, biota, etc. In addition, recognition that water levels and flows are dynamic, changing with the seasons, weather, and natural cycle. Fens play a central role in the overall health of the watershed and the connected system, and all areas within the MLWC's watershed are important for consideration in monitoring and management (MLWC SC 2021).

The MLWC serves as an important place for cultural, spiritual, and sustenance-providing activities to the Indigenous Peoples of the area. Such practices are integral in the transmission of knowledge from one generation to the next, serving as on-the-land teaching grounds. ITK holders have described the educational role of the MLWC and surrounding area:

> *"Well what other place is gonna give us some nature stuff like we can use for the people, you know, cause to my generation you do, well I'm not gonna say, it's not me I'm gonna say, it's my daughter, I teach my daughter lots, like, well, her kids and kids' kids, what're they gonna say about that? What happened to the lake? Like how come we go so far to pick up all these native culture medicine or whatever, you know? You make use out of moose, we can make moccasins, jackets, or mukluks, or stuff like that off of moose. That's where we all go, like even the rats, you can make rat hat or maybe make gloves out of it, or whatever you want, right."* (MCFN ITK holder, MCFN 2019)

> *"...If we were to lose a lot of that, like a lot of people that do which plants to look for and that, and if it's not there, then they can't pass that knowledge on to the younger generation"* (MCFN ITK holder, MCFN 2019).

ITK holders have noted that the land and water in the MLWC has provided an area with all materials needed to survive in one place, being likened to a sustainable "grocery store" where Indigenous Peoples could go to harvest everything needed, from medicine, to edible plants, to sources of meat and furs. The presence of sacred sites, camping areas, and gravesites reinforces the importance of the MLWC area, and its role as a place of settlement linked to the availability of resources. An ITK holder describes the area:

> *"So it's like being able to walk into a store when you go there, you know what I mean? Might as well cut it short and say that, cause everything is growing there, it's all in the same place, so we just cutting it short, you know what I mean?"* (MCFN ITK holder, MCFN 2019).

The provision of all those things required for survival has been attributed by ITK holders to the relationships in place and the functionality of the ecosystem:

> *"Even the birds and the ducks, the ducks, they feed on whatever, whatever they feed on is mostly the worms like in the bottom, the beetles, and the bloodsuckers, like the one we were talking about bait there? The birds eat that, geese and ducks eat those. And those little things that walk on top of the water, I don't know what they call them, you ever go to a lake and you see those little creatures walking on the top of the water? … that's what they eat, fish eat them. So whenever you see that, fish eat that too. Mostly, everything eats whatever, it's walking underwater or it's got something to do with the water, you know what I mean?"* (MCFN ITK holder, MCFN 2019)

> *"While you're walking you can tell they're breaking the grass or the [weeds], when they're walking through, don't see signs of that anymore out there. You can tell like, birds are leaving that place cause, no water, and in order to bring that water up now, everything will come back, bring the rats and stuff like that, it would be more than everything there when the water was higher"* (MCFN ITK holder, MCFN 2019).

ITK holders have stressed that, while monitoring indicators of individual components of the environment is important, it is the holistic nature of these indicators through the seasons that is important in assessing the overall health of the MLWC area.

Rather than being presented in a stand-alone section, ITK has been incorporated into the description of the pre-development and pre-mining baseline conditions (Sections 2.3 and 2.5) related to specific environmental topics (e.g., wildlife, vegetation, fish, water quality). This approach has been taken to reflect that ITK should be woven throughout the baseline discussion, being presented as equal to, and in tandem with, western scientific knowledge.

2.2. Work Completed Prior to Operational Plan Development

Prior to development of this OP, many years of monitoring data have been collected from the MLWC. These data have been reviewed and analyzed frequently to help FHEC evaluate sampling designs and assess whether pre-mining baseline monitoring programs needed to be modified. To support the development of the OP Proposal (FHEC 2018), an analysis was completed of the monitoring data that had been collected through 2017 (Golder 2018). Following submission of the OP Proposal to Alberta Energy Regulator (AER) in December of 2018, FHEC developed annual Progress Reports (FHEC 2020, 2021a) for authorization by the AER, which included updates on the collection and analysis of monitoring data. Analysis and reporting activities associated with synthesis of monitoring data from annual reports that FHEC has completed since the approval of the Fort Hills Oil Sands Project (Fort Hills Project) in 2002 are summarized in Table 2.2-1.

To complement the monitoring and data analysis activities completed for individual disciplines, in 2017 FHEC also initiated a four-year interdisciplinary paleo-environmental study of the MLWC and surrounding watershed. The purpose of the study was to provide a historical reconstruction of the wetland and lake, and estimate how key environmental factors have changed over the past 11,000 years in the wetland (Vitt and House 2020) and from approximately 1750 to 2018 in the lake (Zabel et al. 2019). A summary of the findings of the peatland paleo-ecology study and McClelland Lake paleolimnology study is provided in Section 2.3.3.

The results of the paleo-environmental study were integrated with more recent climate data, and a conceptual model of relationship between present-day water chemistry and vegetation in the MLWC was developed. This conceptual model divides the MLWC into Ecohydrology Zones (EHZs), as described in Section 2.4.

For development of the OP, FHEC utilized the EHZ Conceptual Model framework to re-evaluate the monitoring data, which includes incorporation of data collected since completion of the 2018 Data Synthesis report (Golder 2018). This updated evaluation is presented in Section 2.4. FHEC has reviewed the ITK provided through the SC and has identified where the ITK supports or departs from the results of the monitoring data analysis and this has been incorporated into the description of the pre-development and pre-mining baseline conditions throughout this Objective.

Table 2.2-1: Summary of Reports Synthesizing Monitoring Data and the Measured Range of Variability, and Indigenous Traditional Knowledge Contributing to Objective 1

Document Title	Author	Date	Discipline Section
Traditional Ecological Knowledge and Family History for RFMA 2137	Highwood Environmental Management in Association with Fort McKay IRC	June 2002	Indigenous Traditional Knowledge, land use, culture, family history
McClelland Lake Wetland Complex Summary of interviews	Human Environment Group on behalf of the Fort McKay Métis Sustainability Centre	September 2017	Indigenous Traditional Knowledge, land use, culture, McClelland Lake wetland complex
Mikisew Cree First Nation Indigenous Knowledge Related to Use in the McClelland Lake Area	Fekete, S. on behalf of MCFN	2018	Indigenous Traditional Knowledge, land use, culture, wetlands
2018 McClelland Lake Wetland Complex Data Synthesis	Golder Associates Ltd.	August 2018	Soils, vegetation, climate, hydrology, hydrogeology, water quality, interdisciplinary
McClelland Lake Wetland Complex *Water Act* Approval No. 151636-01 Condition 3.11 Proposal	Fort Hills Energy Corporation	December 2018	Topography, soils, surface water hydrology, geology, water quality, vegetation, aquatic ecology, birds, wildlife
McClelland Lake Wetland Complex 2018 Progress Report *Water Act* Approval No. 151636-01 Condition 3.12	Fort Hills Energy Corporation	January 2019	Topography, soils, surface water hydrology, geology, water quality, vegetation, aquatic ecology, birds, wildlife
Final Report: Mikisew Cree First Nation Cultural Indicators for McClelland Lake and Fen	Firelight Research Inc. on behalf of MCFN	October 2019	Indigenous Traditional Knowledge, land use, culture, wetlands

Table 2.2-1: Summary of Reports Synthesizing Monitoring Data and the Measured Range of Variability, and Indigenous Traditional Knowledge Contributing to Objective 1

Document Title	Author	Date	Discipline Section
McClelland Lake Wetland Complex 2019 Progress Report *Water Act* Approval No. 151636-01 Condition 3.12	Fort Hills Energy Corporation	January 2020	Topography, land cover classification, soils, surface water hydrology, hydrogeology, water quality, vegetation, aquatic ecology, birds, wildlife, paleo-environmental
Fort McKay Métis Nation and Fort McKay First Nation Traditional Land Use Study - Fort Hills Oil Sands Project and the McClelland Lake Wetland Complex and surrounding area	Fort McKay Métis Sustainability Centre and Integral Ecology Group, Ltd.	February 2020	Indigenous Traditional Knowledge, land use, culture, wetlands
Hermansen indicators: Baseline report	Dertien-Loubert, K. on behalf of FCM	February 2020	Indigenous Traditional Knowledge, land use, culture, wetlands
McClelland Lake Wetland Complex 2020 Progress Report *Water Act* Approval No. 151636-01 Condition 3.12	Fort Hills Energy Corporation	January 2021	Paleo-environmental context, surface water hydrology, groundwater levels, surface water and groundwater quality, vegetation, aquatic health, wildlife
McClelland Lake Wetland Complex Indigenous Knowledge Baseline Report: Suncor Fort Hills Oil Sands Project	Integral Ecology Group (IEG) on behalf of SC	March 2021	Indigenous Traditional Knowledge, land use, culture, wetlands
McClelland Lake Wetland Complex Integrated Indicators and Methodology Report	Ann Garibaldi on behalf of SC	March 2021	Indigenous Traditional Knowledge, Indigenous values, ecological function, aspects of biodiversity

FCM = Fort Chipewyan Métis; IRC = Industry Relations Corporation; MCFN = Mikisew Cree First Nation; SC = Sustainability Committee.

In addition to data collected from the MLWC, data has been collected from the Audet Lake Wetland Complex (ALWC) and the Gipsy Gordon Wetland Complex (GGWC), both of which include a lake near a patterned fen. The ALWC is located about 30 kilometres (km) northeast of the MLWC and the GGWC is located approximately 140 km southeast of the MLWC (Figure 2.2-1). The southern portion of Audet Lake and the ALWC is within the Northern Lights lease, which is held by Total and SinoCanada Petroleum Corporation, with Total as the operating partner. The lease area overlaps with approximately 40% of the Audet Lake watershed; thus, development within the Northern Lights lease could affect Audet Lake and the ALWC and diminish its value as a reference site. In contrast, Birch Lake and the GGWC occur within the Gipsy Gordon Wildland Provincial Park. Surface impacts from development are not expected to occur within this protected area; thus, the GGWC is expected to persist as a viable reference monitoring location throughout the operational and closure stages of the Fort Hills Project. Reference site data are discussed for hydrogeology, surface water hydrology, surface water quality, aquatic resources, vegetation, and wildlife in Section 2.5, and results are integrated in Section 2.6.1.

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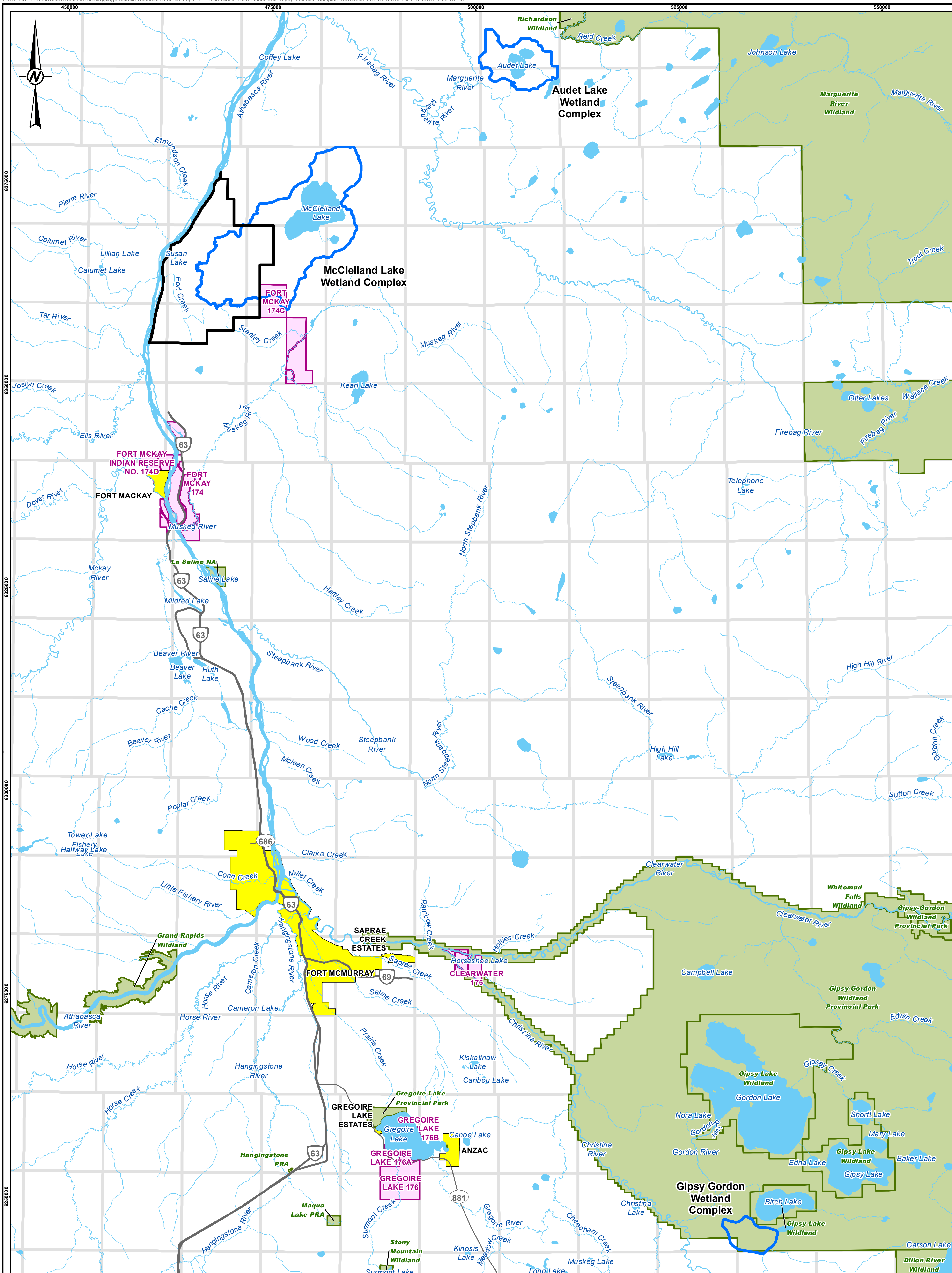

LEGEND

- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- WATERCOURSE
- FIRST NATION RESERVE
- FORT HILLS *OIL SANDS CONSERVATION ACT AND WATER ACT* BOUNDARY
- PARK / PROTECTED AREA
- POPULATED PLACE
- WATERBODY
- WATERSHED BOUNDARY

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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
McCLELLAND LAKE WETLAND COMPLEX, AUDET LAKE WETLAND COMPLEX, AND GIPSY GORDON WETLAND COMPLEX

FORT HILLS
Operated by Suncor Energy

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PREPARED	LB
REVIEWED	ZG
APPROVED	JH

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2.3. Pre-Development Baseline Conditions

A summary of the results of the recent ITK study and Paleo-Environmental study is provided in this section, with additional details available in Vitt and House (2020) and Zabel et al. (2019). Results of the Paleo-Environmental study can be grouped into two categories: paleo-ecology of the peatland and paleolimnology of McClelland Lake.

2.3.1. Indigenous Use of the Land and Resources

Indigenous Peoples have inhabited the land on which the MLWC is situated for generations. Prior to industrial development (e.g., pre-1960s), unhindered access and use of the land and waters in the area included hunting, trapping, fishing, berry picking, and other plant foods, medicinal and ceremonial plant harvesting, wood, and water collection. Several ITK holders have described the land as providing everything that was needed for survival and waters as being connected through the entire area (IEG 2021). Water is connected thru the entire area-groundwater, surface water. Fen, lakes, creeks, rivers; all the valued and necessary water sources are connected (FCM ITK holder, FCM 2019).

ITK holders have shared that water quality, including ice and snow, was excellent prior to industrial development in the area. Moose Creek, McClelland Creek, McClelland Lake, Eight Lakes, and the surrounding small lakes were all used as sources of drinking water, with no taste, smell, or cloudiness to the water. ITK holders have shared that ice integrity was good and strong for winter sled-dog travel across the lake, and snow was used for drinking water (FCM ITK holder, FCM 2019). Water levels were high enough that members of FMFN and FMMN were able to routinely travel by water to preferred areas within the McClelland Lake Wetland Complex and surrounding area (FMMN and FMFN ITK holders, IEG 2021). Water quantity experienced included the outflow of McClelland Creek, described as an old riverbed, which was high in spring, enough to swim in during spring and summer. It was not a fast-flowing river and depending on where beavers dammed, for example upstream, the creek could also be dry at times. McClelland Creek fed into Moose Creek, which always had lots of water and a swift current. The water level of the Firebag River in spring was high, and the current was swift. After May, the southern areas of McClelland Lake were too wet for travel, and previous trapline holder Felix Beaver had to detour over Edmo's trapline (FCM ITK holder, FCM 2019). The waters in and around the MLWC provided important habitat for fish, shellfish, frogs, fir bearers and birds, all of which were harvested by Indigenous Peoples. Fur quality of otter and beaver also depended on having good water and ice (FCM ITK holder, FCM 2019). The Firebag River was accessed to hunt bear, which would forage for joint grass (a type of horsetail) near sloughs in the spring. The Firebag River was also the location of beaver and otter habitat, and nesting grounds for grouse and sandhill crane. Bird eggs would be harvested in abundance in the area, and would be shared with family and friends when found in abundance (IEG 2021).

ITK holders have shared that prior to development, the MLWC area provided numerous important plant species to Indigenous Peoples, including mosses important for water retention on the land through warmer drier months as a natural fire retardant, medicinal plants (e.g., wild mint [*Mentha arvensis*], rat root [Acorus americanus], sweetgrass [*Hierochloe odorata*], red willow [*Cornus stolonifera*], and diamond willow fungus [*Trametes suaveolens*], saskatoon berries [*Amelanchier alnifolia*], pin cherries [*Prunus pensylvanica*], blueberries [*Vaccinium myrtilloides*], and low-bush cranberries/mooseberries [*Vaccinium edule*]. Members explained they would pick edible and medicinal plants while in the area and that the area is an ideal location for picking certain medicines because of the wetland terrain. Within the area, a key location for harvesting medicinal plants is where the fen meets the lake. (FCM ITK holder, FCM 2019). Cranberries were harvested in wetter, mossy areas, while rosehips, raspberries and strawberries tended to grow alongside willows in drier areas. Blueberries were found in more sand areas. Balsam bark blisters along the Athabasca and Firebag Rivers were collected for medicinal and other uses (FCM ITK holder, FCM 2019). Where you find muskeg you find Labrador (muskeg) tea (FCM ITK holder, FCM 2019). FMMN and FMFN ITK holders have described pre-development conditions for plant gathering in the MLWC as ideal, with rich biodiversity of culturally important plant species. One ITK holder described how raspberries were so plentiful that berries would weigh down the branches, something that doesn't happen anymore. It was noted that blueberries, cranberries, mint, chokecherry, and diamond willow fungus were also important harvested species around McClelland Lake. Blue eye grass was historically harvested on sandy ridges near the old fire tower in the Fort Hills. This is also where many of the best berry patches were (Berry hill/mountain cabin). It is believed this area has now been destroyed by resource extraction activities in the region (IEG 2021). ITK holders have expressed that they are facing many impacts from cumulative effects in the area around McClelland Lake (for example the clearing of trees). ITK holders are concerned about how changes to the landscape will impact water flows.

2.3.2. Peatland Paleo-Ecology

This section provides insight regarding historical reconstructions of the wetland, how key environmental factors have changed over the past 11,000 years, and present-day water chemistry and vegetation. Unless otherwise noted, information discussed in this section is summarized from Vitt and House (2020).

2.3.2.1. Historical Development of McClelland Lake Wetland Complex

2.3.2.1.1. Holocene Initiation and Development of Peatlands in Northeastern Alberta

Peatlands, including fens and bogs, cover approximately 406,000 square kilometres (km^2), or 23% of the land base in the boreal plain of Alberta, Saskatchewan, and Manitoba (Halsey et al. 1998). Non-patterned fens and bogs in north central Alberta typically have peat depths between 160 and 285 centimetres (cm), while patterned fens in northeastern Alberta typically have peat depths between 360 and 630 cm (Halsey and Devito 2006). Less than 5% of fens and bogs reach depths greater than 450 cm (Vitt and Wieder 2008).

The Younger Dryas, which had colder temperatures, occurred from 12,900 to 11,600 calendar years before present (cal yr BP), followed by a period of warmer temperatures (Carlson 2013). An approximately 1,450-year climatic periodicity occurred post-glacially (Bond et al. 1997; Campbell et al. 1998), which, in western Canada, has been identified as wet and dry cycles in Late Holocene sediments (Campbell et al. 1998). Cyclicity in peat accumulation rates have been linked to these regular interval wet periods, lasting 200 to 600 years each, in fens in Alberta (Yu et al. 2003, 2014). The wet periods have also been linked to warm periods (Bond et al. 2001). These timelines concur with those indicating that deglaciation of the northeastern part of Alberta took place circa (ca.) 11,000 cal yr BP (Dyke et al. 2003), with peatland initiation occurring after 7,000 to 7,500 cal yr BP (Campbell et al. 1998); ice blocked flowing waters until deglaciation, which opened drainages, resulting in the discharge of meltwaters.

Reconstructing postglacial vegetation at poor fen peatlands at Mariana Lakes, south of Fort McMurray, has allowed a chronology in this area to be developed. Peatlands began to appear around 11,000 cal yr BP, were almost eliminated between 8,300 and 6,200 cal yr BP, then reappeared during an extensive period of paludification after 7,000 cal yr BP. The following chronology has been developed for an area examined in northeastern Alberta:

- 13,100 to 12,400 cal yr BP: sparse vegetation dominated by forbs and graminoids was present
- 12,400 cal yr BP: *Picea glauca* (white spruce) forests were present
- 11,300 to 10,700 cal yr BP: *Sphagnum-Picea mariana* (black spruce) peatlands developed
- after 8,300 cal yr BP: decreases in *Sphagnum*-dominated sites and upland *Picea glauca* sites
- 8,300 to 6,200 cal yr BP: *Populus* spp. (aspen) reached its maximum Holocene occurrence, *Sphagnum*-dominated peatlands almost disappeared
- beginning around 7,300 to 6,800 cal yr BP: peatlands increased with extensive paludification (Hutton et al. 1994)
- 9,100 to 8,000 cal yr BP: early peatland formation from lake infilling occurred
- beginning around 5,700 cal yr BP: extensive paludification occurred (Nicholson and Vitt 1990)
- 5,700 to 5,000 cal yr BP: differentiation of bog islands interspersed with fen water tracks became evident
- by 4,800 cal yr BP: organic terrain extended to one-third of the present-day peatlands

2.3.2.1.2. Initiation and Development of McClelland Lake Wetland Complex

Macrofossil profiles from 10 long (Figure 2.3-1) and 13 short peat cores (Figure 2.3-2) were investigated to understand the development of the MLWC. Peatland development began at MLWC shortly after the Younger Dryas (11,200-11,300 cal yr BP). Cores were used to estimate the quantity of material identifiable by structural components and bryophyte species. Structural components identified in long and short cores included sedge roots, leaves, and seeds; wood and bark; shrub leaves, twigs, and roots; ectomycorrhizal roots; tree needles; *Menyanthes trifoliata* (buck-bean); charcoal; and minerals. Bryophyte species identified in short cores included common fen species (e.g., *Aulacomnium palustre*, *Campylium stellatum*, *Hamatocaulis vernicosus*, *Sphagnum warnstorfii*).

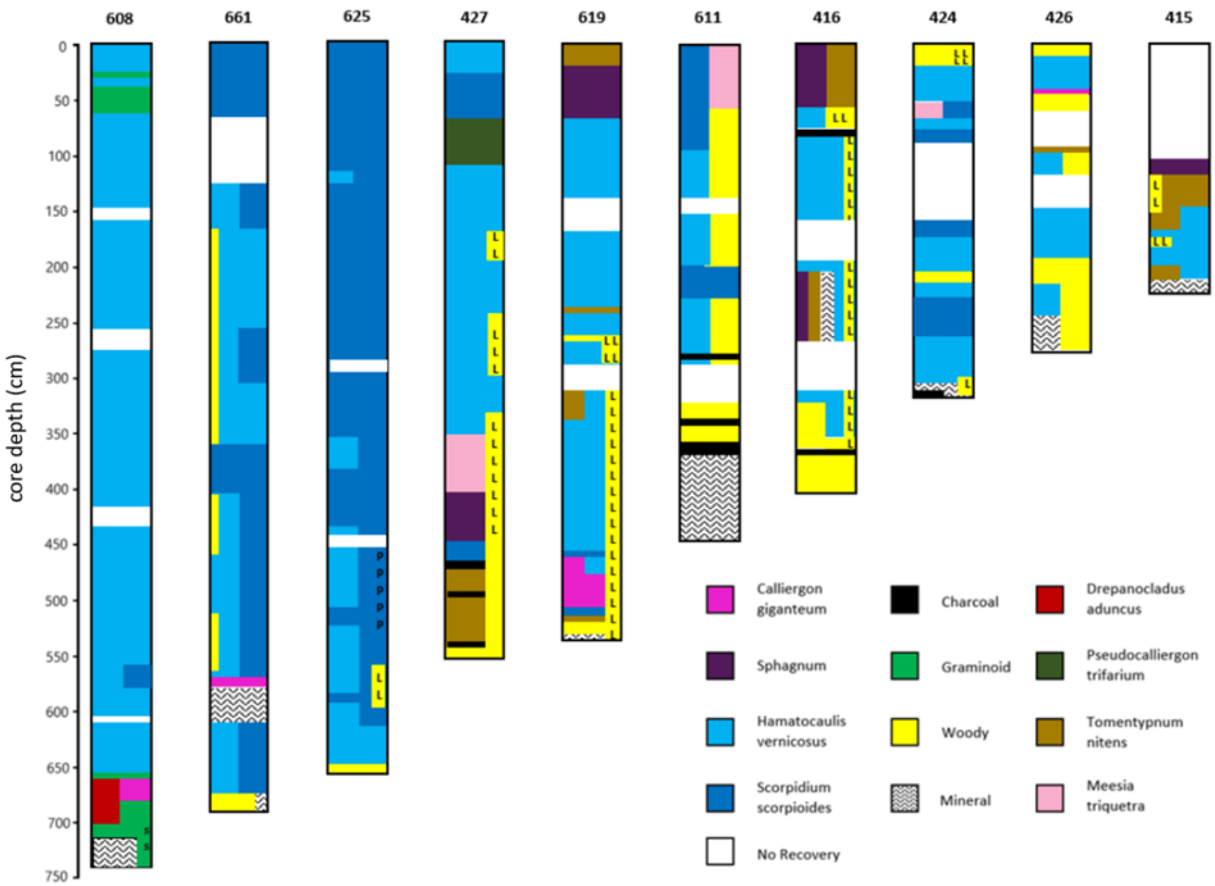
Note: Yellow numbers in rectangles represent the locations of 10 long peat cores extracted between 2018 and 2020. White numbers in ellipses represent the locations of four long peat cores extracted in 2017.

Figure 2.3-1: Location of Long Peat Cores

Note: White bordered squares represent the locations of 13 short peat cores extracted in 2018 and 2019. Black squares represent the locations of six proposed short peat cores that have not yet been extracted.

Figure 2.3-2: Location of Short Peat Cores

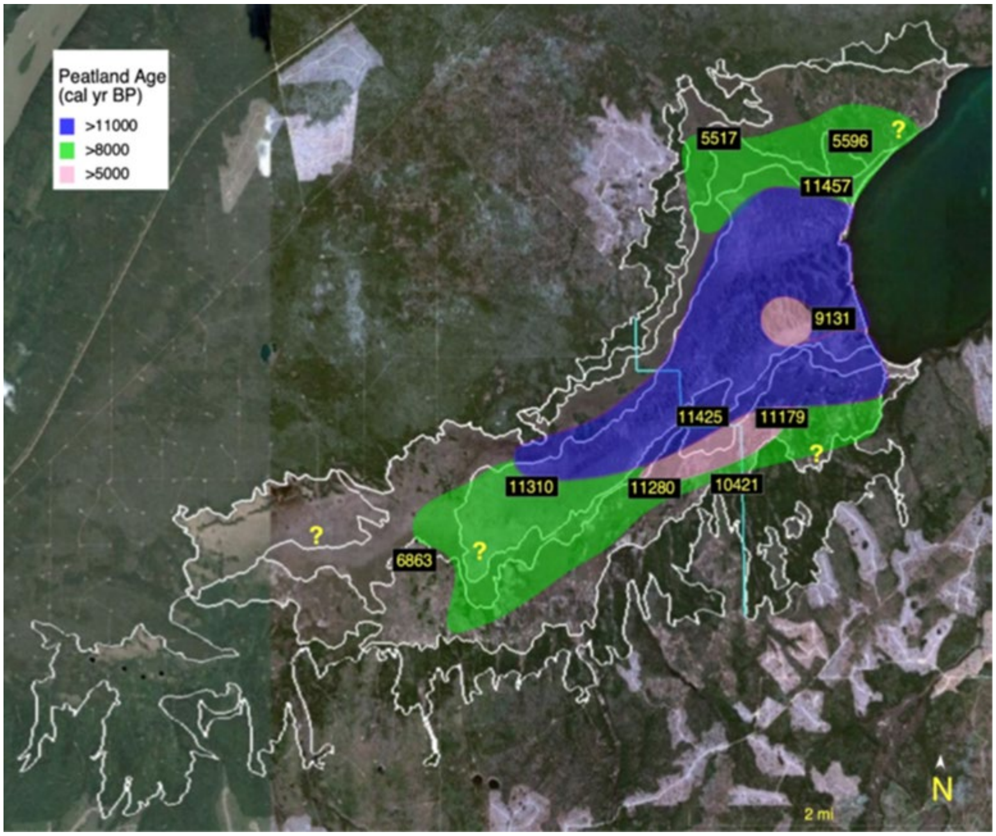
Long cores from MLWC were analyzed for fossil bryophytes, other macrofossils, and vascular plant structural components (Figure 2.3-3). Cores were dated and dates were calibrated.



cm = centimetre; L = *Larix laricina* (larch); P = *Picea mariana* (black spruce); S = shrubs.

Figure 2.3-3: Summarized Profiles of Core Lithologies for Ten Long Cores, Dominant Macrofossil Components Colour-Coded

Peatland development was first evident at MLWC at 11,200 to 11,300 cal yr BP, which is synchronous with deglaciation. Initially, lower portions of the basin seemed to have a wet sandy landscape with shrubs and graminoids, while *Larix laricina* (larch) and *Picea mariana* were present at higher elevations (Figure 2.3-4). These wooded sites had transitioned to moss-dominated fens by 10,000 cal yr BP, while paludification continued until 6,000 cal yr BP as peat accumulated from swampy Larix laricina forests (Figure 2.3-4). Marginal sites are still *Picea mariana* or *Larix laricina* dominated fens in present-day. Bryophyte species present at 6,000 cal yr BP, including *Hamatocaulis vernicosus* in the north and *Scorpidium scorpioides* in the south, are still dominant on flarks today. The patterned portion of the fen likely developed around 7,000 cal yr BP once elevational gradients were present. The persistence of these species over thousands of years indicates that the water regime in the patterned portion of the fen is resilient to environmental changes and has remained stable throughout time.



cal yr BP = calendar years before present.

Figure 2.3-4: Estimated Extent of Peat Accumulation Area Coloured by Date, Expressed in Calendar Years Before Present

2.3.2.1.3. Peat Accumulation and Bulk Densities

Northern peatlands store significant amounts of carbon, estimated at 54 petagrams (1 petagram = 10^{15} grams or 10^{9} metric tonnes) in continental western Canada (Vitt et al. 2000). Peat accumulates when organic inputs are greater than the losses from decomposition and runoff. Decomposition occurs primarily in the aerobic zone, at 10 to 20 cm deep in fens; however, the peat column is anaerobic and minimal decomposition occurs. Accumulation rates over the 11,457 cal yr BP period averaged 0.557 millimetres per year (mm/yr), which is similar to the 0.529 mm/yr reported near Calling Lake, Alberta (Bauer et al. 2003).

Bulk densities generally remained constant throughout the peat column, only increasing near the bottom of the peat column. At MLWC, bulk densities of the upper (7 to 247 cm) peat column averaged 0.115 grams per cubic centimetre (g/cm^3), the mid (253 to 359 cm) peat column averaged 0.114 g/cm^3, and the lower (397 to 549 cm) peat column averaged 0.157 g/cm^3.

Deep peat layers are often characterized by only a few species or structural components. Peat developed in wet habitats is primarily composed of *Hamatocaulis vernicosus*, *Scorpidium scorpioides*, and sedge roots and leaves, while peat developed in drier habitats is primarily composed of woodier components from *Larix laricina* or *Picea mariana*, as well as *Tomentypnum nitens*. These species found in deep peat layers match the species currently growing in their respective habitats. This indicates that these foundational species are important in structuring the plant community and for the continued functioning of the peatland, have a disproportional effect on the remainder of the community, and thus, are key to the resilience of a wetland community (Dayton 1972). Changes in base cation concentrations and water levels can cause shifts in foundation species, affecting carbon sequestration and peat accumulation.

2.3.2.1.4. String Stability During the Last Millennium

Strings and flarks are characteristic of aapa mires in the northern boreal region. Flarks are linear, wet, hollow landforms that are adjacent to strings; strings are drier, elongated hummocks. Changes in string structure were investigated from approximately 900 cal yr BP at 50 cm depth to 1,800 cal yr BP at 100 cm depth. The sum of macrofossils from strings, which have woody vegetation, was calculated. Strings in the patterned fen have heterogeneous tree cover, comprised of scattered trees on hummocks interspersed with shrubs and/or depressions. Strings are currently dominated by *Betula glandulifera* (bog birch) in the west and by *Larix laricina* in the central and east portions of the fen; in the past some *Picea mariana* individuals were also present. Depressions were dominated by *Menyanthes trifoliata*, *Hamatocaulis vernicosus*, and sometimes *Typha latifolia*, with hummocks were dominated by *Tomentypnum nitens*, *Helodium blandowii*, and intermittently species of *Sphagnum*. While hummocks and depressions can replace each other, there is no evidence that strings have formed or moved within the past 1,000 years, indicating that overall, strings have remained stable over time. These samples did not include small strings and flarks near the water source or large ones near the lake.

2.3.2.1.5. Reconstructed Historical Ca^{+2}/Mg^{+2} Concentrations and Water Levels

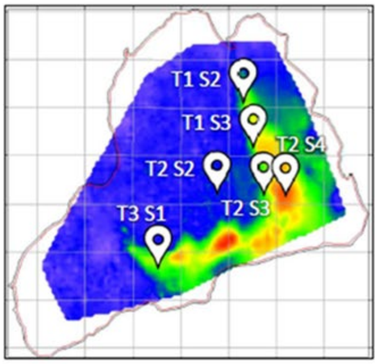
Ca^{+2} and Mg^{+2} concentrations were lower in areas with *Sphagnum* (19 to 35 milligrams per litre [mg/L]) and *Larix laricina* (40 to 65 mg/L), in areas that are often associated with lower water levels. Areas with non-*Sphagnum* vegetation had higher and more variable Ca^{+2} and Mg^{+2} concentrations (35 to 133 mg/L). Water levels varied throughout the patterned area of the fen (11 to 32 cm below the surface) but remained relatively consistent over time at individual locations within the fen.

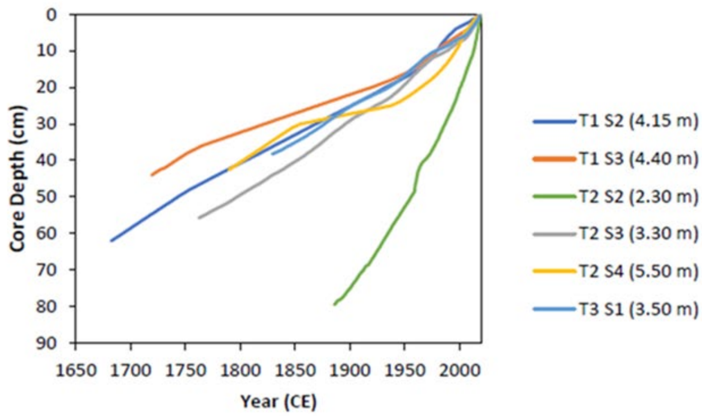
2.3.3. McClelland Lake Paleolimnology

Past hydrological and limnological conditions at McClelland Lake were reconstructed using paleolimnological methods. Unless otherwise noted, information discussed in this section is summarized from Zabel et al. (2019). Sediment cores collected from eight locations along three transects were analyzed to establish a sediment chronology. Additionally, the cores were analyzed to determine sediment composition and whether organic matter originated from terrestrial or aquatic sources. Sediment composition and origin information was used to reconstruct nutrient balance and cycling, historical lake water balance, historical algal abundance and community composition, changes in water chemistry and habitat, sediment deposition environments, wildfire history, and baseline polycyclic aromatic compounds (PAC) concentrations.

2.3.3.1. Summary of Sediment Core Age-Depth Relations

Age-depth relations were established for six of the eight sediment cores (Figure 2.3-5). Using radiometric analyses, ‘wiggle-matching’ from the Loss-of-Ignition stratigraphies, and Bayesian modelling, it was determined that the age at depth of the sediment cores spanned approximately 130 to 320 years.





cm = centimetre; CE = common era; m = metre; S = site number (i.e., 1, 2, 3, or 4); T = transect number (i.e., 1, 2, or 3).

Figure 2.3-5: Paleolimnological Study Coring Locations (Left) and Age-Depth Relations (Right) for the Six Cores Included in the Age-Depth Analysis

2.3.3.2. Summary of the Paleohydrology of McClelland Lake using Cellulose-Inferred $\delta^{18}O_{lw}$

Lake water oxygen isotope composition was reconstructed using preserved aquatic cellulose. Results indicated that hydrological conditions of McClelland Lake have been very resilient during the past 270 years, and evaporation losses balanced out with precipitation and groundwater inputs (Figure 2.3-6). Cellulose-inferred lake-water oxygen isotope ($\delta^{18}O_{lw}$) values, from which hydrologic inputs and losses can be inferred, remained relatively constant between ca. 1750 and 1830, hydrological variability increased between ca. 1830 and 1870, returned to relatively constant values between ca. 1870 and 1920, decreased between ca. 1920 and 1945, then increased steadily until the present. The current increase in hydrological variability indicates increasing evaporation and/or decreasing hydrological (i.e., precipitation and groundwater) inputs to McClelland Lake.

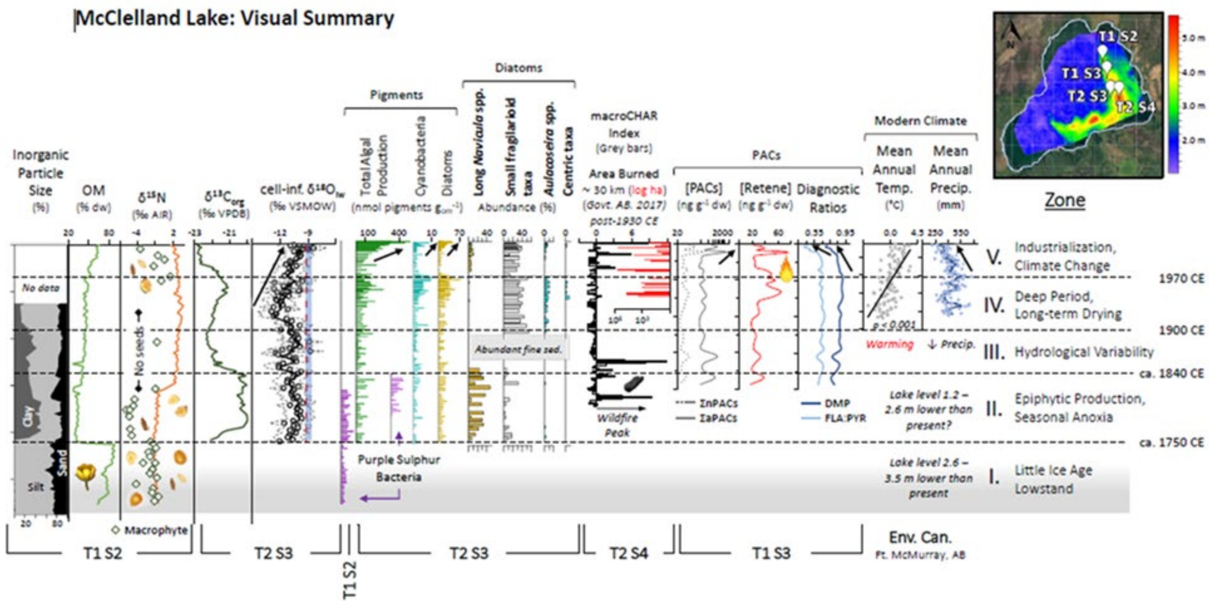


Figure 2.3-6: McClelland Lake Wetland Complex Paleolimnological Results Summary

2.3.3.3. Summary of the Phototrophic Community in McClelland Lake

Results indicate that McClelland Lake has undergone three major periods of phototrophic community changes (Figure 2.3-6):

1. high primary production, and diverse algal and anoxygenic bacteria community composition between ca. 1695 and 1840, when water levels were lower
2. variable primary production between ca. 1850 and 1970, in response to subtle water levels changes and watershed inputs
3. a noticeable increase in primary production, and increased cyanobacteria and golden algae, likely due to a warming climate and increased wildfires, from ca. 1970 to present

2.3.3.4. Summary of the Diatom Community in McClelland Lake

Four stratigraphic zones, identifying periods of different diatom community compositions (Figure 2.3-6), were identified in sediment cores. Between ca. 1750 to 1860, there was a diverse community of benthic taxa that preferred acidic/circumneutral conditions and higher dissolved organic carbon (DOC) concentrations. Between ca. 1860 and 1895, there were low concentrations of early colonizer diatoms that were not concentrated enough to be counted. Between ca. 1895 and 1974, small alkaliphilic, benthic, and epiphytic taxa that preferred clear water were dominant. Between ca. 1945 and 1970, planktonic centric diatoms were present, indicating deeper water and/or more nutrients. Between ca. 1974 and 2018, there was an increase in diatom diversity and concentration, likely due to climatic changes and increased nutrient loading from anthropogenic activities.

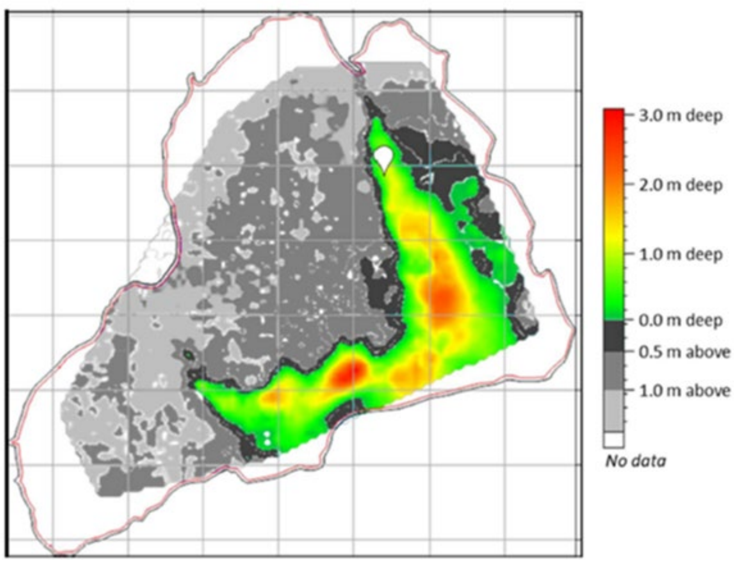
2.3.3.5. Summary of Polycyclic Aromatic Compounds in McClelland Lake

The PAC concentrations were primarily driven by wildfire prior to oil sands development in 1967. Exceedances in PAC concentrations in freshwater sediments relative to the Canadian Council of Ministers of the Environment (CCME) guidelines before and after oil sands development were associated with wildfires (Figure 2.3-6). Increased PAC concentrations from the Athabasca Oil Sands began in ca. 1980, likely due to increased vehicular activity in the area, but these concentrations do not exceed concentrations observed from pre-development natural processes.

2.3.3.6. Paleoenvironmental History of McClelland Lake

There were five distinct periods of differing hydrological and limnological conditions identified during the past 320 years. The first period (ca. 1695 to 1750) includes the height of the Little Ice Age, during which water levels were likely lower than present, restricting McClelland Lake to the deeper portions in the eastern and southern basin (Figure 2.3-7), with a diverse algal community that was tolerant of higher UV exposure, and purple sulphur bacteria, which only live in anoxic conditions.

The second period (ca. 1750 to 1840) includes the end of the Little Ice Age, when lake levels were still lower than present, but water balance remained relatively stable with higher algal production and increased diversity of benthic and epiphytic diatom communities, including seasonal anoxic conditions. Increased wildfire activity resulted in increased PAC concentrations in lake sediment.



Note: Inferred by macrophyte remains and stable isotopes. T1 S2 is indicated using the white marker. Grey areas indicate presently submerged regions of the lake that were above lake level during this period; white areas within the lake's perimeter indicate regions for which bathymetric data are not available. Graticule is composed of 1 x 1 km squares.

m = metre.

Figure 2.3-7: Bathymetric Map Showing Low Water Levels During Period 1 (ca. 1695 to 1750)

The third period (ca. 1840 to 1900) had high hydrologic variability, with lots of fine sediments, few diatoms (all of which were tolerant of harsh conditions), a higher water column, and reduced anoxic conditions. Increased disturbance events during this period resulted in higher PAC concentrations.

The fourth period (ca. 1900 to 1970) had relatively stable hydrological and limnological conditions, accompanied by increased algal production and the appearance of other planktonic diatoms, indicating deeper water levels. Several wildfires resulted in increased PACs, which, combined with increased water levels, resulted in more turbid waters and thus, smaller-sized tolerant benthic species.

The fifth period (ca. 1970 to 2018) indicated changes resulting from anthropogenic activities and climate change, including declines in precipitation, increased annual temperatures, PAC deposition from regional industrial activities, and increased algal production and diatom concentrations, likely from increased nutrient inputs. Changes in climate conditions may have resulted in lower lake water levels, and thus, increased benthic diatom concentrations.

2.4. Ecohydrology Zone Conceptual Model

Following completion of the paleo-environmental study described in Section 2.3, the data from that study was used along with the monitoring data to develop an ecohydrological conceptual model for the MLWC. Two specific features of the current environmental context of the MLWC were evaluated during development of the conceptual model – String and Flark Patterning and Permafrost – which are described in Sections 2.4.1 and 2.4.2, respectively. Using this information, an EHZ conceptual model was developed. Information discussed in Sections 2.4.1.1, 2.4.2, and 2.4.3 is summarized from Vitt and House (2020) and information discussed in Section 2.4.1.2 is summarized from Hatfield (2020).

It should be noted that the ecohydrological zones (EHZs) developed for the ecohydrology conceptual model in Objective 1 are distinct from the hydrological response areas (HRAs) developed for Objective 3 to support the conceptual model developed as part of the 2020 MLWC HGS Integrated Numerical Flow Model (2020 MLWC HGS model). This is because the EHZs take into account primarily ecohydrological considerations in their delineation whereas the HRAs take into account those factors and additional ones such as bedrock topography, bedrock permeability, substrate depth, climate etc. (Devito et al 2005). As well, the application of the EHZs and HRAs differ as well; EHZs provide a framework to generate deeper ecological understanding of a system whereas HRAs are developed to generate a deeper understanding of system hydrological functioning. Because of considering different factors in their delineation, EHZs and HRAs developed for the same site can be differently shaped. ITK holders have stressed the connectivity of the ecohydrological system in the MLWC area, highlighting that groundwater, surface water, muskeg, and precipitation are all parts of the same system (IEG 2021). The Conceptual Model included in Objective 3 incorporates this concept of connectivity in the overall approach to modelling.

2.4.1. String and Flark Patterning

2.4.1.1. String and Flark Formation

Peatlands form as organic matter builds up under wet conditions, which can either occur on mineral soil through paludification, or as the bottom of a lake or shallow pond undergoes terrestrialization. Once sufficient peat has accumulated, pattern formation can begin (Foster et al. 1983; Kubiw et al. 1989; Charmin 1995). As conditions changed during the early Holocene, hollows containing pools of water developed on top of the peat (Karofeld 1998; Belyea and Malmer 2004). This may have occurred due to flows changing from channel flow to sheet flow, which may have been amplified by microtopography such as hummocks that have faster organic buildup compared to hollows. As water flowed along the slopes, carrying litter with it, hollows may have merged into linear flarks (Foster et al. 1983; Foster and King 1984; Glaser 1992). Pattern development can be broken down into three mechanisms (Eppinga et al. 2009): nutrient accumulation (Rietkerk et al. 2004) on strings resulting in higher vegetation growth and production, water ponding (Kulczynski 1949) adjacent to flarks enlarging them, and peat accumulation (Belyea and Clymo 2001) due to limited plant growth caused by water stress.

Patterned fens have microtopography such as hollows and hummocks, and surface water flow direction is not always consistent at smaller scales throughout the fen. A net pattern of linear strings and flarks can develop as surface water flows perpendicular to the linear topography. Flarks become larger and deeper over time (Foster et al. 1983; Belyea and Clymo 2001). When a patterned peatland is adjacent to a lake, flarks tend to become smaller as distance increases from the lake, which improves one's ability to identify them and ascertain the direction of surface water flow.

At MLWC, large oval flarks near McClelland Lake have developed as ponding and organic accumulation raised the water level. Reticulate patterns developed in areas with multi-directional water flow. Patterns and string/flark orientations indicate that there are five surface water input areas at MLWC; these include from the north, the west, the south, the southeast, and the non-patterned wetness gradient from south to north.

2.4.1.2. Remote Sensing Analysis of String and Flark Features

Strings and flarks often develop perpendicular to the direction of water flow. As strings have been stable for the past millennium at MLWC, changes to string presence and/or orientation may be indicative of changes to the hydrological regime in the area. Information discussed in this section is summarized from Hatfield (2020).

2.4.1.2.1. String and Flark Features

String perimeters were digitized and examined for potential changes over time. String perimeters were extracted from Light Detection and Ranging (LiDAR) point cloud data and high resolution multi-spectral satellite imagery in 2017, and string perimeters and centrelines were extracted from LiDAR data in 2019. A canopy height greater than 0.2 m was used to separate strings from flarks within the patterned portion of the fen. The digitized strings were evaluated to determine the permanence, position, and orientation of strings from 2005 to 2019. Flarks were also delineated and evaluated, under the assumption that they followed an inverse pattern compared to strings.

String persistence was evaluated by counting the number of years in which each string occurred. Overall, string persistence was consistent between years, with a few exceptions. Strings in the central portion of the patterned fen were identified in most or all years, indicating that there has been no substantial change in geographic position from 2005 to 2019 (Figure 2.4-1). The margins of the patterned fen were often identified in fewer years, likely due to difficulty in separating strings from noise as the patterned fen transitions into non-patterned areas, resulting in less clearly defined strings along the perimeter of the patterned fen. The wide string directly west of McClelland Lake was also infrequently identified as a string, likely because it was generally too wide and contained vegetation that was too tall to be included as a string during the string extraction process. Additionally, some portions of the patterned fen, closer to the lake, were not covered in strings in 2005 due to limited spatial coverage of LiDAR data in that year.

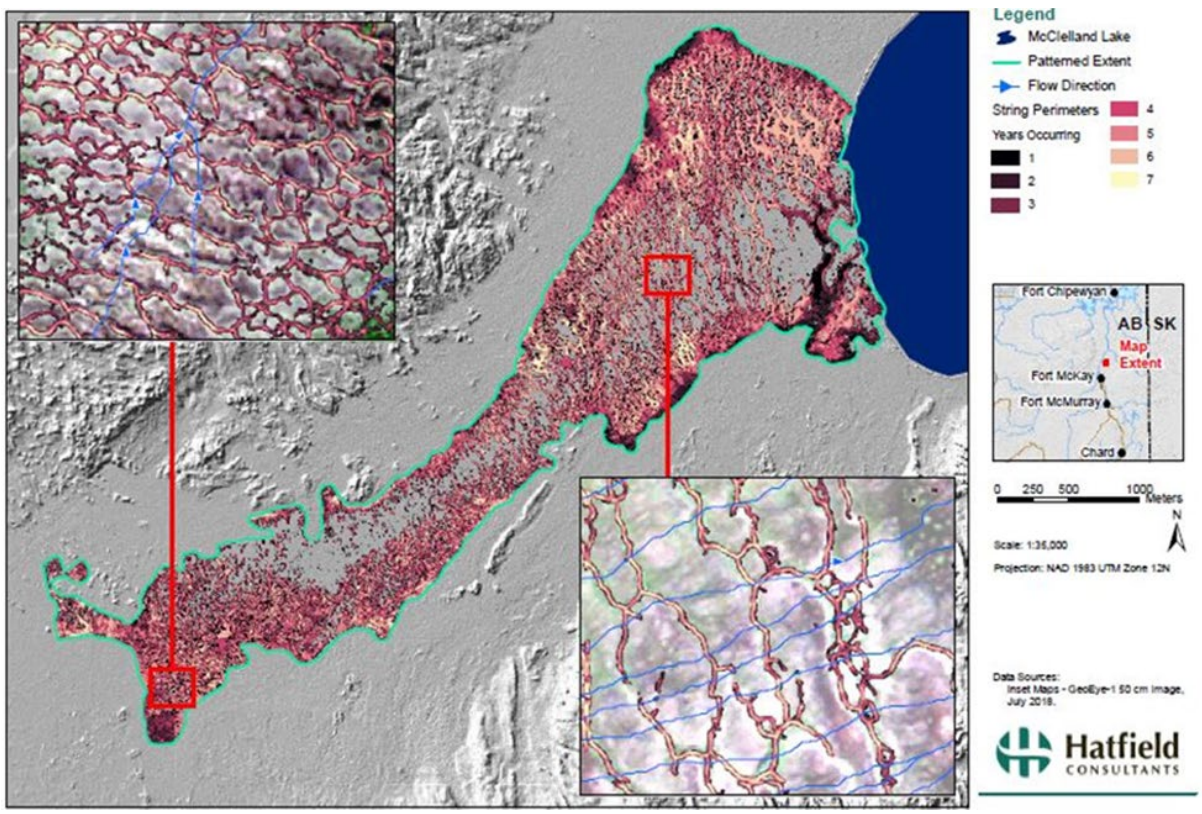


Figure 2.4-1: String Orientation and Persistence between 2005 and 2019

Flark persistence was evaluated using similar methodology to string persistence, and similar to strings, flark persistence was consistent among years (Figure 2.4-2). Flarks often occurred in either one year or in all seven years. Flarks occurring in only one year were likely due to detection errors. Flarks occurred in all seven years more frequently than strings, likely because they tend to cover larger areas than strings, and are thus more likely to be captured in the analysis.

The remote sensing data included in Section 2.4.1.2 are used to characterize string and flark patterning over 14 years during the pre-mining period. Although this 14-year period may be too short to determine whether string features are moving considerably over time (i.e., whether changes have occurred since the pre-development period), if changes are seen within a short time period in the future, it is likely indicative of significant impacts to the underlying hydrological regime.

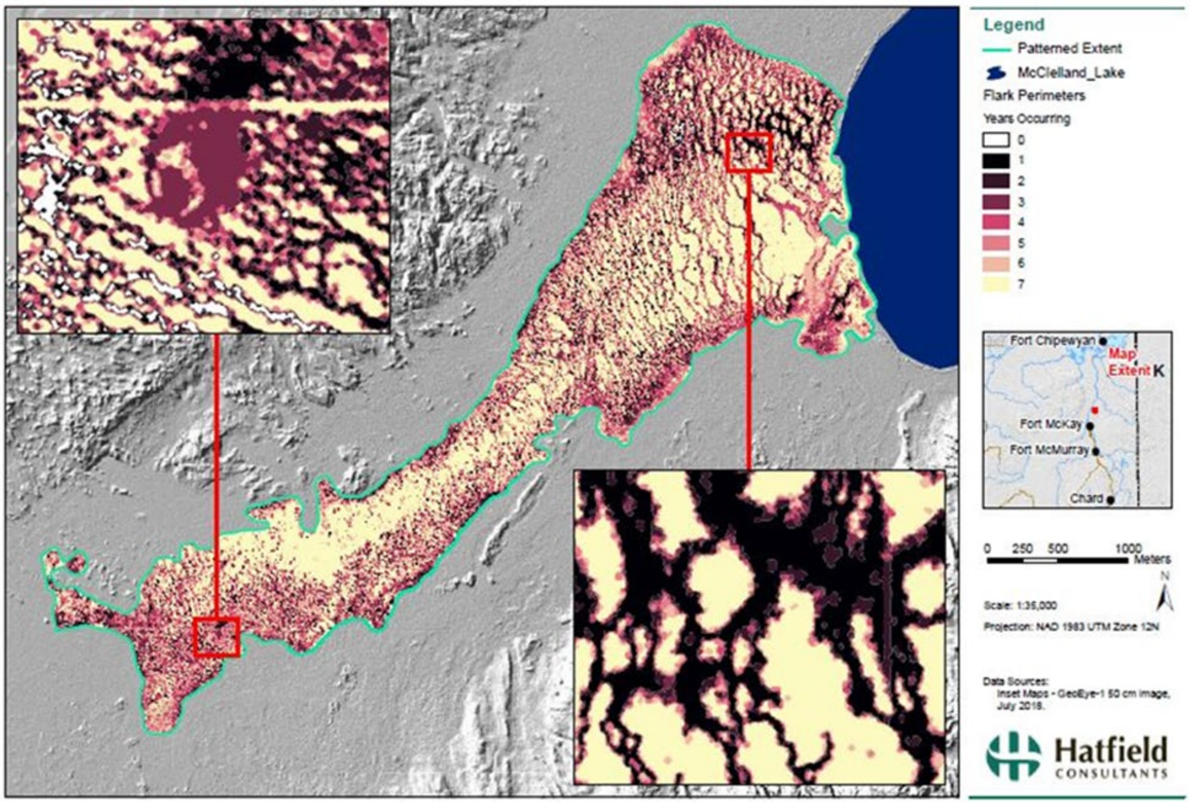


Figure 2.4-2: Flark Persistence between 2005 and 2019

2.4.1.2.2. Surface Water Flow as it Relates to Strings and Flarks

Strings tend to be oriented perpendicular to the direction of water flow. Thus, hydrological flow was modelled to determine whether strings may be changing over time. Elevation data for strings were removed and interpolated elevation models based on hydrology were used to model hypothetical flow paths. In the models, water flowed in two distinct directions within the patterned fen, both of which matched the perpendicular orientation to the strings in those areas (Figure 2.4-1). Prominent elevation features in the 2008 and 2019 datasets were similar (Figure 2.4-3), suggesting that surface hydrology has not changed significantly between these years.

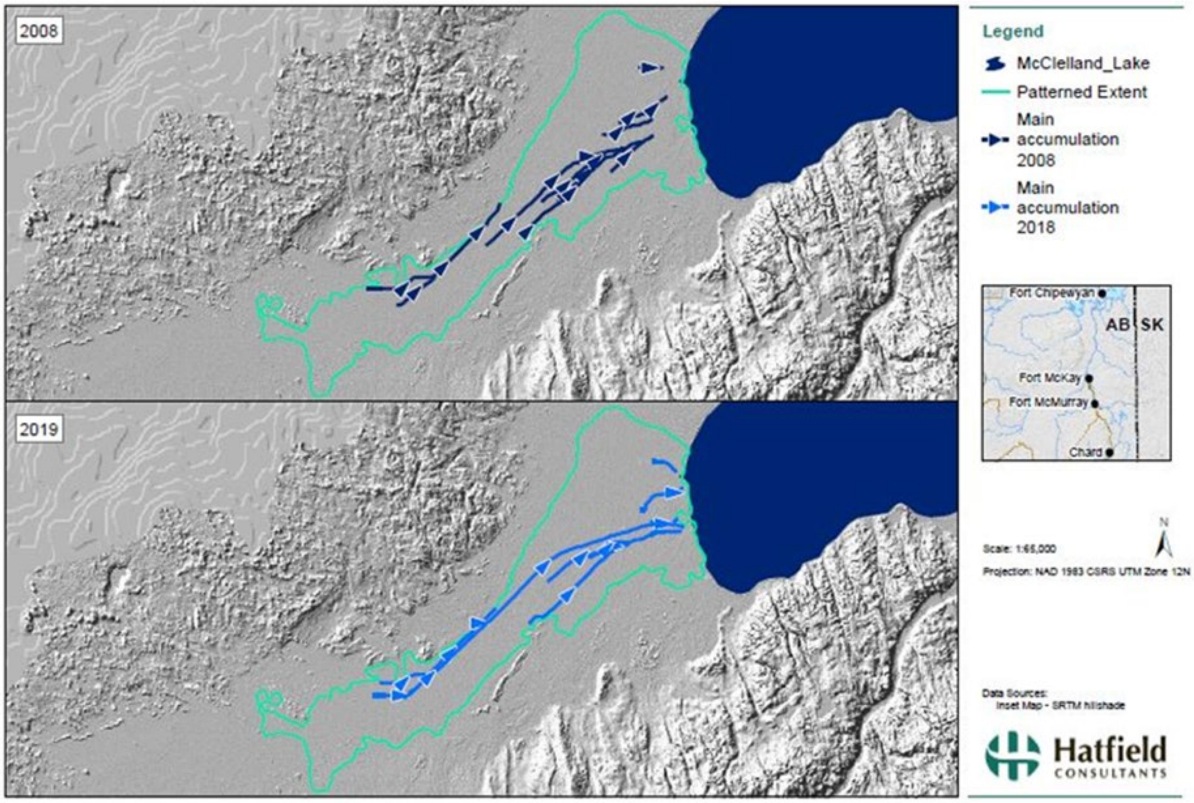


Figure 2.4-3: Model of Surface Water Flow without Influence of Strings

2.4.2. Permafrost

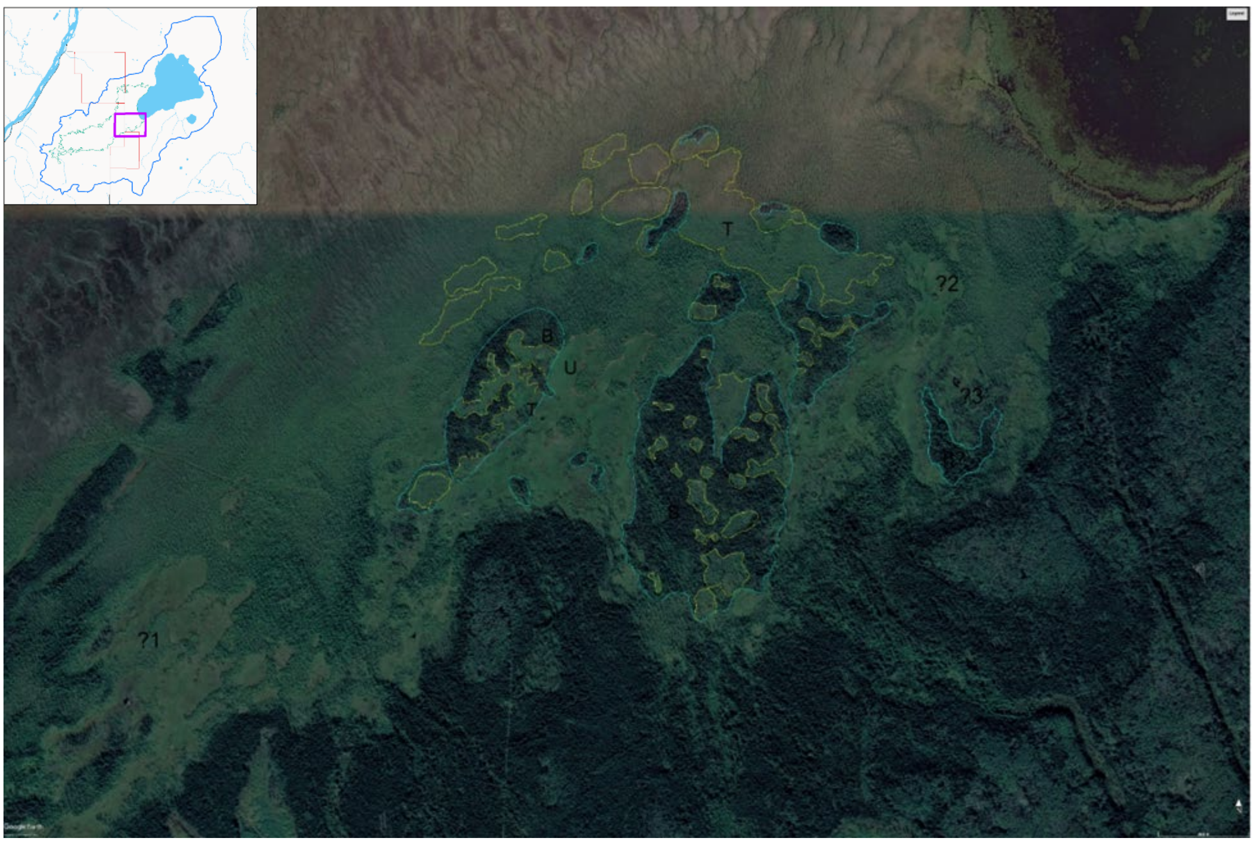
During the Little Ice Age (650 cal yr BP to 100 cal yr BP), permafrost developed on northern boreal and subarctic landscapes. In ombrotrophic bogs, upper peat layers were insulated by Sphagnum and developed permafrost landforms (Vitt et al. 1994). North, in the subarctic and more northerly boreal zones, peat plateaus can be found where bogs have a continuous layer of permafrost. Farther south, areas of permafrost are interspersed with areas without permafrost in bogs (Beilman et al. 2000). Shallow permafrost also developed in some wooded fens, such as at MLWC, in areas with increased elevations and drier conditions. Areas with permafrost often have higher cover of fruticose lichens (e.g., *Cladonia* spp.) and feather mosses (e.g., *Pleurozium schreberi*). As permafrost thaws, areas collapse and these dry areas are suddenly flooded. Collapsed areas associated with peat plateaus maintain similar acidic conditions; however, if the hydrology of collapsed areas contacts the surrounding minerotrophic fen waters, then they transition to similar flora as the surrounding areas.

2.4.2.1. Permafrost Landforms in the McClelland Lake Wetland Complex Watershed

There are three areas in the MLWC watershed with permafrost and areas of thaw: along the southern edge of the fen (Figure 2.4-4), southwest of the patterned fen (Figure 2.4-5), and northeast of the northeastern portion of the patterned fen (Figure 2.4-6). The MLWC watershed contains four permafrost related landforms:

- *Picea mariana*-dominated bogs with internal lawns
- Bog islands with dense *Picea mariana* and no evidence of thaw
- *Larix laricina*-dominated woodland fens with a shallow layer of either permafrost or late seasonal ice
- *Larix laricina*-dominated woodland fens with permafrost thaw

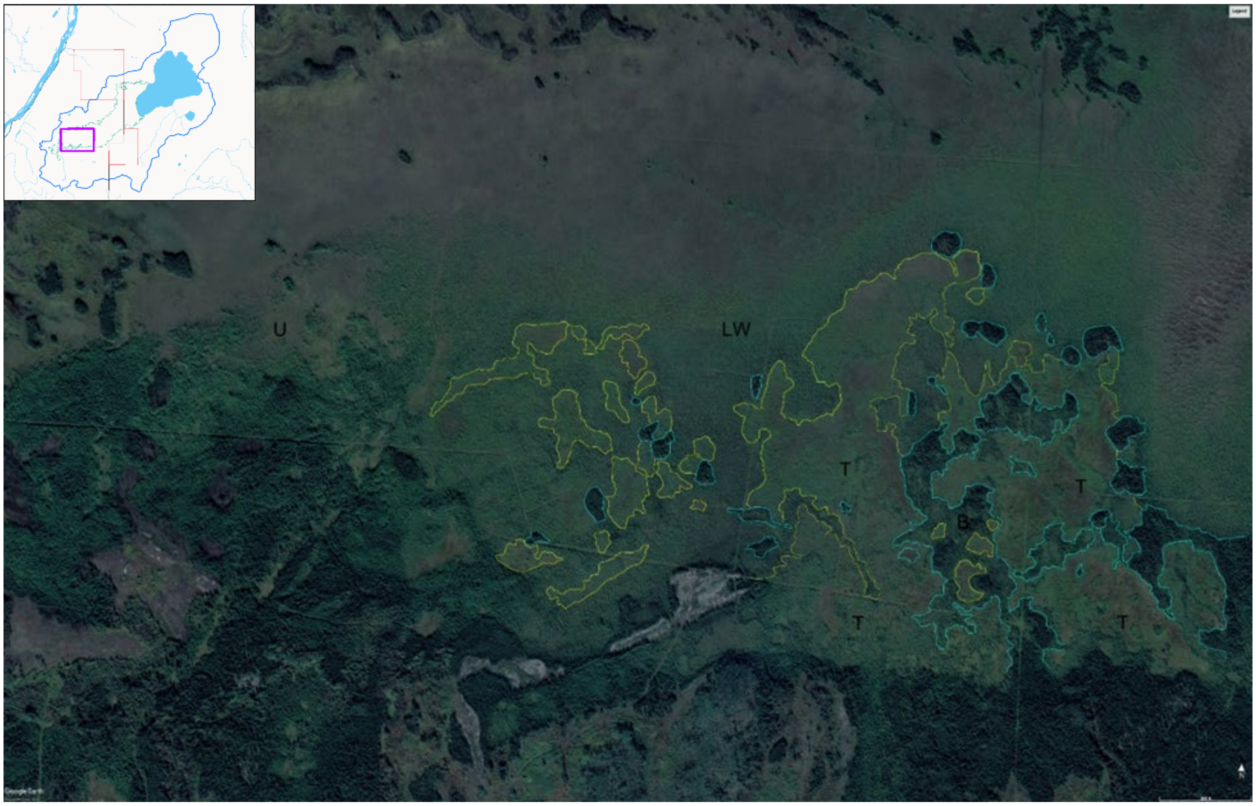
Permafrost persists under areas with woody vegetation, but once the permafrost thaws, the newly wet areas become dominated by sedges, mosses, and standing dead trees. All three areas have had considerable thaw of permafrost recently.



Note: Interpreted from Google Earth images. Areas outlined in blue contain permafrost; areas outlined in yellow are areas with past or current permafrost thaw. Purple rectangle in inset shows location within the MLWC watershed.

B = bog; LW = *Larix* woodland; T = areas with permafrost thaw; U = unknown pattern, including areas ?1, ?2 and ?3 – these areas appear to be regions of water discharge not necessarily related to permafrost thaw.

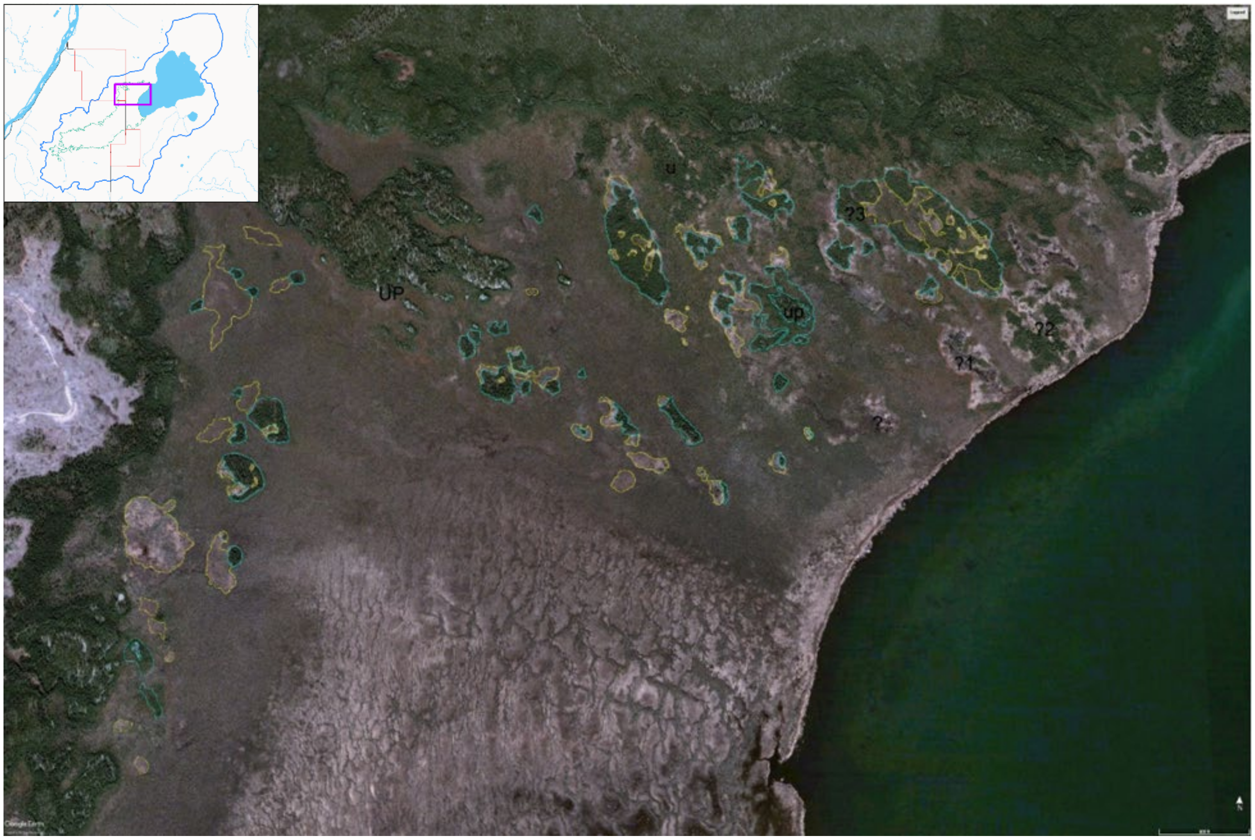
Figure 2.4-4: Permafrost Landforms and Associated Areas of Thaw Along the Southern Edge of the Fen



Note: Interpreted from Google Earth images. Areas outlined in blue contain permafrost; areas outlined in yellow are areas with past or current permafrost thaw. Purple rectangle in inset shows location within the MLWC watershed.

B = bog; LW = *Larix* woodland; T = areas with permafrost thaw; U = unknown pattern.

Figure 2.4-5: Permafrost Landforms and Associated Areas of Thaw in the Southwestern Portion of the Wetland



Note: Interpreted from Google Earth images. Areas outlined in blue contain permafrost; areas outlined in yellow are areas with past or current permafrost thaw. Purple rectangle in inset shows location within the MLWC watershed.
UP/up = upland; u = unknown; ?1, ?2, ?3 = regions of water discharge of unknown origin.

Figure 2.4-6: Permafrost Landforms and Associated Areas of Thaw in the Northeastern Portion of the Wetland

2.4.3. Ecohydrology Zones

The EHZ information discussed in this section is summarized from Vitt and House (2020). The MLWC watershed consists of a variety of wetland site-types (Vitt et al. 2003), which are organized into complex patterns based on water chemistry and vegetation. Wetlands include moss-graminoid moderate-rich and extreme-rich fens, wooded rich fens, bog islands, peat plateaus, wooded swamps, shrubby swamps, and marshes, and occur as six EHZ (Figure 2.4-7) with specific ecological and hydrological characteristics.

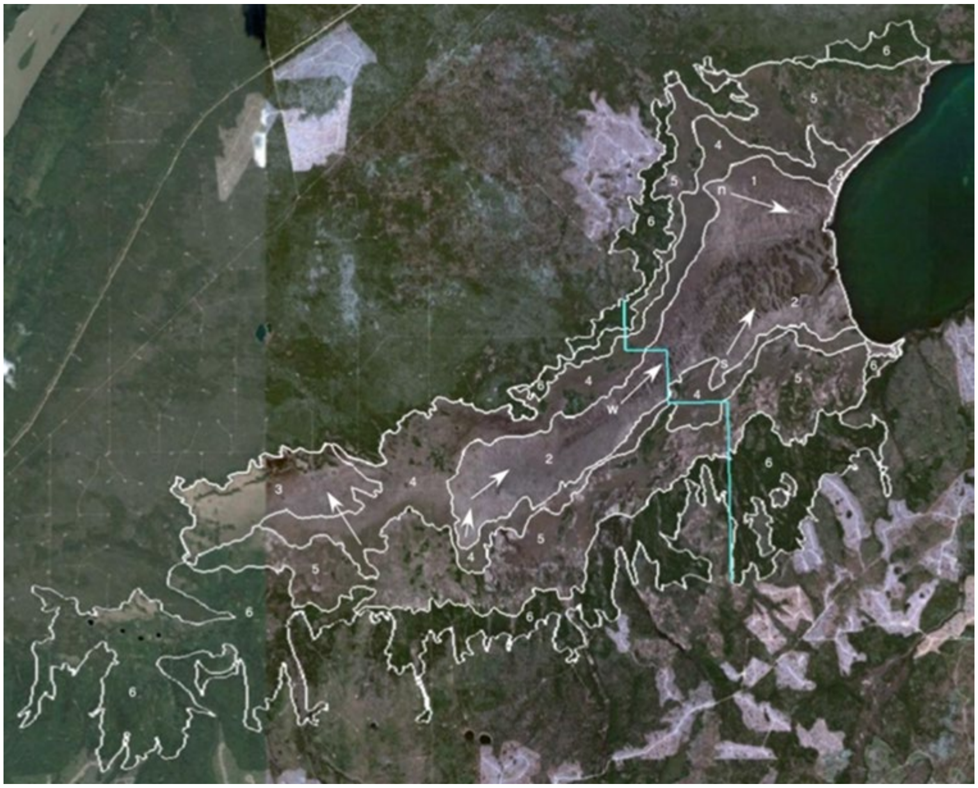


Figure 2.4-7: Location of the Six Ecohydrology Zones at the McClelland Lake Wetland Complex

The zones can be described as:

- Ecohydrology Zone 1: Situated in the northeastern portion of the patterned part of the fen, it covers 136 hectares (ha) (Figure 2.4-7). It is a patterned, moderate-rich fen, which is characterized by well-organized strings and flarks with water flowing east-southeast, exiting the wetland through a northern outlet to McClelland Lake. *Hamatocaulis vernicosus* is the dominant bryophyte species in flarks in EHZ 1. EHZ 1 and 2 are separated by chemistry and vegetation differences, as well as poorly organized strings and flarks.
- Ecohydrology Zone 2: Situated at the central part of the MLWC, it covers 576 ha (Figure 2.4-7). It is a patterned extreme-rich fen characterized by large flarks in the east, which become smaller and better organized in the west. In the west, flarks change orientation, indicating a south/north change in water flow direction, along with an eastward flow direction, and water ultimately exits the fen through a southern outlet to McClelland Lake. Flark vegetation is dominated by bryophytes (e.g., *Meesia triquetra* and *Scorpidium scorpioides*), while strings are dominated by *Larix laricina* in the east and shrubby *Betula glandulifera* in the west.
- Ecohydrology Zone 3: Situated in two small areas at the lake shore and to the northwest, it covers 213 ha (Figure 2.4-7). This EHZ is characterized by high water levels which flow from the south, no patterning, and relatively shallow peat depth (less than 1.5 to 2.0 metres [m]). Vegetation is dominated by bryophyte and graminoid species, specifically by *Scorpidium scorpioides* and *Carex lasiocarpa* (hairy-fruited sedge) in the northwest. The northwest area is dissected by an upland

sandy esker, and water levels are higher on the south side of the esker compared to the north, indicating that water flows from the south.

- Ecohydrology Zone 4: Bordering on EHZ 1 and 2 to the west, north, and south, this EHZ covers 662 ha (Figure 2.4-7). This *Larix laricina*-dominated rich fen has mineral islands in the north, and areas bordering EHZ 1 and 2 are dominated by uniform forest that transitions to shrubby fen in the northwest.
- Ecohydrology Zone 5: Situated along the southern boundary of the wetland, extending to EHZ 4 and northeast of EHZ 1, it covers 1,084 ha (Figure 2.4-7). This permafrost/bog/fen/swamp complex has *Larix laricina* in the southeast and some graminoid-dominated areas with pooled water, indicating water movement through saturated peat.
- Ecohydrology Zone 6: Situated along the southern margin of the wetland and south along tributary streams, it covers 1,161 ha (Figure 2.4-7). This riparian swamp margin is on shallow organic soils, and contains wooded swamps dominated by *Picea mariana*, with some *Larix laricina* and *Picea glauca*, which is less abundant along the northern boundary.

2.5. Pre-Mining Baseline Conditions

As noted in Section 2.2, FHEC has analyzed the monitoring data collected from the MLWC several times during development of the OP. These assessments were completed prior to the development of the EHZ conceptual model, and only considered data collected prior to the assessment.

The main task for the OP in relation to Objective 1 that was identified in the OP Proposal was to finalize calculation of the MRV of the monitoring data. This section presents an updated assessment of the MLWC monitoring data collected through the end of 2020 and is presented within the EHZ conceptual model. In addition, reference site data from ALWC and GGWC are discussed for hydrogeology, surface water hydrology, surface water quality, aquatic resources, vegetation, and wildlife. Knowledge holders have shared ITK to inform both pre-development, as well as pre-mining conditions. ITK relating to each topic has helped to inform the focus of each, providing historical and current information on aspects of the terrestrial and aquatic environments of importance to Indigenous Peoples. ITK has provided a better understanding of pre-mining baseline conditions by describing change, if any, from pre-development baseline conditions, attributing perspectives of potential causes of that change. While ITK did not yet necessarily directly contribute data to the MRV, it placed it in context to the NRV.

2.5.1. Analytical Approach for Characterization of the Measured Range of Variability

The analytical approach for characterization of the MRV for the pre-mining baseline dataset varies by discipline. Data maxima and minima, measures of variation in central tendency (e.g., mean; median), measures of spread around the mean (e.g., standard deviation), and visualization of frequency distribution (e.g., box and whisker plots) are used in Section 2.5 to describe the MRV as applicable to each discipline. In addition to these basic summary statistics, normal ranges were calculated by some disciplines with suitable datasets (i.e., water quality and vegetation) to identify the bounds within which future observations are predicted to occur.

Analytical procedures applicable to more than one discipline are summarized here and include calculation of normal ranges, characterization of species diversity profiles, and implementation of before-after-control-impact (BACI) analyses. Discipline-specific analyses are described as they come up within each discipline section.

2.5.1.1. Normal Range

Normal range is a statistical technique that is used by some disciplines in Section 2.5 to characterize the MRV. Measured normal range can be calculated to describe "normal" conditions based on pre-mining baseline or reference site data for applicable indicators (e.g., water quality parameters, percent cover of plant species indicator groups, and plant species diversity metrics). The approach involves comparing observations from individual wetland sample units during mine operations to the MRV, as described by the normal range, among observations from baseline or reference site data.

Normal ranges presented in this document were developed based on methods used for calculating prediction intervals outlined in Barrett et al. (2015). Prediction intervals are used to estimate a range of expected future observations based on a reference site dataset. This method has been used in a variety of forecasting applications and has been applied to environmental monitoring to identify unusual observations suggestive of environmental effects (Barrett et al. 2015). Prediction intervals differ from percentiles in that percentiles are used to define a proportion of data in a sample (e.g., 50% of sample data are below the 50^{th} percentile), whereas prediction intervals are used to estimate a range of expected observations.

Prediction intervals are defined under the assumption that observations follow a normal distribution. The formulas for the lower bound (*L*) and upper bound (*U*) are:

$$L = \bar{x} - t_{a/2,n-1} S \sqrt{1 + \frac{1}{n}} \quad \text{Equation 1}$$

$$U = \bar{x} + t_{a/2,n-1} S \sqrt{1 + \frac{1}{n}} \quad \text{Equation 2}$$

where: $\bar{x}$ = the mean of the samples from reference plots

$t_{a/2,n-1}$ = the $1 - a/2$ fractile of a *t*-distribution with n-1 degrees of freedom

α = 0.05

S = the standard deviation

n = number of sample units

Normality is assessed using the Shapiro-Wilk test, using $p < 0.05$ to detect a significant departure from normality. When data are not normally distributed, but normality could be achieved using the Box-Cox power transformation, the normal range is calculated on the power transformed data. If both the untransformed and power-transformed data are non-normal, the normal range bounds are defined using a non-parametric method. The lower and upper bounds are defined as $\left(\frac{\alpha}{2}\right)^{th}$ and $\left(1 - \frac{\alpha}{2}\right)^{th}$ quantiles, respectively, averages of a bootstrapped dataset generated using 10,000 random samples of the reference dataset. When calculated prediction intervals are outside of the range of potential values (e.g., percentages of less than 0 or greater than 100), the limits are truncated to the limit of potential values (i.e., 0 or 100). For non-normally distributed water quality data, normal ranges were defined by the quantile of the dataset. The normal ranges presented in the OP will be re-calculated as additional pre-mining baseline data are collected.

2.5.1.2. Species Diversity Profile

A suite of diversity metrics was calculated using a similar method to diversity analyses reported by Armada (2019), which places species on a continuum of similarity. Diversity profiles are presented for various q index values, which control the weight given to species abundance in addition to grouping species that are functionally similar (e.g., q = 0 gives all species equal weight but as q approaches infinity, functionally similar species are combined to give rare species less weight) (Leinster and Cobbold 2012). Similar to analyses reported by Armada (2019), q values examined included: 0, 2, and 5 in which a q index of zero is representative of species richness, a q index of 1 is related to the Shannon-Weiner Index, and a q index of 2 is related to the Simpson's Diversity Index. In a similarity matrix used to assign values to functionally similar species, where two species were identical they were assigned a value of 1, where two species were within the same taxonomic genus, they were assigned a value of 0.75, where two species were within the same lifeform grouping, they were assigned a value of 0.50; all other species were assigned a value of 0 (Armada 2019).

2.5.1.3. Before-After-Control-Impact Experimental Design

The BACI experimental design (Underwood 1992) 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.

2.5.2. Geology and Hydrostratigraphy

2.5.2.1. Overview of Pre-Mining Baseline Data

ITK holders noted the abundance of sandy areas in the MLWC area, and have identified areas of open water where the waterbody bottom was similar to quicksand, and not safe to traverse. Limestone and clay were other substrates identified in the area by ITK holders. ITK Holders remembered:

> *"But I know from boating around, the bottom is like quicksand. Maybe it's because it just sits there for so long, turn everything in to quicksand, that part is dangerous too. We would get in trouble if went too far in to the lake."*(FMFN ITK holder, March 3, 2021 workshop)

> *"I know there's a lot of limestone through there. Now the water, course, is sitting on this limestone. It doesn't fall through the limestone, maybe some places. And there's clay in there too, and water don't go through clay..... What about the fen? What's underneath the fen? There's water. There's tar sand under the fen and then the limestone? Because I know the limestone from there runs right to Fort McMurray, past Fort McMurray. The furthest north I've seen it was at the Firebag, and I could be wrong. It could be further north yet too, but I know the Firebag. So the water then, it's sitting... Okay, it's limestone, tar sand, water, and the floating muskeg on top. That's the way I'm picturing it."* (FCM ITK holder, March 3, 2021 workshop).

The surface outflow from McClelland Lake, McClelland Creek, has been referred to by an ITK Holder as being an old creek bed.

> *"McClelland Creek, it varies, one year it will be dry and one year there's abundance of water. And years ago, there had seemed to be more water in that creek than the later years. And then when I say more water, probably I would say in the '50s, there was a lot more water, but then in the '60s, sometimes you can just walk across there with just your rubber boots. Sometimes, you've got to walk across, just about up to your neck because I've done that.*

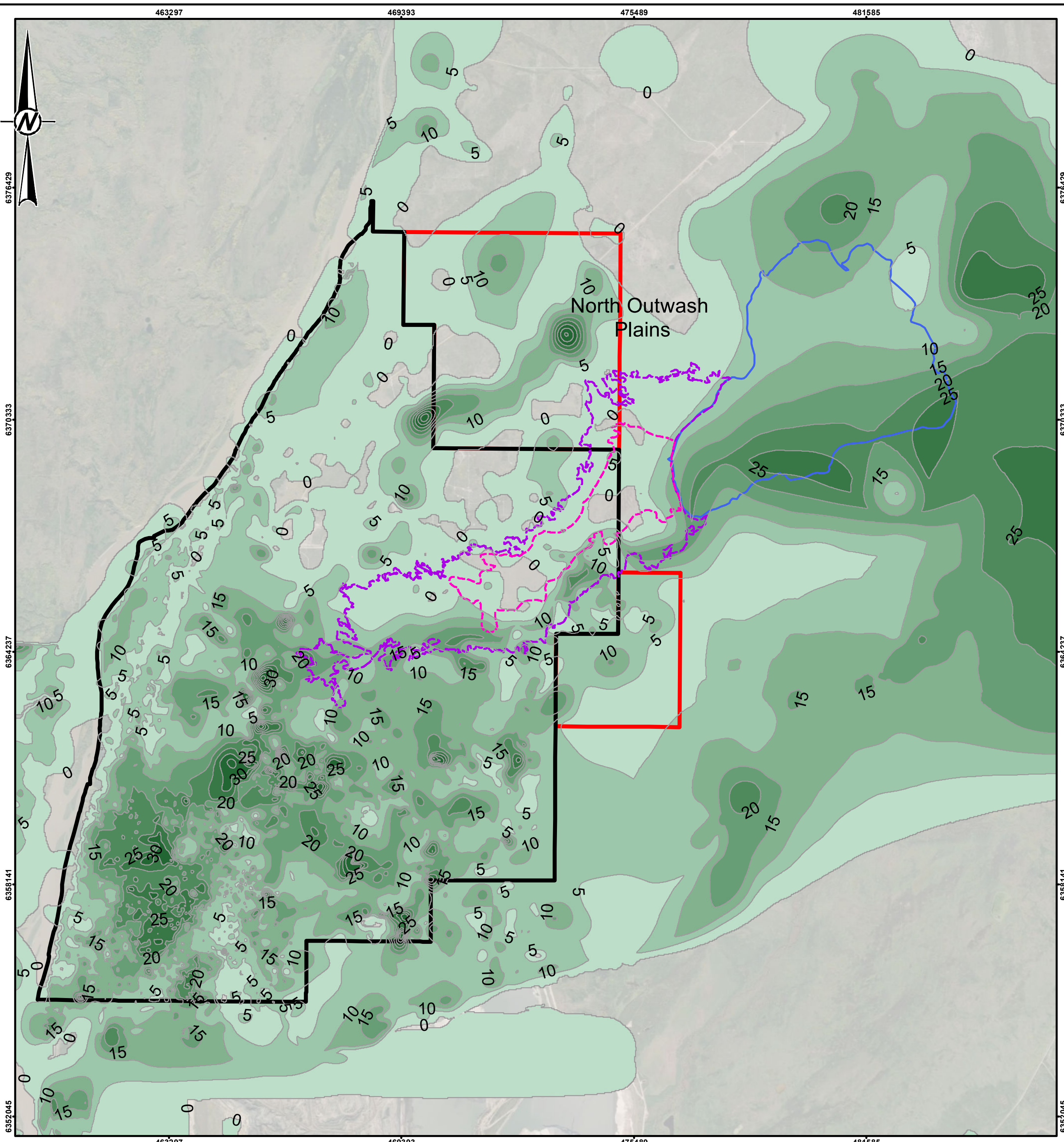
> *But I guess maybe it varies again, because it depends on the beavers' dams on the creek, but if you look at the creek bed, the last time I was there, I took a good look at it. You could see the creek bed, some places probably at a quarter mile (I won't say half a mile), but quarter of a mile wide, where you could see the line of the big trees, and then it goes down and only willows through in the lower area. You can tell that that used to be a creek bed before where the high trees and the pines, where there was no creek running through there."* (FCM ITK holder, March 3, 2021 workshop)

The 2020 Unified Geomodel was created by Aquanty Inc. (Aquanty 2021) from the Quaternary geological model (originally prepared by Matrix Solutions Inc.) and FHEC's FH19a geomodel. This geomodel is constrained by geological data from 1,218 monitoring and pumping locations drilled within the Fort Hills lease. This section contains a description of the Quaternary and Holocene deposits in the MLWC.

At the base of the Quaternary there is an extensive clay till aquitard (Clay Till 2) overlying the Cretaceous Clearwater and McMurray bedrock in the area, which is overlain by a complex Quaternary geology. The distribution of the Clay Till 2 layer is shown in Figure 2.5-1; this layer underlies most of the MLWC.

In the south and east of the MLWC on the Fort Hills Upland Complex, an aquifer and patchy aquitard sequence overlies the Clay Till 2 and extends beneath the Fort Hills. In this area, a silty sand aquifer (AQ4) overlies the Clay Till 2 and extends beneath the Fort Hills. Rafted McMurray (PGKM) has been found within the silty sand aquifer. Overlying the AQ4 unit is a patchy sandy silt aquitard (AT2). This progression of silty sand aquifer and patchy sandy silt aquitard is repeated, with AQ2 silty sand aquifer material, and AT4 sandy silt aquitard material, overlain by silty sand aquifer material (AQ1/AQ2). This sequence can be seen in cross-sections (Figure 2.5-2, Figure 2.5-3, and Figure 2.5-4).

In the north and west of the MLWC, a second laterally extensive clay till layer (Clay Till 1) overlies the Clay Till 2 unit. This unit underlies most of the MLWC and extends to the north and west of McClelland Lake and the fen (Figure 2.5-5). As this unit extends eastward, it overlies portions of the Fort Hills aquifer/aquitard sequence (Figure 2.5-6). Overlying the Clay Till 1 layer is an extensive, thick, sand aquifer, referred to as the Surface Sands; these sands are the North Outwash Plain (NOP). This unit extends beneath the MLWC and reaches to the western and northern extents of the MLWC area (Figure 2.5-6). There is a patchy silty clay overlying the surface sands, in the southwest of the area. Most of this silty clay occurs between the Fort Hills Upland Complex (FHUC) and the fen extents, with a significant area of silty clay also occurring beneath most of McClelland Lake (Figure 2.5-7).



LEGEND

- Approved Project Area
- Extension Areas as proposed in the Integrated Plan Amendment Application
- Patterned Fen
- Non-patterned Fen
- McClelland Lake

Clay Till 2 Thickness (m)

- 0
- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35

0 1 2
Kilometres

1 " = 4 kilometres

NOTE(S)
CONTOUR INTERVAL: 5 M

REFERENCE(S)
1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
3. GEOMODEL SOURCE: SUNCOR

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

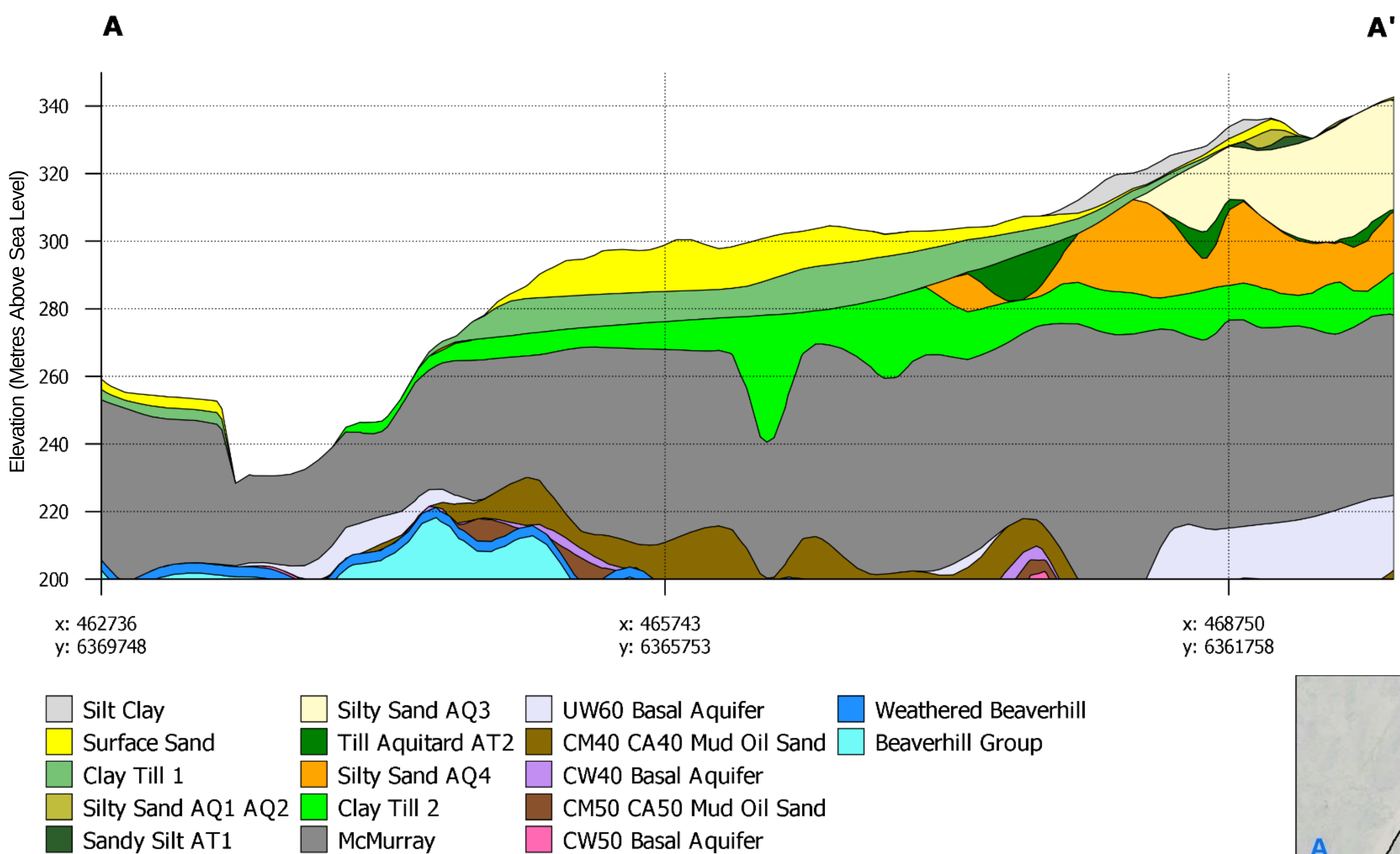
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-10
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE
CLAY TILL 2 ISOPACH

PROJECT NO.	CONTROL	REV.	FIGURE
20140450	-	0	2.5-1

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



Scale: 1:48,000

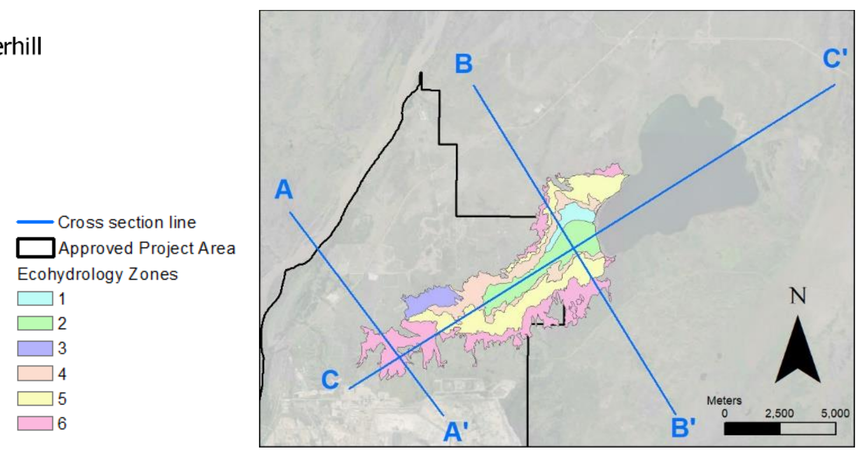
Vertical exaggeration: 30x

0 m 2,000 m

Location

A: 462736, 6369748

A': 469631, 6360588



NOTE(S)
- Geomodel source: Suncor
- Units are defined in Section 2.5.2

CLIENT
FORT HILLS ENERGY CORPORATION

FORT HILLS
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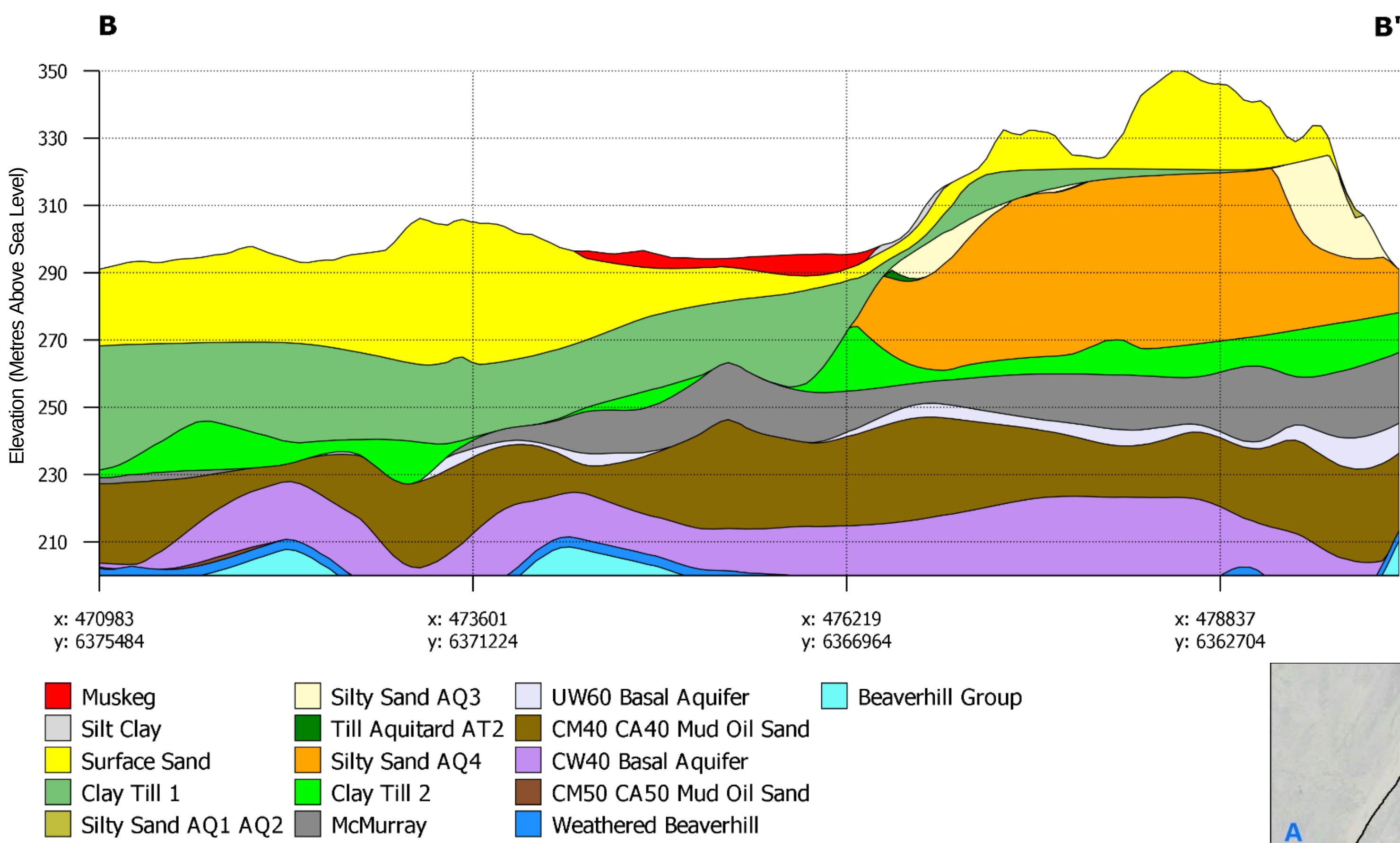
PREPARED	JH
DESIGN	RS
REVIEW	ZG
APPROVED	JH

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

TITLE
Cross Section A-A'

PROJECT No. 20140450 --
Rev. 0
FIGURE 2.5-2



Scale: 1:71,000

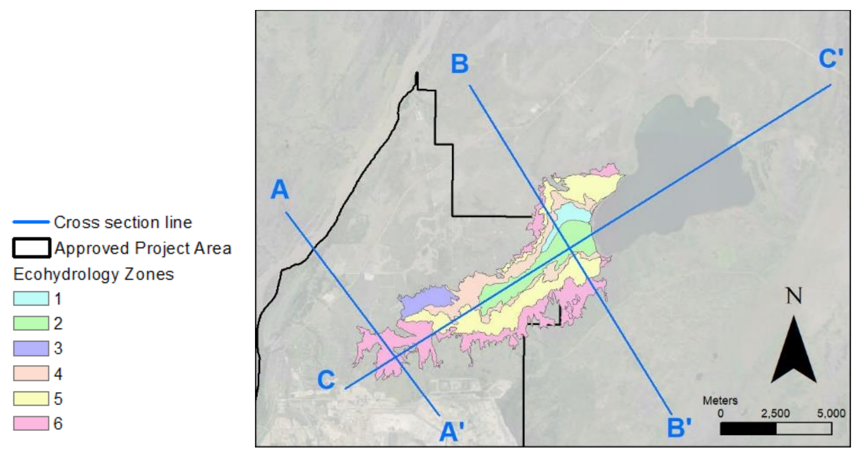
Vertical exaggeration: 45x

0 m 2,000 m

Location

B: 470983, 6375484

B': 480091, 6360664



NOTE(S)
- Geomodel source: Suncor
- Units are defined in Section 2.5.2

CLIENT
FORT HILLS ENERGY CORPORATION

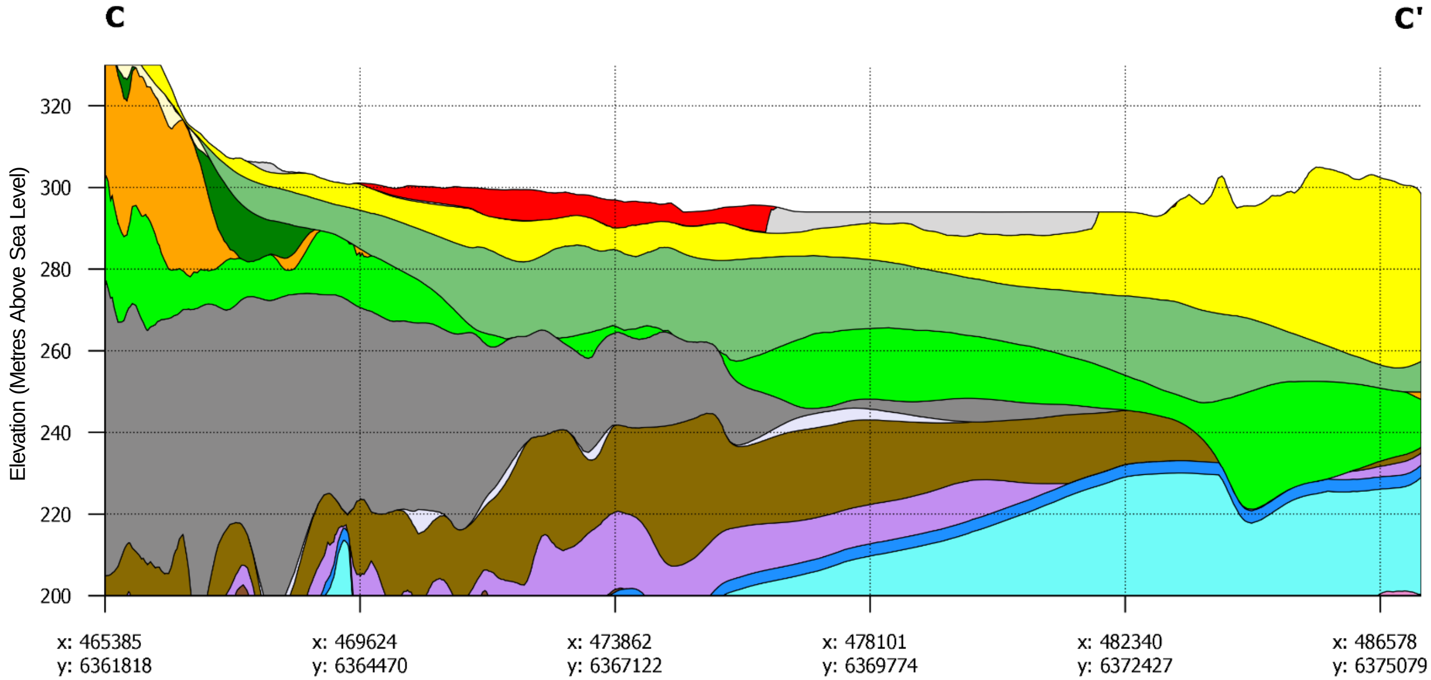
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-10
PREPARED	JH
DESIGN	RS
REVIEW	ZG
APPROVED	JH

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

TITLE
Cross Section B-B'

PROJECT No.		Rev.	FIGURE
20140450	--	0	2.5-3



- Muskeg
- Silt Clay
- Surface Sand
- Clay Till 1
- Silty Sand AQ1 AQ2
- Sandy Silt AT1
- Silty Sand AQ3
- Till Aquitard AT2
- Silty Sand AQ4
- Clay Till 2
- Clearwater
- McMurray
- UW60 Basal Aquifer
- CM40 CA40 Mud Oil Sand
- CW40 Basal Aquifer
- CM50 CA50 Mud Oil Sand
- Weathered Beaverhill
- Beaverhill Group
- Upper Prairie Aquifer

Scale: 1:110,000

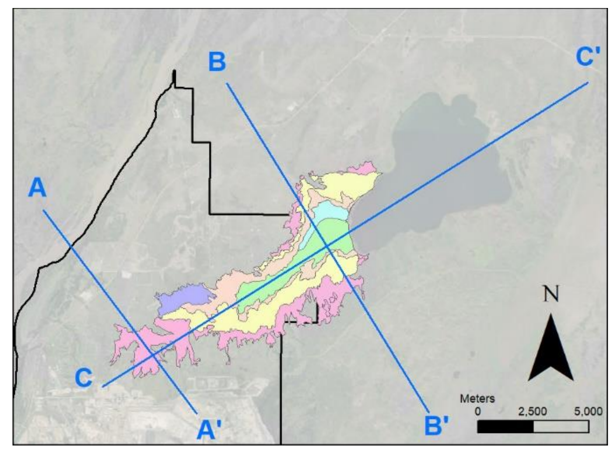
Vertical exaggeration: 80x

0 m 6,000 m

Location

C: 465385, 6361818

C': 487260, 6375505



NOTE(S)
- Geomodel source: Suncor
- Units are defined in Section 2.5.2

CLIENT
FORT HILLS ENERGY CORPORATION

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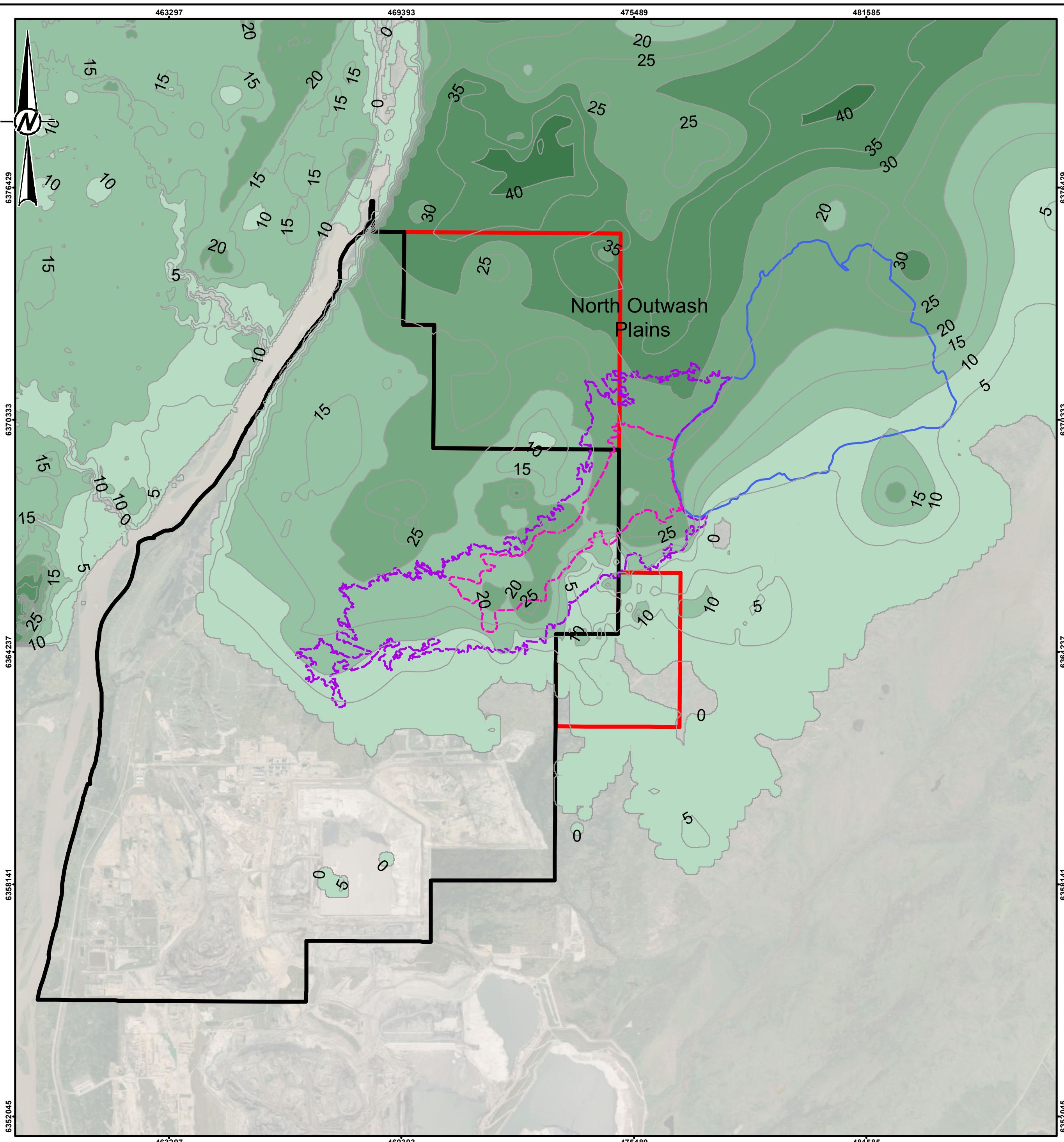
YYYY-MM-DD	2021-12-10
PREPARED	JH
DESIGN	RS
REVIEW	ZG
APPROVED	JH

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

TITLE
Cross Section C-C'

PROJECT No.		Rev.	FIGURE
20140450	--	0	2.5-4



LEGEND

- Approved Project Area
- Extension Areas as proposed in the Integrated Plan Amendment Application
- Patterned Fen
- Non-patterned Fen
- McClelland Lake

Clay Till 1 Thickness (m)

- 0
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60

0 1 2
Kilometres

1 " = 4 kilometres

NOTE(S)
CONTOUR INTERVAL: 5 M

REFERENCE(S)
1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
3. GEOMODEL SOURCE: SUNCOR

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-10
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE
CLAY TILL 1 ISOPACH

PROJECT NO.	CONTROL	REV.	FIGURE
20140450	-	0	2.5-5

R:\ComplexData\Suncor_2020\2020_FHX_OPTA_MLWC\Hydrogeology Data\05_Technical_Work\04_Analysis\MLWC Data Assessment\01_Input_Files\02_Data_Processed\Isopach_maps\Figure2.5-5_Isopach_clay_till_1.mxd

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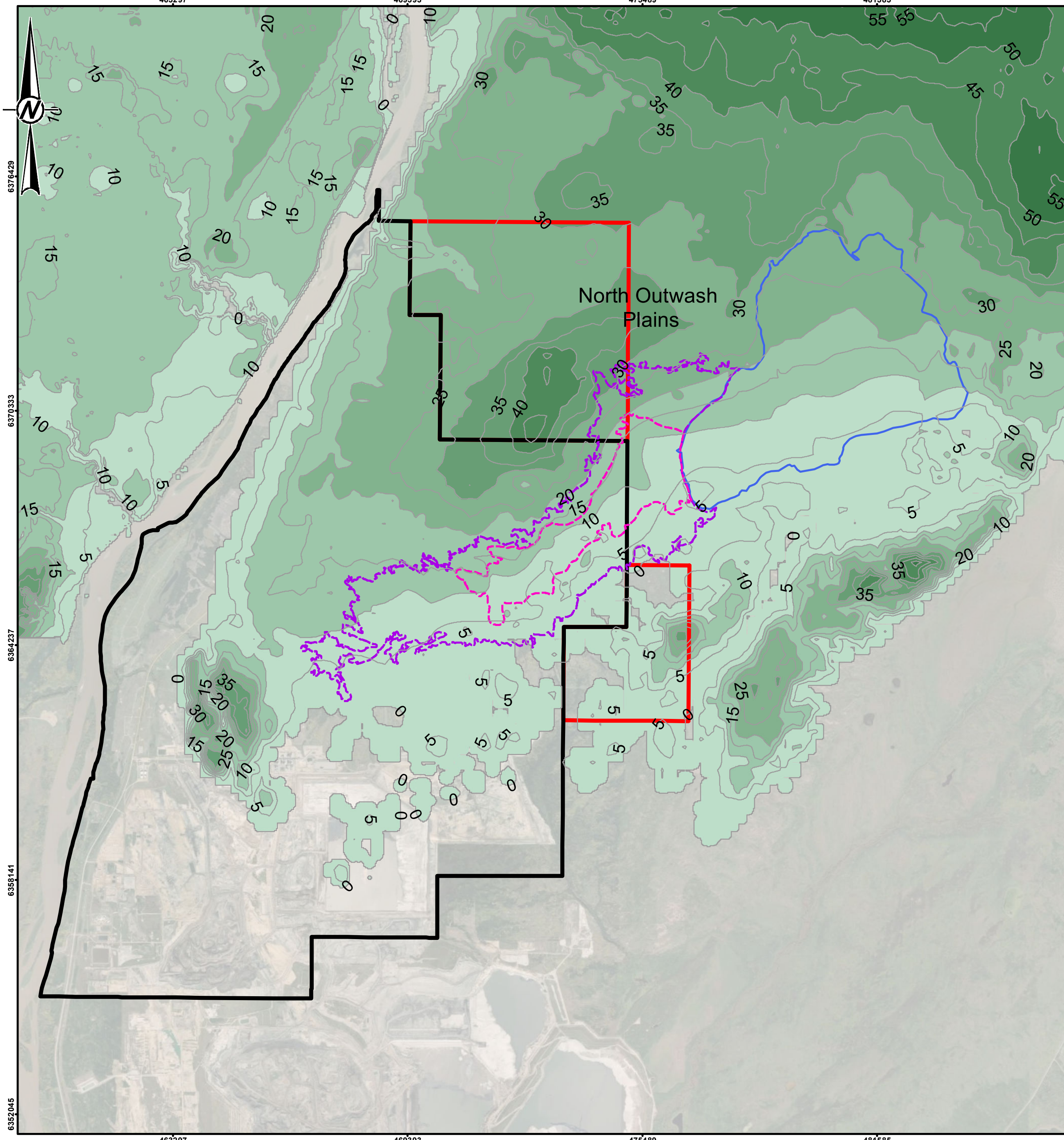
0 1 in



LEGEND

- Approved Project Area
- Extension Areas as proposed in the Integrated Plan Amendment Application
- Patterned Fen
- Non-patterned Fen
- McClelland Lake

Surface Sand Thickness (m)

- 0
- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70

0 1 2
Kilometres

1 " = 4 kilometres

NOTE(S)
CONTOUR INTERVAL: 5 M

REFERENCE(S)
1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
3. GEOMODEL SOURCE: SUNCOR

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

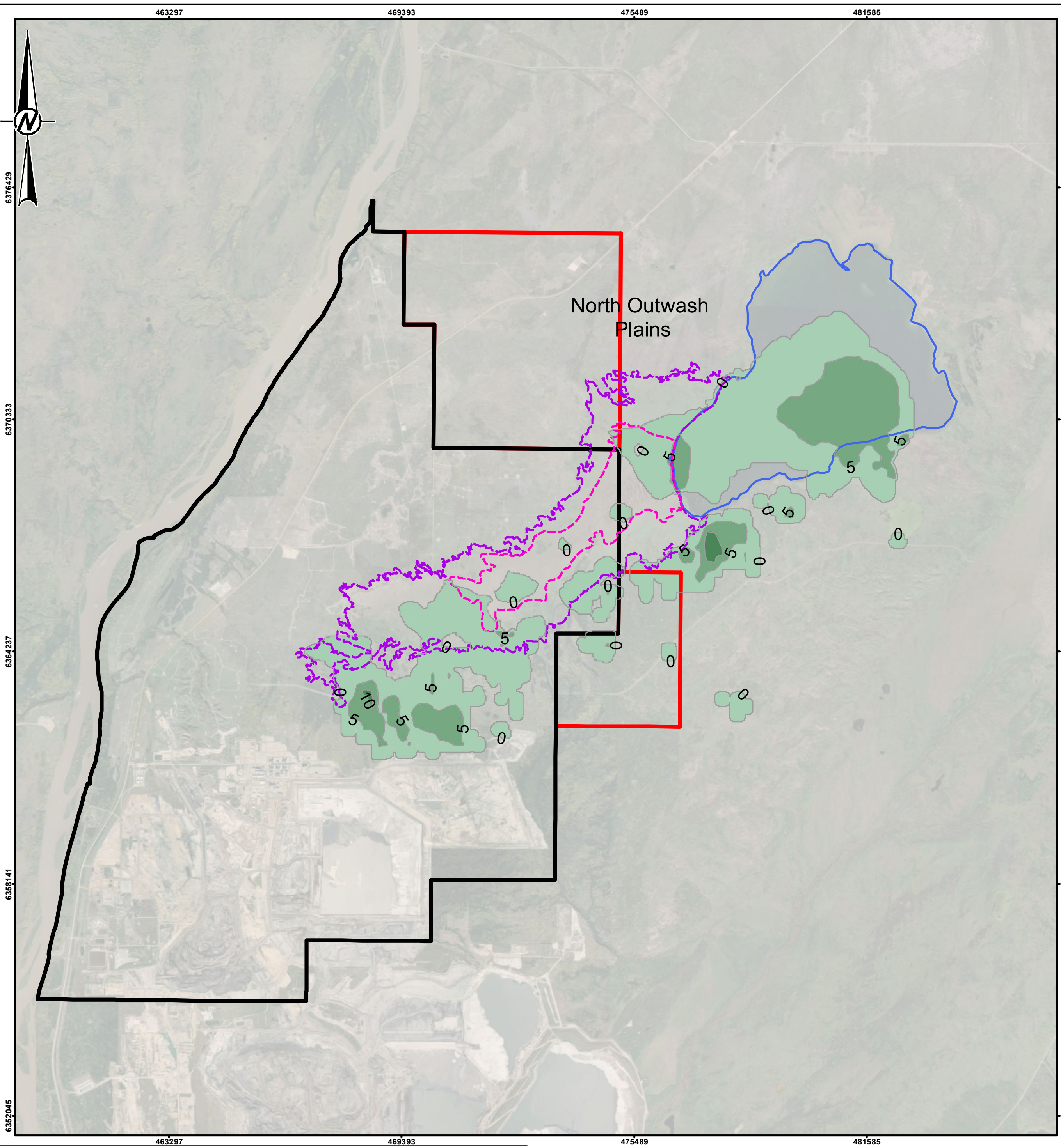
YYYY-MM-DD	2021-12-10
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE
SURFACE SAND ISOPACH

PROJECT NO.	CONTROL	REV.	FIGURE
20140450	-	0	2.5-6

R:\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\05 Technical Work\04_Analysis\MLWC Data Assessment\01_Input_Files\02_Data_Processed\Isopach_maps\Figure2.5-6_surface_sand.mxd

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



LEGEND

- Approved Project Area
- Extension Areas as proposed in the Integrated Plan Amendment Application
- Patterned Fen
- Non-patterned Fen
- McClelland Lake

Silt Clay Thickness (m)

- 0
- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20

0 1 2

Kilometres

1 " = 4 kilometres

NOTE(S)

CONTOUR INTERVAL: 5 M

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
3. GEOMODEL SOURCE: SUNCOR

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-10
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE

SILT CLAY ISOPACH

PROJECT NO.	CONTROL	REV.	FIGURE
20140450	-	0	2.5-7

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

1 in

0

2.5.3. Topography

2.5.3.1. Overview of Pre-Mining Baseline Data

ITK holders have indicated that the MLWC area was an important harvesting and travel location for Indigenous Peoples for generations. High points in the topography would be used as travel routes when ice conditions made safety lake travel difficult. Cutlines were made in the early 1970s following and significantly widening the old dog team trails around areas of McClelland Lake that were made before mining in the region (IEG 2021). Low lying wetland areas were used for harvesting, with some areas of shallow open water avoided to concerns over bottom-stability and 'quicksand'-like conditions. Beavers played an important role in shaping the topography of the area, controlling water flows and soil conditions (IEG 2021).

2.5.3.1.1. Bathymetry

In 2017, a bathymetry survey of the McClelland Lake bottom was completed to update 2001 lake depth data. The 2017 bathymetric survey was completed using electrical resistivity imaging, high-frequency sub-bottom profiling and multi-channel sub-bottom profiling. The 2017 bathymetry survey results defined an average depth of 2 m and a maximum depth of 5 m.

2.5.3.1.2. String and Flark Remote Sensing

High resolution Light Detection and Ranging (LiDAR) acquisition was completed in 2019 in addition to previously completed programs in 2005, 2008, 2013, 2015, 2017 and 2018. In 2009, historical aerial imagery from 1949, 1972, 1989, and 1998 was obtained for the shoreline of McClelland Lake and the patterned fen. In 2018, additional historical imagery was gathered from the Provincial Archive of Alberta for the entire MLWC watershed. In total, 634 photos within the MLWC watershed were obtained and included images taken in 1950, 1953, 1967, 1972, 1980, 1984, 1986, 1987, 1989, 1994, 1998, and 2003 (Appendix A).

As discussed in Section 2.4.1.2, multiple years of LiDAR data were analyzed in 2019 to assess string and flark configurations; the years analyzed included 2005, 2008, 2013, 2015, 2017, 2018, and 2019. The position and persistence of the string features were assessed using the extracted geometry from the LiDAR data set. Associated with the string extraction, the flark geometry was also assessed for persistence throughout the time series of LiDAR. After using a combination of qualitative and quantitative methods, it was determined that little change in string and flark configuration occurred between 2005 and 2019.

The following methods were used in 2019 for analyses of multi-year LiDAR datasets (Hatfield 2020). Similar methods will be used in the future, but methodology may be adapted, as necessary. Prior to beginning analysis, the data were assessed to confirm there were no quality issues and that the data covered the extent of the patterned fen. Data were then gridded to a 1 m spatial resolution and restricted to the area known to be patterned fen. The texture was assigned a Gray-Level Co-Occurrence Matrix (GLCM) Dissimilarity, with large chessboard segmentation (size 25), and a mean canopy height model (CHM) threshold set to 0.2 m, to distinguish between strings and flarks. Different rules were required for the older LiDAR data as it was collected using different methods and had different sensitivities compared to newer LiDAR data; only methods for the newer LiDAR data are described here, as that will likely be more pertinent to future LiDAR datasets.

To account for variation in LiDAR acquisition methods and quality between years and flight patterns, the mean locations of strings (i.e., centerlines) were extracted using Python Scikit-Image morphology module's skeletonize method (van der Walt et al. 2014). This method extracts string perimeters for each year and produces binary rasters for each centerline, which were found to be good spatial estimates of the string centerlines. These raster skeletons were converted to polygons and buffered by 1 m. Buffers from geometries in one feature class from all years were merged, and then a union performed. This eliminates issues arising from raster to vector conversions and splits overlapping geometries into separate polygons.

A spatial SQL query was performed in SpatiaLite, using a group-by query on the geometry field, to determine the number of overlapping string centerline features between years. This was also carried out for the polygons representing raw extracted string perimeters. This indicates the number of times a particular geometry overlaps (i.e., the number of years in which a string occurs). String features were considered such when string perimeter geometries occurred in more than one year. String persistence and characteristics can be assessed in the future by considering whether string features still overlap with baseline geometries.

A similar method was used to extract the geometries of flarks, which are separated by strings and may contain semi-permanent shallow water. Similar to strings, flark persistence and characteristics can be assessed in the future by considering whether flark features still overlap with baseline geometries.

2.5.4. Hydrogeology

In general, the groundwater conditions within the fen were assessed for the following parameters:

- groundwater flow patterns
- hydraulic parameters
- natural variability in groundwater levels
- trends in water levels
- natural variability in vertical groundwater gradients

The supporting tables and figures for the groundwater levels are included in Appendix B. A total of 978 groundwater monitoring locations, consisting of both groundwater monitoring wells and vibrating wire piezometers (VWPs) have been installed as of December 31, 2020 in the MLWC, excluding shallow water quality monitoring wells and counting multi-level monitoring wells as single wells. A selected subset of 394 locations was used for detailed analysis. These wells were selected because they are completed in the near surface sand units or in the peat and are in or around the MLWC watershed.

The hydrostratigraphy of the region has been interpreted using the geological data as discussed in Section 2.5.2, and hydraulic testing results. The hydrostratigraphy is represented in the 2020 Unified Geomodel (Aquanty 2021).

For this report, the 2020 Unified Geomodel was used to correlate the completion formations of the historic wells in the MLWC area to the recently reinterpreted hydrostratigraphic units. The master well list for groundwater wells and VWPs in the MLWC is provided in Appendix B.

2.5.4.1. McClelland Lake Wetland Complex Pre-Mining Baseline Conditions

ITK holders have identified sources of groundwater and hydrological connectivity in the MLWC area. Spring water was an important source of drinking water for Indigenous Peoples using the area, including during winter months when the spring water coming up from the ground would remain unfrozen below an area of thin ice. The area north of Fox Creek was noted as containing a spring, while a number of cabin sites were located in close proximity to springs (IEG 2021). One ITK holder remembers:

> *"And there is some little creeks that don't freeze in the winter the, but those are probably more like springs that are heading towards the river and on the river. But there's no really big creeks on towards the Athabasca River, from between McLennan Lake and Athabasca River, except for springs."* (FCM ITK holder, March 3, 2021 workshop)

ITK holders have indicated that areas of muskeg provided important habitat for traditionally harvested wildlife and vegetation prior to mining, but also posed a significant safety risk. Children were cautioned against walking through such areas, as they could plunge through the four feet of 'hanging' muskeg into the waters below. The southwest shores of McClelland Lake were known to have sporadic muskeg 'holes'. During the winter, areas of muskeg would freeze and become suitable to travel across on foot (IEG 2021). One ITK holder remembers:

> *"[the area south/east of McClelland Lake, including Baby Lake] my dad, my mom, they would never let us walk alone, we had to carry a stick, because of all the hanging muskeg in there. It hangs - about 4 feet of ground, then straight water underneath. then it was that thick clay. .... but there's lots of other places like that.... My grandfather used to say, if we sunk in that muskeg, we weren't coming back up, which I think it's true. Because when I went fire fighting after I grew up, you can see after where the muskeg gets burned, that its deep. Because, we were on fire watch we had to put out smouldering ashes and stuff. Yeah. And there it was, you could see that in some places, it [muskeg] was like about eight feet deep... Well, I guess there is some danger in not listening to your mum and dad anyways."* (FMFN ITK holder, March 3, 2021 workshop)

ITK holds several waterbodies as being connected through streams, wetlands, and groundwater. For example, Baby Lake was considered to be connected overland to McClelland Lake, but also through groundwater sources. Indeed, the large lakes surrounding McClelland Lake are considered to be connected via muskeg and groundwater. Some have cited groundwater leeching through 'veins' the muskeg as the source of the tinted colour in the Firebag River and Moose Creek. The Firebag River and the Muskeg River are, in turn, connected to the Athabasca River, all of which are culturally important to Indigenous Peoples (IEG 2021). One ITK holder remembers:

> *"I would say that there's—well, there is some creeks feeding the Moose Creek, and—but there is a lot of underground water that also feeds it. And I don't know if you would—because Moose Creek got a tint. It's got a tint in its water. Whenever there's tint in water—well, Firebag has too. So I would say that would have—that's probably underground water through muskeg for that—where it gets its—that tint. Because the Athabasca don't have it on clear. I don't know why. There is a lot of muskeg feeding in there, just like the lake. But down in this kind of light coloured tea, that's how the Firebag looks. And Moose Creek is the same way."* (FCM ITK holder, FCM 2019)

ITK holders have noted concern that mining in the MLWC area jeopardizes the fen and water levels in the wetlands, resulting in the destruction of this important environment. Concern has also been expressed that there is no effective mitigation for such impacts of mining. Moose Creek, McClelland Creek, and Baby McClelland Lake have all been identified by ITK holders as important sites (IEG 2021).

2.5.4.1.1. Data Quality Assessment and Corrections

Well Coordinates and Depths

Well coordinates and completion depths were taken from Golder (2018) and Matrix (2020a,b,c,d).

Lithology Check and Corrections

The well formations assigned in the reviewed reports (Golder 2018; Matrix 2020a,b,c,d) were updated to match the 2020 Unified Geomodel naming conventions by mapping the well completions to a corresponding formation in the geomodel. When the 2020 Unified Geomodel unit conflicted with the original completion lithology (e.g., a well reported as completed in Quaternary aquifer mapped to a clay till unit in the 2020 Unified Geomodel), the original reported lithology was used. This resulted in assigning wells as undifferentiated Quaternary aquifer or aquitard material to align with the lithology encountered during drilling. Wells without completion depths or coordinates were assumed to be in undifferentiated Quaternary.

Wells used as part of the calculation of vertical fluxes were always updated to use the unit naming conventions from the 2020 Unified Geomodel even if those units conflicted with the originally reported unit or conflicted with the lithology of the geomodel. For these wells, the borehole logs were reviewed and the hydrostratigraphic unit assigned was updated if required, although the lithology of the unit was not changed (i.e., wells previously designated as “Quaternary sand” were mapped to a sand lithologic unit).

Groundwater Level Checks and Corrections

Groundwater level data was assembled from a variety of tabulated spreadsheets, and reports. Both manual water levels and transducer data, where available, were included in this report. In general, there were three types of groundwater level data:

- The VWP data which consisted of transducer measurements but did not include manual measurements (approximately 60% of groundwater level data).
- Groundwater wells which had a transducer installed in the well and manual water level measurements (approximately 15% of groundwater level data):
  - The transducers in these wells were corrected for barometric pressure effects and a barometric compensation was applied using barometric pressure data collected at GT0788 and Pond 10 between June 2000 and September 2020.
- Groundwater wells where no transducer was installed in the well, but manual measurements were collected (approximately 25% of groundwater level data).

All hydrographs shown in Appendix B include the available hydraulic head data, both manual and transducer, for each well.

Vertical Gradient Calculation

The vertical gradients were calculated using pairs of groundwater elevation data from two separate monitoring wells, or by two succeeding transducers in one borehole. Each of the water levels recorded at the same dates between the pair were subtracted from each other. These values were then divided by the difference between the midscreen elevations of the paired monitoring wells (or by the difference between the elevations of the two transducers), producing the set of vertical gradients per paired borehole.

Details on the vertical gradients are presented in sections below.

2.5.4.1.2. Groundwater Levels

The measured range of groundwater levels at wells in MLWC is presented in Table 2.5-1, organized by EHZ, with additional subdivisions for the FHUC wells (south and east of the fen) and the NOP wells (north and west of the fen). The observation time period of the data presented in Table 2.5-1 (and Appendix B) extends from January 11, 1997 to October 29, 2020.

Hydrographs of the measured water level elevations are presented in Appendix B, which for ease of review, is grouped by EHZ, as follows:

- Appendix B1: Hydrographs for Ecohydrology Zone 1
- Appendix B2: Hydrographs for Ecohydrology Zone 2
- Appendix B3: Hydrographs for Ecohydrology Zone 3
- Appendix B4: Hydrographs for Ecohydrology Zone 4
- Appendix B5: Hydrographs for Ecohydrology Zone 5
- Appendix B6: Hydrographs for Ecohydrology Zone 6
- Appendix B7: Hydrographs for Fort Hills Upland Complex
- Appendix B8: Hydrographs for North Outwash Plain

Table 2.5-1: Groundwater Level Elevations – Measured Range of Variability

Ecohydrology Zone	Completion Hydrostratigraphic Unit	Number of Wells	Measured Groundwater Elevation All Wells [masl]		Measured Range in Elevations All Wells [m]	Measured Range in Elevations (individual well basis)	
			Min	Max		Min	Max
1	Peat	3	294.4	294.7	0.3	0.15 (MW08-305B)	0.17 (MW08-305A)
	Surface Sand	3	294.9	295.5	0.6	0.33 (FH17-WR418-SN2)	0.58 (FH19-ES608-SN1)
	Till 2	1	295.2	295.4	0.2	0.21 (FH19-ES608-SN1)	0.21 (FH19-ES608-SN1)
	Quaternary Aquifer	1	284.4	285.8	1.4	1.38 (FH17-WR418-SN1)	1.38 (FH17-WR418-SN1)
	Rafted McMurray	1	276.0	276.1	0.1	0.11 (FH19-ES608-SN1)	0.11 (FH19-ES608-SN1)
2	Peat	14	294.3	299.9	5.6	0.19 (FH19-ES625-SN1)	0.81 (MLWC2-P560)
	Surface Sand	15	294.4	300.1	5.7	0.08 (FH17-WR404-SN2)	3.71 (FH17-WR427-SN1)[a]
	Till 2	2	296.8	298.5	1.7	0.77 (FH17-WR401-SN1)	0.94 (GT07-092A)
	Clay Till 1	1	295.1	298.1	3.0	3.00 (FH17-WR404-SN1)	3.00 (FH17-WR404-SN1)
	McMurray Basal Aquifer[b],[c]	9	269.5	296.7	27.2	6.89 (FH18-ES424-MR1)	27 (FH17-WR401-MR1)(d)
	Basal Aquitard[a]	2	287.1	292.5	5.4	10.74 (FH17-WR401-MR1)	38.4 (FH17-WR404-MR1)
	Rafted McMurray	2	293.1	297.9	4.8	0.47 (FH19-ES620-SN1)	0.73 (FH17-WR401-SN1)
	Beaverhill[b]	4	267.0	299.9	32.9	2.89 (FH18-ES424-MR1)	35.93 (FH17-WR404-MR1)
3	Peat	1	299.2	299.7	0.5	0.56 (GT07-090C)	0.56 (GT07-090C)
	Surface Sand	2	298.8	300.2	1.4	1.05 (GT07-090A)	1.06 (GT07-090B)
4	Peat	3	294.6	295.0	0.4	0.22 (MW-08-308C)	0.39 (MW08-308B)
	Surface Sand[e]	11	295.6	301.4	5.8	0.08 (FH20-WR664-SN1)	2.63 (GT07-095B)[f]
	Till 2	2	296.5	300.5	5.0	0.78 (FH17-WR445-SN1)	1.46 (FH19-ES615-SN1)
	Confined Sands	1	293.6	297.9	4.3	4.26 (FH17-WR451-SN1)	4.26 (FH17-WR451-SN1)
	Clay Till 1	1	296.5	300.5	4.0	1.15 (FH17-WR445-SN1)	1.15 (FH17-WR445-SN1)
	Quaternary Aquitard	1	296.7	297.3	0.6	0.57 (FH17-WR445-SN1)	0.57 (FH17-WR445-SN1)
	Rafted McMurray	3	296.4	297.8	1.4	0.11 (FH20-WR664-SN1)	1.43 (FH19-ES615-SN1)
	Basal Aquifer[g]	6	265.4	272	6.6	3.87 (FH17-WR451-MR1)	4 (FH17-WR445-MR1)
	Basal Aquitard[h]	5	271.4	281.8	10.4	1.07 (FH17-WR451-MR1)	10.4 (FH17-WR445-MR1)
	Beaverhill[d]	4	271	276	5	3.3 (FH17-WR451-MR1)	4.94 (FH17-WR406-MR1)
5	Peat	7	294.5	301.9	7.4	0.27 (MLWC5-P100)	0.81 (FH17-WR423-SN1)
	Surface Sand[i]	17	294.5	302.6	8.1	0.02 (FH19-ES631-SN2	1.49 (FH17-WR441-DR1)
	Till 2	3	294.7	297.8	3.1	0.73 (FH17-WR447-SN1)	2.89 (FH17-WR439-SN1)
	Confined Sands[j]	3	296.1	302.5	6.4	0.83 (FH17-WR421-SN1)	2.5 (FH17-WR422-SN1)
	Clay Till 1	1	301.2	301.9	0.7	0.69 (FH17-WR423-SN1)	0.69 (FH17-WR423-SN1)
	Rafted McMurray	11	286.9	301.2	14.3	0.14 (FH19-ES631-SN1)	9.81 (FH18-ES426-SN1)
	Basal Aquifer[i],[k]	7	264.1	271.5	7.4	1.30 (FH17-WR441-MR1)	6.98 (FH17-WR421-MR1)
	Basal Aquitard[l]	3	283.4	294.5	11.1	2.1 (FH17-WR441-MR1)	6.46 (FH17-WR421-MR1)
	Beaverhill	2	267.7	279.7	12	1.29 (FH17-WR441-MR1)	11.93 (FH17-WR402-MR1)
6	Peat	1	301.6	301.8	0.2	0.2 (FH17-WR424-SN1)	0.2 (FH17-WR424-SN1)
	Surface Sand	3	294.2	302.7	8.5	0.19 (SH17-WR424-SN1)	0.83 (FH18-ES431-SN1)
	Clay Till	4	304.8	316.9	8.5	0.86 (FH17-WR437-SN1)	4.10 (FH17-WR436-SN1)
	Till Aquitard AT2	4	297.4	318.9	21.5	0.27 (FH19-ES691-SN1)	1.80 (FH20-WR684-SN1)
	Confined Sands	20	294.2	317.5	23.3	0.19 (FH19-ES651-SN1)	1.31 (FH17-WR436-SN1)[n]
	Clay Till 1	3	295.8	306.1	10.3	0.57 (FH20-WR680-SN1)	1.29 (FH17-WR437-SN1)
	Quaternary Aquitard	3	296.9	311.5	14.6	0.53 (FH20-WR680-SN1)	1.30 (FH20-WR684-SN1)
	McMurray Basal Aquifer	8	249.5	272.4	22.9	0.94 (FH17-WR403-MR1)	7.83 (MW07-122)
	Basal Aquitard	3	270.3	294.4	24.1	4.76 (FH17-WR403-MR1)	9.24 (FH17-WR438-MR1)
	Indeterminate	1	301.5	301.7	0.2	0.18 (FH17-WR424-SN1)	0.18 (FH17-WR424-SN1)
	Beaverhill	4	263.4	273.0	9.6	1.08 (FH18-ES431-MR1)	4.60 (FH17-WR448-MR1)
	Rafted McMurray	19	296.6	318.9	22.3	0.56 (FH19-ES676-SN1)	3.02 (FH19-ES668-SN1)[o]
Fort Hills Upland Complex[p]	Peat	4	294.3	318.0	23.7	0.69 (FH19-ES672-SN3)	0.87 (FH18-ES421-SN1)
	Surface Sand	9	283.8	341.7	57.9	0.04 (FH19-ES640-SN2)	1.13 (FH17-WR409-SN1)[q]
	Till Aquitard 2	1	316.0	332.2	16.2	16.19 (A-20-AQ3)	16.19 (A-20-AQ3)
	Confined Sands	60	294.6	338.0	43.4	0.05 (FH18-ES441-SN1)	30.86 (FH18-ES436-DR1)[r]
	Clay Till 1	4	294.9	318.0	23.1	0.17 (FH17-WR405-SN1)	1.63 (FH17-WR426-SN1)
	Quaternary Aquifer	10	292.0	329.7	37.7	1.04 (FH17-WR409-SN1)	2.13 (FH17-WR425-SN1)
	McMurray Basal Aquifer[s]	9	238.2	294.5	56.3	0.90 (FH18-ES440-MR1)	7.17 (MW-07-119)
	Beaverhill	2	268.6	279.9	11.3	0.48 (FH17-WR405-MR1)	0.89 (FH18-ES440-MR1)
	Rafted McMurray[t]	43	280.9	320	39.1	0.04 (FH19-ES670-SN2)	15.95 (FH19-ES663-SN2)

Table 2.5-1: Groundwater Level Elevations – Measured Range of Variability

Ecohydrology Zone	Completion Hydrostratigraphic Unit	Number of Wells	Measured Groundwater Elevation All Wells [masl]		Measured Range in Elevations All Wells [m]	Measured Range in Elevations (individual well basis)	
			Min	Max		Min	Max
North Outwash Plain(k)	Surface Sand(u)	96	279.7	341.5	61.8	0.05 (FH19-ES613-SN2)	14.36 (FH18-ES419-DR1)(v)
	Clay Till	9	287.1	301.7	14.6	0.68 (FH17-WR429-SN1)	7.72 (FH17-WR442-SN1)
	Confined Sands	9	266.4	304.5	38.1	0.07 (FH19-ES630-SN1)	1.01 (FH18-ES401-SN1)(w)
	Clay Till 2	2	287.8	292.0	4.2	0.81 (FH18-ES412-MR1)	0.93 (AA-10-20-97-10)
	Quaternary Aquitard	2	292.8	305.2	12.4	12.36 (FH17-WR444-SN1)	12.36 (FH17-WR444-SN1)
	McMurray Basal Aquifer	14	255.9	294.6	38.7	0.14 (FH17-WR407-MR1)	6.37 (FH19-GL570-MR1)(x)
	Beaverhill(y)	7	251.7	291.9	40.2	0.14 (FH17-WR407-MR1)	12.69 (FH19-GL565-MR1)
	Rafted McMurray(z)	17	267.9	299.8	31.9	0.13 (FH19-ES604-SN1)	3.47 (FH18-ES411-SN1)(aa)
	Unknown	1	298.1	298.3	0.2	0.26 (FH19-ES609-DR1)	0.26 (FH19-ES609-DR1)

(a) The first manual water level is at 296.5 masl and may be an outlier. All subsequent measurements resulted in water levels greater than 299 masl.
(b) The observed maximum water levels in the basal aquifer and aquitard were 329.6 masl and 325.5 masl, respectively. These maximum water levels were observed at the time of installation and recede to the ranges presented above within a few weeks. The ranges for the individual wells were not truncated to remove these data points.
(c) There appears to be an artificial drawdown event in the spring of 2018 that is observed in the basal aquifer and the Beaverhill wells. This drawdown event lowered water levels to approximately 264 masl around well FH17-WR446-MR1. The ranges for the individual wells were not truncated to remove these data points.
(d) Approximate range.
(e) FH17-WR451-SN2 has an outlier minimum water level as its first reading. This single manual water level is omitted in the range presented.
(f) Transducer measurements at this well indicate a water level range of only 0.8 m. The shown range is from the manual readings.
(g) The observed maximum water levels in the basal aquifer, basal aquitard, and the Beaverhill were 305.6 masl, 297.8 masl, and 308.3 masl respectively. These maximum water levels were observed at the time of installation and recede to the ranges presented above within a few weeks. Also removed from these water level ranges is a drawdown event in spring 2018.
(h) Minimum water level is observed in the south west of the EHZ. The maximum is in the north east. The two wells are on opposite sides of the zone (FH17-WR406-MR1 and FH17-WR451-MR1).
(i) FH17-WR449-SN1 and FH17-WR449-SN1 are not included in this range. The data from these monitoring wells goes up to 318.8 masl, significantly higher than the surrounding wells in the same unit (there may be a data quality issue, e.g., the datum is off or the atmospheric pressure is not accounted for). An outlier data point from FH17-WR447-SN1 was removed that was at 290.9 masl.
(j) There appear to be datum issues in the confined sands well data sets. The maximum water level does not include the most extreme data points from FH17-WR422-SN1.
(k) FH17-WR421-MR2 was not included.
(l) The observed maximum water levels in the basal aquifer and basal aquitard were 300.7 masl and 298.1 masl respectively. These maximum water levels were observed at the time of installation and recede to the ranges presented above within a few weeks. Also removed from these water level ranges is a drawdown event in spring 2018.
(m) All data from the wells in EHZ 6, as presented in Appendix B6, are included in these ranges. None of the wells had obvious conflicts between manual measurements and transducer of vibrating wire measurements.
(n) FH19-ES676-SN2 has an outlier measurement in October 2019 where the water levels range over 11.65 m.
(o) FH19-ES668-SN2 has a range of 13.23 m, the value shown is for the second largest range.
(p) The large range of water levels in the Fort Hills Upland Complex and the North Outwash Plain is influenced by the large area these sectors cover.
(q) FH17-WR434-SN1 has water levels ranging over 18.43 m within the surface sand (there are two sensors at two different levels within the sand). The value shown in the table is for the second largest water level range.
(r) There appears to be some boundary effect inducing water level changes in this well and the wells around it.
(s) The measured, regional water level range within the basal formations was greater than fluctuations caused by the drawdown event in spring 2018.
(t) FH19-ES663-SN2 has an outlier data point at 329.2 masl. This point is not included in the data range presented.
(u) FH18-ES404-SN1 is north of the lake and has a maximum observed water level of 341.5 masl. FH19-GL565-SN1 has vibrating wires installed at 72 m and 122 m below ground surface with an observed water level minimum of 210.5 masl. The records received by Golder indicate that this well was only drilled 40 m deep and, as such, we have chosen to omit the date from the 72 m and 122 m deep sensor at FH19-GL565-SN1 from the presented data range. This vibrating wire data set may have been mislabelled (there is a well FH19-GL565-MR1 that has a sensor installed at 72 m and 122 m bgs).
(v) There appears to be some boundary effect inducing water level changes in this well and the wells around it.
(w) FH18-ES419-SN1 and FH19-GL534-SN1 have ranges of 13 and 19 m, respectively. There appears to be some boundary effect inducing water level changes these wells.
(x) FH19-GL565-MR1, MR2, and MW08-19BA are not included for the maximum individual well water level ranges. Each of these wells has ranges greater than 25 m.
(y) FH19-ES565-MR2 is a basal aquifer well with a minimum water level of 229.5 masl and this minimum was omitted from the presented range. This minimum was recorded by a transducer and the long-term manual water level readings are all above 260 masl. FH19-GL565-MR1 has a drawdown event in spring 2019 that does not appear to be natural, this drawdown event was also omitted from the presented range.
(z) FH20-WR623-SN1 was removed from the ranges presented here due to extreme outliers in the most recent water levels that exceed 460 masl.
(aa) FH20-WR623-SN1 and FH19-ES606-SN1 have ranges of 168 and 24 m, respectively.
m = metre; masl = metres above sea level.

Ecohydrology Zone 1

Recorded water levels in both the peat and surface sand wells in EHZ 1 indicate a narrow range of variations in groundwater elevations (0.3 m of range overall). Generally, water levels in the surface sand wells show seasonal response, with levels in the shallow surface sand increasing in the spring (due to increased infiltration during freshet), with summer fluctuations, and with decreases at the start of winter. Water levels in most years increase slightly over the winter season. In the deeper surface sand completions, seasonal variations are muted. Within the peat, seasonal variability is observed, with generally higher levels in the spring and decreased levels over the winter months; no transducer data is available for peat wells in this zone to provide detailed information on seasonal effects in peat wells.

Ecohydrology Zone 2

In the peat wells, while the overall range is 5.6 m, in individual wells the range in elevations is 0.19 to 0.81 m. Fluctuations in the peat wells occur seasonally (Appendix B2), with rise in the spring and lower levels in the winter. In locations with larger datalogger datasets, peat water levels are observed to rise slightly over the winter season.

Similarly, the overall range in the surface sand wells is 5.6 m, but the range in individual wells is 0.08 to 3.71 m. In general, water levels in the surface sand rise in the spring, respond to precipitation in the summer, with lower levels in the winter (Appendix B2).

Wells in the rafted McMurray, basal McMurray and Beaverhill Formations do not show seasonal variation; data in the basal McMurray show the slow recovery in the aquifer from sampling or development events.

Ecohydrology Zone 3

One well, with three completions (peat, surface sand, and deeper surface sand) was assessed in EHZ 3. The hydrographs (Appendix B3) show that the response in the units is similar, with a similar pattern in water level elevation data at each level. At this location, the response was noted to be slightly more muted with depth. This location shows generally decreasing water levels during winter, with increases during spring freshet and fluctuations over the summer months likely related to precipitation.

Ecohydrology Zone 4

In EHZ 4, hydraulic responses are similar to those in EHZ 1 to 3. Data generally shows seasonal patterns of higher levels in the spring and summer months (freshet and precipitation events), with lower values in the winter. In some instances, water levels show a slow rise over the winter months. The range in elevations in the peat wells is 0.4 m, while the individual well groundwater elevation range is 0.08 to 2.63 m within the surface sand completions. As shown in the hydrographs (Appendix B4), the groundwater elevation response becomes slightly more muted with depth between the shallow sand and deeper sands.

Ecohydrology Zone 5

Within the peat wells in EHZ 5, groundwater elevation range in individual wells is 0.27 to 0.81 m. Groundwater elevation changes follow similar patterns to other zones in the fen, with increases during freshet, and decreases before winter, with slight increases over winter months. A similar pattern exists in the surface sand wells. The confined sand wells have limited data sets and do not indicate seasonal variability within the datasets that extend over freshet months.

Ecohydrology Zone 6

Water levels in EHZ 6 follow a similar pattern to the other fen zones. Water levels in the peat are generally within a narrow range (0.2 m), and between 0.19 to 0.83 m in the surface sands. Responses in the peat and unconfined sands generally follow the same seasonal pattern as EHZ 1 to 5, and similar to EHZ 5, seasonal fluctuations are not observed in the confined sands.

Fort Hills Upland Complex

Within the FHUC, most transducer data is limited to less than one year and therefore seasonal patterns cannot be examined at this time. The data available indicate limited range in groundwater levels in the peat (0.69 to 0.87 m in individual wells) and the surface sand (0.04 to 1.13 m in individual wells).

North Outwash Plain

In the NOPs, transducer data is relatively limited. The data indicate that within the surface water wells near the fen, seasonal patterns similar to those observed within the fen are evident. At locations further from the fen (e.g., FH18-ES401-SN1 – 11.5 metres below ground surface [mbgs] and 29.5 mbgs), the same seasonal pattern is evident (Appendix B8). Rapid changes in water levels are observed in NOP wells with more closely spaced data sets (e.g., FH19-ES512-SN2 – 12 mbgs and 20.8 mbgs, FH19-ES519-SN2 10.6 and 22.4 mbgs), indicative of strong responses to precipitation in NOP wells.

2.5.4.1.3. Groundwater Flow Patterns

Groundwater monitoring wells are installed around the MLWC in the peat, Quaternary sand, and basal watersand hydrostratigraphic units (Figure 2.5-8 through Figure 2.5-11). Water level data collected at the monitoring wells is used to develop the conceptual model of groundwater flow.

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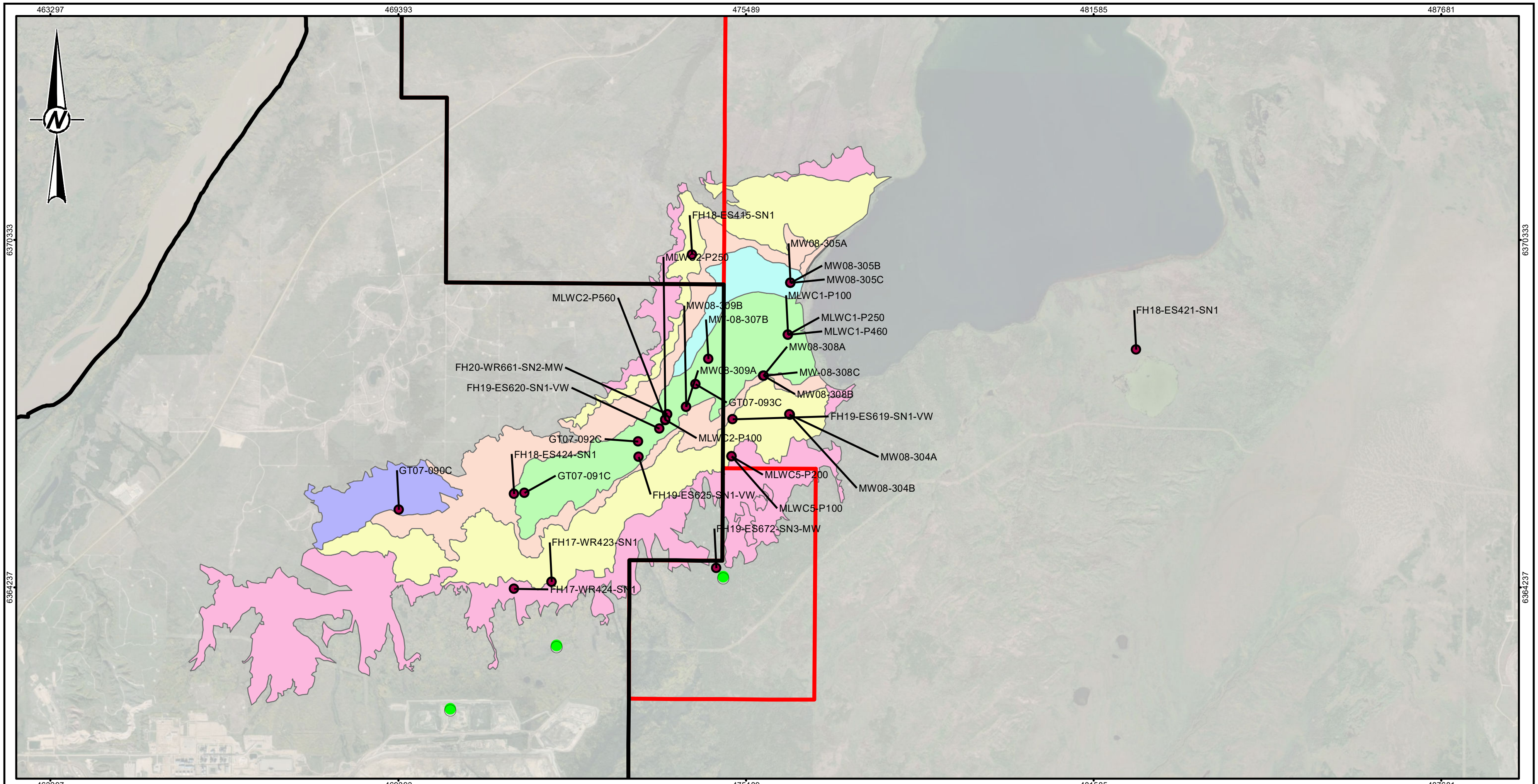

LEGEND

Approved Project Area

Extension Areas as proposed in the Integrated Plan Amendment Application

Well

Groundwater Flow Window

Ecohydrology Zones

1
2
3
4
5
6

0 1 2

Kilometres

1 " = 3 kilometres

NOTE(S)

1. ECOHYDROLOGY ZONES ARE DEFINED IN OBJECTIVE 1, SECTION 2.4.3

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
3. ECOHYDROLOGY ZONES: VITT AND HOUSE (2020)

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-10
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE
GROUNDWATER MONITORING WELLS (PEAT WELLS)

PROJECT NO.	CONTROL	REV.	FIGURE
20140450	-	0	2.5-8

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

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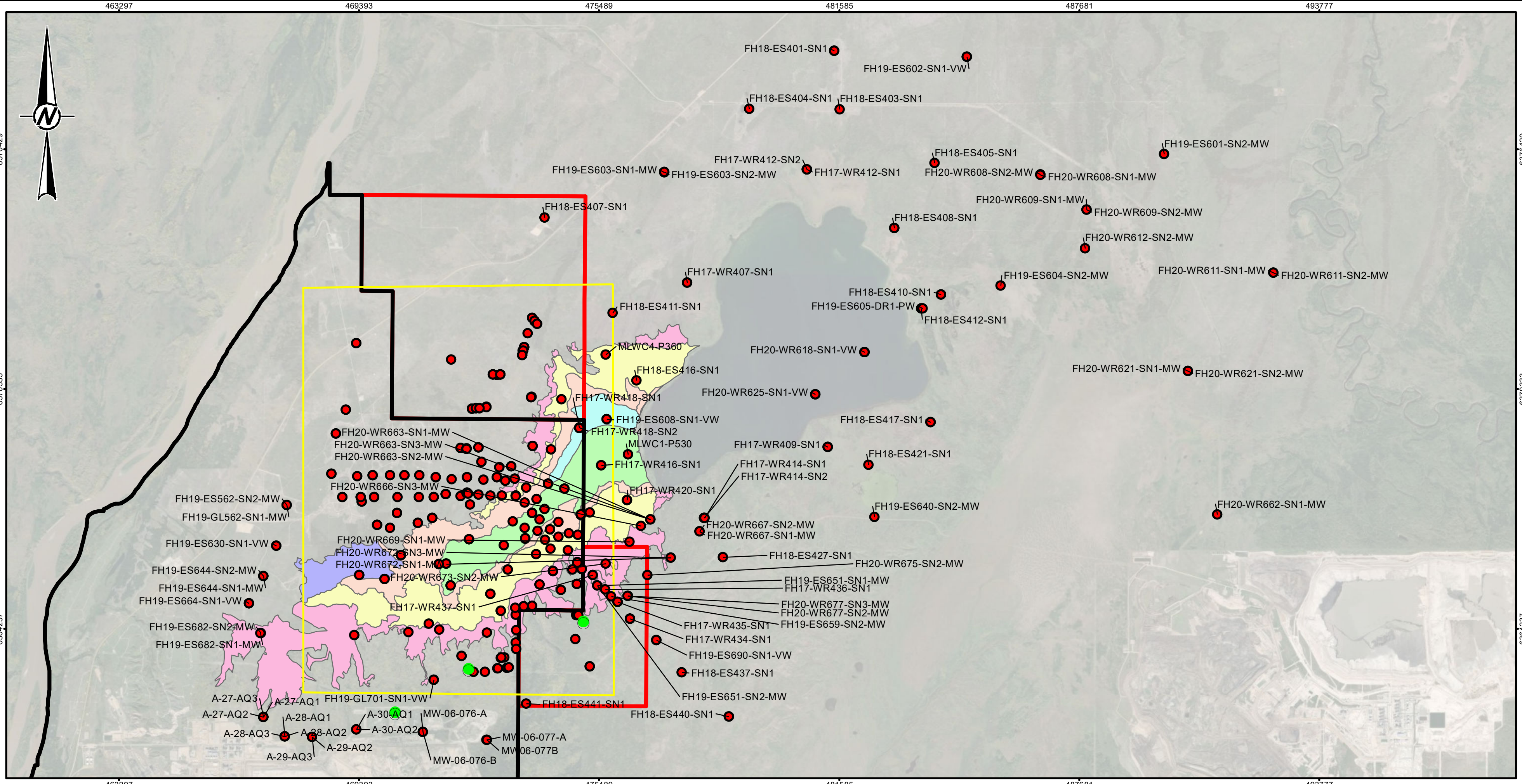

LEGEND

- Approved Project Area
- Extension Areas as proposed in the Integrated Plan Amendment Application
- Extent of Figure 2.5-10
- Well
- Groundwater Flow Window

Ecohydrology Zones

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

0 1 2
Kilometres

1 " = 4 kilometres

NOTE(S)

1. ECOHYDROLOGY ZONES ARE DEFINED IN OBJECTIVE 1, SECTION 2.4.3

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
3. ECOHYDROLOGY ZONES: VITT AND HOUSE (2020)

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-10
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE
GROUNDWATER MONITORING WELLS (QUATERNARY SAND WELLS)

PROJECT NO.	CONTROL	REV.	FIGURE
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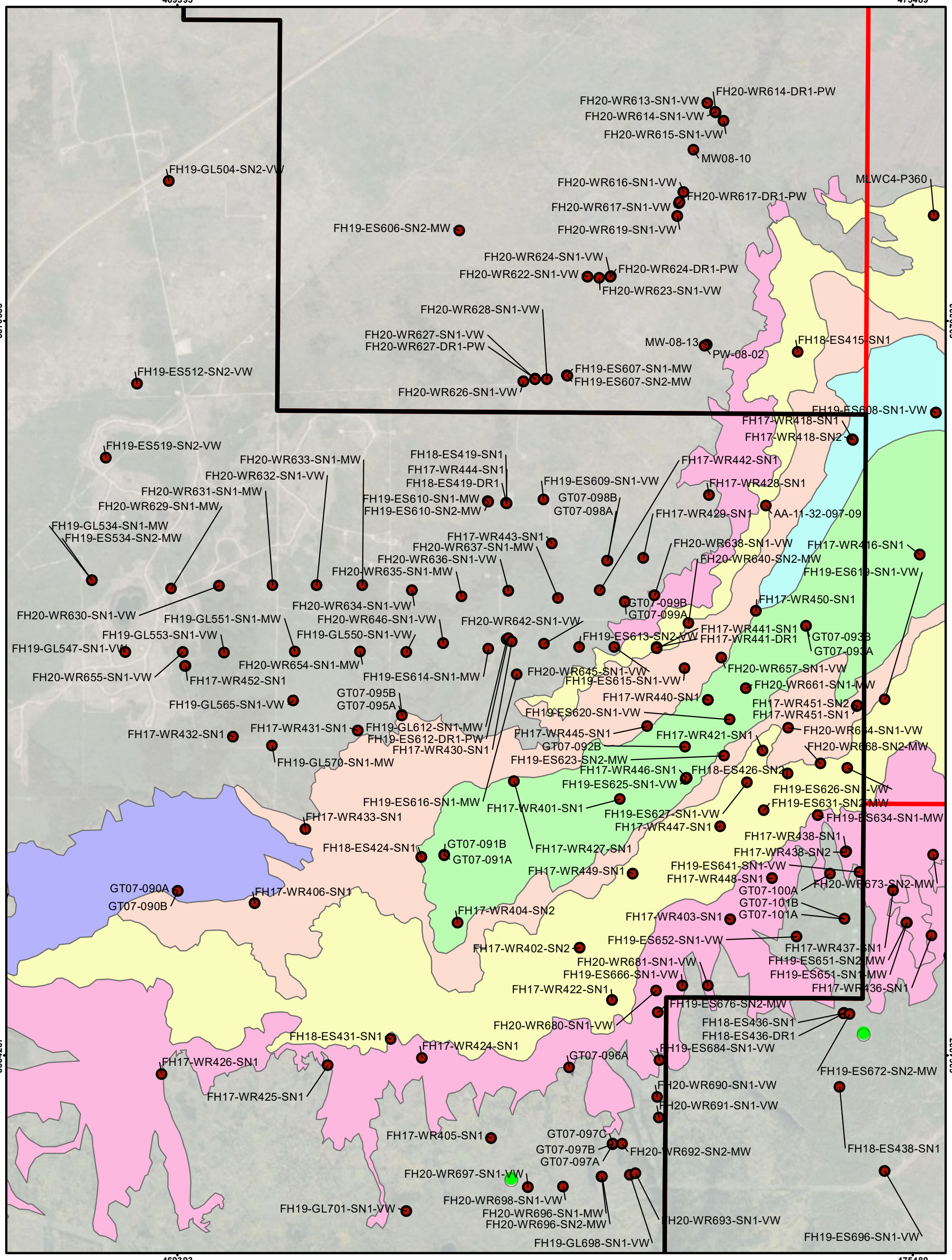

LEGEND

- Approved Project Area
- Extension Areas as proposed in the Integrated Plan Amendment Application
- Well
- Groundwater Flow Window

Ecohydrology Zones

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

0 1 2

Kilometres

1 " = 1 kilometres

NOTE(S)

1. ECOHYDROLOGY ZONES ARE DEFINED IN OBJECTIVE 1, SECTION 2.4.3

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
3. ECOHYDROLOGY ZONES: VITT AND HOUSE (2020)

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

FORT HILLS
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YYYY-MM-DD	2021-12-10
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE
GROUNDWATER MONITORING WELLS (QUATERNARY SAND WELLS) – CLOSE-UP OF MLWC AREA WITHIN APPROVED PROJECT AREA

PROJECT NO.	CONTROL	REV.	FIGURE
20140450	-	0	2.5-10

R:\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\05 Technical Work\04_Analysis\MLWC Data Assessment\01_Input_Files\02_Data_Processed\Well_locations\Figure2.5-10_MLWC_wells_quaternary2.mxd

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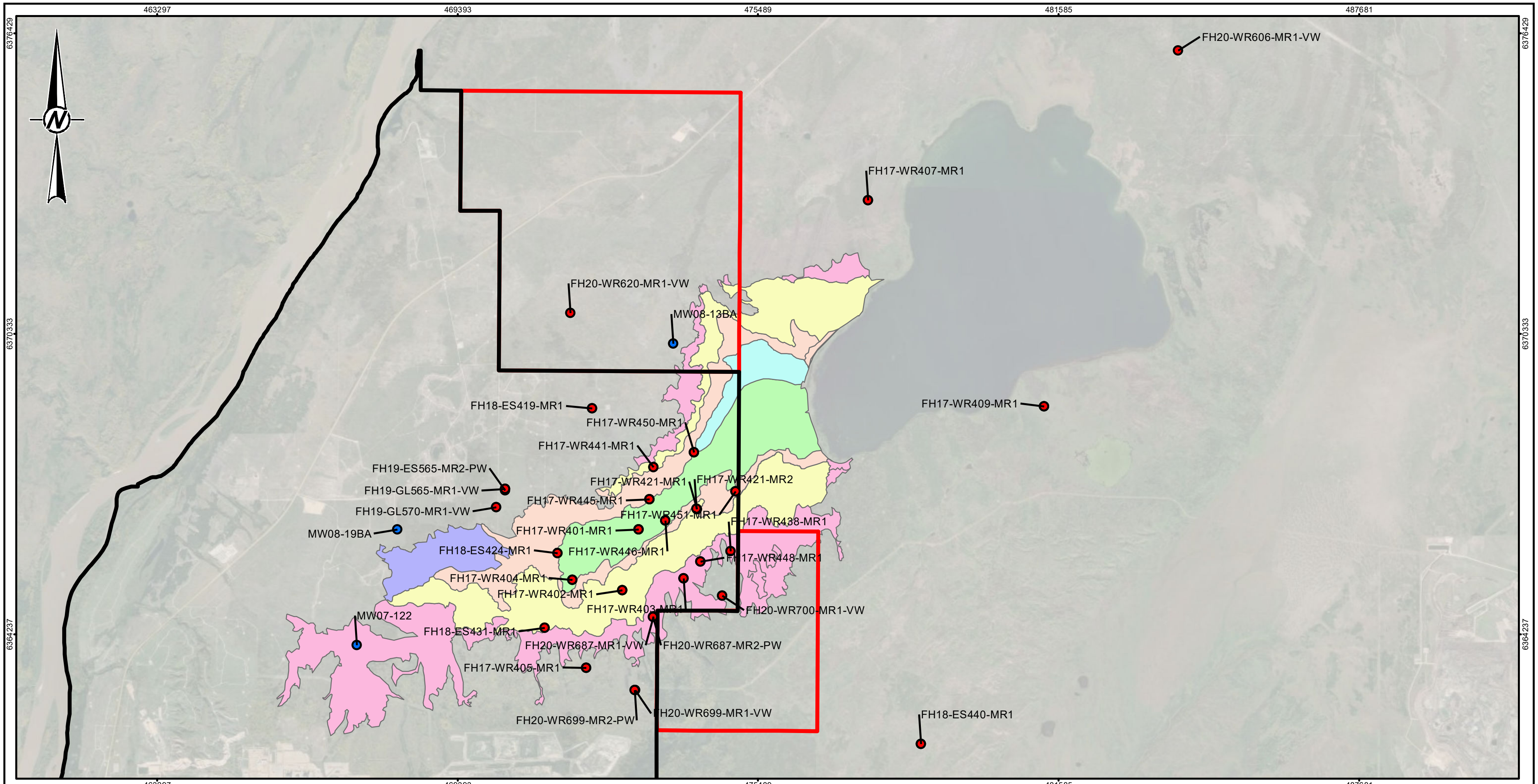

LEGEND

- Approved Project Area
- Extension Areas as proposed in the Integrated Plan Amendment Application
- Wells used in 2018 report[4]
- Wells installed post-2018 report[4]

Ecohydrology Zones

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

0 1 2
Kilometres
1 " = 3 kilometres

NOTE(S)

1. ECOHYDROLOGY ZONES ARE DEFINED IN OBJECTIVE 1, SECTION 2.4.3

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCE: ESRI, MAXAR, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
3. ECOHYDROLOGY ZONES: VITT AND HOUSE (2020)
4. GOLDER (2018)

CLIENT
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PROJECT
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FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-10
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE
GROUNDWATER MONITORING WELLS (BASAL WELLS)

PROJECT NO.	CONTROL	REV.	FIGURE
20140450	-	0	2.5-11

The conceptual hydrogeologic model for the MLWC watershed is divided into a deeper flow system and shallow flow system. The deeper flow system contains the basal watersands and Devonian aquifers, which are separated from the shallow Quaternary aquifers around the MLWC by a thick, continuous aquitard sequence and as such have limited effect on the MLWC fen. However, the shallow Quaternary system is the hydrogeologic setting for the peat and is in hydraulic communication with the fen. The flow patterns and conceptual model for groundwater flow in the Quaternary sediments that form the setting for the MLWC is discussed in detail as follows.

Using the water level data collected at groundwater monitoring wells and VWPs, potentiometric surface maps for the Quaternary sand units for April and October 2018 (Figure 2.5-12 and Figure 2.5-13) were prepared. The figures show that the groundwater flow in Quaternary sands in the FHUC is generally northerly, towards McClelland Lake and the fen. In the NOP, groundwater flow is generally southerly towards McClelland Lake and the fen; however, in this zone there is an interpreted groundwater divide (Figure 2.5-12 and Figure 2.5-13). The location of this divide is expected to be variable as the unconfined sands in the NOP respond to precipitation and seasonal changes in groundwater storage. Based on the April and October 2018 results, the groundwater divide is expected to run roughly northwest/southeast.

Shallow groundwater flow within the fen complex is interpreted to be towards McClelland Lake. This is consistent with flow directions in the peat, which is indicated by the patterning of strings and flarks in the fen; surface water flow in the fen is orthogonal to the patterning (Vitt and House 2020).

The water table around the MLWC varies seasonally and with precipitation. Water levels from monitoring data used to construct potentiometric surface maps must be taken from the same time periods to present a coherent groundwater flow system.

Conceptual Model of Groundwater Flow Within the North Outwash Plain

The NOP has unconfined sands at surface; the sands are highly permeable in this area and infiltration is high, as previously noted, and shown by the lack of perennial streams in this area. The highly permeable nature of these sands is interpreted to result in a more dynamic water table in this area than previously assumed. A groundwater divide occurs within the NOP to the west/northwest of the fen (Figure 2.5-12 and Figure 2.5-13). Groundwater in the Surface Sand unit to the north and west of the groundwater divide drains toward the Athabasca and to the south and east of the divide it drains towards the MLWC. Generally, the water table in this area is relatively flat; however, as significant precipitation events or freshet occur, the water table will respond as water infiltrates this area quickly; the groundwater divide will then migrate westward, until the groundwater storage is depleted, and the divide migrates eastward. This process results in complicated local flow systems; the effects of rapid infiltration will result in more rapid localized mounding in areas where the water table or capillary fringe are closer to the surface, such as the MLWC lowlands, and localized flow systems can develop when this mound is dissipating. This local flow system can result in flow towards the upland area, which represents a groundwater flow reversal. This is because groundwater mounding from the infiltration will take longer to reach the groundwater table in the uplands, due to a deeper water table in the uplands. Once the effects of infiltration reach the water table in the upland areas, or the groundwater mounding in the lowlands areas dissipates, the groundwater flow pattern will revert to the typical topographically influenced pattern. These effects of groundwater mounding and rapid infiltration will also drive the groundwater divide towards the west, and as the effects dissipate, the groundwater divide will migrate back towards the east. The effects of rapid infiltration/recharge in the highly permeable NOP sands are expected to be of relatively short duration.

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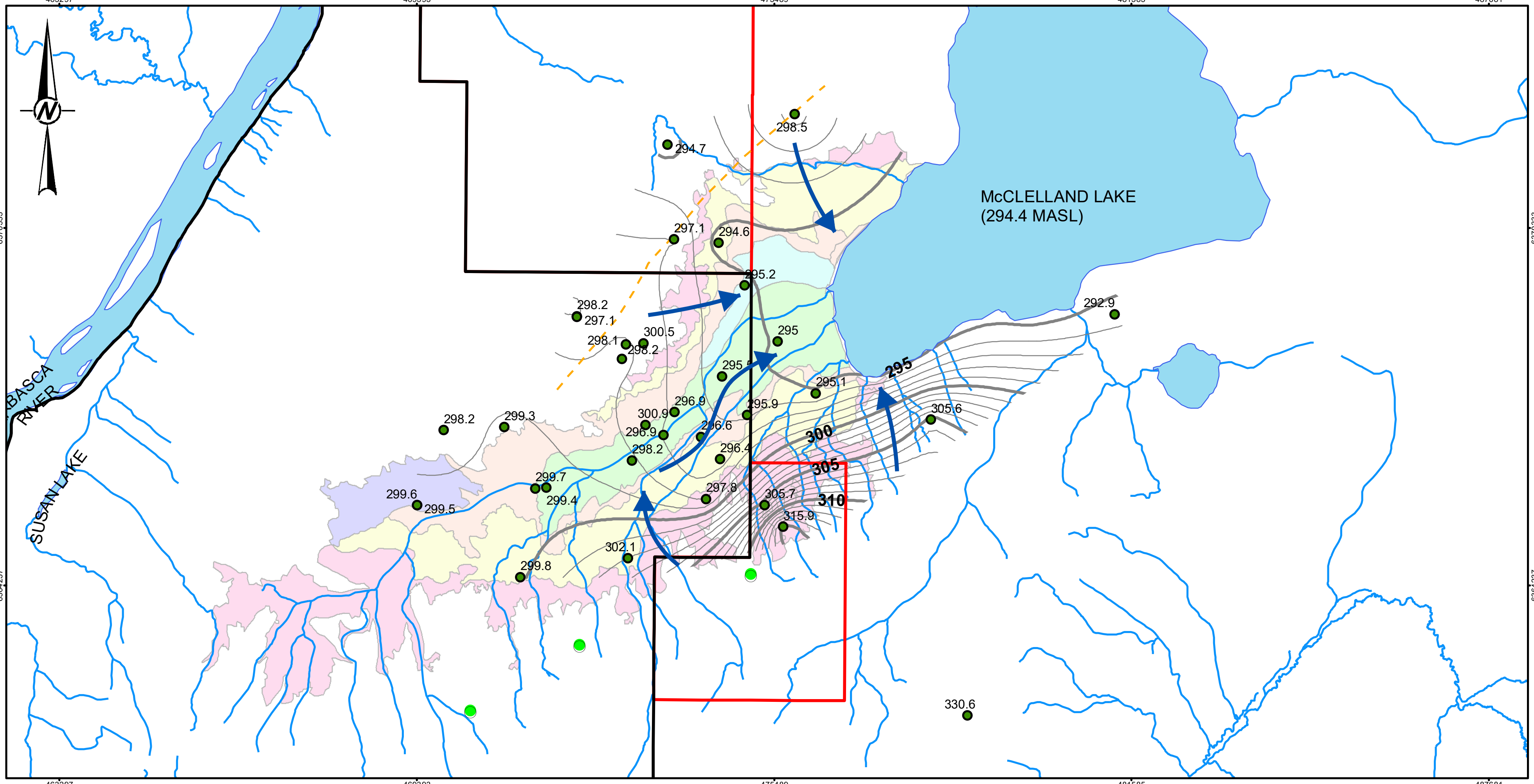

LEGEND

- Approved Project Area
- Extension Areas as proposed in the Integrated Plan Amendment Application
- Waterbodies
- Water Elevation Contour (masl)
- Flow Direction
- Interpreted Groundwater Divide
- Water Level Measurement Point[2]
- Groundwater Flow Window

Ecohydrology Zones

1
2
3
4
5
6

0 1 2
Kilometres

1 " = 3 kilometres

NOTE(S)

1. MASL = METRES ABOVE SEA LEVEL
2. LABELS = WATER LEVEL READING ON APRIL 28, 2018
3. ECOHYDROLOGY ZONES ARE DEFINED IN OBJECTIVE 1, SECTION 2.4.3

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. ECOHYDROLOGY ZONES: VITT AND HOUSE (2020)

CLIENT
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FORT HILLS
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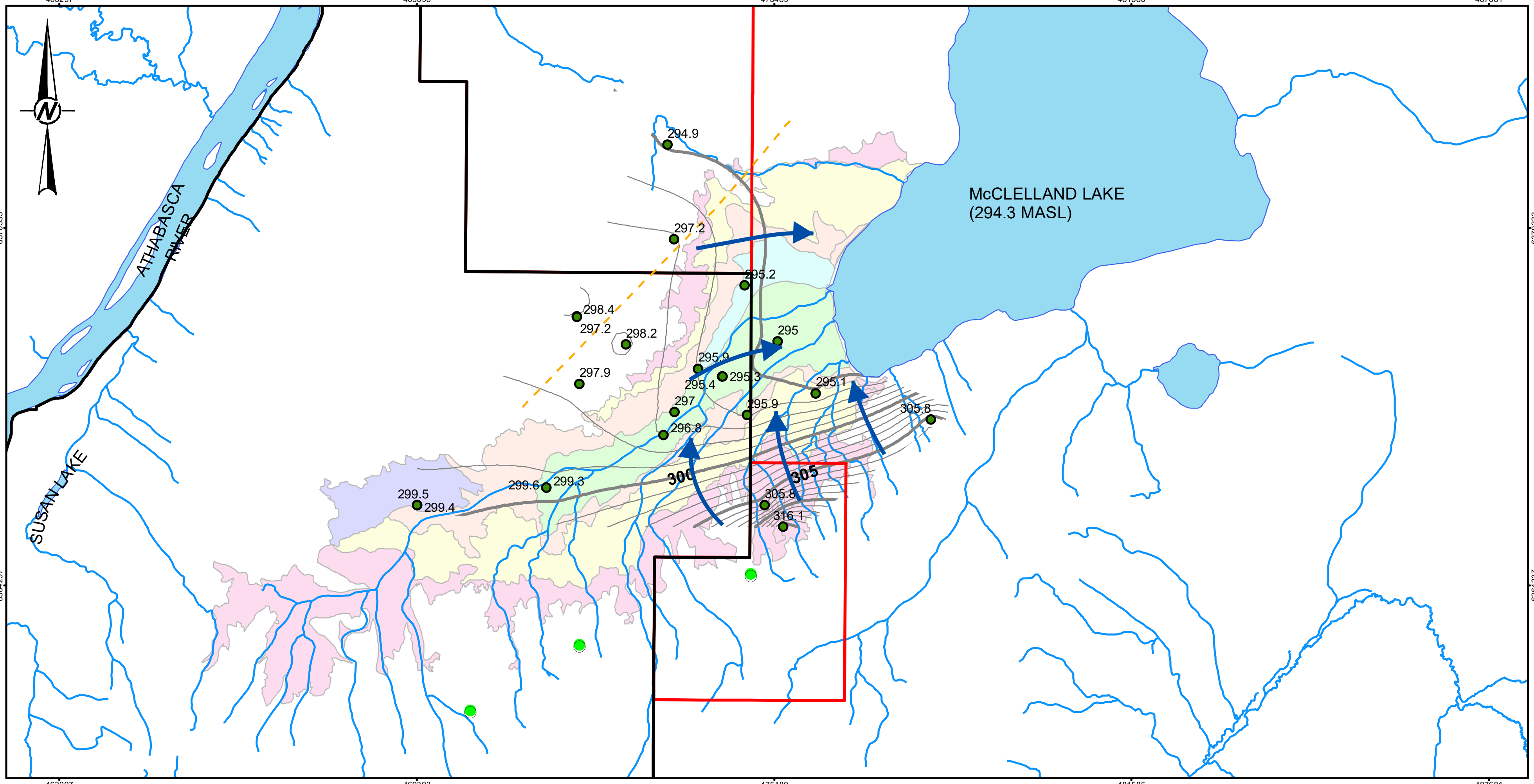
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE
GROUNDWATER ELEVATION CONTOURS (APRIL 28, 2018)

PROJECT NO.	CONTROL	REV.	FIGURE
20140450	-	0	2.5-12

R:\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\05_Technical_Work\04_Analysis\MLWC Data Assessment\01_Input_Files\02_Data_Processed\Potentiometric_surfaces_map\Figure2.5-13_MLWC_Potentiometric_surf_sep20181.mxd



LEGEND

- Approved Project Area
- Extension Areas as proposed in the Integrated Plan Amendment Application
- Waterbodies
- Water Elevation Contour (masl)[1]
- Flow Direction
- Interpreted Groundwater Divide
- Water Level Meaasurement Point[2]
- Groundwater Flow Window

Ecohydrology Zones

1
2
3
4
5
6

0 1 2

Kilometres

1 " = 3 kilometres

NOTE(S)

1. MASL = METRES ABOVE SEA LEVEL
2. LABELS = WATER LEVEL READING ON SEPTEMBER 7, 2018
3. ECOHYDROLOGY ZONES ARE DEFINED IN OBJECTIVE 1, SECTION 2.4.3

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. ECOHYDROLOGY ZONES: VITT AND HOUSE (2020)

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-13
DESIGNED	RS
PREPARED	JH
REVIEWED	ZG
APPROVED	JH

TITLE
QUATERNARY SAND HYDRAULIC HEAD CONTOURS (SEPTEMBER 7, 2018)

PROJECT NO.	CONTROL	REV.	FIGURE
20140450	-	-	2.5-13

The effect of precipitation in the NOP is affected by the depth of the groundwater table under the uplands and the amount of time infiltration will take to reach the table. A more rapid response to precipitation, called groundwater ridging, is expected in the lowland areas. In the areas near the fen where the capillary fringe is at or near the ground surface, precipitation causes a more rapid rise in the groundwater table. This results in a ridge of groundwater in these locations, with increased gradients towards the fen and discharge to surface.

Conceptual Model of Groundwater Flow Within the Fort Hills Upland Complex

Groundwater flow within the shallow flow unconfined system under the FHUC is generally driven by topography, with the shallower aquifers (above AQ4) either infiltrating to AQ4, or discharging to surface flow systems along the lower elevations of the FHUC. Groundwater flow in these shallower aquifers is generally unconfined. Surface sands along the FHUC discharge to McClelland Lake or to the fen.

The thickest and most continuous aquifer under the FHUC is AQ4, as discussed in Section 2.5.3. The AQ4 is semi-confined by an overlying sequence of aquitards and other aquifers and is recharged regionally along the topographic highs of the FHUC. The overlying sequence of aquitards is not continuous, which has resulted in distinct “windows” above the AQ4 where there is a lack of hydraulic containment for the aquifer. At these locations, the AQ4 discharges into the overlying shallow aquifers and to the ground surface.

Hydraulic Parameters

The compiled hydraulic conductivity values are provided in Table 2.5-2. These compiled hydraulic conductivities represent data across the Fort Hills Project lease (FHEC 2021b).

Table 2.5-2: Hydraulic Conductivity Data Summary

Screened Formation	Number of Tests	Hydraulic Conductivity Data [m/s]		
		Min	Max	Geometric Mean
Peat	5	5×10^{-6}	7×10^{-4}	7×10^{-5}
Surface Sand	64	5×10^{-6}	7×10^{-4}	7×10^{-5}
Silty Sand AQ3	6	1×10^{-6}	4×10^{-4}	8×10^{-5}
Silty Sand AQ4	35	3×10^{-7}	5×10^{-4}	2×10^{-5}
Quaternary Unconfined Sand (not assigned AQ code)	10	3×10^{-7}	2×10^{-4}	1×10^{-5}
Quaternary Confined Sand (not assigned AQ code)	139	2×10^{-9}	7×10^{-4}	1×10^{-5}
Clearwater	2	1×10^{-8}	6×10^{-5}	9×10^{-7}
Basal Aquifer	78	6×10^{-12}	8×10^{-4}	1×10^{-5}
Devonian	37	5×10^{-12}	3×10^{-4}	4×10^{-9}

m/s = metres per second.

2.5.4.1.4. Vertical Gradients

Vertical gradients were calculated at selected subsets of well pairs, using both pressure transducer and manual water level elevations.

Peat-Peat Well Pairs

Locations of the peat-peat well pairs are presented in Figure 2.5-8. The results indicated vertical gradients varied between 0.7 and 0.18 (Table 2.5-3). Three of the four well pairs had gradients that varied from negative (upward) to positive (downward) over time; at the MW08-305 well pair, measured gradients were consistently negative (upward). This well pair is located at the edge of the patterned fen and is on the upgradient (NW) side of McClelland Lake, near the lake edge. The current conceptual model of groundwater flow supports the upward gradients in the peat at this location, as discharge to McClelland Lake is expected in this area.

Peat-Sand Well Pairs

Five peat-sand well pairs were used to calculate vertical gradients from manual water level measurements (Table 2.5-4). Gradients varied between 0.19 to 0.22 overall. Within the non-patterned fen, well pair GT07-090 had upward gradients. This well is located at the southwest extent of the non-patterned fen (Figure 2.5-10). Within the patterned fen, gradient patterns were variable. Well pairs along the centreline of the fen were chosen for assessment. The furthest well pair to the southwest was the GT07-091 pair, followed by the GT07-092 pair, the GT-07-093 pair and finally the MLWC1-P460 – MLWC-P530 well pair, located closest to McClelland Lake. The gradients at these locations were variable; GT07-91 and GT07-093 well pairs had upward and downward gradients, while GT07-092 generally showed upward gradients, as did the MLWC1-P460 – MLWC-P530 well pair. The GT07-092 well pair generally had downward gradients.

Pressure transducer data, where available, allows for a more detailed assessment of gradient changes over time. This allows for an assessment of potential gradient changes over a shorter time frame, providing additional granularity on gradient changes over time. This is important for the conceptual model understanding of groundwater flow and gradients.

Vertical gradients in a subset of the peat-sand well pairs were also assessed using recent pressure transducer data, summarized monthly. This assessment provides further granularity on changes in vertical gradients with more detailed water level measurements. The analysis used the groundwater elevation data as measured on the 15th of every month at noon for gradient calculation. A summary of the transducer monthly data is provided in Table 2.5-5. Based on the results, seasonal variability appears to be low, as the direction of the vertical gradient at each location is generally consistent.

At the interface of the patterned and non-patterned fen, water levels at FH18-ES424-SN1 (installed in 2018) show generally upward gradients (-0.47 to 0, measured from 2018 to 2020). This is consistent with the recent gradient calculated at nearby peat-sand well pair at GT07-091C (measured on 2018-08-11, -0.05). At locations FH19-ES620-SN1 and FH19-ES625-SN1, vertical gradients were downward over the measurement period (2018 to 2020).

Table 2.5-3: Peat-Peat Vertical Gradients

Ecohydrology Zone	Well ID	Area	Ground Elevation [masl]	Screen Bottom Elevation [masl]	Screen Top Elevation [masl]	Mid Screen Elevation [masl]	Vertical Mid Screen Separation [m]	Interpreted Hydrostratigraphic Unit	Vertical Gradients [m/m]			Overall Flow Direction
									Min	Max	Number of Measurements	
1	MW08-305A	Patterned Fen	294.51	293.71	294.51	294.11	0.35	Peat	-0.46	0.00	18	Upward
	MW08-305C		294.51	293.01	294.51	293.76		Peat				
2	MLWC1-P100	Patterned Fen	294.67	293.67	293.87	293.77	3.58	Peat	-0.03	0.03	23	Upward/ Downward
	MLWC1-P460		294.69	290.09	290.29	290.19		Peat				
2	MLWC2-P250	Patterned Fen	296.55	294.05	294.25	294.15	3.10	Peat	-0.11	0.18	22	Upward/ Downward
	MLWC2-P560		296.55	290.95	291.15	291.05		Peat				
5	MLWC5-P100	Non-Patterned Fen	296.02	295.02	295.22	295.12	0.90	Peat	-0.70	0.04	16	Upward
	MLWC5-P200		296.12	294.12	294.32	294.22		Peat				

ID = identification; masl = metres above sea level; m = metre; m/m = metres per metre.

Table 2.5-4: Peat-Sand Vertical Gradients (Manual Measurements)

Ecohydrology Zone	Well ID	Area	Ground Elevation [masl]	Screen Bottom Elevation [masl]	Screen Top Elevation [masl]	Mid Screen Elevation [masl]	Vertical Mid Screen Separation [m]	Interpreted Hydrostratigraphic Unit	Vertical Gradients [m/m]			Overall Flow Direction
									Min	Max	Vertical Number of Measurements [m/m]	
2	MLWC1-P460	Patterned Fen	294.69	290.09	290.29	290.19	0.76	Peat	-0.05	0.22	21	Upward/ Downward
	MLWC1-P530		294.63	289.33	289.53	289.43		Surface Sand				
2	GT07-093C	Patterned Fen	295.51	292.77	294.29	293.53	2.52	Peat	-0.19	0.12	24	Upward/ Downward
	GT07-093B		295.51	290.63	291.39	291.01		Surface Sand				
2	GT07-092C	Patterned Fen	297.08	289.15	292.20	290.68	3.60	Peat	-0.16	0.04	21	Upward/ Downward
	GT07-092B		297.08	286.31	287.83	287.07		Surface Sand				
3	GT07-091C	Patterned Fen	299.44	293.65	296.70	295.18	3.51	Peat	-0.05	0.09	20	Upward/ Downward
	GT07-091B		299.44	290.90	292.43	291.67		Surface Sand				
3	GT07-090C	Non-Patterned Fen	299.58	296.84	298.36	297.60	2.74	Peat	-0.13	0.01	21	Flat, Upward
	GT07-090B		299.58	294.09	295.62	294.86		Surface Sand				

ID = identification; masl = metres above sea level; m = metre; m/m = metres per metre.

Table 2.5-5: Peat-Sand Monthly Vertical Gradient Summary (Transducer Data)

Ecohydrology Zone	Well ID	Area	Ground Elevation [masl]	Vibrating Wire Elevation [masl]	Vibrating Wire Number	Interpreted Hydrostratigraphic Unit	Vertical Mid Vibrating Wire Separation [m]	Vertical Gradients [m/m]		Flow Direction
								Min	Max	
2	FH18-ES424-SN1	Patterned Fen	299.82	297.32	VWP D	Peat	1.5	-0.47	0	Upward
				295.82	VWP C	Quaternary-Aquifer				
2	FH19-ES620-SN1-VW	Patterned Fen	297.11	293.61	VWP C	Peat	6	0.2	0.21	Downward
				287.61	VWP B	Surface Sand				
2	FH19-ES625-SN1-VW	Patterned Fen	298.01	292.41	VWP B	Peat	5.5	0.21	0.28	Downward
				286.91	VWP A	Surface Sand				
5	FH18-ES415-SN1	Non-Patterned Fen	295.5	293.4	VWP C	Peat	6.8	-0.05	-0.02	Upward
				286.6	VWP B	Surface Sand				

ID = identification; masl = metres above sea level; m = metre; m/m = metres per metre.

A subset of the available recent transducer data was also used to assess seasonality. Table 2.5-6 shows the monthly results for several of the wells with recent data; one year of data, where available, and over spring freshet where one year was not available. The results of the assessment indicate that based on monthly values, little effect is observed to vertical gradients over the freshet in well pairs FH19-ES625-SN1 VWPB/VWPA and FH18-ES415-SN1 VWP C/B. At FH18-ES424-SN1, there is an effect during freshet (May), where the upward gradients flatten.

The transducer data were further used to assess vertical gradients on a higher measurement density, as summarized in Table 2.5-7. As shown in the table, the overall range is similar to the monthly results; often the improved data density results in a slightly wider range of measured variability. This indicates that for the peat-sand interface well pairs, variability in gradients is likely not related to periodicity of data (at the level of periodicity available) and is generally consistent seasonally.

Quaternary Sand (sand-sand well pairs)

Calculated vertical gradients for manual measurements at selected sand-sand well pairs are presented in Table 2.5-8. At two well pairs within the patterned fen, the vertical gradient in the sand unit ranges from relatively flat (GT07-93A/B) to more strongly downward (FH17-WR418-SN2/SN1). One sand-sand well pair in the patterned fen was assessed, with vertical gradients relatively flat at this location as well (GT07-090A/B). Within the FHUC, vertical gradients are more variable; well pairs exhibit strongly downward and upward gradients, as well as relatively flat gradients within well pairs installed in silty sand AQ4. This is consistent with the conceptual model in the FHUC, where the AQ4 material is interpreted to be hydraulically connected to overlying units through windows in confining tills. It is expected that nearer these windows, gradients will likely increase in the aquifer.

Vertical gradients were also calculated using transducer data collected at a subset of the newly installed wells, as shown in Table 2.5-9. These wells are completed in the non-patterned fen, or in the NOP (northwest) or FHUC (southeast). The wells within the non-patterned fen have a generally flat vertical gradient (FH17-WR422-SN1, FN17-WR437-SN1), or upward gradient (FH17-WR436-SN1). The location with upward gradients is within the FHUC and is likely indicative of a location near where the FHUC sands are discharging to surface.

Table 2.5-6: Peat-Sand Monthly Vertical Gradients – Detail (Transducer Data)

Ecohydrology Zone	Paired Well ID and Vibrating Wire	Area	Ground Elevation [masl]	Vibrating Wire Elevation [masl]	Vertical Vibrating Wire Separation [m]	Water Level Date	Vertical Gradient [m/m]	Flow Direction
2	FH18-ES424-SN1 VWP D FH18-ES424-SN1 VWP C	Patterned Fen	299.82	297.32 295.82	1.5	2018-03-15 12:00	-0.12	Upward
						2018-04-15 12:00	0.00	
						2018-05-15 12:00	-0.08	
						2018-06-15 12:00	-0.09	
						2018-07-15 12:00	-0.09	
						2018-08-15 12:00	-0.31	
						2018-09-15 12:00	-0.31	
						2018-10-15 12:00	-0.31	
						2018-11-15 12:00	-0.31	
						2018-12-15 12:00	-0.31	
						2019-01-15 12:00	-0.31	
						2019-02-15 12:00	-0.30	
						2019-03-15 12:00	-0.30	
2	FH19-ES625-SN1-VW VWP B FH19-ES625-SN1-VW VWP A	Patterned Fen	298.01	292.41 286.91	5.5	2019-03-15 12:00	0.22	Downward
						2019-04-15 12:00	0.21	
						2019-05-15 12:00	0.22	
						2019-06-15 12:00	0.22	
						2019-07-15 12:00	0.22	
						2019-08-15 12:00	0.22	
						2019-09-15 12:00	0.24	
						2019-10-14 6:00	0.28	

Table 2.5-6: Peat-Sand Monthly Vertical Gradients – Detail (Transducer Data)

Ecohydrology Zone	Paired Well ID and Vibrating Wire	Area	Ground Elevation [masl]	Vibrating Wire Elevation [masl]	Vertical Vibrating Wire Separation [m]	Water Level Date	Vertical Gradient [m/m]	Flow Direction
5	FH18-ES415-SN1 VWP C FH18-ES415-SN1 VWP B	Non-Patterned Fen	295.50	293.40 286.60	6.8	2018-03-15 12:00	-0.018	Upward to Flat
						2018-04-15 12:00	-0.021	
						2018-05-15 12:00	-0.009	
						2018-06-15 12:00	-0.011	
						2018-07-15 12:00	-0.024	
						2018-08-15 12:00	-0.011	

ID = identification; masl = metres above sea level; m = metre; m/m = metres per metre.

Table 2.5-7: Summary of Detailed Gradients at Peat Sand Well Pairs (Transducer Data)

Ecohydrology Zone	Well Pair	Assessment Period	Periodicity of Data	Vertical Gradients [m/m]		Consistent with Monthly Gradients?
				Min	Max	
2	FH18-ES424-SN1 VWP D FH18-ES424-SN1 VWP C	March 1, 2018 - June 30, 2018	Hourly/Every 3 hours	-0.34	0.067	Yes, slightly wider range
2	FH19-ES625-SN1-VW VWP B FH19-ES625-SN1-VW VWP A	March 3, 2019 – June 30, 2019	Every 6 hours	0.21	0.22	Yes
5	FH18-ES415-SN1 VWP C FH18-ES415-SN1 VWP B	March 1, 2018 - June 30, 2018	Every 3 hours	-0.056	0.002	Yes, slightly wider range

m/m = metres per metre.

Table 2.5-8: Sand-Sand Vertical Gradients (Manual Water Levels)

Ecohydrology Zone	Well ID	Area	Ground Elevation [masl]	Screen Bottom Elevation [masl]	Screen Top Elevation [masl]	Mid Screen Elevation [masl]	Vertical Mid Screen Separation [m]	Interpreted Hydrostratigraphic Unit	Vertical Gradients [m/m]			Overall Flow Direction
									Min	Max	Number of Measurements	
1	FH17-WR418-SN2	Patterned Fen	295.31	278.81	281.81	280.31	27.32	Surface Sand	0.34	0.39	8	Downward
	FH17-WR418-SN1		295.39	252.24	253.74	252.99		Silty Sand AQ4				
2	GT07-093B	Patterned Fen	295.51	290.63	291.39	291.01	3.58	Surface Sand	-0.08	0.04	23	Upward/ Downward
	GT07-093A		295.51	286.67	288.19	287.43		Surface Sand				
3	GT07-090B	Non-Patterned Fen	299.58	294.09	295.62	294.86	4.42	Surface Sand	-0.02	0.02	25	Flat
	GT07-090A		299.58	288.91	291.96	290.44		Surface Sand				
FHUC	A-29-AQ2	Outside Fen - Fort Hills	337.44	323.44	326.44	324.94	23.50	Silty Sand AQ3	0.00	0.05	12	Downward
	A-29-AQ3		337.42	299.94	302.94	301.44		Silty Sand AQ4				
FHUC	GT07-097C	Outside Fen - Fort Hills	318.26	308.76	311.86	310.31	30.00	Silty Sand AQ4	-0.06	0.09	6	Downward/ Upward
	GT07-097A		318.41	278.81	281.81	280.31		Silty Sand AQ4				
FHUC	GT07-101B	Outside Fen - Fort Hills	318.34	301.53	304.57	303.05	20.37	Silty Sand AQ4	-0.33	0.06	23	Upward
	GT07-101A		318.35	281.15	284.20	282.68		Silty Sand AQ4				
FHUC	MW06-077B	Outside Fen - Fort Hills	344.60	293.70	298.88	296.29	15.11	Silty Sand AQ4	-0.67	0.33	13	Upward/ Downward
	MW-06-077-A		344.58	278.13	284.23	281.18		Silty Sand AQ4				
FHUC	FH17-WR414-SN2	Outside Fen - Fort Hills	316.69	295.99	298.99	297.49	26.80	Silty Sand AQ3	-0.01	0.02	7	Upward/ Downward
	FH17-WR414-SN1		316.89	269.14	272.24	270.69		Silty Sand AQ4				
NOP	FH17-WR412-SN2	Outside Fen - Northeast	294.91	275.10	278.15	276.63	33.00	Surface Sand	0.35	0.36	8	Downward
	FH17-WR412-SN1		294.90	242.10	245.15	243.63		Silty Sand AQ4				

Note: Minimum vertical gradient for MW06-077-A and -B well pair is based on a suspect water level measured at MW06-077B.

ID = identification; masl = metres above sea level; m = metre; m/m = metres per metre.

Table 2.5-9: Sand-Sand Monthly Vertical Gradient Summary (Transducer Data)

Ecohydrology Zone	Well ID	Area	Ground Elevation [masl]	Vibrating Wire Elevation [masl]	Vibrating Wire Number	Interpreted Hydrostratigraphic Unit	Vertical Mid Vibrating Wire Separation [m]	Vertical Gradients [m/m]		Flow Direction
								Min	Max	
5	FH17-WR422-SN1	Non-Patterned Fen - Southeast	302.44	283.44	VWP C	Silty Sand AQ4	8.8	-0.01	-0.01	Flat
				274.64	VWP B	Silty Sand AQ4				
FHUC	FH17-WR434-SN1	Outside Fen - Southeast	345.26	341.26	VWP D	Surface Sand	21.3	0.80	0.84	Downward
				319.96	VWP C	Surface Sand				
6	FH17-WR437-SN1	Non-Patterned Fen - Southeast	305.63	291.63	VWP C	Silty Sand AQ4	16	-0.01	-0.01	Flat
				275.63	VWP B	Silty Sand AQ4				
NOP	FH19-ES512-SN2-VW	Outside Fen - Northwest	301.60	289.60	VWP C	Surface Sand	8.8	-0.14	-0.13	Upward
				280.80	VWP B	Surface Sand				
NO	FH19-GL504-SN2-VW	Outside Fen - Northwest	296.89	283.29	VWP B	Surface Sand	9.9	-0.05	-0.05	Upward
				273.39	VWP A	Surface Sand				
NOP	FH19-GL550-SN1-VW	Outside Fen - Northwest	305.45	293.95	VWP B	Surface Sand	11.7	-0.07	-0.07	Upward
				282.25	VWP A	Surface Sand				
NOP	FH18-ES419-SN1	Outside Fen - Northwest	306.83	294.83	VWP C	Surface Sand	26.6	0.00	0.02	Flat
				268.33	VWP B	Quaternary-Aquifer				

FHUC = Fort Hills Upland Complex; ID = identification; masl = metre above sea level; m = metre; m/m = metres per metre; NOP = North Outwash Plain; VWP = vibrating wire piezometer.

At locations with transducer data sets, additional analysis of gradients was completed using the available data. As previously discussed, the additional data provides further granularity on gradient changes over time, which is important information for conceptualization of groundwater flow. Most points have data available every 3 to 6 hours as shown in Table 2.5-10, and generally vertical gradients at this timescale are consistent with the gradients developed using monthly measurements. However, at location FH19-ES419-SN1, data was available on a finer timescale in 2018; data ranged from every 3 hours down to every minute. At this location, the assessment indicated that stronger downward gradients were observed using the transducer data set (0.16 m/m) as compared to the manual measurements (0.02 m/m); this is supportive of the conceptual model, with transmissive sands in the NOP experiencing larger and more transitory gradients due to rapid infiltration and dissipation of temporary groundwater mounds.

Table 2.5-10: Summary of Detailed Monthly Gradient Calculations – Sand-Sand Well Pairs (Transducer Data)

Ecohydrology Zone	Well Pair	Assessment Period	Periodicity of Data	Vertical Gradient [m/m]		Consistent with Manual Measurement?
				Min	Max	
5	FH17-WR422-SN1-VWPC and VWPB	March-June 2017	Every 3 hours	-0.013	-0.008	Yes
		March – June 2018	Every 3 hours	-0.011	-0.008	Yes
		All 2018	Every 3 hours	-0.015	-0.008	Yes
FHUC	FH17-WR434-SN1-VWPD and VWPC	March 2017	Every 3 hours	0.83	0.84	Yes
		March – June 2018	Every 3 hours	0.80	0.84	Yes
		All 2018	Every 3 hours	0.80	0.80	Yes
6	FH17-WR437-SN1-VWPC and VWPB	March to June 2018	Every 3 hours	-0.017	-0.013	Yes
		All 2018	Every 3 hours to an hour	-0.017	0.013	Yes
NOP	FH19-ES512-SN2-VWPC and VWPB	March to June 2019	Every 6 hours	-0.14	-0.13	Yes
		All 2019	Every 6 hours	-0.14	-0.13	Yes
NOP	FH19-GL504-SN2-VWPB and VWPA	March to June 2019	Every 3 hours	-0.052	-0.048	Yes
NOP	FH19-GL547-SN1-VWPB and VWPA	March to June 2019	Every 3 hours	3.11	3.10	Yes
NOP	FH19-GL550-SN1-VWPB and VWPA	March to June 2019	Every 3 hours	-0.074	-0.070	Yes
NOP	FH18-ES419-SN1-VWPC and VWPB	March 2018	Ranges from every 3 hours to every minute	0.005	0.16	More strongly downward
		April-June 2018	Every 3 hours	0.004	0.016	Yes
		All 2018	Ranges from every 3 hours to every minute	-0.022	0.16	More strongly downward

FHUC = Fort Hills Upland Complex; m/m = metres per metre; NOP = North Outwash Plain.

2.5.4.2. Reference Site Baseline Conditions

Groundwater data has not been collected at reference sites to date.

2.5.5. Surface Water Hydrology

2.5.5.1. Introduction

The MLWC watershed, as shown in Figure 2.5-14, drains much of the east side of the Fort Hills Project leases. This watershed is approximately 203 km^2 and consists of 15% lake surface, 24% fen, swamp, and other wetland, and 61% sandy upland. Surface water flows are directed through channels, pools and open waterbodies that are interspersed with ridges and form characteristic surface patterns. ITK holders have noted that water levels in the MLWC area have been lower when compared with the past, and that changes in the distribution of plants is a potential indicator of site-specific impacts, particularly related to drying of the site (IEG 2021).

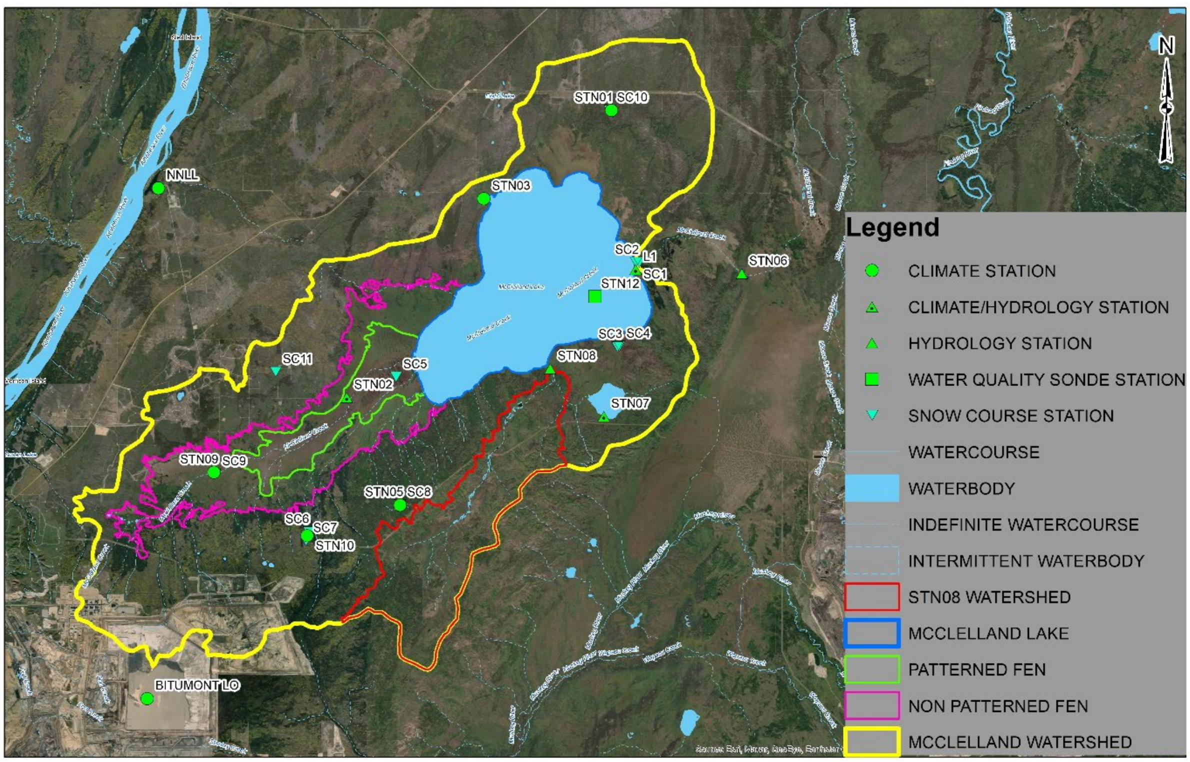


Figure 2.5-14: McClelland Lake Watershed and Sub-Watershed

The MLWC is part of the watershed with a peatland dominated boreal wetland complex covering approximately 45.4 km^2 (i.e., 38.3 km^2 on the westside, 2.3 km^2 on the northeast, and 4.9 km^2 on the south side of the lake) (Vitt et al. 2020) with a contributing surface watershed area of 203 km^2. A summary of various areas for the MLWC watershed is provided in Table 2.5-11. The MLWC watershed includes non-patterned fen, swamp, bog, patterned fen, uplands, and McClelland Lake.

Table 2.5-11: Summary of Sub-Watersheds

Areas	Lake [km²]	Swamp [km²]	Patterned Fen (South and North) [km²]	Graminoid Fen [km²]	Non-Patterned Fen [km²]	Other Wetlands [km²]	Upland Area [km²]	Total Area [km²]	Total Area [%]
Fort Hills West	-	-	-	-	-	-	37.7	**37.7**	**18.6**
Fort Hills East	-	-	-	-	-	-	32.5	**32.5**	**16.0**
North Outwash Plain West	-	-	-	-	-	-	23.5	**23.5**	**11.6**
North Outwash Plain East	-	-	-	-	-	-	29.3	**29.3**	**14.5**
McClelland Lake	30.5	-	-	-	-	-	-	**30.5**	**15.0**
Fen	-	-	7.4	2.4	16.9	-	-	**26.7**	**13.2**
Northeast wetland	-	-	-	-	-	2.5	-	**2.5**	**1.2**
South wetland (to Unnamed Lake and McClelland Lake)	0.80	-	-	-	-	5.5	-	**6.3**	**3.1**
Swamp (North, South and West)	-	13.8	-	-	-	-	-	**13.8**	**6.8**
Total	**31.3**	**13.8**	**7.4**	**2.4**	**16.9**	**8.0**	**123.0**	**202.8**	**100.0**

% = percent; km² = square kilometre; - = no value.

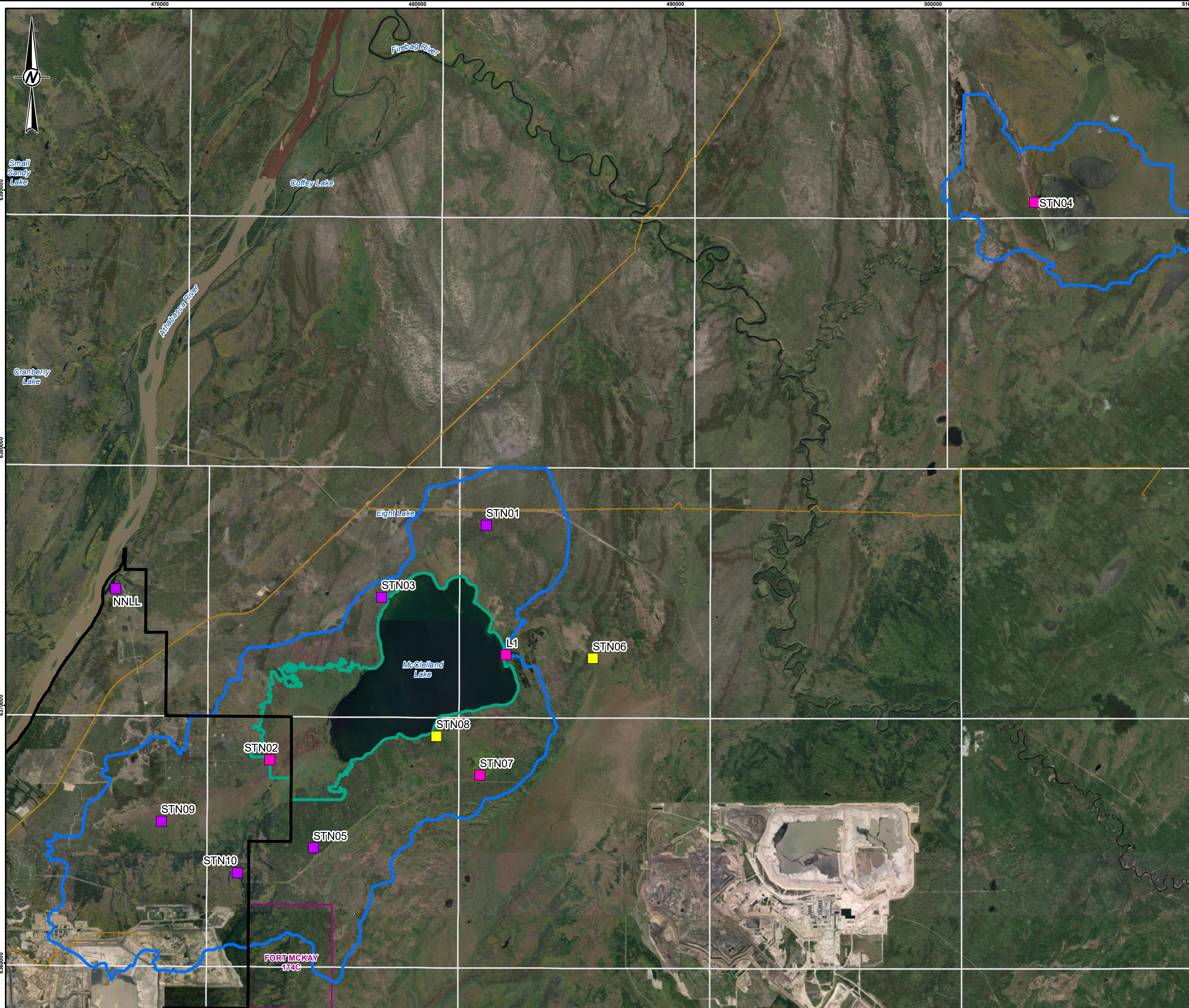
The climate in the region is characterized by long cold winters and short cool summers. At Fort McMurray, the mean annual temperature is about 0.2°C, January temperatures average about -19.5°C, and July temperatures average 16.7°C. Average annual precipitation at the Fort McMurray climate station (1920 to 2020) is 428 mm with about 75% falls as rain and 25% falls as snowfall.

Precipitation and potential evapotranspiration (PET) in the MLWC vary over both seasonal and interannual cycles. The general seasonal pattern in the region is high PET and high precipitation in the summer, and negligible PET and relatively low precipitation in the winter. In addition, actual evapotranspiration (AET) is expected to vary spatially because of variations in soil moisture availability and vegetation type.

The relative abundance and total population of different plant species are spatially heterogeneous, thus, results in spatial variation of AET within the MLWC. The dynamic nature of soil water storage and the water table depth, which fluctuate seasonally and interannually. In upland areas, the depth of the water table creates a volume for soil water storage which when filled is slowly redistributed as groundwater flow. Therefore, the dynamics of infiltration versus partitioning to runoff is to a large degree controlled by the in-situ soil moisture condition.

Various hydrology monitoring programs have been conducted in the MLWC watershed since the early 2000s as part of regional pre-mining baseline monitoring. In addition, meteorology and hydrology data have been collected from Audet Lake (Figure 2.5-15) and meteorology data collected near GGWC at Gordon Lake Outlook (Figure 2.5-16).

The water related monitoring data are limited to the surficial or near-surface water fluxes and include precipitation, air temperature, evapotranspiration, relative humidity, wind speed and direction, solar radiation, snow accumulation and melt, surface water levels and flows, shallow subsurface flow.



LEGEND

- LOCAL ROAD
- FIRST NATION RESERVE
- FORT HILLS *OIL SANDS CONSERVATION ACT AND WATER ACT* BOUNDARY
- NON-MINED PORTION OF THE MLWC
- WATERSHED BOUNDARY

MONITORING STATIONS

- HYDROLOGY STATION
- METEOROLOGY STATION
- METEOROLOGY/HYDROLOGY STATION

0 3 6

1:150,000 KILOMETRES

NOTE(S)

1. NNLL = NO NET LOSS LAKE
2. McCLELLAND LAKE WETLAND COMPLEX

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
McCLELLAND LAKE WETLAND COMPLEX AND AUDET LAKE WETLAND COMPLEX METEOROLOGY AND HYDROLOGY MONITORING LOCATIONS

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
DESIGNED	GB
PREPARED	LB
REVIEWED	ZG
APPROVED	JH

PROJECT NO.	CONTROL	REV.	FIGURE
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LEGEND

PARK / PROTECTED AREA

WATERSHED BOUNDARY

LOCAL ROAD

MONITORING STATIONS

METEOROLOGY STATION

0 3 6

1:135,000 KILOMETRES

REFERENCE(S)

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CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

TITLE

BIRCH LAKE AND GIPSY GORDON WETLAND COMPLEX METEOROLOGY AND HYDROLOGY MONITORING LOCATIONS

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
DESIGNED	CZ
PREPARED	LB
REVIEWED	ZG
APPROVED	JH

PROJECT NO.	CONTROL	REV.	FIGURE
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2.5.5.2. Hydrology Related Pre-Mining Baseline Conditions

2.5.5.2.1. Indigenous Traditional Knowledge

During the 1990s, and at times since, ITK holders noted that, at multiple periods, the water levels in McClelland Lake were lower than usual based on changes in the land and vegetation (e.g., the presence of new cattail stands, riparian grasses). Some have suggested that this may be related to variation in annual precipitation during this time, while others attributed fluctuations to beaver activity in the lake and tributaries (FMFN, FMMN, FCM ITK holders March 12, 2020 workshop and IEG 2021). Generally, seasonal water levels follow a cycle of high water in spring, reductions by mid-summer, and low water levels in fall, all depending on winter snow, ice quality, and spring rains. Similarly, ITK holders have noted lowering of the water table in fens over the past decade, and a resulting change in vegetation (IEG 2021). ITK holder remembered:

> *"The water changing, we're losing water from somewhere, and the moose all the survivors that are living, depending on the water, all moved away. Cuz you know, the water is getting kind of low."* (MCFN ITK holder, MCFN 2019)
>
> *"Well it needs more water there, but to what the water was, cause the water's too low right now, or lower, cause actually the water's sitting somewhere where they're taking the water from..."* (MCFN ITK holder, MCFN 2019)
>
> *"For one thing, how far the cattails—I can't remember cattails in that area. But I noticed that there was a lot of cattails. There was, like—just like a little channel where it never used to be a little channel. Used to be, like, water was right up to the—to pretty well the main ground where you could just step from the main ground into your boat."* (FCM ITK holder, FCM 2019)
>
> *"What I saw about the lake was that there's a lot of grass around there, like a lot of along the shore which tells me that that lake probably is, the water is probably going down."* (MCFN ITK holder, MCFN 2019)

The following conversation took place with ITK holders at the edge of the fen (5-98-9-W4M):

> *"Back where we parked, up to there – you couldn't walk. it used to be just straight water. Remember? Just water up to here (hitting his leg just above the knee) Now... well you can walk out here. There's no water. It used to be standing water. I haven't been out here for three, maybe four years.....that used to be right full of water and now its dried up...even with the amount of rain we had this year....* (FMMN ITK holder, FMMN 2017)
>
> *"Yep – I remember. You couldn't even walk over here it would be water up to here (shows to his knees). .....Now if you were walking over there (points to the trees) – that would be more.. muskeg I guess you'd call it, where you can feel it its really soft under your feet, bouncy, ..."* (FMMN ITK holder, FMMN 2017)

McClelland Creek, particularly at the outflow , was valued in the past for recreational purposes as it was not a fast-flowing river. The Creek has been observed by ITK holders to exhibit annual variations in wetting. In some years it is dry, while in years with abundant precipitation it is full. Generally, though, the Creek is considered to have less water in it than in the past, with ITK holders noting the frequency of drying, and the absence of beavers. Moose Creek was, according to ITK holders, characterized by typically higher water levels and a swifter current than McClelland Creek (IEG 2021). One ITK holder remembers:

> *"I've always noticed Moose Creek always seem to keep its level quite high... I was born in '54, I can only remember probably from about '58 maybe. I have a long memory. The reason why I have good memory of water, because whenever there was water to cross that was deep, my mother had to piggyback me on her back to take me across. That's how I know – I had to hang on for dear life. Yeah. And then that was McLennan Creek and Moose Creek. It used to happen that it was high."* (FCM ITK holder, March 3, 2021 workshop)

Some of the lakes in the MLWC area were known to have varying ice qualities during the winter months. The three lakes in a "V" form close to McClelland Lake were known to have weak ice that did not freeze solid during the winter and this has been attributed to high salt content in the immediate area, as suggested by the frequent presence of deer using the ground for its salt content (FMFN ITK holder, March 3, 2021 workshop). The south end of McClelland Lake has also been noted as an area of weak ice, and Baby Lake and the creek near the Fort Hills area were observed to seldom freeze in winter. With respect to tributaries that do not freeze over, ITK holders have identified that on the powerline going east, on the north side is a tributary that does not freeze and it leads to a pond. (FMMN ITK Holder, March 3, 2021)

During mid-winter, ice breaking and piling was not uncommon on the waterbodies in the MLWC area, though ITK holders have not been able to explain the phenomenon, as one remembers:

"I've seen a lot of unexplainable things on the lake. Like, I've seen ice piled up like this and it looked like something came ... a bulldozer walked around there. The look on the snow looks like a bulldozer was walking. But the ice was broken from underneath because it came up this way... piled on top of that ice. And this pile looked big - like ginormous pile.... Like as big as - Like one of those lakes - those round lakes. Big. And I'm using those lakes same, because my grandfather used to say that's where his grandfather would travel, in between those three lakes and he used to say that's what you see in the snow, looks like bulldozer tracks." (FMFN ITK holder, FMMN 2017)Some ITK holders have noted that, in years when the Athabasca River is low, so too are the wetlands around which the hunt, trap, and gather plants, and this has been attributed to increased industrial activity and associated water withdrawals along the river since development began, but also to climate change and lower precipitation levels in recent years (FMFN ITK holder, March 3, 2021 workshop). Since the 1960s, FMFN and FMMN ITK holders have observed changes to water quantity and quality within the MLWC and surrounding area and expressed that water levels have gone down in the McClelland Lake area since nearby industrial projects became active (FMFN and FMMN ITK holders, IEG 2021).

2.5.5.2.2. Climate Data

The climate regime including precipitation, evapotranspiration, and other climate variables is one of the main drivers determining the hydrology and influencing the ecological conditions in the MLWC watershed. Hence characterizing and quantifying the climate regime is crucial to the understanding of the watershed characteristics and hydrologic processes in the watershed.

As part of the climate data compilation and analysis for this study, climate data were obtained from several sources, including the Environment and Climate Change Canada (ECCC) monitoring stations, Alberta Forestry lookout monitoring stations, the Regional Aquatics Monitoring Program (RAMP) monitoring stations that are now operated under the Oil Sands Monitoring (OSM) Program, as well as FHEC climate station installed in the MLWC watershed and the reference site at Audet Lake.

The mean monthly values of important climate variables for the region: precipitation, air temperature, relative humidity, solar radiation, evaporation, and evapotranspiration are provided in Table 2.5-12. The existing climate database is good for parameters that can be directly measured. Long-term information in the MLWC is not available, but precipitation and temperature data are available from the regional stations will be used to characterize the pre-mining baseline information and will be used for input to the integrated water models used to complete Objective 3.

Table 2.5-12: Mean Monthly Climate Statistics – Based on Fort McMurray Data

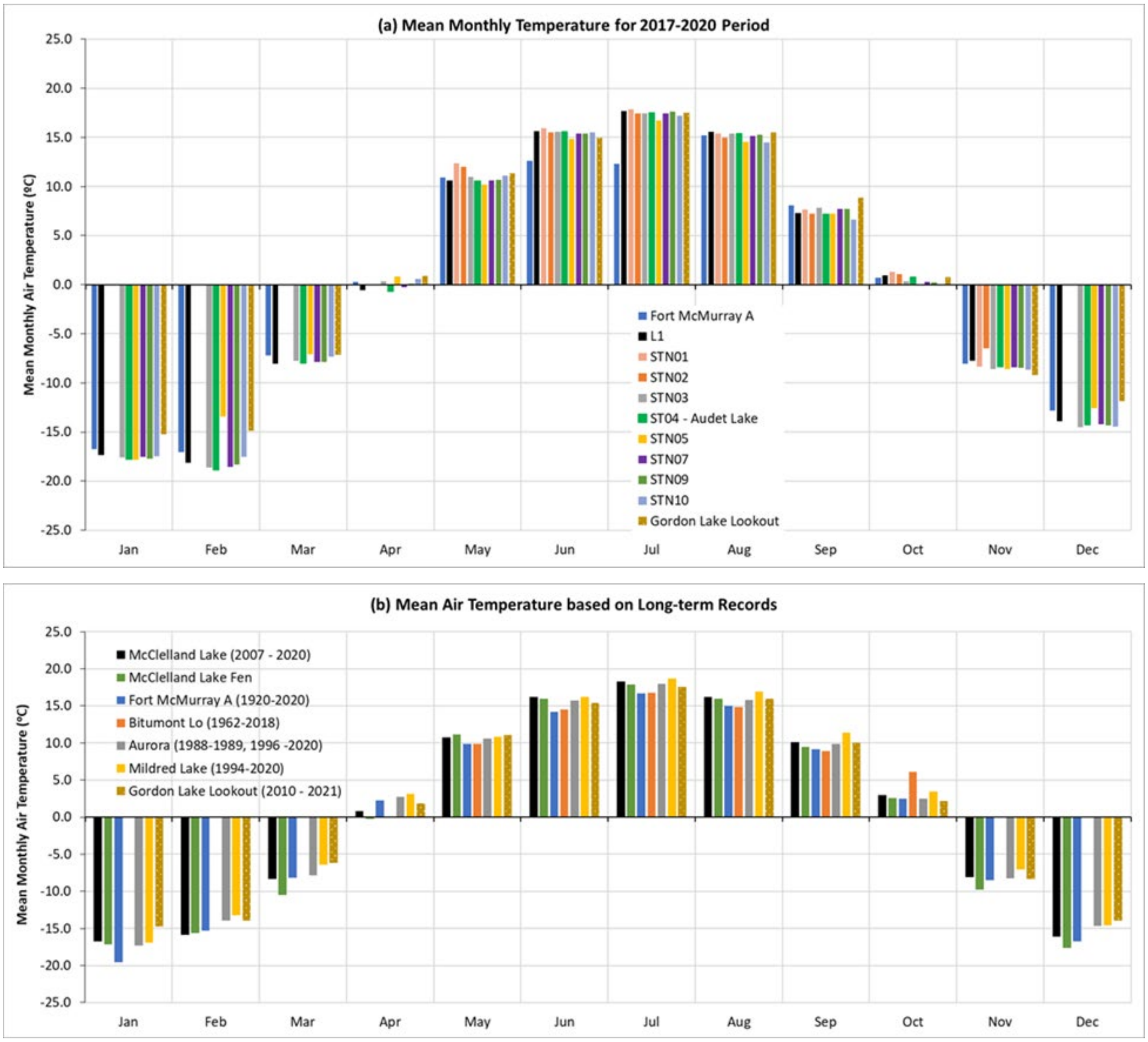
Month	Air Temperature[a] [°C]	Precipitation[a] [mm]	Potential Evapotranspiration[b] [mm]	Potential Evaporation[b] [mm]	Relative Humidity[b] [%]	Solar Radiation[b] [W/m²]	Wind Speed[b] [km/hr]
January	-19.6	19.6	-2	0	76	20.3	10.2
February	-15.4	15.0	-1	-1	73	51.0	10.6
March	-8.2	18.5	18	4	67	108	11.5
April	2.3	20.1	83	37	59	165	13.1
May	9.9	34.1	147	81	56	205	12.6
June	14.3	65.2	155	104	63	215	12.0
July	16.8	78.4	156	116	68	209	11.4
August	15.0	63.0	121	102	72	171	11.4
September	9.1	47.4	56	58	74	105	12.0
October	2.5	26.7	17	20	74	58.1	12.4
November	-8.5	21.8	-1.0	6	79	24.3	11.5
December	-16.8	20.1	-3	2	78	13.8	10.1
Annual	**0.2**	**429**	**745**	**529**	**70**	**112**	**11.6**

Based on data from the Fort McMurray climate station, 1919 to 1943, and Fort McMurray Airport, 1944 to 2019.
Based on data from the Fort McMurray airport, 1953 to 2019.
% = percent; °C = degree Celsius; km/hr = kilometres per hour; mm = millimetre; W/m² = watts per square metre

Air Temperature

Long-term continuous temperature records are available at the Fort McMurray climate station, from 1908 to 1944, and at the Fort McMurray Airport climate station, which has been in operation since 1944. The records at the Fort McMurray climate station have several data gaps from 1908 to 1918. The differences between the recorded monthly air temperatures at the two stations in 1944 were usually less than 1°C. This slight difference allowed the two records to be combined, resulting in a continuous air temperature record for Fort McMurray from 1919 to 2019. Relatively long-term air temperature is also available in several other regional local stations including Aurora (1988 to 1989, 1996 to 2020), Mildred Lake (1994 to 2020), Bitumont Lookout (1962 to 2018), McClelland Lake (2007 to 2020), and Gordon Lake Lookout (2010 to 2020).

Comparison of mean monthly air temperature for data collected within the MLWC watershed and at the regional stations, for the period from the past three years (2018 to 2020), is shown in Figure 2.5-17(a). Comparison of mean monthly air temperature based on relatively long-term data collected at five locations is shown in Figure 2.5-17(b).

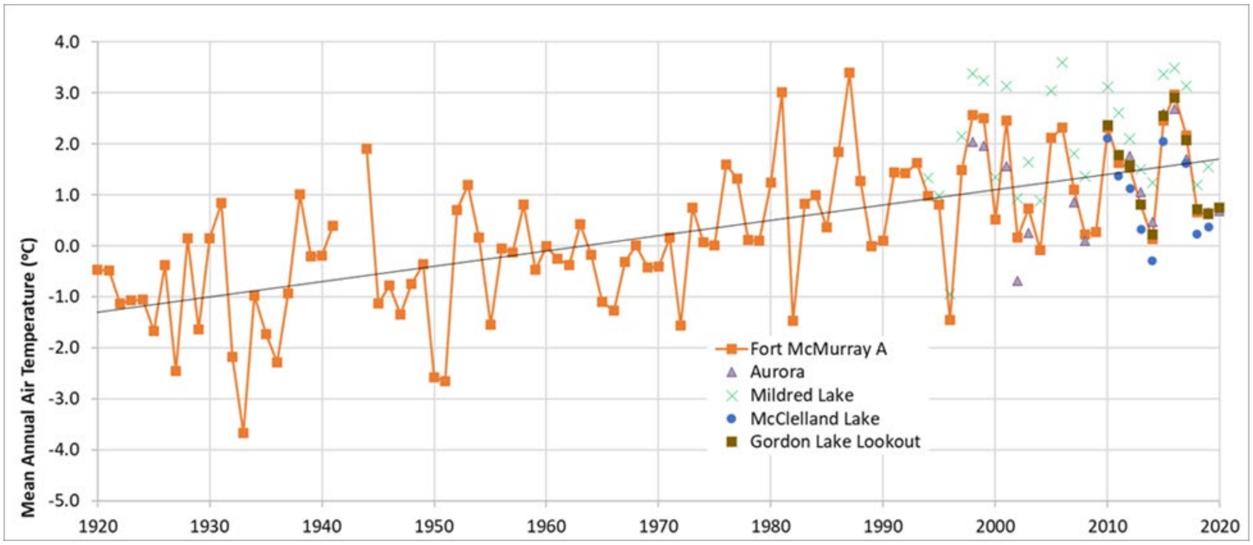


°C = degree Celsius.

Figure 2.5-17: Comparison of Monthly Air Temperatures

Mean annual air temperature at McClelland Lake is about 1.0°C based on recorded long-term data at RAMP station L1. Site specific data collected within the MLWC watershed at various locations (2010 to 2015 and 2017 to 2020) have several missing data. However, based on recorded short-term data collected within the watershed, mean annual temperature varies from 0°C to maximum of 0.4°C.

Based on recorded data over the past 100 years at Fort McMurray Airport station, an increasing trend in annual temperature is observed as shown in Figure 2.5-18.



°C = degree Celsius.

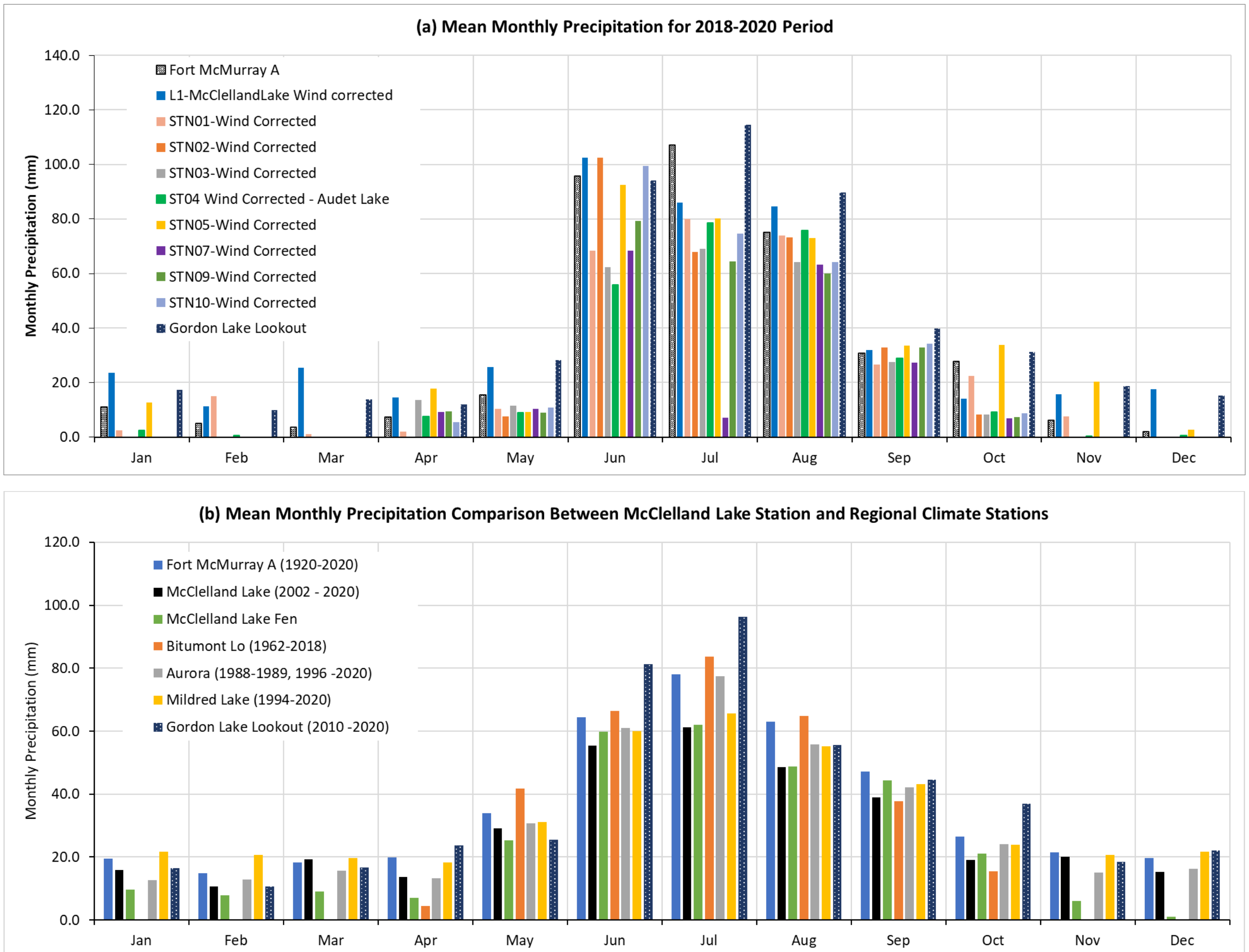
Figure 2.5-18: Long-term Trend in Air Temperature

Precipitation

Precipitation is the primary water input to the watershed and one of the most spatially variable climate parameters that is sensitive to elevation and rain-shadow effects. On a short time scale, say daily, local precipitation can be highly variable due to factors such as small scale but intense convective precipitation events, slope and elevation variations, and localized influences from wind and ground cover. ITK holders have suggested that seasonal snowfall is often consistent, but have noted that on rare occasions, the timing of the first snowfall may vary. For example, in a year before 1960, there was no snow until Christmas, which was unusual (IEG 2021).

The MLWC watershed experiences roughly 350 mm of precipitation per year (RAMP L1 McClelland Lake precipitation gauge corrected for gauge and wind undercatch 2002 to 2020), of which approximately 20 to 30% falls as snow and is stored on the surface until springtime when the snowpack is released to the watershed. Mean monthly total precipitation varies from 11 mm in February to 61 mm in July.

As there is limited elevation change within the watershed, it is anticipated that there will be little systematic precipitation gradients due to orographic effects and the majority of the variability will be derived by convective precipitation variability throughout the watershed. Comparison of monthly precipitation for data collected within the MLWC watershed and at the regional stations, for the period from the past three years (2010 to 2015 and 2017 to 2020), is shown in Figure 2.5-19(a). Comparison of monthly precipitation data based relatively long-term data collected at five locations is shown in Figure 2.5-19(b).

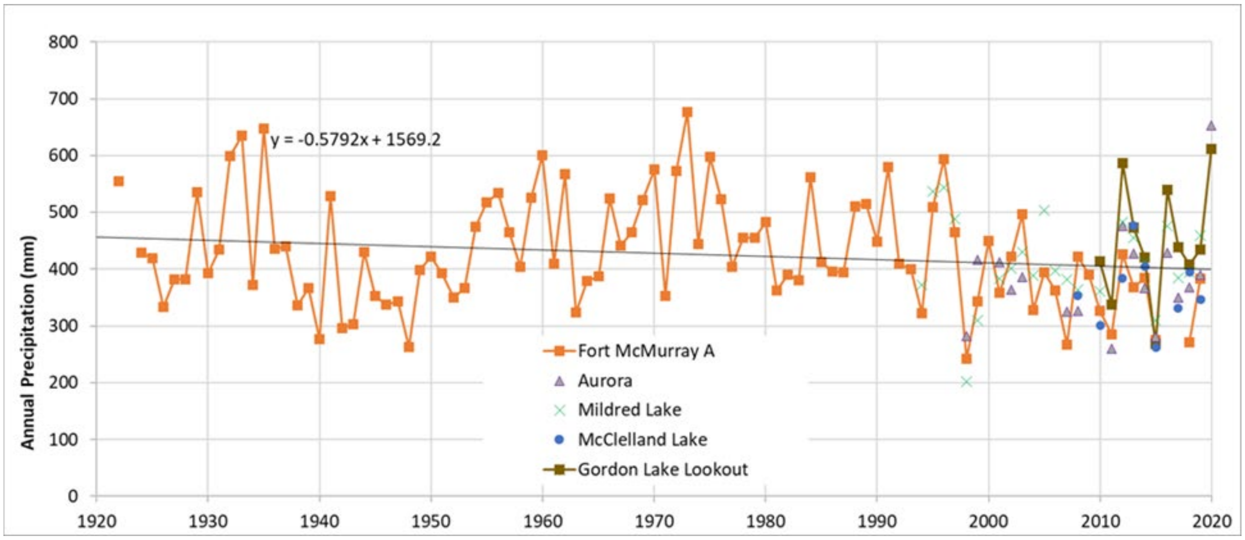


mm = millimetre.

Figure 2.5-19: Comparison of Monthly Precipitation

Site specific data collected within the McClelland Lake watershed at various locations have several missing data. However, based on limited data collected from 2018 to 2020, there is small variation in precipitation within the watershed though the June precipitation amount recorded in the stations located close to the MLWC (i.e., STN02 and STN05) is slightly higher than those recorded at stations located north of McClelland Lake (i.e., STN01 and STN03). In addition, the precipitation measured at the Audet Lake reference site is similar to precipitation measured at the McClelland Lake watershed. The monthly precipitation measured at Gordon Lake Outlook is slightly higher than McClelland Lake data specifically for June and July, which indicates that the climatic condition at GGWC is wetter than MLWC. However, relatively long-term and quality data are required to correctly establish the variation of precipitation statistics within the McClelland Lake watershed.

Based on recorded data over the past 100 years at Fort McMurray Airport station, a decreasing trend in annual precipitation is observed as shown in Figure 2.5-20. The trend for Gordon Lake Outlook is also similar to Fort McMurray Station except that the site receives slightly higher precipitation.



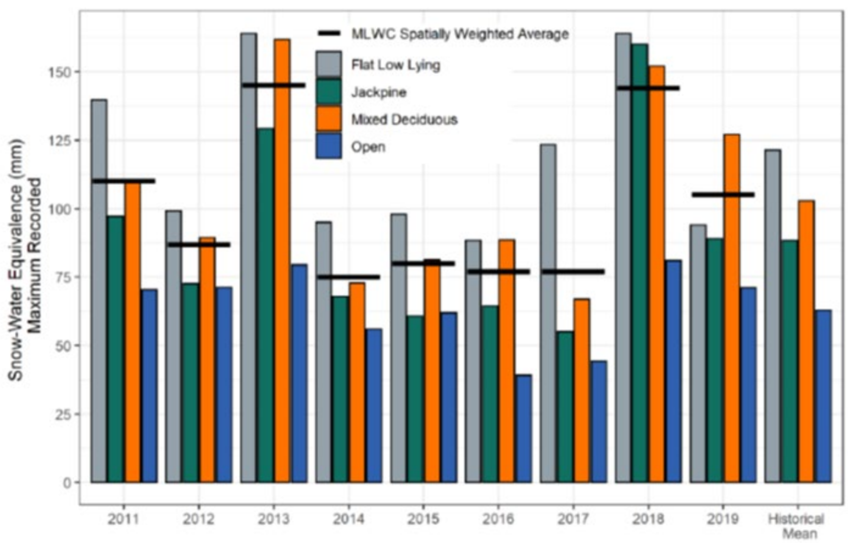
mm = millimetre.

Figure 2.5-20: Long-term Trend in Precipitation

From a water balance perspective, spatial differences in snow water equivalent (SWE) are important. Hydrologic processes differ between land classes. By assessing SWE in the dominant land classes, and spatially distributing measured SWE across these land classes, water balances within these classes can be assessed conceptually and/or through numerical modelling.

It is expected that snow accumulations may also vary across the MLWC. Three common mechanisms may be responsible for this variability and include (i) snow-canopy interactions, (ii) wind-induced snow redistribution or sublimation and (iii) orographic influences on snow fall (Frey and Holzmann 2015). The SWE data from the regions (e.g., RAMP 2018) routinely confirm that, relative to a sheltered opening, snowpack accumulation is lower in coniferous and mixed deciduous stands due to canopy interception, and is even lower in unsheltered open areas, such as lakes and large mine areas due to wind-driven losses.

The RAMP (later known as Joint Oil Sands Monitoring [JOSM] Program and now OSM Program) snow survey program has collected SWE data at the eastern and southern end of McClelland Lake since 2004, and in three other areas of the Oil Sands region. In addition, FHEC collected SWE data within the McClelland Lake watershed starting in 2016 through 2020. Spatial variability of SWE within the McClelland Lake watershed is relatively large (Figure 2.5-21) with the highest SWE being recorded in areas covered by mixed deciduous and in the open fen area, potentially reflecting redistribution of snow by wind.



Note: Historical data were collected at RAMP snowcourses MCLL-FL-A (MLWC SC3; flat low-lying), MCLL-JP-A (MLWC SC4; jackpine), MCLL-MD-A (MLWC SC2; mixed deciduous), and MCLL-OP-A (MLWC SC1), by Alberta Environment and Parks
mm = millimetre.

Figure 2.5-21: Historical Snow-Water Equivalent by Land Cover (Hatfield 2019)

Evaporation and Evapotranspiration

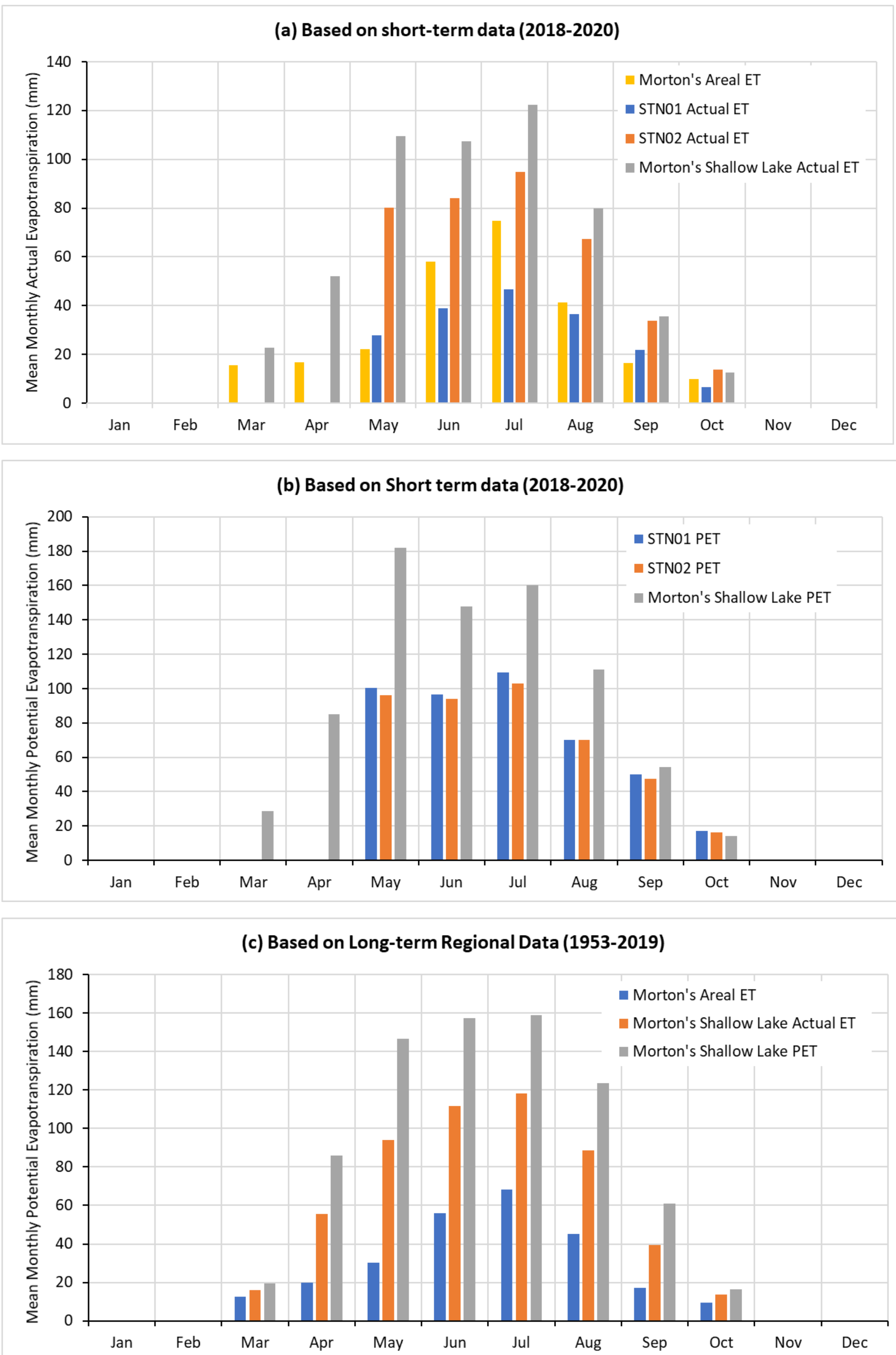
Evaporation (E) and Evapotranspiration (ET) are the dominant losses of water from the watershed. They are a function of air temperature, relative humidity, solar radiation, wind velocity, soil moisture, vegetation, and groundwater level. With the possible exception of wind velocity, these parameters are not expected to vary significantly within the same region. Hence, applying the lake evaporation and potential ET rates that are calculated based on climate data recorded at Fort McMurray A station for the McClelland Lake watershed is a reasonable option, until sufficient local records are available.

Based on estimated E and ET using long-term climate data from Fort McMurray A Station (1953 to 2019), actual/areal evapotranspiration on land is estimated to vary between about 180 and 370 mm/yr near Fort McMurray (about 250 mm/yr on average). Shallow lake evaporation is higher and varies between about 425 and 670 mm/yr (about 528 mm/yr on average). ET is also expected to vary across the MLWC, depending on the area where evapotranspiration is occurring (e.g., over open water, bare ground, forest, grassland).

Within the MLWC, there are three predominant land cover types that could generate spatial variability in ET: open water, wetland, and forested uplands. Open water sources, such as lakes, are expected to have the largest potential for evapotranspiration within wetlands, and forest stands (specifically, deciduous, mixed wood, conifer, and shrubby), grasslands, and bare ground areas decreasing in evapotranspiration potential for each class, respectively. Based on estimated potential ET using long-term climate data from Fort McMurray A Station, mean potential ET in the region is about 760 mm.

The ET was monitored at two locations in the McClelland Lake watershed using eddy covariance gas flux towers. Comparison of E and ET recorded data within the McClelland Lake watershed and computed by Morton model using climate data recoded at the Fort McMurray A station is shown in Figure 2.5-22.

- Actual ET recoded at the station located north of the McClelland Lake (i.e., at STN01) is significantly less than the Actual ET recoded within the Fen (i.e., at STN02).
- Actual ET recorded within the Fen (i.e., at STN02) is higher than areal ET computed using Morton model but less than shallow lake actual ET computed using Morton model.



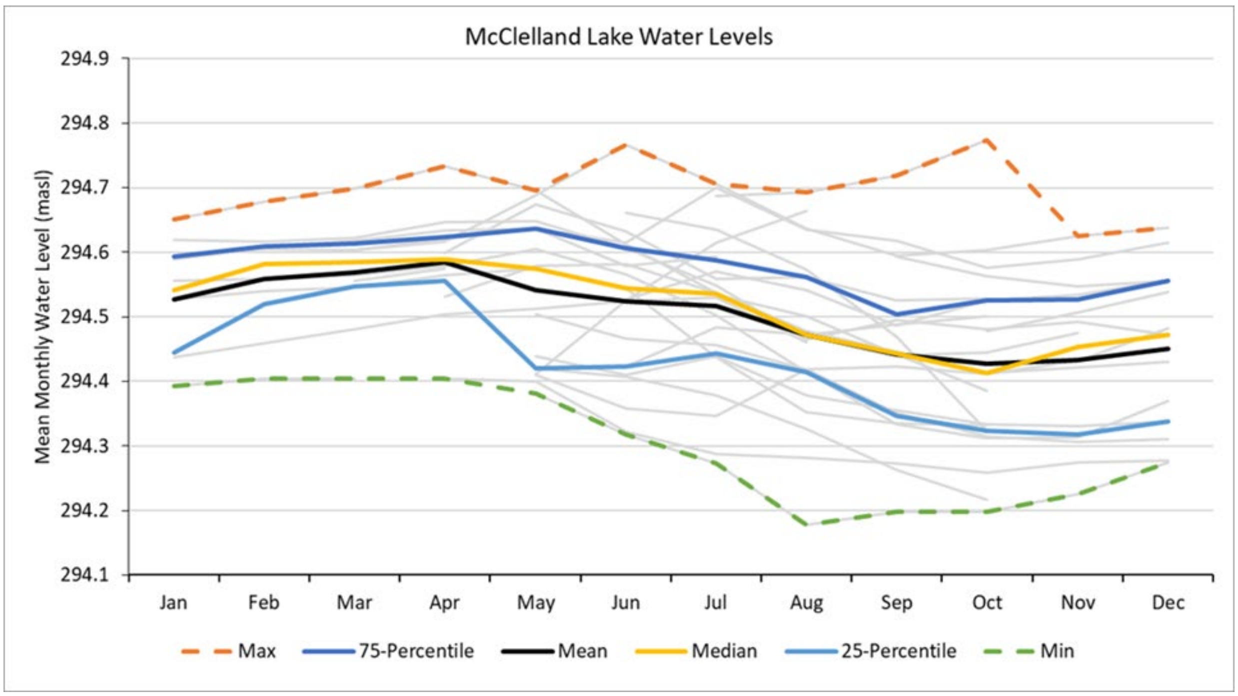
ET = evapotranspiration; mm = millimetre; PET = potential evapotranspiration.

Figure 2.5-22: Evaporation and Evapotranspiration

2.5.5.2.3. Water Level Data

McClelland Lake – Recorded Data

McClelland Lake has a surface area of approximately 30.5 km^2, an average depth of approximately 2 m and a maximum depth of approximately 5.5 m. Monitoring data collected by RAMP and AEP from June 1997 through October 2020 indicated that the level of McClelland Lake fluctuated approximately 0.68 m (between 294.11 and 294.79 m). The average level of McClelland Lake is approximately 294.50 m (Figure 2.5-23). ITK holders identified that water levels in McClelland Lake are already much lower compared to pre-development baseline conditions, while one ITK holder identified that they had never seen McClelland Lake lower than what it was when they were out there (in August 2019) (FCM ITK holder, March 3, 2021 workshop). The water level increases during winter and spring and decreases during summer and fall season. The ice build-up on the shallow lake shore around the lake outlet is a possible explanation for the winter water level increase. However, this needs to be verified by field observations. ITK holders have noted that there are seasonal fluctuations in the water levels which are controlled by beavers in the area (beavers let old water out through their dams in the spring and in the fall they dam the lake to keep the fresh water in) (FMFN and FFMN ITK holder, IEG 2020).



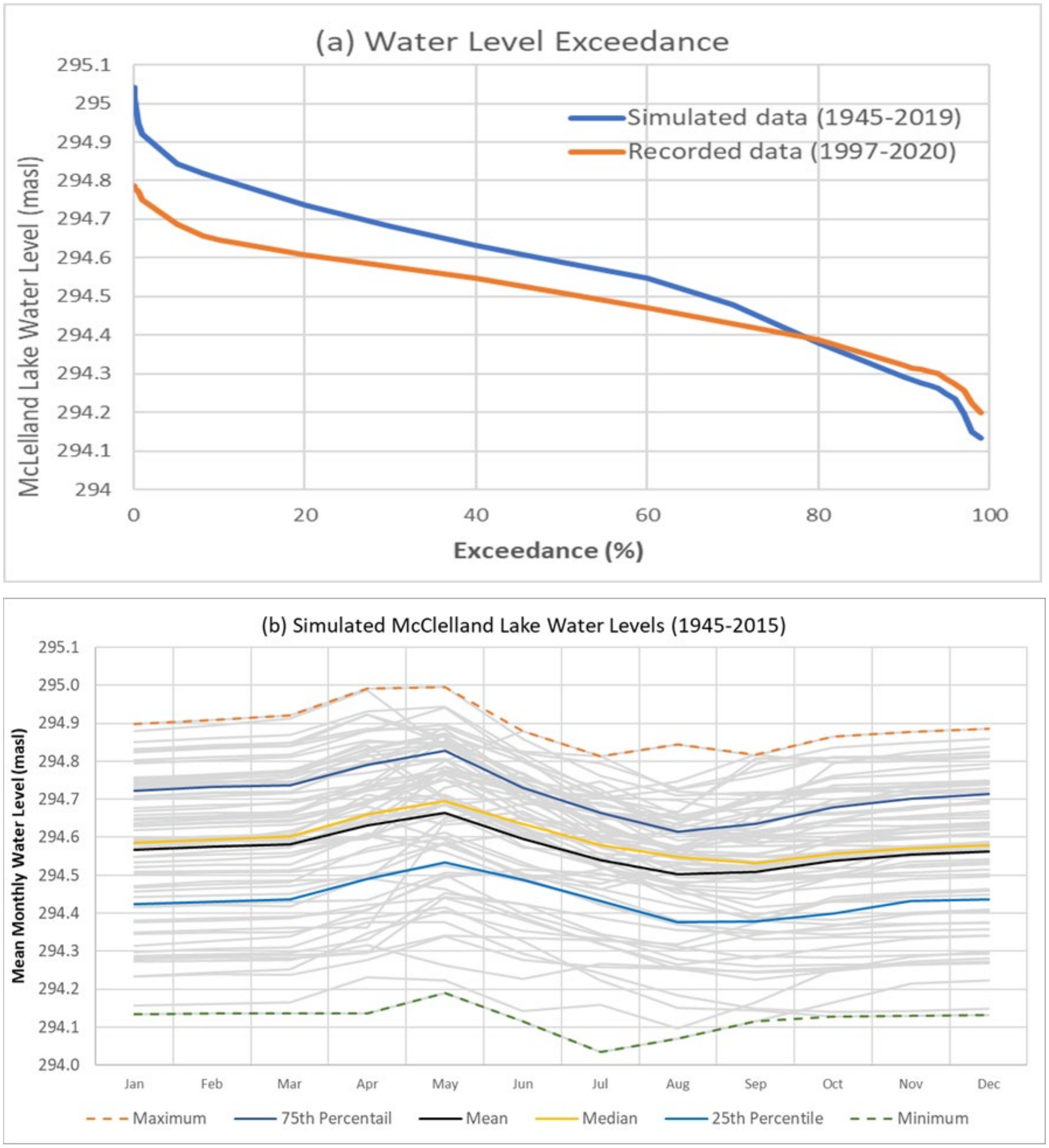
masl = metres above sea level.

Figure 2.5-23: McClelland Lake Water Level – Based on Data from 1997 to 2020

McClelland Lake – Model Simulated Data

Due to the short time period available for recorded data, simulated data was used to infer lake water levels over a longer time period. Long-term water level simulation for McClelland Lake was completed using a fully integrated surface and subsurface flow model, 2020 MLWC HGS model (Aquanty 2021).

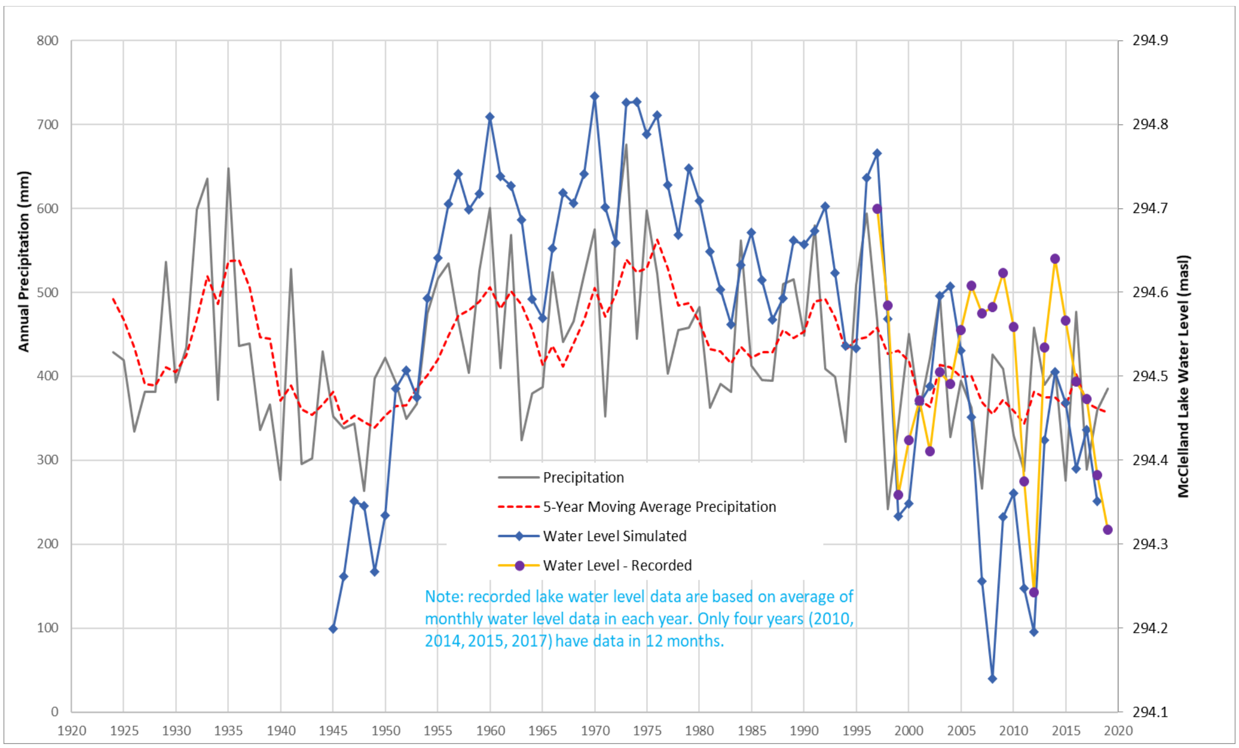
Simulated water level data for the period 1945 to 2019 indicates that the level of McClelland Lake fluctuated approximately 1.04 m (between 294.00 and 295.04 m). The average level of McClelland Lake is approximately 294.57 m (Figure 2.5-24).



% = percent; masl = metres above sea level.

Figure 2.5-24: McClelland Lake Water Level – Based on Simulated Data

The simulated water levels are comparable to recorded water levels as shown in Figure 2.5-25 except the simulated water levels for the period from 2007 to 2012 that is significantly affected by relatively low precipitation recorded at Fort McMurray Airport station. An ITK holder visited the McClelland Lake area several times for periods of time in the 1990s and made the observations that: “McClelland Lake was low”; “It was not where the water used to be”; “You can tell by the land where the water used to be” (FCM 2019). The simulated water levels also reflect the dry hydrologic conditions documented in the late 1940s and 1950s. A member of the SC Technical Advisory Group (TAG) also noted that the 1950s is considered to be one of the driest decades on record in the last century. An FMFN Elder spoke of a time when she was a girl and the water in McClelland Lake was very low – so low there was a fairly wide sand beach almost all the way around the lake, but especially on the north and east shores. As this Elder was born in 1934, this memory also supports the notion that water levels were lowest in the 1940s (Oloriz 2000, pers. comm.).



masl = metres above sea level; mm = millimetre.

Figure 2.5-25: McClelland Lake Water Level – Comparison of Simulated and Recorded Data

A series of aerial images of McClelland Lake during the period from 1950 to 2017 were created for the 2018 McClelland Lake Wetland Complex Data Synthesis Report (Golder 2018), and copies of those figures are provided in Appendix A. Inspection of the 1950 aerial image indicates significantly lower water levels in McClelland Lake, as evidenced from a large beach area on the western edge of the Lake. Precipitation records from this period indicate drought conditions throughout the region. Cross referencing the historical images with bathometric readings taken from McClelland Lake indicate that the lake was between 1.0 and 1.5 m shallower in 1950 than the current depth of the lake.

Water Level in the Fen - Recorded Data

ITK holders have stated that water levels in the fen are decreasing, and in the last 10 years or so, they have seen changes in the amount of surface water and shallow groundwater in the fen, and this is changing the vegetation.

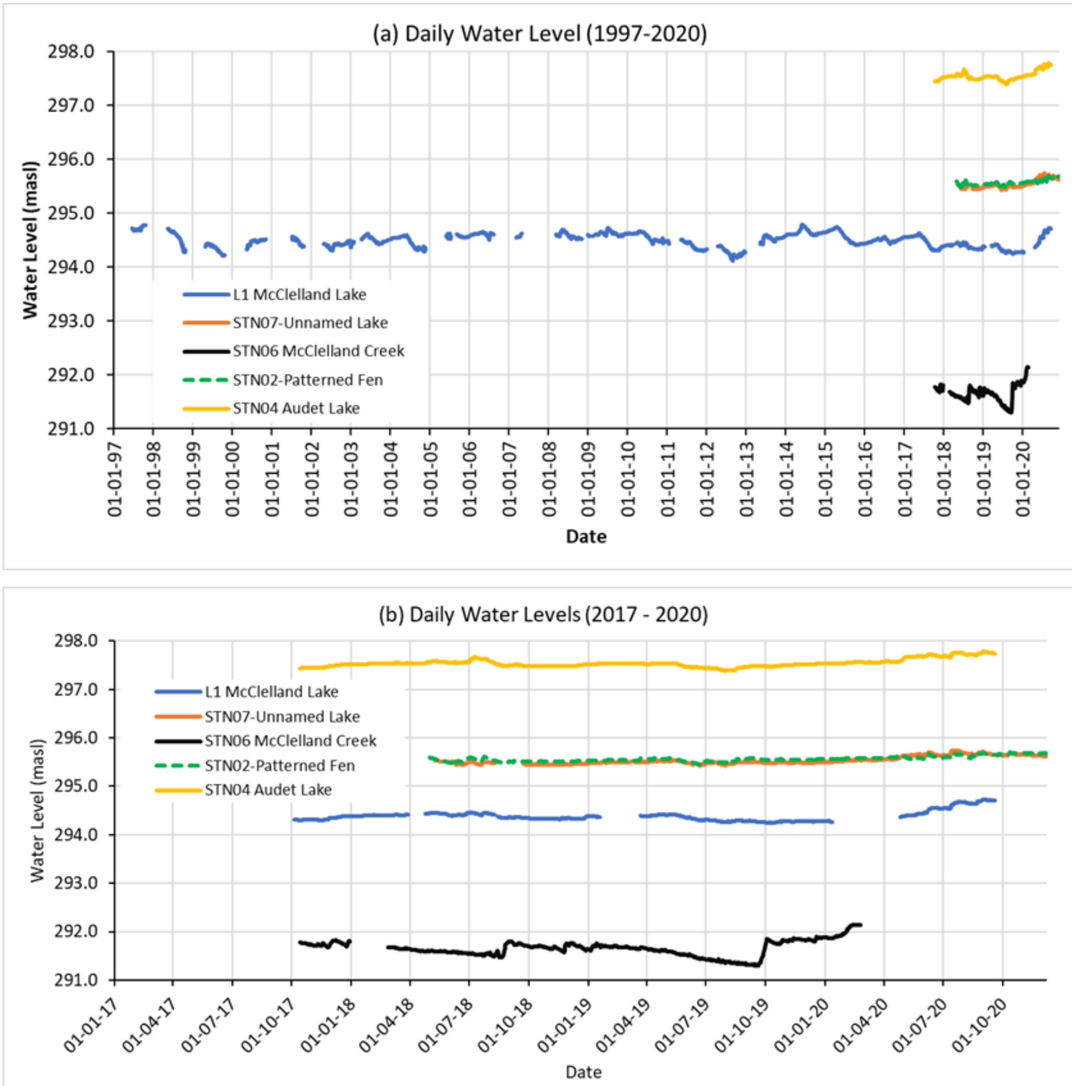
> "*Back where we parked, up to there – you couldn't walk. it used to be just straight water. Remember? Just water up to here (hitting his leg just above the knee) Now... well you can walk out here. There's no water. It used to be standing water. I haven't been out here for three, maybe four years.....that used to be right full of water and now its dried up...even with the amount of rain we had this year....*" (FMMN ITK holder, FMMN 2017)

> *"Yep – I remember. You couldn't even walk over here it would be water up to here (shows to his knees). .....Now if you were walking over there (points to the trees) – that would be more.. muskeg I guess you'd call it, where you can feel it its really soft under your feet, bouncy, ..."* (FMMN ITK holder, FMMN 2017)

Water level monitoring data indicates that water levels in the fen can vary and closely reflect surface topography, which is consistent with the evidence presented by Vitt and House (2020), which suggests that water levels in the fen have been relatively consistent over a 10,000 year period. Based on recorded data from 2018 to 2020, water levels in the fen (i.e., STN02) varied by 0.26 m (between 295.45 and 295.71 m) with average water level being about 295.57 m. Historical water levels in the MLWC range from 0.06 to 0.32 m below the ground surface with water level relatively near the surface in the southern portion of the fen (i.e., 0.06 to 0.20 m below surface) and relatively deeper in the northern portion of the fen (i.e., 0.16 to 0.32 m below surface) (Vitt and House 2020). Water levels in the patterned portion of the wetland vary from 0.11 to 0.28 m below surface (Vitt and House 2020). The average water level in the fen, measured at STN02, is about 1 m higher than the average water level of McClelland Lake.

Peatlands are generally characterized by linear landforms of wet hollows (flarks) and associated with drier, elongated hummocks (strings). Water levels vary over the season owing to two factors: the seasonal draw-down after the spring freshet and the annual vertical growth of the ground layer. In general, water levels in most flarks varied from 0.05 to 0.12 m below the ground layer surface (with a few flarks having water levels 0.01 to 0.05 m above the ground layer surface) (Vitt and House 2020). On most strings, water levels vary from 0.04 to 0.19 m below the ground layer surface (Vitt and House 2020).

Based on recorded data for the past 23 years for McClelland Lake (i.e., Figure 2.5-26(a)), there is no visible temporal trend in the water level data. The pattern of water level fluctuation for McClelland Lake (i.e., L1), in the fen (i.e., STN02), Unnamed Lake (i.e., STN07), and at reference Audet Lake (i.e., STN04) are similar as shown in Figure 2.5-26(b).



masl = metres above sea level.

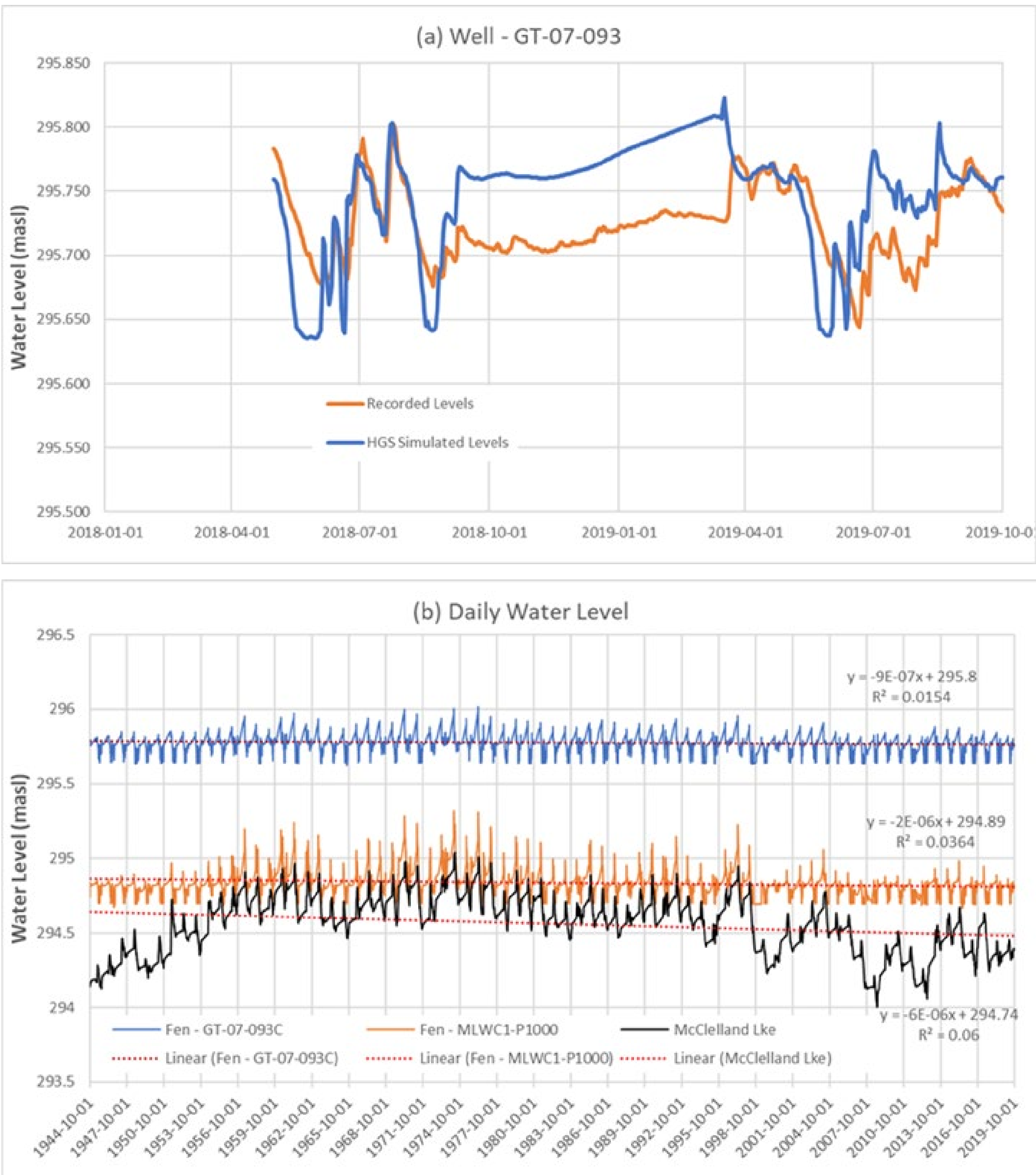
Figure 2.5-26: Water Level Measured within the McClelland Lake Watershed and at Reference Audet Lake Site

Water Level in the Fen – Model Simulated Data

Long-term water level simulation for the fen was also completed using the 2020 MLWC HGS model. Simulated water level data for the period 1945 to 2019 indicates that the water level in the fen at the monitoring station (STN02) fluctuated approximately 0.394 m (between 295.623 and 296.017 m). The average water level in the fen is approximately 294.773 m.

The simulated water levels are comparable to recorded water levels, as shown in Figure 2.5-27, except the simulated water levels for the winter period (i.e., October 2018 to March 2019) that is affected partly by the limitation of the 2020 MLWC HGS model to simulate the effect of winter groundwater inflow into the fen.

Based on simulated water level data for the past 75 years for McClelland Lake (i.e., Figure 2.5-27(a)), the Water levels have varied within a metre and with patterns as described by ITK holders (i.e., lower in the 1940's, higher in the 1960's, low in the 1990's, and lower since) (FCM and FMFN ITK holders, March 3, 2021 workshop and FCM 2019). The pattern of water level fluctuation for McClelland Lake and in the fen are similar. However, McClelland Lake water level is more affected by dry period than the water level in the fen as shown in Figure 2.5-27(b).



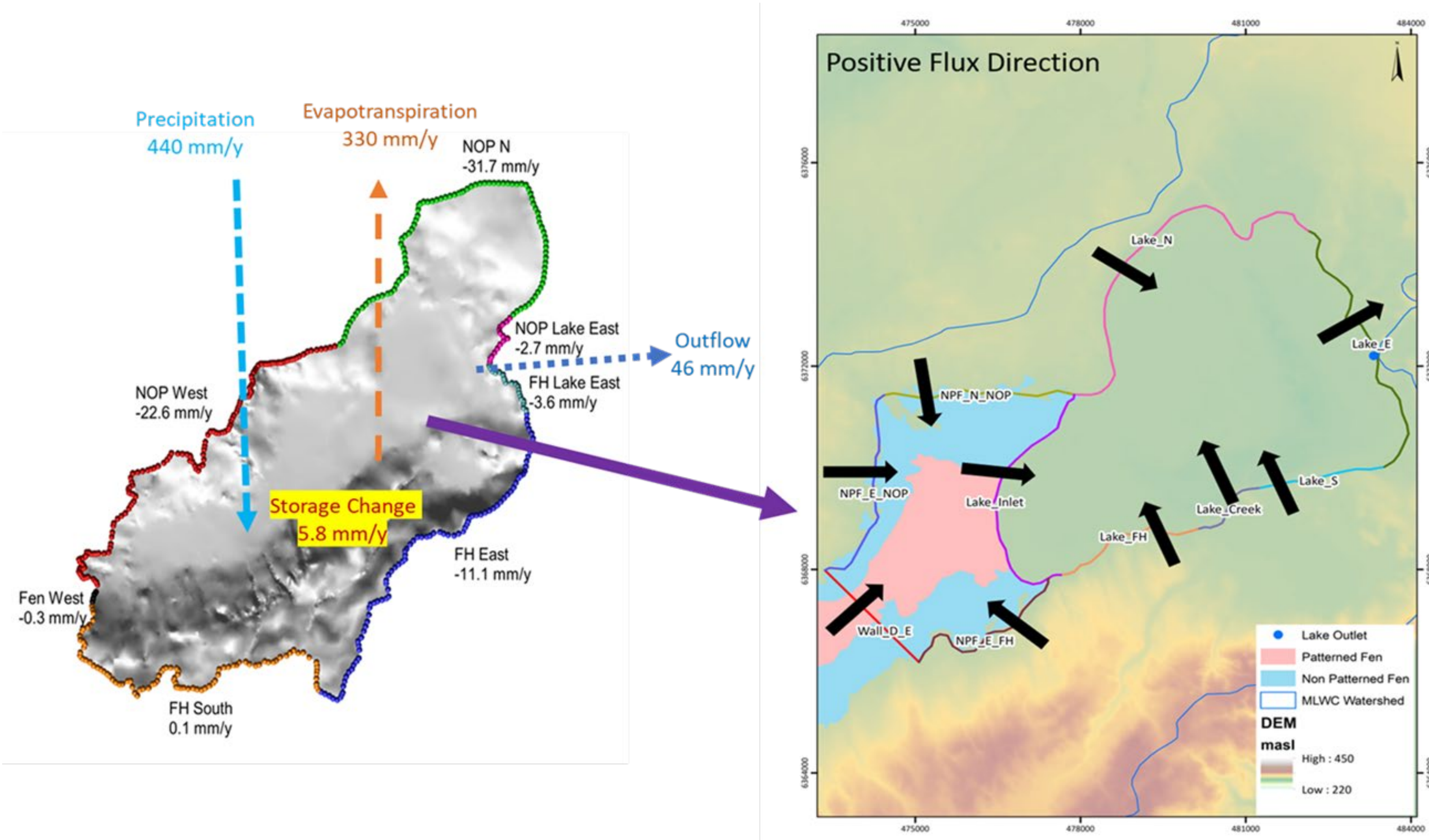
masl = metres above sea level.

Figure 2.5-27: Simulated Water Levels in the Fen and for McClelland Lake

2.5.5.2.4. Water Balance

The water source for the MLWC is a combination of surface water and groundwater, with groundwater determined to be responsible for the maintenance of the MLWC after the spring freshet. Surface water in the fen likely plays a role mostly in spring, when freshet water is able to 'flush the fen' as it pools and drains over the frozen peat layer. An ITK holder noted that periodic flooding and times of lower water is fairly common in the MLWC, and the highwater in 2020 was part of the natural cycle, and the flooding was good for cleaning out some of the rivers and scrubbing the shoreline (FMFN ITK holder, December 7, 2020 meeting). Members of MCFN have provided ITK that water levels in the MLWC vary – in the spring, water levels are high. Water levels remain high until mid-summer. Water levels are lower in the fall. Spring water levels depend on the amount of winter snow, ice quality and strength, and the amount of spring precipitation (affecting ice jams) (MCFN 2019).

The conceptual water balance of the MLWC is driven by a number of component water fluxes into, within and out of the watershed, fen and the lake, as illustrated in Figure 2.5-28.



Source: Aquanty (2021)
mm/y = millimetres per year.

Figure 2.5-28: Water Balance for McClelland Lake Watershed and Fluxes into, within and out of the Fen and the Lake (based on simulated flows from 1944 to 2019)

The conceptual water balance for the MLWC watershed is based on the current understanding of the watershed, observation from the field programs, informed by an ongoing remote sensing assessment, data from other regional studies, and fluxes simulated using 2020 MLWC HGS model.

Predominant water fluxes into and out of the MLWC and to each of the sub-watersheds considered in the McClelland Lake watershed, which directly impact the water balance, include:

- precipitation
- evaporation and evapotranspiration
- surface water outflow
- local and regional groundwater outflow

Other internal water fluxes, within the MLWC, or water sinks include:

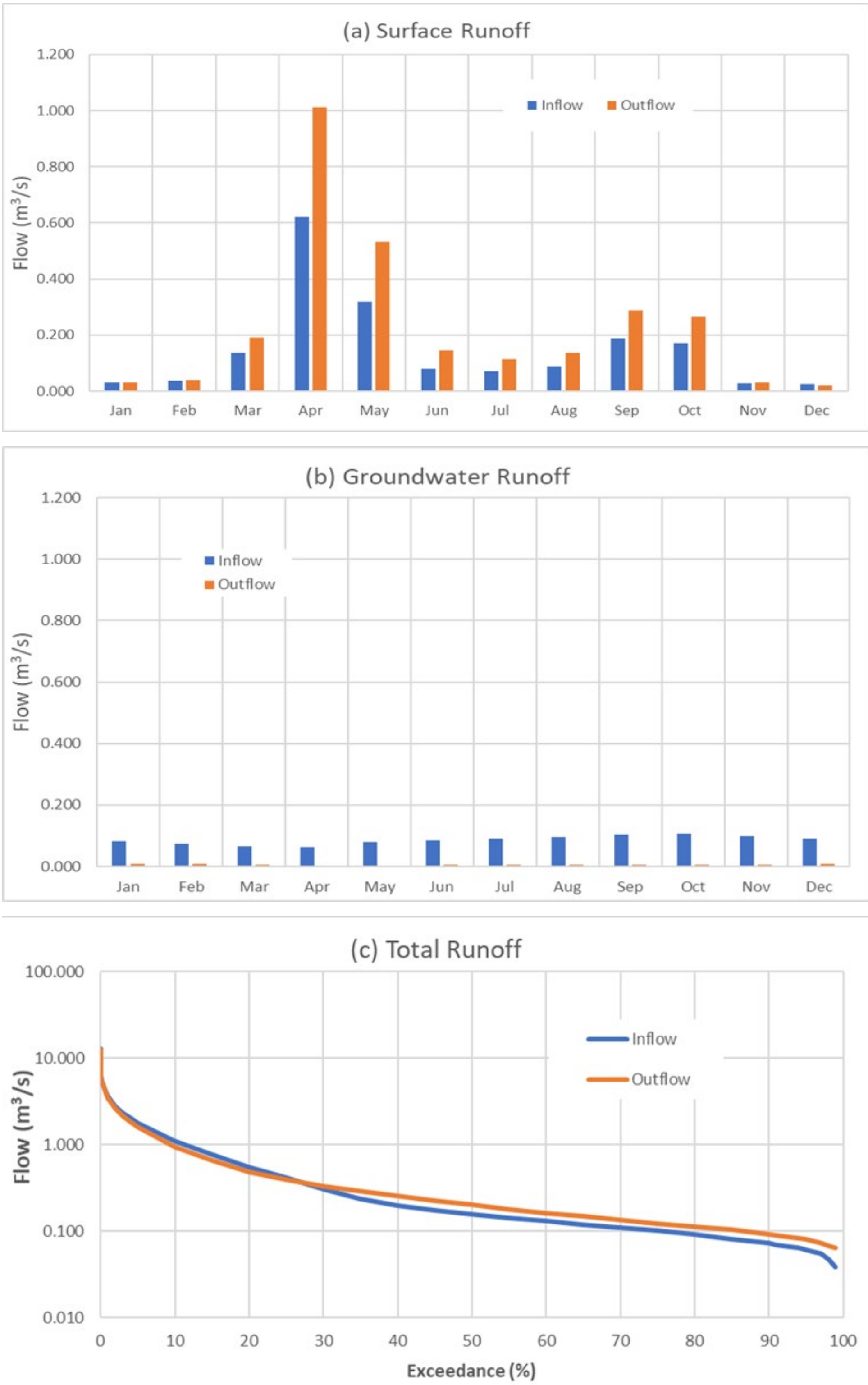
- surface water flow and storage
- infiltration and recharge
- local groundwater flow and storage
- unsaturated soil water storage and flow

Water Balance for the Fen

The fen system is located centrally between the FHUC and the NOP. Based on simulated flows using the 2020 MLWC HGS model, for the non-mined portion of the fen, surface runoff, groundwater, and direct precipitation contribution represent about 35%, 20%, and 45% of the total inflow, respectively. The majority of surface runoff to the fen comes from the southwest direction (i.e., about 92.6%) and from south (6.8%). There is little surface runoff from the NOP. Groundwater runoff contribution to the fen includes about 57% from NOP, 31% from the south, and 13% from the southwest side.

Outflow from the fen to McClelland Lake occurs mostly as surface runoff (i.e., about 55%) and evapotranspiration (i.e., about 42%) with groundwater representing only about 3%. Change in storage represents less than 0.02% and change in groundwater contribution represents less than 0.3% over a period of 75 years. Mean monthly inflows to and outflows from the fen are shown in Figure 2.5-29.

A summary of the average annual water balance for the non-mined portion of the fen is provided in Table 2.5-13



% = percent; m^3/s = cubic metres per second.

Figure 2.5-29: Surface, Groundwater, and Total Runoff to and from Fen

Table 2.5-13: Annual Water Balance

Parameters	Non-Mined Portion of Fen [mm]	McClelland Lake [mm]
Precipitation	448	448
Evapotranspiration/Evaporation	(410)	(567)
Surface water - Inflow	351	348
Surface water - Outflow	(545)	(268)
Groundwater - Inflow	202	78
Groundwater - Outflow	(29)	(12)
Change in System Storage	(3)	(20)
Residual[(a)]	(14)	(7)

(a) Residual indicates errors in modelled annual water balance.
Note: Values in brackets are flows leaving the system.
mm = millimetre

Water Balance for McClelland Lake

McClelland Lake is primarily fed by direct precipitation and excess surface water and groundwater flowing through the fen. Based on simulated flows using the 2020 MLWC HGS model, surface runoff, groundwater, and direct precipitation contribution represent about 39%, 9%, and 52% of the total inflow, respectively. Surface water into the McClelland Lake is mainly from the west (i.e., about 71% from the fen) and from the south (i.e., about 25% through small creek and south lake). There is no groundwater outflow from the lake and negligible groundwater inflow from the east side from a regional groundwater system (i.e., outside the watershed) into the lake.

Outflow from the lake appears to leave the watershed through a depression at the eastern end of McClelland Lake. This outflow zone is dominated by non-channelized flow appearing as saturated ground, with short distances of channelization. Seasonal or event-based surface flow during high water periods is the expected mechanism for flow at the outlet of lake. Change in groundwater contribution represents less than 0.05% over a period of 75 years. Mean monthly inflows to and outflows from McClelland Lake are shown in Figure 2.5-30. ITK observations about lake outflow include similar fluctuation in flow.

> *"McClelland Creek, it varies, one year it will be dry and one year there's abundance of water. And years ago, there had seemed to be more water in that creek than the later years. And then when I say more water, probably I would say in the '50s, there was a lot more water, but then in the '60s, sometimes you can just walk across there with just your rubber boots. Sometimes, you've got to walk across, just about up to your neck because I've done that.*
>
> *But I guess maybe it varies again, because it depends on the beavers' dams on the creek, but if you look at the creek bed, the last time I was there, I took a good look at it. You could see the creek bed, some places probably at a quarter mile (I won't say half a mile), but quarter of a mile wide, where you could see the line of the big trees, and then it goes down and only willows through in the lower area. You can tell that that used to be a creek bed before where the high trees and the pines, where there was no creek running through there."* (FCM ITK holder, March 3, 2021 workshop)

Change in groundwater contribution represents less than 0.05% over a period of 75 years. Mean monthly inflows to and outflows from McClelland Lake are shown in Figure 2.5-30.

% = percent; m^3/s = cubic metres per second.

Figure 2.5-30: Surface, Groundwater, and Total Runoff to and from McClelland Lake

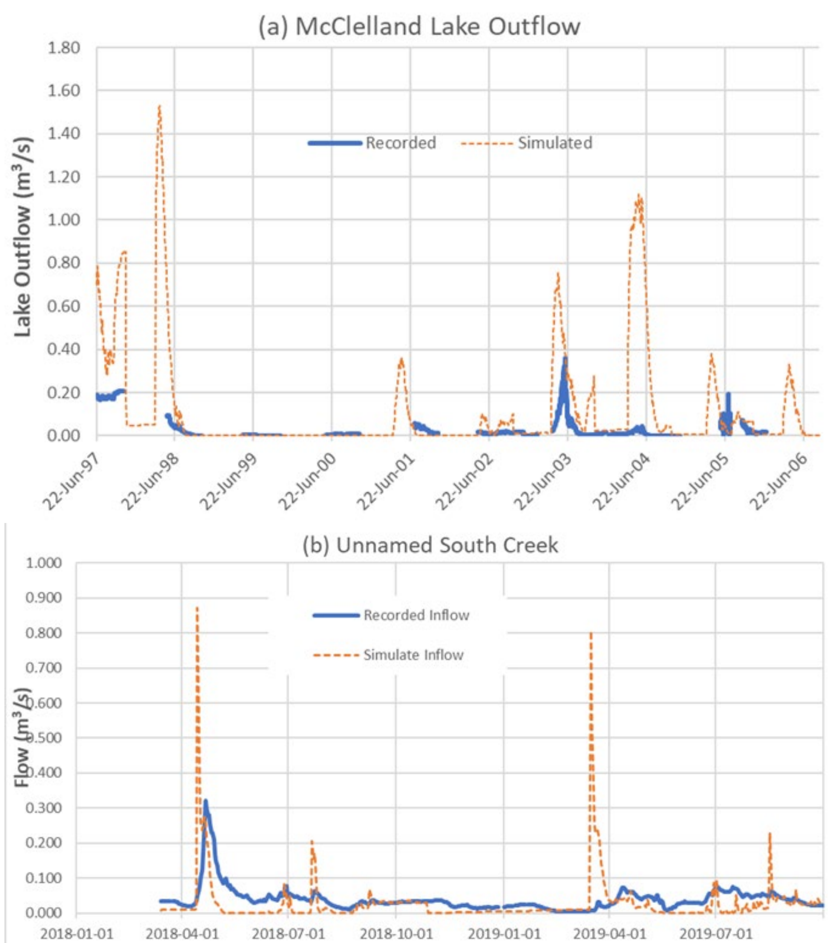
A summary of average annual water balance for the McClelland Lake is provided in Table 2.5-13.

McClelland Lake Outflow - Simulated

A comparison of recorded and simulated (using the 2020 MLWC HGS model) outflow from McClelland Lake is shown in Figure 2.5-31(a). The outflow from McClelland Lake is through a poorly channelized outlet and although the outflow was gauged from 1997 to 2006, the results have generally been considered unreliable (Golder 2018). The main reason for this is that stream gauging has not been able to capture some of the diffuse outflow through the shallow subsurface (peat and perhaps sand) at the east end of the lake. Additionally, anecdotal evidence suggests that there is at least occasionally a second outflow from the lake at a location to the north of the principal outflow point.

Inflow to McClelland Lake from Unnamed South Creek – Simulated

Comparison of recorded and simulated inflow from the creek in the south to McClelland Lake is shown in Figure 2.5-31(b). Inflows from the creek may also be affected by wildlife, as ITK holders identified that depending on where beavers dammed, the creek could also be dry at times (IEG 2021). The simulated flows in the unnamed south creek are much peakier than the recorded flows.



m^3/s = cubic metres per second.

Figure 2.5-31: Comparison of Recorded and Simulated Outflow

2.5.5.3. Reference Site Pre-Mining Baseline Conditions

Available climate data and water level data (2017 to 2020) at Audet Lake reference site and climate data at Gordon Lake Lookout station were summarized in Figure 2.5-15, Figure 2.5-18, and Figure 2.5-25. Based on recorded data, water levels in the Audet Lake varied by 0.394 m (between 297.784 and 297.39 m) with average water level being about 297.543. The pattern of water level fluctuation is similar that of the water level of the McClelland Lake and the MLWC Fen as shown in Figure 2.5-27. There is no available water level measurement at GGWC.

2.5.6. Surface Water and Groundwater Quality

2.5.6.1. Introduction

Prior to industrial development, McClelland Lake was seen as a high-quality source of drinking water for Indigenous Peoples. ITK holders, would like to see the waterbody to have the same level of quality it once had. Water filtration is provided by the intact muskeg around McClelland Lake and this area is one of the few clean water sources left that run into the Athabasca River (via the Firebag) (MCFN ITK holder, MCFN 2019). Water was collected from deeper, colder parts of the lake for drinking to avoid sediment and other materials present closer to shore. Access to high quality drinking water contributes to the ability of people to stay on the land for extended periods of time for practicing and teaching culturally and spiritually important traditional activities and skills. Maintaining good water quality is also essential for the health of the species that Indigenous Peoples harvest in the area, such as beaver, moose, and ducks (IEG 2021).

ITK holders have noted that indicators of water quality include colour, odour, the presence of algae and other uncommon visible characteristics that can negatively affect both human and animal use. Since industrial development began in the area, concerns have come up about the safety of water for drinking, and while some may still choose to drink water from the lake, there has been an overall decline in use of the lake as a potable water source. Some still consider the water in McClelland Lake to be a viable source of water for washing and household use, but the change in water quality in the lake observed by ITK holders is beyond the normal variation for the lake seen in the past. Some have expressed concern over adjacent tailings ponds, and associated dust and sand deposition into McClelland Lake as a key contributor to declining water quality (IEG 2021). One ITK holder remembers:

> *"I wouldn't drink the water now out of the lake unless you boiled it. We used to drink it, just strain it and drink the water. We never got sick from it. Now I wouldn't drink it at all. I figure there's a lot of pollutants in there. Out of the stacks, whatever. All these plant sites all that stuff. Do you know how much tailings sand falls a day? It's right in McKay. You wash your truck in the morning, there's a film of sand on your truck, and over here it's the same thing. The truck gets dirtier. It's not good. All that's falling in the lake here, constantly. Now that Albian you see over there, their tailings piles/ponds. All that sand, all that's blowing over here. Once Suncor gets going it's gonna be the same thing and it's gonna be even worse. If you go over here you see Suncor Firebag on the far east side, you can see their tailings pond right from the lake. Now Suncor over here (Fort Hill site), and there's gonna be another one. Pretty soon the lake's gonna fill up with sand (laughs). I wouldn't drink it. I wouldn't drink the water out of here anymore. Never got sick from the water. No, my children drank it. All we'd do is put a cloth in, strained it, make sure there's no little bugs, or whatever. Drank it right out of the pail like that without even boiling it. Now ... I wouldn't drink that water. My wife drank that water - How many times, eh? We never brought any water from McKay or anything, lake water that's what we drink. We look at it so different now, it's not clean*

anymore. It's not clean water anymore. It looks clean, but it's not." (FMFN ITK holder, FMMN 2017)

A long-term water quality sampling network was established in 2007 to characterize the pre-mining baseline surface water and groundwater quality conditions in the MLWC watershed. Water quality data collected prior 2007 (since 2000) collected less frequently as part of other investigations/studies was included in the dataset. Pre-mining baseline water quality measured between 2000 and 2017 summarized in the 2018 McClelland Wetland Complex Data Synthesis Report (Golder 2018) was compiled with more recent 2018 and 2019 data (FHEC 2020) and data collected by InnoTech between 2017 and 2019 (FHEC 2021c). The RAMP data collected at McClelland Lake outlet station MCL-1 (AB07DA2290) between 2000 and 2016 was added to the surface water dataset. A summary of sampling locations and frequencies is provided in Table 2.5-14, and locations are shown in Figure 2.5-32. The pre-mining baseline water quality dataset includes a total of 795 surface water samples collected from 48 surface water quality sampling locations and 2,144 groundwater samples collected from 207 groundwater well locations.

The water quality sampling program implemented in recent years (2018 and 2019) followed the same monitoring design as previous years (FHEC 2020). Appropriate QA/QC procedures were performed during data collection, including data completeness checks, review of detection limits, ion balance analysis, and relative percent difference analysis of duplicate samples (Suncor 2020). Water quality parameters included: field measurements (pH, electric conductivity, temperature, and dissolved oxygen), major ions, nutrients, total and dissolved metals, organics, and polycyclic aromatic hydrocarbons (PAHs).

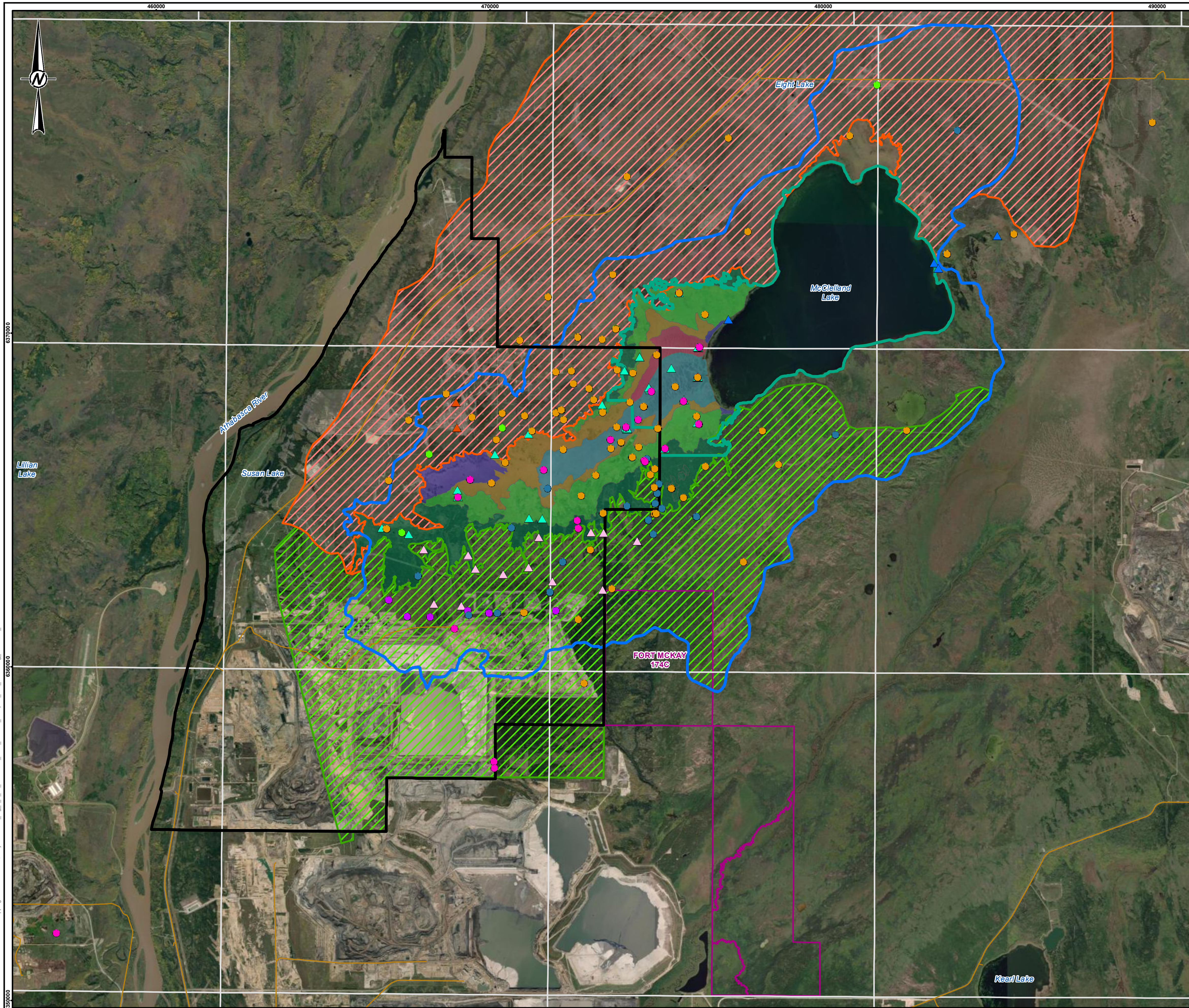
Table 2.5-14: Summary of Sampling Locations and Frequencies for Surface Water and Groundwater Quality Pre-Mining Baseline Characterization at McClelland Lake Wetland Complex, 2000 to 2019

Zone/Area	Number of Sampling Locations	Number of Samples	Years Sampled[a]	Sample Frequency	Notes
Surface Water	**48**	**795**	**2000 to 2019**	-	-
Ecohydrology Zone 1	2	15	2008 to 2010	2 to 3 times per year	The two stations were located less than 20 m apart
Ecohydrology Zone 2	12	85	2002 to 2019	2 to 3 times per year	Most of the locations were clustered into 5 areas, with 30 to 60 m between sampling clusters
Ecohydrology Zone 3	8	8	2017 to 2019	once per year	data collected by InnoTech
Ecohydrology Zone 4	9	9	2017 to 2019	once per year	data collected by InnoTech
Ecohydrology Zone 5	9	186	2002 to 2019	2 to 3 times per year	-
Ecohydrology Zone 6	9	185	2002 to 2019	3 to 4 times per year	-
Lowland Fen	2	112	2002 to 2017	2 to 3 times per year	Fen stations outside the Ecohydrology Zones
North Outwash Plain	2	23	2016 to 2019	2 to 3 times per year	-
Fort Hills Upland	9	133	2002 to 2019	3 to 4 times per year	-

Table 2.5-14: Summary of Sampling Locations and Frequencies for Surface Water and Groundwater Quality Pre-Mining Baseline Characterization at McClelland Lake Wetland Complex, 2000 to 2019

Zone/Area	Number of Sampling Locations	Number of Samples	Years Sampled[(a)]	Sample Frequency	Notes
McClelland Lake	3	56	2000 to 2019	1 to 2 times per year	one location along northwest shore of the lake, one location at the outlet (inclusive of RAMP), one location downstream from the lake
Groundwater	**207**	**2,144**	**2000 to 2019**	-	-
Ecohydrology Zone 1	3	94	2009 to 2019	2 to 3 times per year	Peat
	2	16	2017 to 2019	2 to 3 times per year	Quaternary - AQ
Ecohydrology Zone 2	12	371	2002 to 2019	2 to 3 times per year	Peat
	13	213	2008 to 2019	2 to 3 times per year	Quaternary - AQ
	1	8	2017 to 2019	2 to 3 times per year	Quaternary - AT
Ecohydrology Zone 3	2	41	2002 to 2019	2 to 3 times per year	Peat
	2	52	2008 to 2018	2 to 3 times per year	Quaternary - AQ
Ecohydrology Zone 4	3	74	2009 to 2019	2 to 3 times per year	Peat
	7	79	2008 to 2019	2 to 3 times per year	Quaternary - AQ
	1	3	2019	2 to 3 times per year	Quaternary - AT
Ecohydrology Zone 5	7	116	2002 to 2019	2 to 3 times per year	Peat
	12	101	2009 to 2019	2 to 3 times per year	Quaternary - AQ
	1	3	2019	2 to 3 times per year	Quaternary - AT
Ecohydrology Zone 6	7	70	2009 to 2017	2 to 3 times per year	Peat
	11	67	2008 to 2019	2 to 3 times per year	Quaternary - AQ
	7	20	2019	2 to 3 times per year	Quaternary - AT
Fort Hills Upland	7	69	2002 to 2019	2 to 3 times per year	Peat
	37	308	2006 to 2019	2 to 3 times per year	Quaternary - AQ
	25	79	2006 to 2019	2 to 3 times per year	Quaternary - AT
North Outwash Plain	41	306	2008 to 2019	2 to 3 times per year	Quaternary - AQ
	4	18	2018 to 2019	2 to 3 times per year	Quaternary - AT
Basal	2	36	2008 to 2019	1 to 2 times per year	-

(a) Data collected prior to long-term sampling network (2000 to 2006) was sampled less frequently.
AQ = aquifer; AT = aquitard; RAMP = Regional Aquatics Monitoring Program.



LEGEND

- LOCAL ROAD
- FIRST NATION RESERVE
- FORT HILLS *OIL SANDS CONSERVATION ACT AND WATER ACT* BOUNDARY
- NON-MINED PORTION OF THE MLWC
- WATERSHED BOUNDARY

SURFACE WATER SAMPLING LOCATIONS

- FORT HILLS UPLANDS
- LAKE
- LOWLAND-FEN
- NORTH OUTWASH PLAINS

GROUND WATER SAMPLING LOCATIONS

- BASAL
- QUATERNARY-AQUITARD
- QUATERNARY-AQUIFER
- QUATERNARY-PEAT
- QUATERNARY-UNCONFIRMED

ECOHYDROLOGY ZONES

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

QUATERNARY AQUIFER ZONES

- FORT HILLS UPLAND COMPLEX
- NORTH OUTWASH PLAIN

0 2 4

1:115,000 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
McCLELLAND LAKE WETLAND COMPLEX WATER QUALITY MONITORING LOCATIONS

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
DESIGNED	CZ
PREPARED	LB
REVIEWED	ZG
APPROVED	JH

PROJECT NO.	CONTROL	REV.	FIGURE
20140450		0	2.5-32

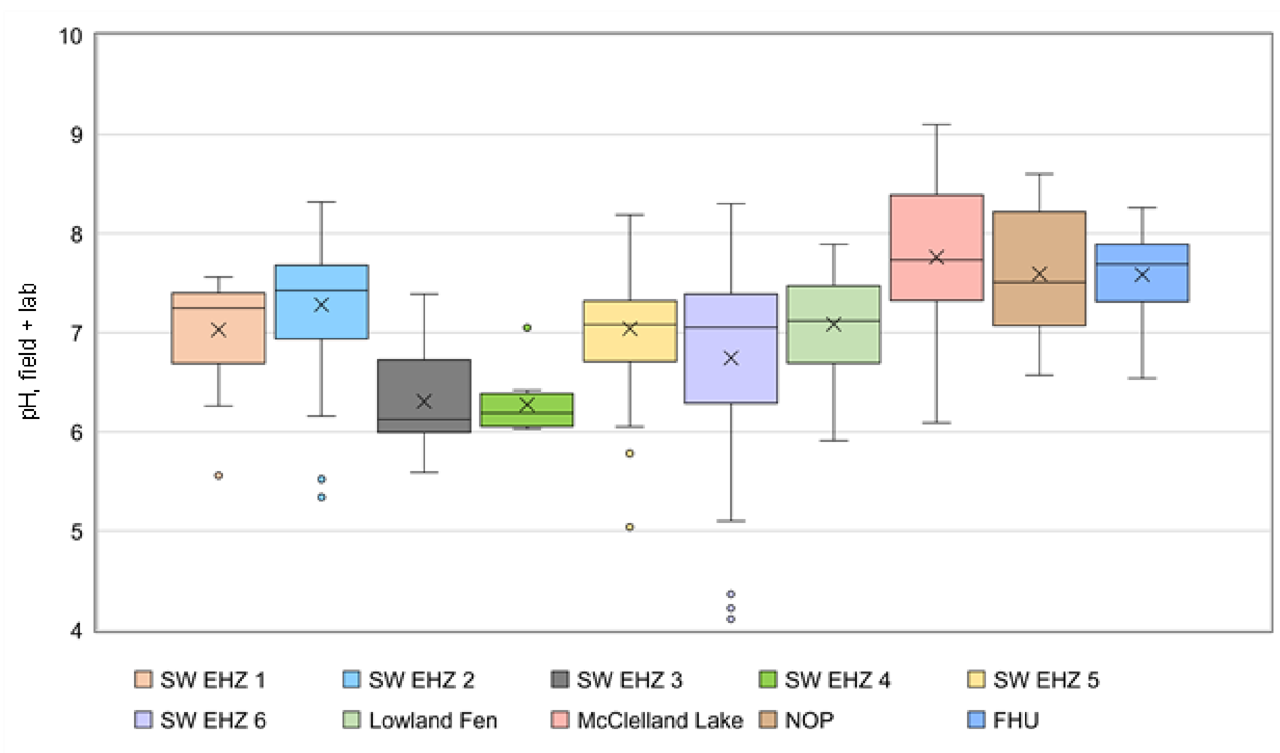
2.5.6.2. McClelland Lake Wetland Complex Pre-Mining Baseline Conditions

Water quality datasets collected under the long-term water quality monitoring network and other focused studies (2000 to 2019) were used to characterize pre-mining baseline conditions and define the MRV.

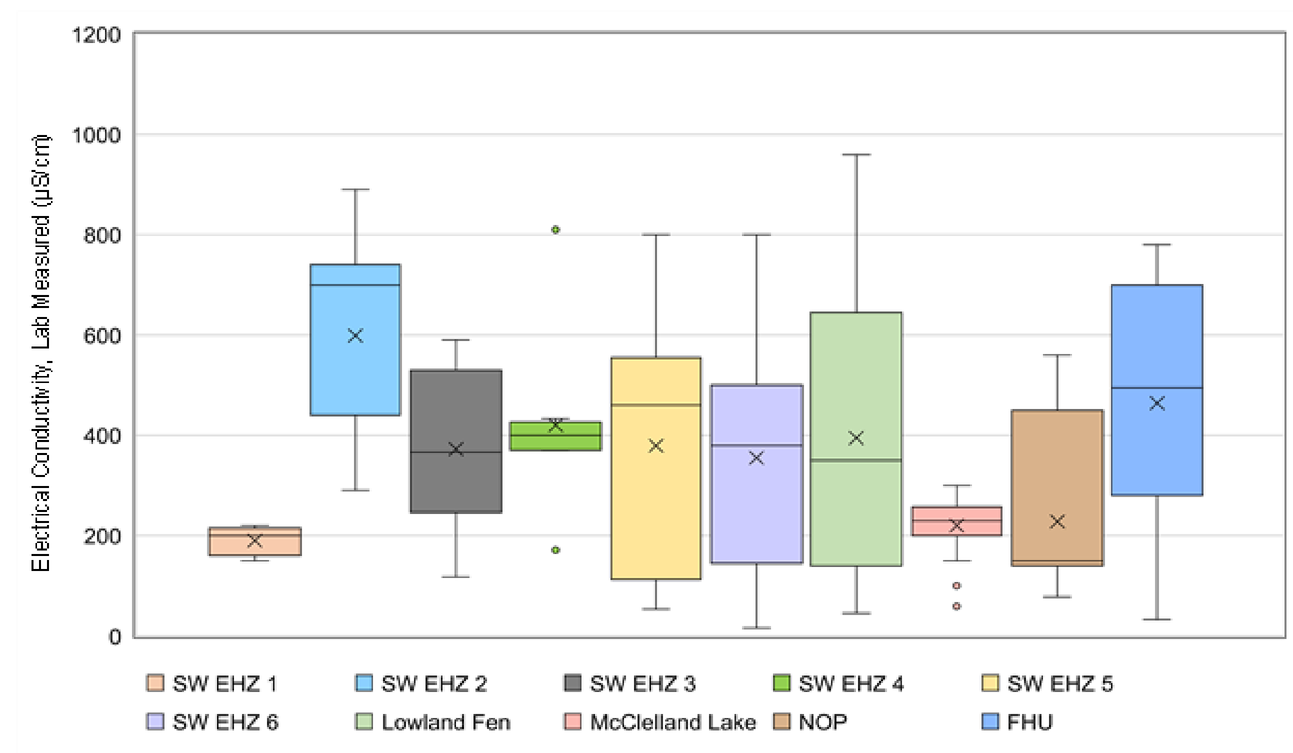
Key water quality indicators selected for analysis of the pre-mining baseline dataset include pH, electrical conductivity, total alkalinity, TDS, and major cations (dissolved calcium, magnesium, sodium, potassium); selection of key indicators is discussed in Section 3.0 (Objective 2). For McClelland Lake, chlorophyll *a* data is also included.

Summary statistics (i.e., median, mean, minimum, maximum, 5th percentile, 95th percentile, standard deviation, and sample size) of surface and groundwater quality parameters for each EHZ are included in Appendix C. Summary statistics of seasonal surface water quality data are also included. Box and whisker plots of key water quality indicators were used to display graphically the pre-mining baseline conditions for each zone and area (Figure 2.5-33 and Figure 2.5-34).

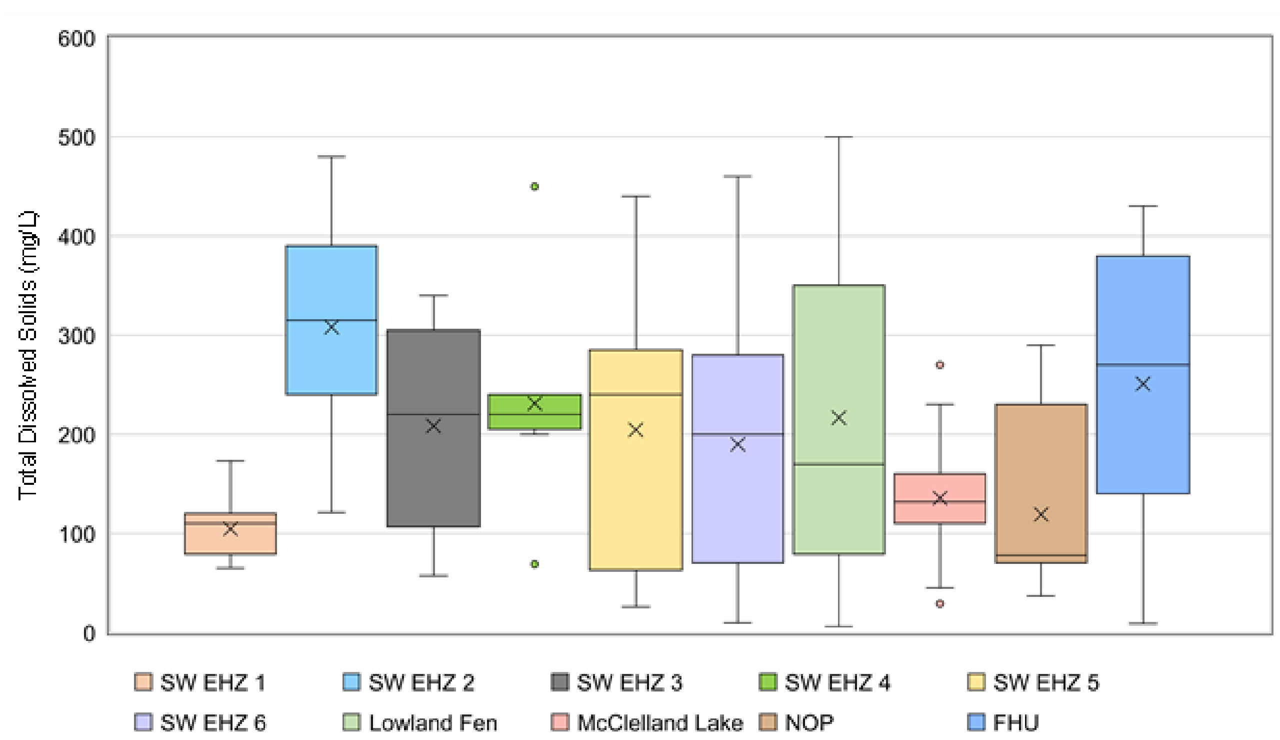
Normal ranges (i.e., MRV) for key water quality indicators were calculated from the measured pre-mining baseline dataset for each surface and groundwater zone using the methods described in Section 2.5.1. The natural range of variation for water quality (as informed by traditional knowledge remembered from pre-development baseline) reflects a higher quality of water then current day conditions and MRV (Section 7.3.3, Objective 6).



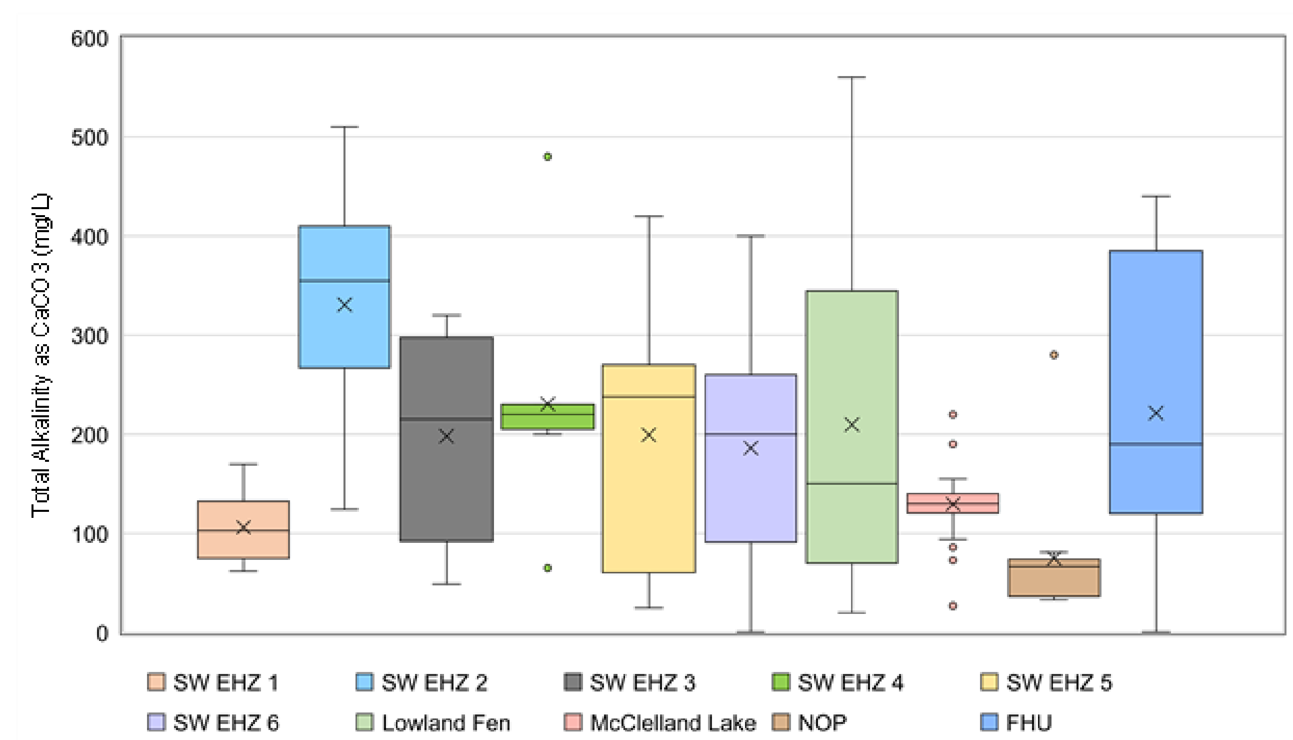
pH, field + lab
10
9
8
7
6
5
4
SW EHZ 1
SW EHZ 2
SW EHZ 3
SW EHZ 4
SW EHZ 5
SW EHZ 6
Lowland Fen
McClelland Lake
NOP
FHU



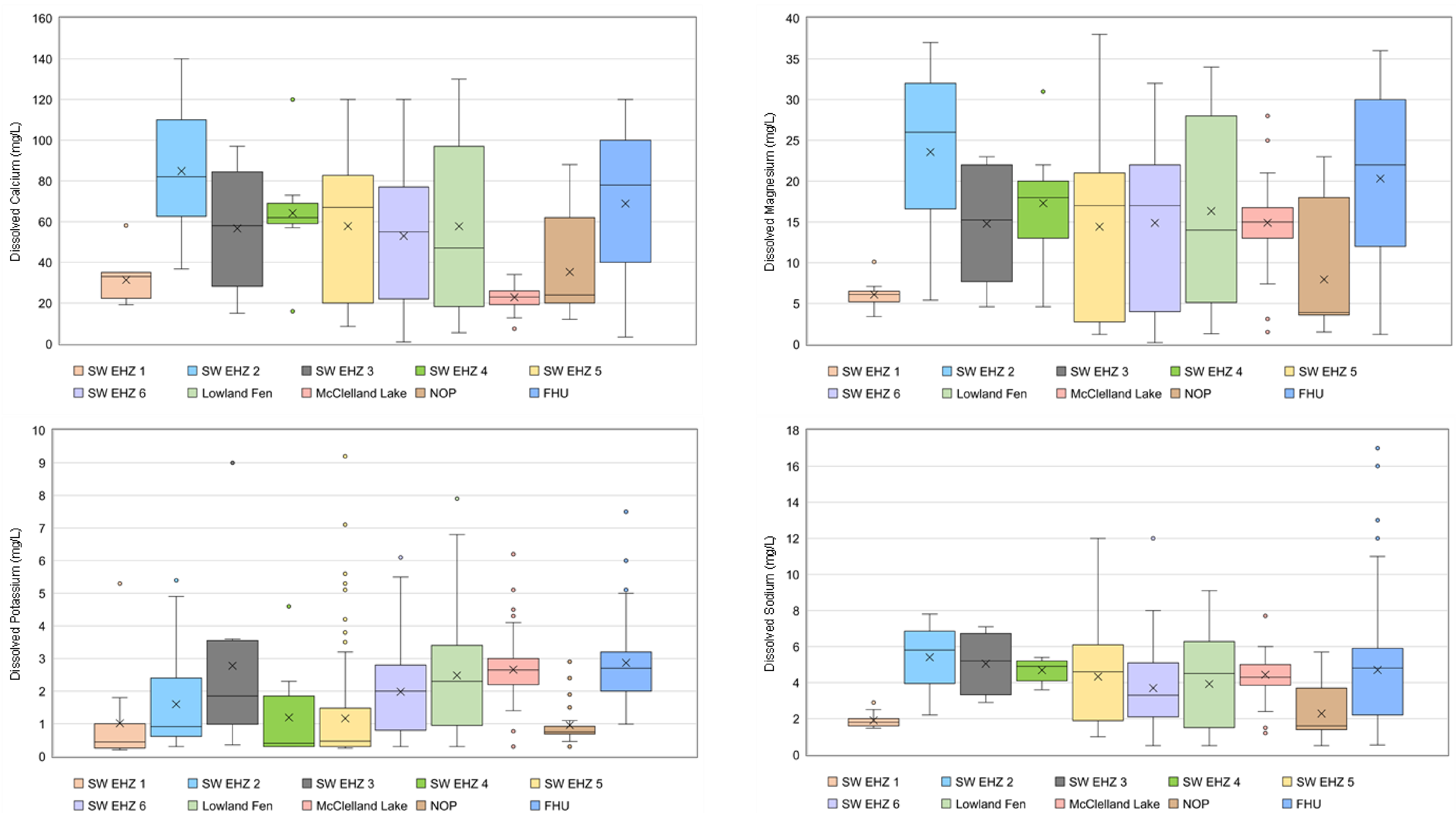
Electrical Conductivity, Lab Measured (µS/cm)
1200
1000
800
600
400
200
0
SW EHZ 1
SW EHZ 2
SW EHZ 3
SW EHZ 4
SW EHZ 5
SW EHZ 6
Lowland Fen
McClelland Lake
NOP
FHU



Total Dissolved Solids (mg/L)
600
500
400
300
200
100
0
SW EHZ 1
SW EHZ 2
SW EHZ 3
SW EHZ 4
SW EHZ 5
SW EHZ 6
Lowland Fen
McClelland Lake
NOP
FHU



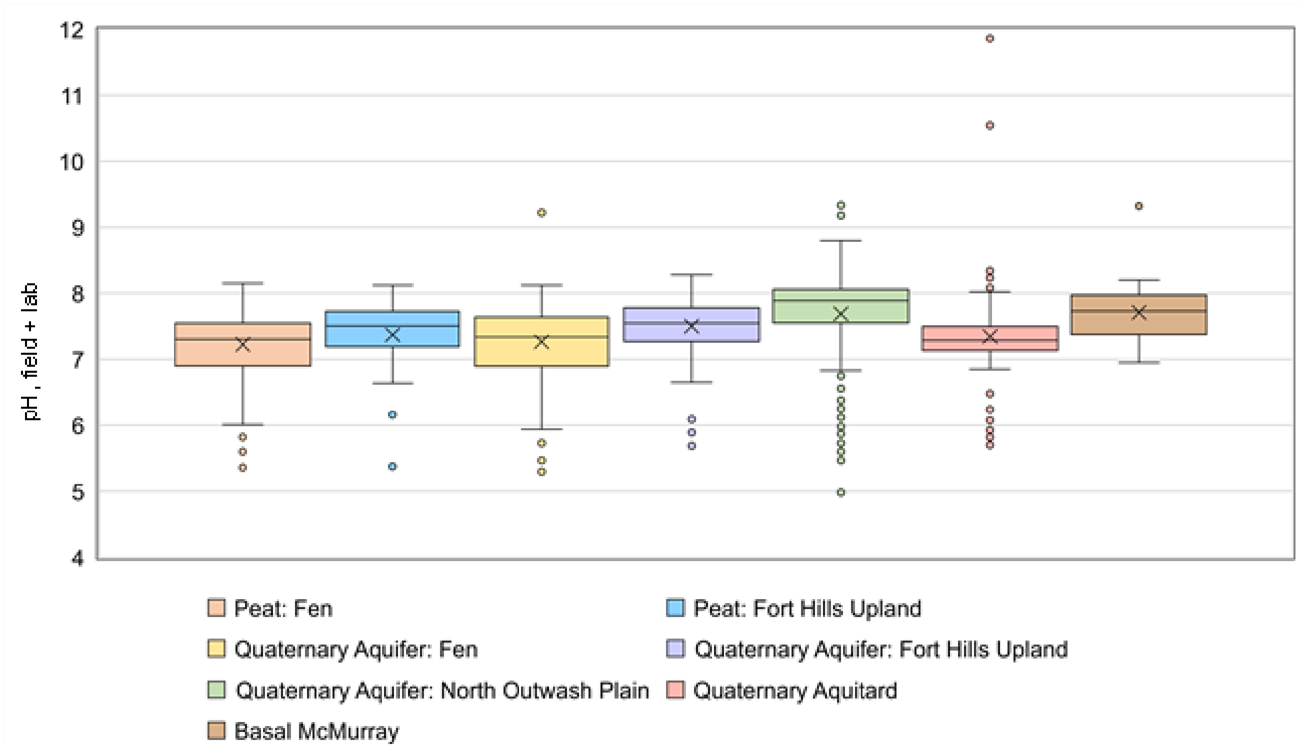
Total Alkalinity as CaCO3 (mg/L)
600
500
400
300
200
100
0
SW EHZ 1
SW EHZ 2
SW EHZ 3
SW EHZ 4
SW EHZ 5
SW EHZ 6
Lowland Fen
McClelland Lake
NOP
FHU

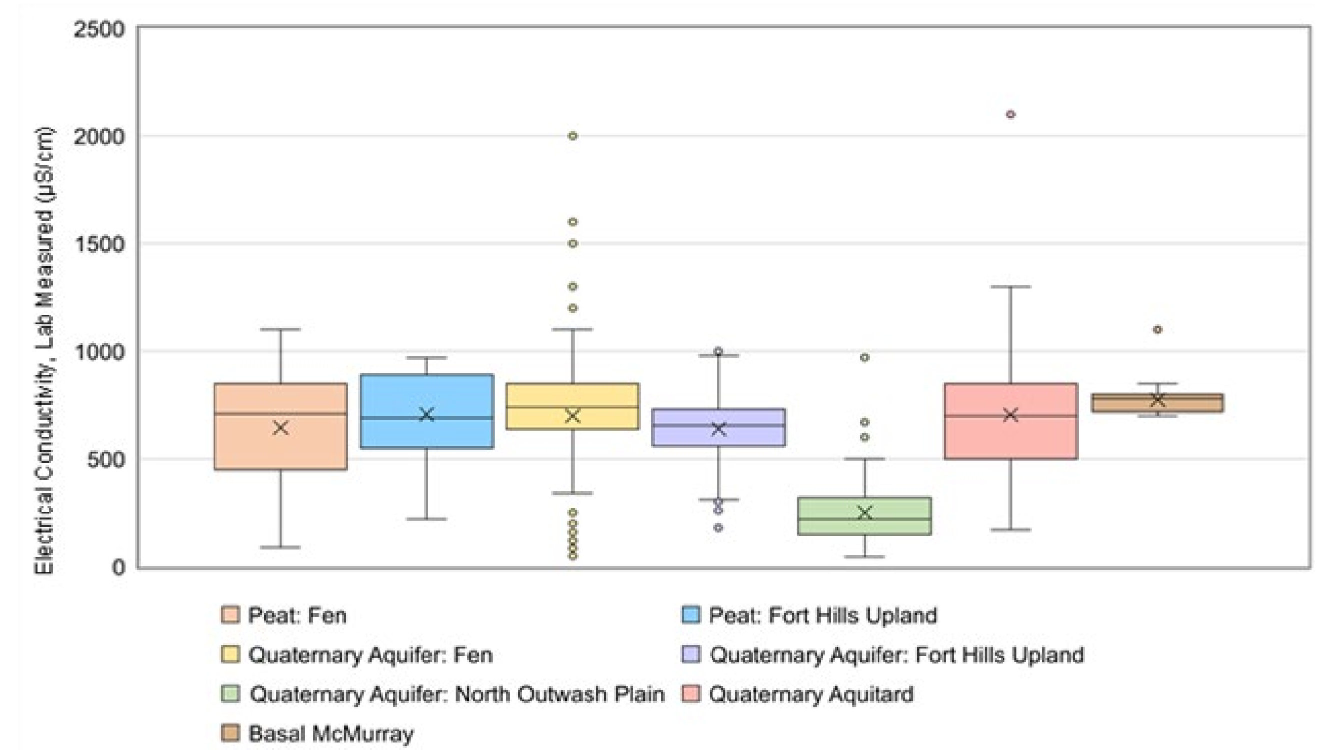


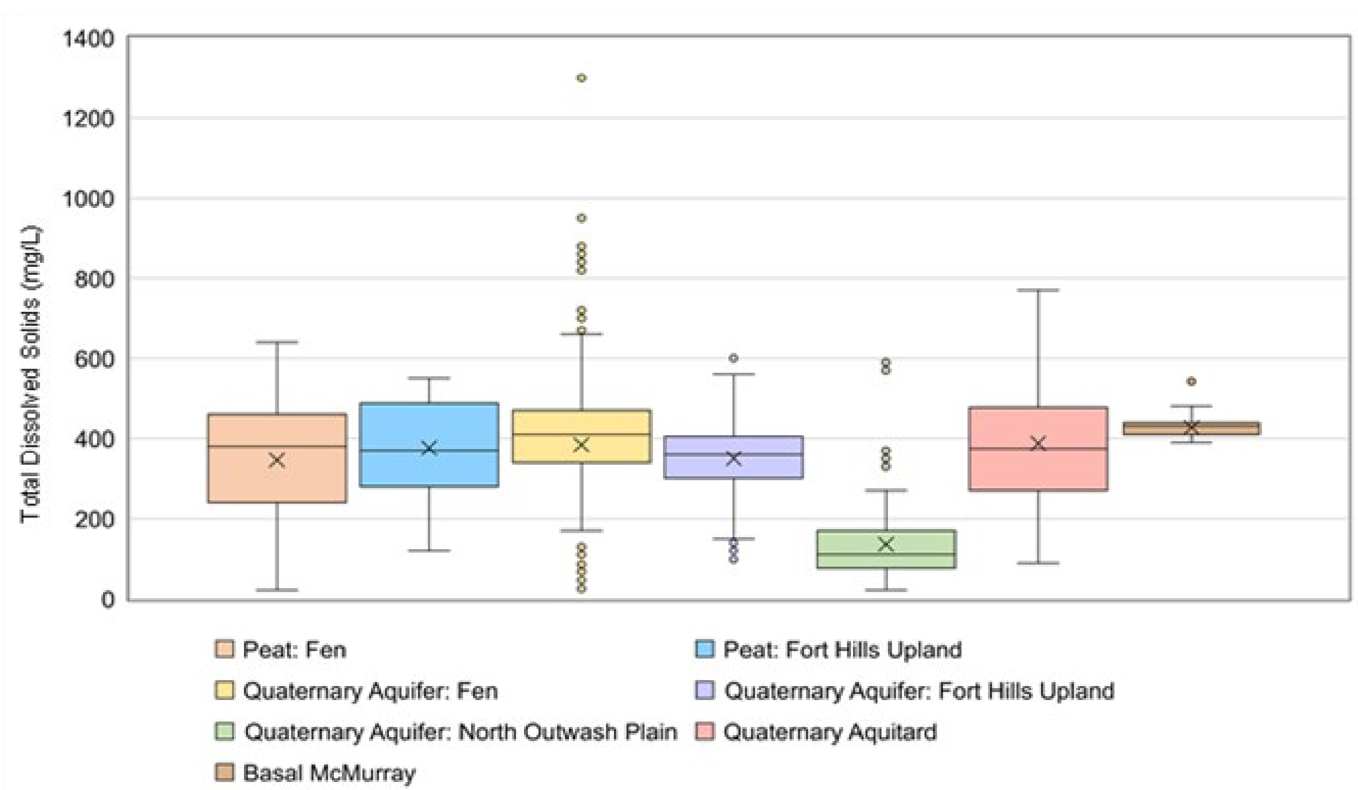
Note: The length of the boxplot represents the inter-quartile range (25th and 75th interquartiles) with the median denoted by the horizontal line and mean by the x symbol. The whiskers represent the minimum and maximum values of the dataset unless outliers are present, in which case the whiskers extend to a maximum of the 1.5 times the inter-quartiles range. Outliers (circles) are values greater than 1.5 times the inter-quartiles range. Electrical conductivity was not measured in the laboratory for SW EHZ 3 and EHZ 4; values are based on specific conductivity measured in the field.

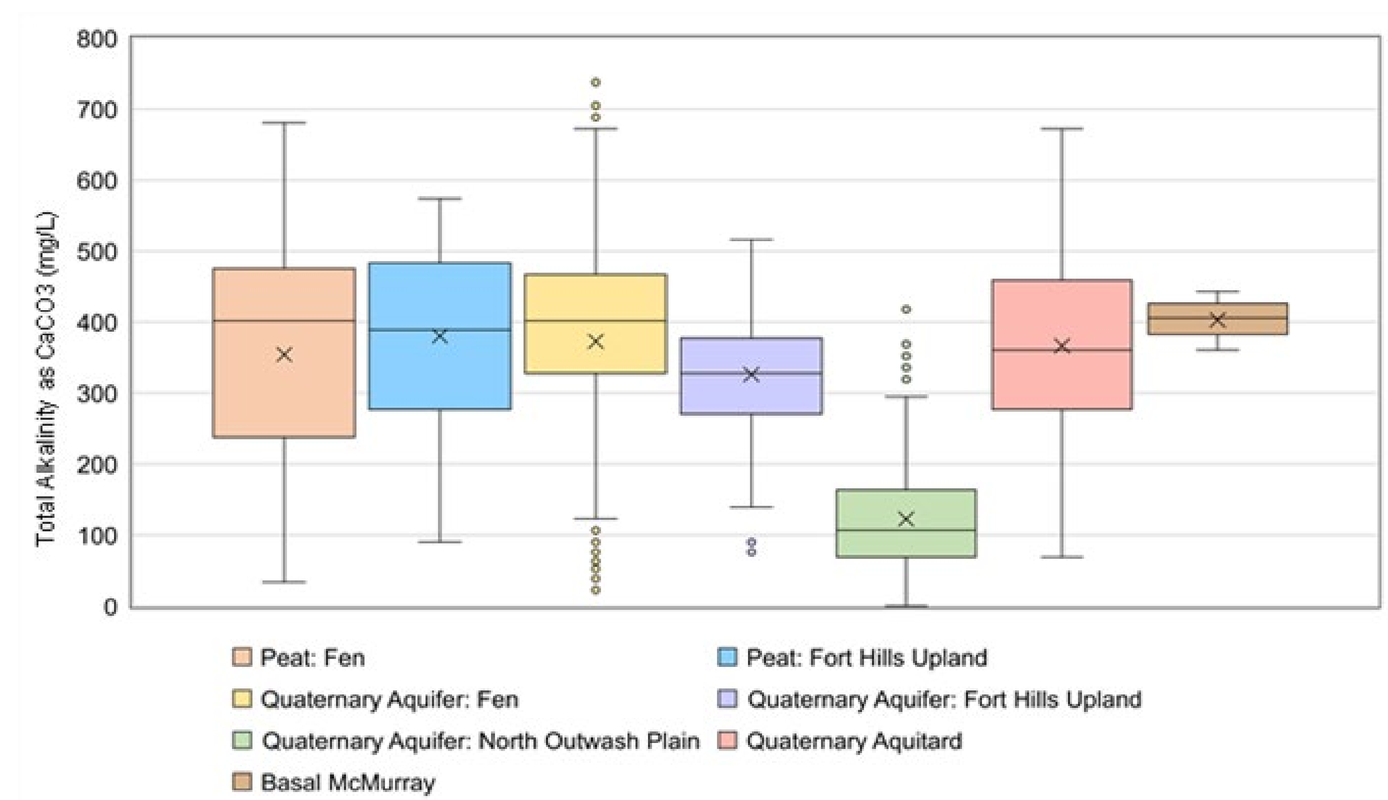
mg/L = milligrams per litre; SW = surface water; EHZ = Ecohydrology Zone; FHU = Fort Hills Upland; NOP = North Outwash Plain.

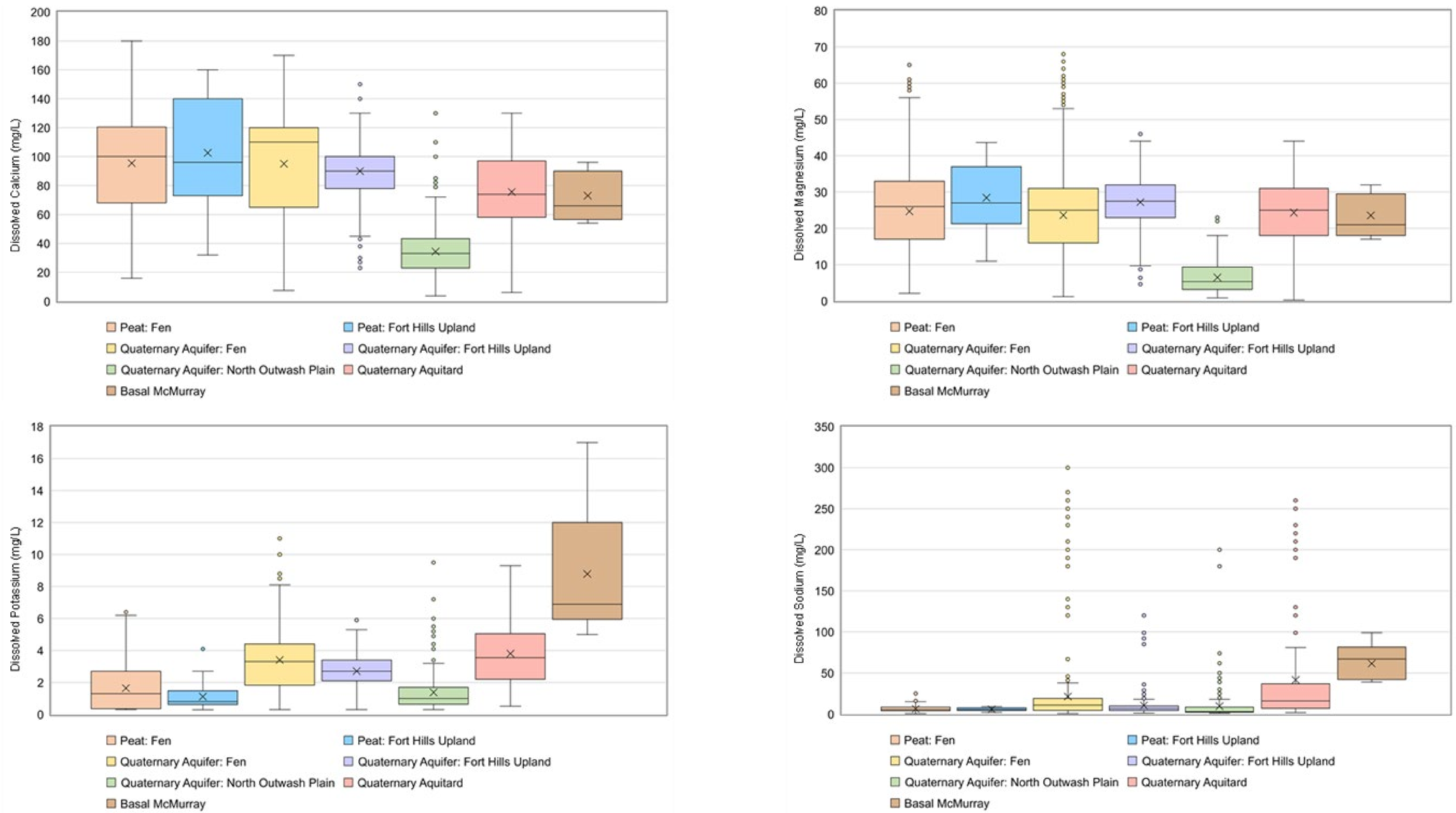
Figure 2.5-33: Box and Whiskers Plots of Key Surface Water Quality Indicators in Different Surface Water Quality Zones, 2000 to 2019


12
11
10
9
8
7
6
5
4
pH, field + lab
Peat: Fen
Peat: Fort Hills Upland
Quaternary Aquifer: Fen
Quaternary Aquifer: Fort Hills Upland
Quaternary Aquifer: North Outwash Plain
Quaternary Aquitard
Basal McMurray


2500
2000
1500
1000
500
0
Electrical Conductivity, Lab Measured (µS/cm)
Peat: Fen
Peat: Fort Hills Upland
Quaternary Aquifer: Fen
Quaternary Aquifer: Fort Hills Upland
Quaternary Aquifer: North Outwash Plain
Quaternary Aquitard
Basal McMurray


1400
1200
1000
800
600
400
200
0
Total Dissolved Solids (mg/L)
Peat: Fen
Peat: Fort Hills Upland
Quaternary Aquifer: Fen
Quaternary Aquifer: Fort Hills Upland
Quaternary Aquifer: North Outwash Plain
Quaternary Aquitard
Basal McMurray


800
700
600
500
400
300
200
100
0
Total Alkalinity as CaCO3 (mg/L)
Peat: Fen
Peat: Fort Hills Upland
Quaternary Aquifer: Fen
Quaternary Aquifer: Fort Hills Upland
Quaternary Aquifer: North Outwash Plain
Quaternary Aquitard
Basal McMurray



Note: The length of the boxplot represents the inter-quartile range (25th and 75th interquartiles) with the median denoted by the horizontal line and mean by the x symbol. The whiskers represent the minimum and maximum values of the dataset unless outliers are present, in which case the whiskers extend to a maximum of the 1.5 times the inter-quartiles range. Outliers (circles) are values greater than 1.5 times the inter-quartiles range.

$CaCO_3$ = calcium carbonate; mg/L = milligrams per litre; µS/cm = microSiemens per centimetre.

Figure 2.5-34: Box and Whiskers Plots of Key Groundwater Quality Indicators in Different Surface Water Quality Zones, 2000 to 2019

Field measurements (e.g., pH, electrical conductivity) were commonly missing from the pre-mining baseline dataset, particularly in early years of monitoring. Normal ranges for pH were calculated on a compiled dataset (using field measurements when available and substituting with laboratory measurements for samples that field data was not available). Measurements of pH in situ are preferred over the laboratory tests, as pH is known to change in time, with temperature, or exposure to atmospheric gases when holding time are exceeded (recommended holding time for pH ranges from 10 minutes to 2 hours). Normal ranges for electrical conductivity were based on laboratory results, except for EHZ 3 and EHZ 4 where specific conductivity measured in the field was used. For water quality indicators that had non-detected values (e.g., dissolved potassium), the value was replaced with half of the detection limit value before being used in the normal range calculation. Normal ranges were not calculated for water quality parameters with more than 50% of results being non-detected values (e.g., potassium in groundwater samples collected from peat in EHZ1; Table 2.5-15). Due to low samples size for EHZ 3 and EHZ 4, normal ranges were represented by the quantiles for these two areas (Table 2.5-16). Normal ranges are expected to become more accurate as more data are collected (particularly for EHZ 1, EHZ 3, and EHZ 4).

Table 2.5-15: Normal Ranges Calculated for Groundwater Quality Pre-Mining Baseline at McClelland Lake Wetland Complex, 2000 to 2019

Zone	n	pH		Electrical Conductivity [µS/cm]		Total Dissolved Solids [mg/L]		Calcium [mg/L]		Magnesium [mg/L]		Sodium [mg/L]		Potassium [mg/L]	
		LR	UR	LR	UR	LR	UR	LR	UR	LR	UR	LR	UR	LR	UR
Aquifer/EHZ 1	14	6.7	7.8	570	990	310	580	20	110	6.4	14	5.4	210	2.3	4.3
Aquifer/EHZ 2	203	6.5	7.9	360	1,200	197	653	42	150	8.6	64	5.2	35	2.6	8.3
Aquifer/EHZ 3	50	6.0	7.8	380	710	210	410	64	130	8.5	18	2.7	10	0.9	3.2
Aquifer/EHZ 4	75	5.9	8.6	65	900	55	527	9.6	130	1.7	30	0.8	130	0.9	6.2
Aquifer/EHZ 5	99	6.4	8.1	85	840	29	470	7.9	130	1.7	36	1.5	46	<0.3	4.6
Aquifer/EHZ 6	63	6.6	8.1	200	1,600	110	950	30	120	6.9	34	2.2	270	0.7	7.0
Aquifer/FHU	274	6.1	7.8	280	890	161	513	43	140	8.8	41	1.9	32	0.7	4.9
Aquifer/NOP	286	5.9	8.4	63	673	31	369	5.8	79	1.3	17	1.3	62	0.4	5.2
Aquitard	124	6.1	8.4	177	1,200	94	728	26	120	4.0	44	2.1	246	0.9	8.2
Peat/EHZ 1	90	6.1	6.5	120	390	62	190	21	63	4.1	10	1.2	2.7	<0.3	<0.3
Peat/EHZ 2	355	6.5	7.9	519	1,100	258	596	71	150	18	56	3.9	16	<0.3	5.8
Peat/EHZ 3	39	5.9	7.9	286	548	137	309	32	100	7.0	24	2.3	11	0.7	3.8
Peat/EHZ 4	70	6.5	7.9	250	930	110	520	31	160	11	31	2.0	7.0	<0.3	1.5
Peat/EHZ 5	113	6.2	7.8	113	619	49	370	19	100	2.5	25	1.4	7.4	<0.3	1.6
Peat/EHZ 6	70	7.5	8.1	461	959	230	599	60	160	19	38	3.2	8.2	<0.3	3.6
Peat/FHU	68	6.0	8.1	369	970	120	540	32	158	11	42	2.1	8.9	<0.3	3.5
Basal	33	7.0	8.7	700	1,100	385	503	54	96	17	32	39	99	5.0	17

< = less than; n = sample size; EHZ = Ecohydrology Zone; FHU = Fort Hills Upland; NOP = North Outwash Plain; LR = lower range; mg/L = milligrams per litre; µS/cm = microSiemens per centimetre; UR = upper range.

Table 2.5-16: Normal Ranges Calculated for Surface Water Quality Pre-Mining Baseline at McClelland Lake Wetland Complex, 2000 to 2019

Zone	n	pH		Electrical Conductivity [µS/cm]		Total Dissolved Solids [mg/L]		Calcium [mg/L]		Magnesium [mg/L]		Sodium [mg/L]		Potassium [mg/L]	
		LR	UR	LR	UR	LR	UR	LR	UR	LR	UR	LR	UR	LR	UR
EHZ 1	15	5.6[a]	7.6	110	278	47	166	18	60	3.4	10	1.5	2.9[a]	<0.3	12[d]
EHZ 2	85	6.1	8.2	300	870	148	472	34	138	6.2	36	2.5	7.6	<0.3	4.9
EHZ 3(b)	8	5.7	7.3	139	581	64	335	17	95	5.1	23	2.9	7.1	0.4	7.1
EHZ 4(b)	9	6.0	6.9	211	735	95	408	24	111	5.9	29	3.7	5.4	<0.3	4.1
EHZ 5	186	6.1	7.9	59	680	33	389	10	110	1.5	29	1.1	8.1	<0.3	5.3
EHZ 6	185	4.3	8.0	29	701	12	390	2.7	110	0.4	31	0.8	8.0	<0.3	5.5
Lowland Fen	112	6.6	8.2	36	769	16	430	3.7	120	1.3	34	0.8	13	1.2	6.0
NOP	23	6.4	8.8	78	560	37	290	12	88	1.5	23	<0.5	8.2	<0.3	3.1
FHU	133	6.1	7.7	50	816	24	440	6.5	130	1.5	33	<0.5	7.9	<0.3	6.8
McClelland Lake	56	5.7[c]	9.7[c]	67	303	60	218	13	33	4.7	24	2.0	6.9	<0.3	6.2

(a) data not normally distributed. normal ranges were calculated using non-parametric method (i.e., quantiles).
(b) due to low sample size, normal ranges are represented by quantiles.
(c) pH measured in field only.
(d) the dataset has one outlier (5.3 mg/L); when it is excluded from the calculation, the upper range limit becomes 4.3 mg/L.
< = less than; n = sample size; EHZ = Ecohydrology Zone; FHU = Fort Hills Upland; NOP = North Outwash Plain; LR = lower range; mg/L = milligrams per litre; µS/cm = microSiemens per centimetre; UR = upper range.

Among the indicators included in the analysis, pH has water quality guidelines (i.e., pH surface water quality guideline for the protection of aquatic life of 6.5 to 9.0; GOA 2018 and CCME 1999). Measured pH in the fen under pre-mining baseline conditions can be outside (i.e., below) the guideline range without the need for triggering action. Although many aquatic species are present in the fen, the guideline was developed for the protection of aquatic life based on data for species that are generally not present in this wetland. Peatlands are sometimes acidic environments, and site-specific guidelines developed for this unique environment would be more appropriate and provide an early warning of changes to water quality (JOSM 2018). An extreme-rich fen has pH greater than 7.0, while a moderate-rich fen has pH between 5.5 and 7.0 (GOA 2015). For those reasons, the pH guidelines are applicable to McClelland Lake samples only. Site-specific guidelines will be developed for fen water quality indicators with the objective of maintaining MLWC ecosystem function (details in Section 7.3.3., Objective 6).

2.5.6.2.1. Surface Water Quality

The MLWC surface water quality is characterized as (detailed statistics summarized in Appendix C1) :

- Pre-mining baseline water quality data show that EHZ 1 has mean field pH of 7.1, mean electrical conductivity of 194 microSiemens per centimetre (µS/cm), mean concentration of TDS of 107 mg/L, calcium of 32 mg/L, magnesium of 6.1 mg/L, potassium of 0.4 mg/L, and sodium of 1.9 mg/L. These values were similar to those presented by Vitt and House (2020) for pH (7.2 to 7.3), electrical conductivity (153 to 448 µS/cm), and calcium (31 to 34 mg/L) in EHZ 1. Values for magnesium, potassium, and sodium concentrations were slightly lower in the pre-mining baseline dataset than those reported by Vitt and House (2020) where magnesium ranged from 9 to 13 mg/L, potassium ranged from 2 to 3 mg/L, and sodium ranged from 3 to 4 mg/L. A slight decline in concentrations of all key indicators between summer and fall was observed for EHZ 1.

- EHZ 2 has overall higher concentrations of key indicators (except potassium) among EHZs, which is consistent with observations presented by Vitt and House (2020). Based on the pre-mining baseline data, EHZ 2 has mean field pH of 6.6, mean electrical conductivity of 610 µS/cm, mean concentration of TDS of 311 mg/L, calcium of 86 mg/L, magnesium of 24 mg/L, potassium of 1.6 mg/L, and sodium of 5.4 mg/L. These values were similar to those presented by Vitt and House (2020) (i.e., calcium ranged from 63 to 74 mg/L; magnesium ranged from 29 to 37 mg/L; potassium ranged from 4 to 7 mg/L; sodium ranged from 7 to 9 mg/L), with exception of slightly higher pH values (7.7 to 7.9) and slightly lower electrical conductivity values (392 to 448 µS/cm) compared to the pre-mining baseline dataset. No seasonal variability in concentrations was observed for EHZ 2.
- Water quality of key indicators in EHZ 1 and 2 fit well into the site-type regional chemistry: EHZ 1 - moderate-rich fen, EHZ 2 - extreme-rich fen (Vitt and House 2020). Base cation concentrations are particularly sensitive indicators of rich fen species distributions and differ between EHZ 1 and 2 (Vitt and House 2020). Calcium, magnesium, and sodium had the highest concentrations across the southern portions of the fen and decreased northwards; potassium showed the same trend but was less distinct (Vitt and House 2020). There is some evidence of lower concentrations of these cations in the plots to the extreme southeast where the flarks may be influenced by a secondary water source. Electrical conductivity and pH have similar patterns: they are highest towards the southern portion of the fen and decrease northward (Vitt and House 2020).
- EHZ 3 has mean field pH of 6.3, mean specific conductivity of 373 µS/cm, mean concentration of TDS of 208 mg/L, calcium of 57 mg/L, magnesium of 15 mg/L, potassium of 2.8 mg/L, and sodium of 5.1 mg/L.
- EHZ 4 has mean field pH of 6.3, mean specific conductivity of 421 µS/cm, mean concentration of TDS of 231 mg/L, calcium of 64 mg/L, magnesium of 17 mg/L, potassium of 1.2 mg/L, and sodium of 4.7 mg/L.
- EHZ 5 has mean field pH of 6.7, mean electrical conductivity of 382 µS/cm, mean concentration of TDS of 205 mg/L, calcium of 59 mg/L, magnesium of 15 mg/L, potassium of 0.53 mg/L, and sodium of 4.4 mg/L. Slightly higher concentrations of TDS, calcium, magnesium, and sodium were observed in summer compared to spring and fall.
- EHZ 6 has mean field pH of 7.3, mean electrical conductivity of 348 µS/cm, mean concentration of TDS of 181 mg/L, calcium of 51 mg/L, magnesium of 14 mg/L, potassium of 1.9 mg/L, and sodium of 3.5 mg/L. No seasonal variation in concentrations was observed for EHZ 6.
- Lowland Fen (outside the EHZs) has mean field pH of 6.8, mean electrical conductivity of 395 µS/cm, mean concentration of TDS of 217 mg/L, calcium of 58 mg/L, magnesium of 16 mg/L, potassium of 2.5 mg/L, and sodium of 3.8 mg/L. No seasonal variation in concentrations was observed for Lowland Fen.
- North Outwash Plain has mean field pH of 7.6, mean electrical conductivity of 228 µS/cm, mean concentration of TDS of 119 mg/L, calcium of 35 mg/L, magnesium of 7.9 mg/L, potassium of 0.94 mg/L, and sodium of 2.3 mg/L. A slightly decline in concentration was observed between spring and summer for NOP.
- Fort Hills Upland has mean field pH of 7.3, mean electrical conductivity of 479 µS/cm, mean concentration of TDS of 262 mg/L, calcium of 72 mg/L, magnesium of 21 mg/L, potassium of 2.8 mg/L, and sodium of 4.8 mg/L. No seasonal variation in concentrations was observed for FHUC.

McClelland Lake has mean field pH of 7.7, mean electrical conductivity of 218 µS/cm, mean concentration of TDS of 136 mg/L, calcium of 23 mg/L, magnesium of 15 mg/L, potassium of 2.6 mg/L, and sodium of 4.4 mg/L. Approximately 14% of pH values in the pre-mining baseline dataset for McClelland Lake were outside the lower range of guideline for the protection of aquatic life (GOA 2018), with highest number of values outside the recommended range occurring in fall (Appendix C1, Table C1-2). Chlorophyll *a* concentrations ranged from less than 0.0005 to 0.51 mg/L (mean concentration of 0.057 mg/L). No seasonal change in concentrations was observed for McClelland Lake with exception of slightly higher pH during fall. Information provided by ITK holders has described McClelland Lake as more clear than other waterbodies/ watercourses in the area, such as the Firebag River and Moose Creek. The waters in the creeks and the lake were clear, though there were different colour tinges to the different sources of water: Firebag River had a slight reddish tinge, Moose Creek like light tea colour, and McClelland Creek and Lake were clearer. Some concern has been raised over water that smells like sulphur, and it has been observed that ice conditions in some areas may be subject to contamination (IEG 2021).

Normal ranges (i.e., MRV) calculated for each zone and key water quality indicators using the methods described in Section 2.5.1 are summarized in (Table 2.5-16). Normal range approach involves comparing future individual observations to the normal ranges defined by the pre-mining baseline stations within MLWC. Additional pre-mining baseline data collected in the upcoming years will be added to the dataset and normal ranges presented in Table 2.5-15 and Table 2.5-16 will be refined.

2.5.6.2.2. Groundwater Quality

Groundwater quality data for MLWC is characterized as (detailed statistics summarized in Appendix C2):

- Peat has mean field pH between 6.2 (EHZ 3) and 6.7 (Fort Hills Upland) and mean electric conductivity between 254 µS/cm (EHZ 1) and 816 µS/cm (EHZ 2). Mean concentrations of TDS in peat in the different zones is between 134 and 439 mg/L, calcium is between 43 and 118 mg/L, magnesium between 7.5 and 33 mg/L, sodium between 1.9 and 8.7 mg/L, and potassium between less than 0.3 and 2.4 mg/L. The lowest mean concentrations of TDS and cations were observed in EHZ 1 and the highest concentrations were in EHZ 2.
- The Quaternary aquifer has mean field pH values in the different zones between 6.5 (EHZ 3) and 7.7 (NOP) and mean electric conductivity values between 250 µS/cm (NOP) and 843 µS/cm (EHZ 2). Mean concentration values of TDS in the Quaternary aquifer in the different zones range between 136 and 465 mg/L, calcium between 34 and 117 mg/L, magnesium between 6.5 and 33 mg/L, sodium between 4.7 and 103 mg/L, and potassium between 1.4 and 4.7 mg/L. The lowest mean concentrations of TDS and cations in Quaternary aquifer were observed in NOP and the highest concentrations were in EHZ 2.
- The Quaternary aquitard has mean field pH of 7.3, mean electric conductivity of 705 µS/cm, mean concentration of TDS of 388 mg/L, calcium of 76 mg/L, magnesium of 24 mg/L, sodium of 42 mg/L, and potassium of 3.8 mg/L.
- Basal groundwater has a mean field pH of 7.4, mean electric conductivity of 774 µS/cm, mean concentration of TDS of 427 mg/L, calcium of 73 mg/L, magnesium of 24 mg/L, sodium of 62 mg/L, and potassium of 8.8 mg/L.

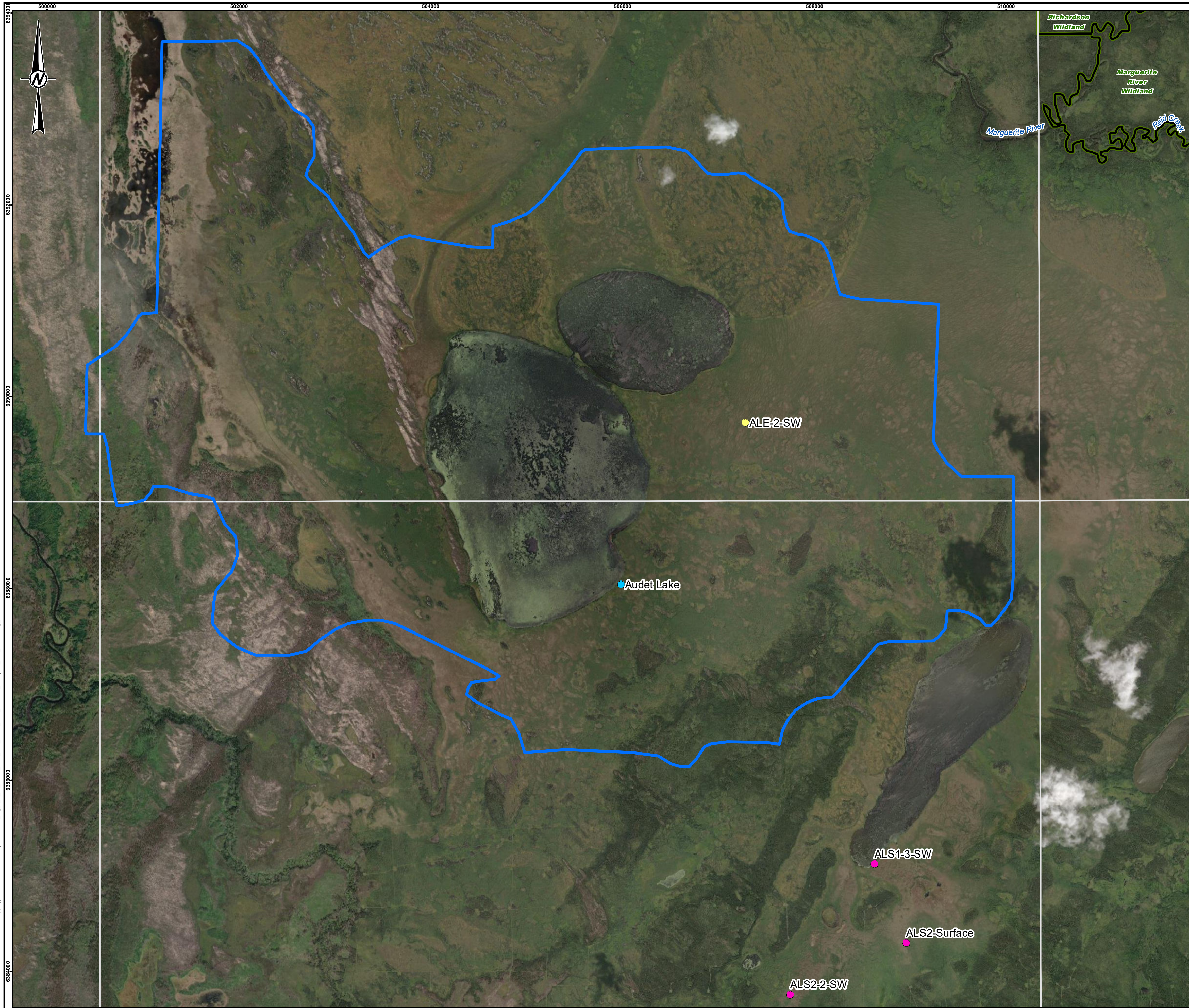
Normal ranges calculated for each zone and key water quality indicators using the methods described in Section 2.5.1 are summarized in Table 2.5-15. Normal range approach involves comparing future individual observations during mine operations to the normal ranges defined by the pre-mining baseline stations within MLWC.

2.5.6.3. Reference Sites Pre-Mining Baseline Conditions

The ALWC (Figure 2.5-35) and GGWC (Figure 2.5-36) were identified as potential reference sites for the MLWC, and surface water quality data have been collected at those locations (Table 2.5-17). Surface water quality monitoring data from ALWC and Audet Lake, GGWC and Birch Lake are summarized herein and compared to water quality data from MLWC and McClelland Lake to determine whether they are appropriate reference sites.

Table 2.5-17: Summary of Surface Water Quality Data Collected at Reference Locations

Area	Number of Sampling Locations	Number of Samples	Years Sampled	Sample Frequency	Notes
Audet Lake Wetland Complex	4	108	2010 to 2019	1 to 6 times per year	2010 – spring and summer 2011 and 2012 – fall 2013 and 2014 – monthly during open water season (May to October) 2015 to 2019 – spring, summer, fall
Audet Lake	1	29	2010, 2013 to 2019	1 to 6 times per year	2010 – summer 2013 and 2014 – monthly during open water season (May to October) 2015 to 2019 – spring, summer, fall
Gipsy Gordon Wetland Complex	5	20	2017 and 2018	1 or 3 per year	2017 – summer 2018 – spring, summer, fall
Birch Lake (near Gipsy Gordon Wetland Complex)	1	4	2017 and 2018	1 or 3 per year	2017 – summer 2018 – spring, summer, fall



LEGEND

PARK / PROTECTED AREA

WATERSHED BOUNDARY

SURFACE WATER SAMPLING LOCATIONS

EAST PATTERNED FEN

SOUTH PATTERNED FEN

LAKE

0 1 2

1:40,000 KILOMETRES

REFERENCE(S)

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

TITLE

AUDET LAKE AND AUDET LAKE WETLAND COMPLEX WATER QUALITY MONITORING LOCATIONS

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
DESIGNED	CZ
PREPARED	LB
REVIEWED	ZG
APPROVED	JH

PROJECT NO.	CONTROL	REV.	FIGURE
20140450		0	2.5-35

25mm

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

PATH: I:\CLIENTS\SUNCOR\20140450\Mapping\Products\WaterQuality\20140450_Fig_2_5_35_Audet_Lake_and_Audet_Lake_Wetland_Complex_WQ_Monitoring_Locations_Rev0.mxd PRINTED ON: 2021-12-09 AT: 5:30:34 PM

LEGEND

PARK / PROTECTED AREA

WATERSHED BOUNDARY

SURFACE WATER SAMPLING LOCATIONS

PATTERNED FEN

LAKE

0 1 2

1:50,000 KILOMETRES

REFERENCE(S)

BASE DATA OBTAINED FROM ALTALIS LTD.© GOVERNMENT OF ALBERTA 2021. ALL RIGHTS RESERVED. PARKS AND PROTECTED AREAS OBTAINED FROM ALBERTA PARKS, GOVERNMENT OF ALBERTA AND ENVIRONMENT AND CLIMATE CHANGE CANADA (ECCC). IMAGERY COPYRIGHT ©20180427 ESRI AND ITS LICENSORS. SOURCE: MAXAR. USED UNDER LICENSE, ALL RIGHTS RESERVED.

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

TITLE

BIRCH LAKE AND GIPSY GORDON WETLAND COMPLEX WATER QUALITY MONITORING LOCATIONS

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
DESIGNED	CZ
PREPARED	LB
REVIEWED	ZG
APPROVED	JH

PROJECT NO.	CONTROL	REV.	FIGURE
20140450		0	2.5-36

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

25mm

Concentrations of water quality indicators (i.e., pH, electrical conductivity, TDS, alkalinity, calcium, magnesium, and potassium) in ALWC were overall similar to the water quality observed in most EHZ within MLWC, with exception of EHZ 1 and Upland North (Figure 2.5-37). Within MLWC, water quality indicators had lower concentrations in EHZ 1 and Upland North compared to the rest of the areas within the wetland. Concentrations of sodium in ALWC (mean concentration of 16 mg/L) were higher than in MLWC (mean concentrations between 1.9 and 5.4 mg/L).

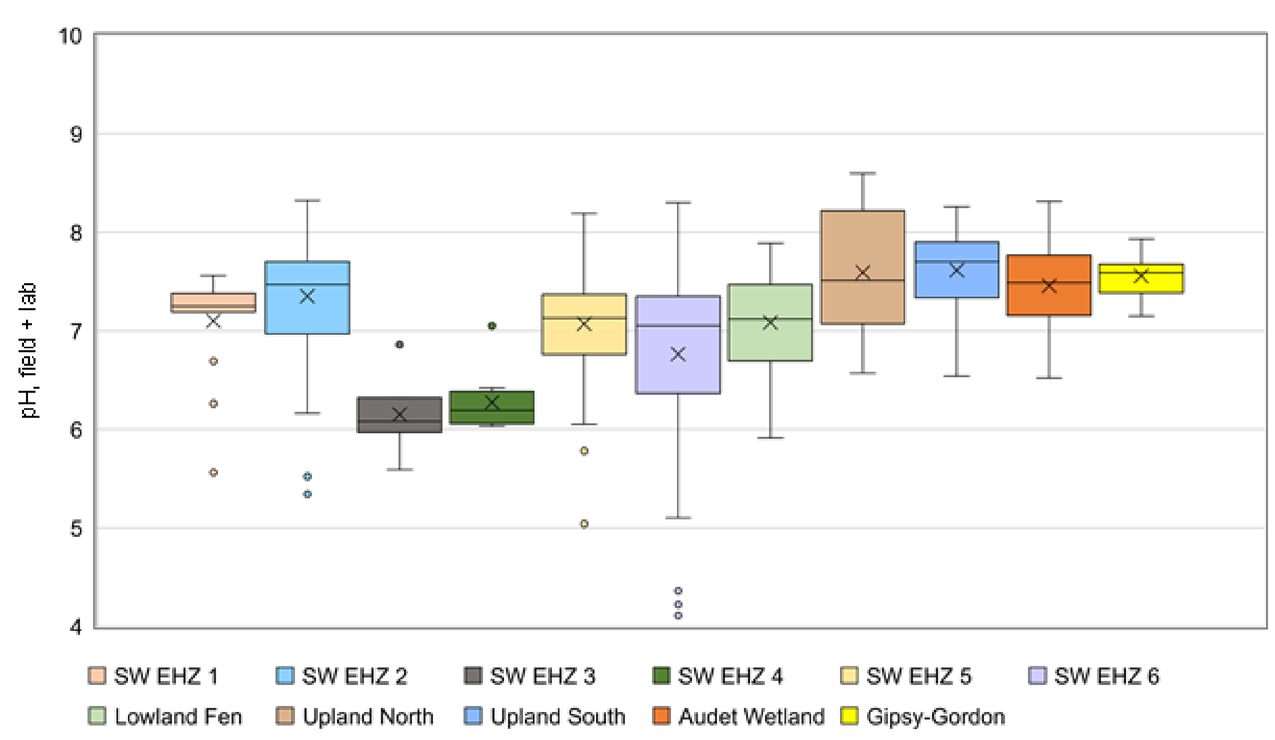
Surface water quality data at ALWC had mean field pH value of 6.8, mean electrical conductivity of 511 µS/cm, mean concentration of TDS of 266 mg/L, alkalinity of 236 mg/L as $CaCO_3$, calcium of 63 mg/L, magnesium of 21 mg/L, potassium of 1.9 mg/L, and sodium of 16 mg/L.

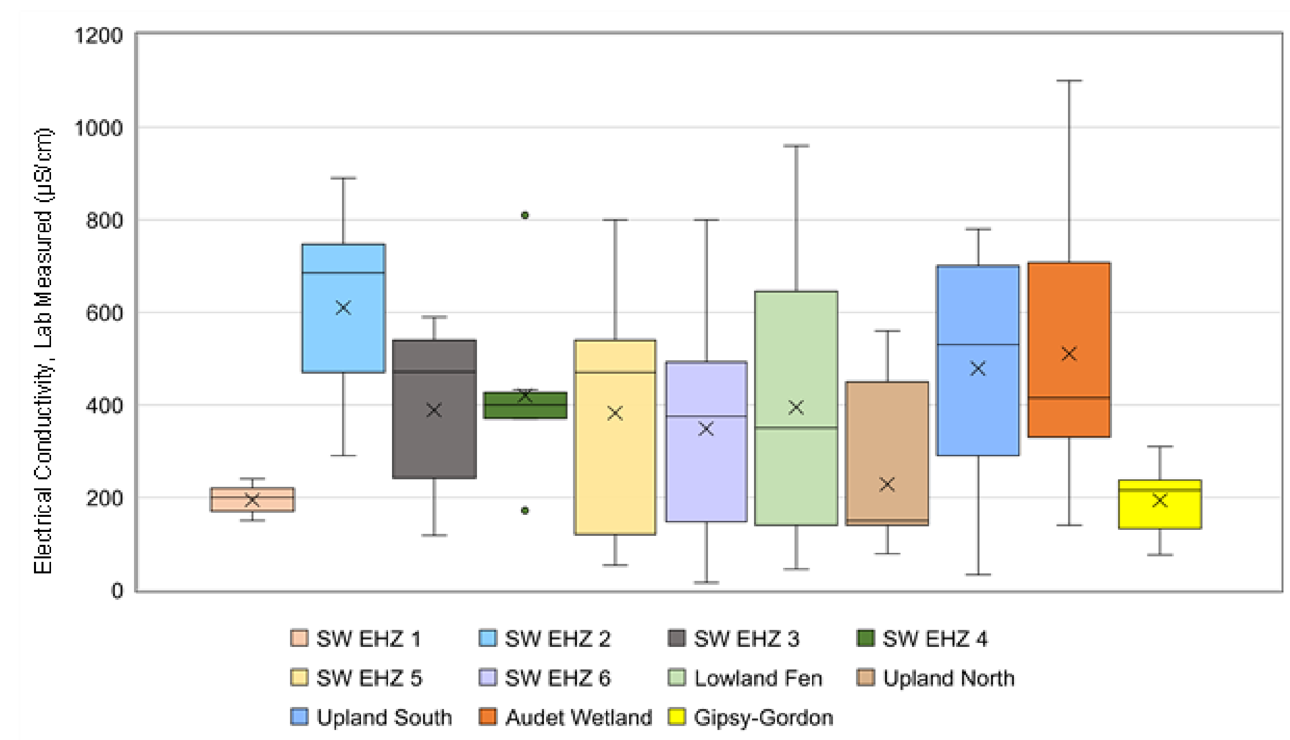
Concentrations of water quality indicators in GGWC were overall similar to EHZ 1 of MLWC and lower than the rest of the areas within MLWC (Figure 2.5-37).

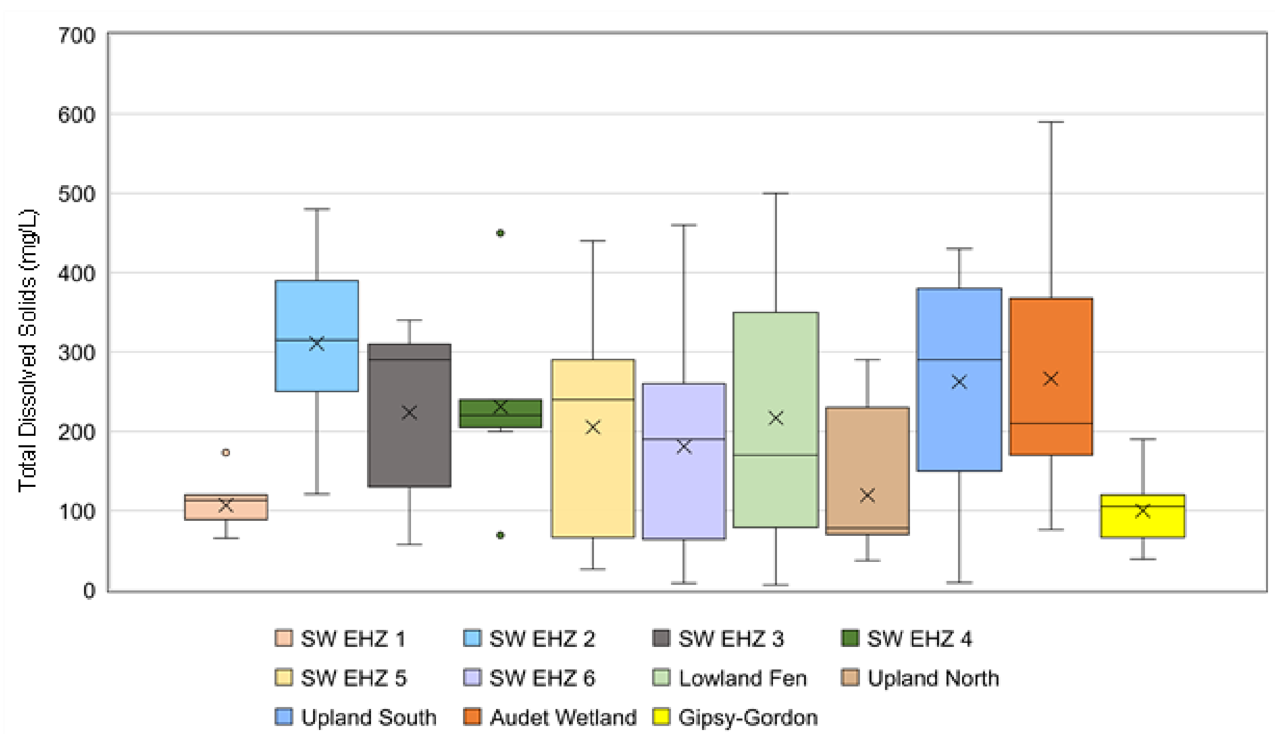
Concentrations of water quality indicators in Audet Lake and Birch Lake were overall similar to the water quality observed in McClelland Lake, with some exceptions. Audet Lake had slightly higher dissolved calcium and lower dissolved potassium than the other two lakes and Birch Lake had higher dissolved sodium than McClelland Lake and Audet Lake (Figure 2.5-38).

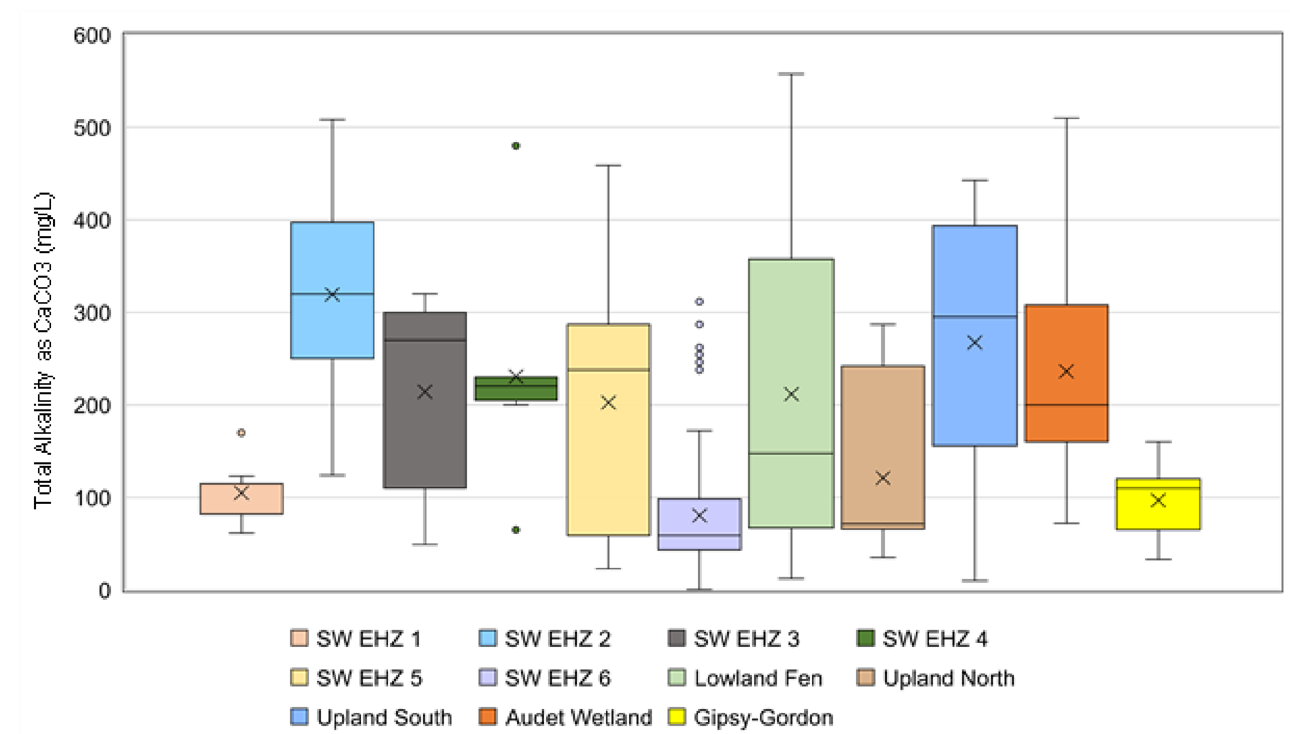
Normal ranges were calculated for key water quality indicators measured at ALWC and GGWC using the methods described in Section 2.5.1. Normal range approach involves comparing future individual observations at MLWC to the normal ranges defined by the reference conditions, which will be refined as more data are collected. Calculated normal ranges for the combined ALWC and GGWC dataset (sample size between 126 and 134) were generally similar to the pre-mining baseline at MLWC (Table 2.5-16), with exception of sodium:

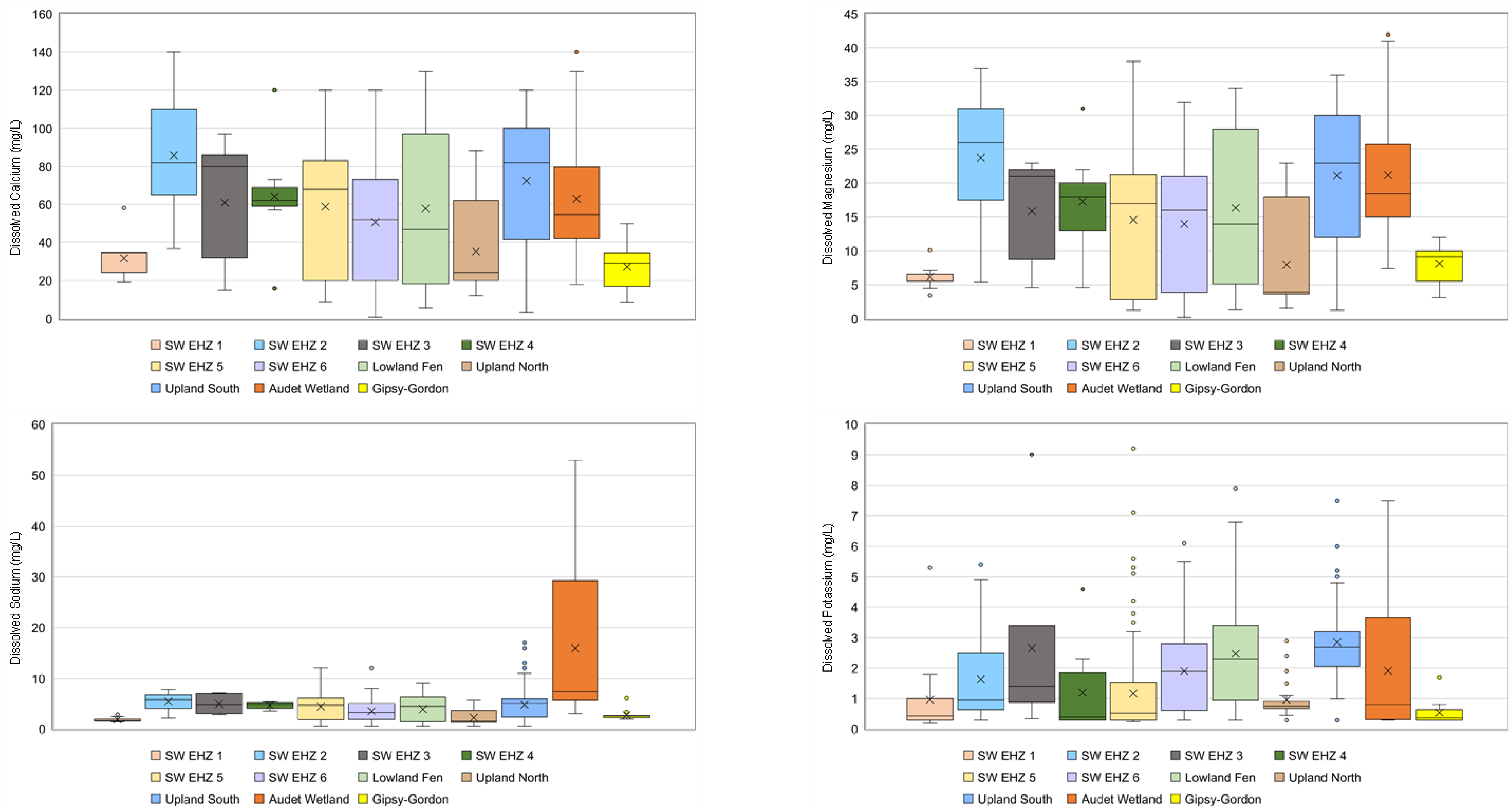
- pH between 5.9 and 8.1
- electric conductivity between 130 and 1,100 µS/cm
- the TDS concentrations between 64 and 570 mg/L
- Alkalinity concentrations between 100 and 499 mg/L as $CaCO_3$
- Calcium concentrations between 17 and 121 mg/L
- Magnesium concentrations between 5.5 and 39 mg/L
- Sodium concentrations between 2.2 and 49 mg/L (both bounds were higher than the MLWC)
- Potassium concentrations between less than 0.3 and 7.0 mg/L


10
9
8
7
6
5
4
pH, field + lab
SW EHZ 1
SW EHZ 2
SW EHZ 3
SW EHZ 4
SW EHZ 5
SW EHZ 6
Lowland Fen
Upland North
Upland South
Audet Wetland
Gipsy-Gordon


1200
1000
800
600
400
200
0
Electrical Conductivity, Lab Measured (µS/cm)
SW EHZ 1
SW EHZ 2
SW EHZ 3
SW EHZ 4
SW EHZ 5
SW EHZ 6
Lowland Fen
Upland North
Upland South
Audet Wetland
Gipsy-Gordon


700
600
500
400
300
200
100
0
Total Dissolved Solids (mg/L)
SW EHZ 1
SW EHZ 2
SW EHZ 3
SW EHZ 4
SW EHZ 5
SW EHZ 6
Lowland Fen
Upland North
Upland South
Audet Wetland
Gipsy-Gordon

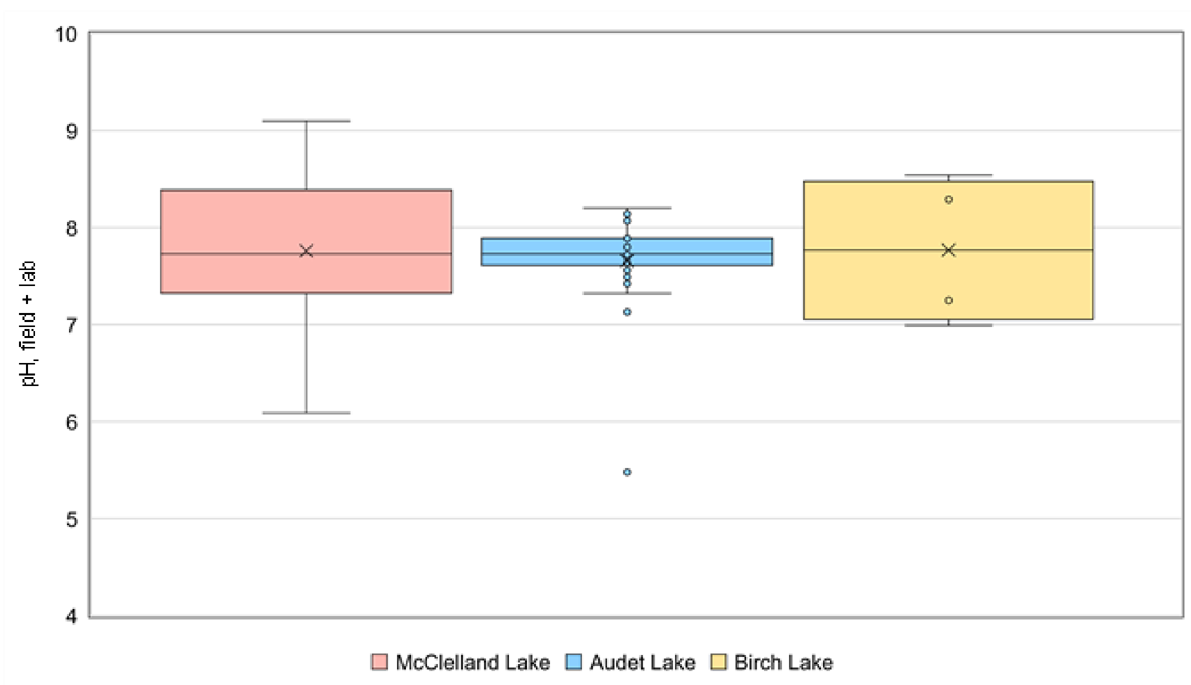

600
500
400
300
200
100
0
Total Alkalinity as CaCO3 (mg/L)
SW EHZ 1
SW EHZ 2
SW EHZ 3
SW EHZ 4
SW EHZ 5
SW EHZ 6
Lowland Fen
Upland North
Upland South
Audet Wetland
Gipsy-Gordon

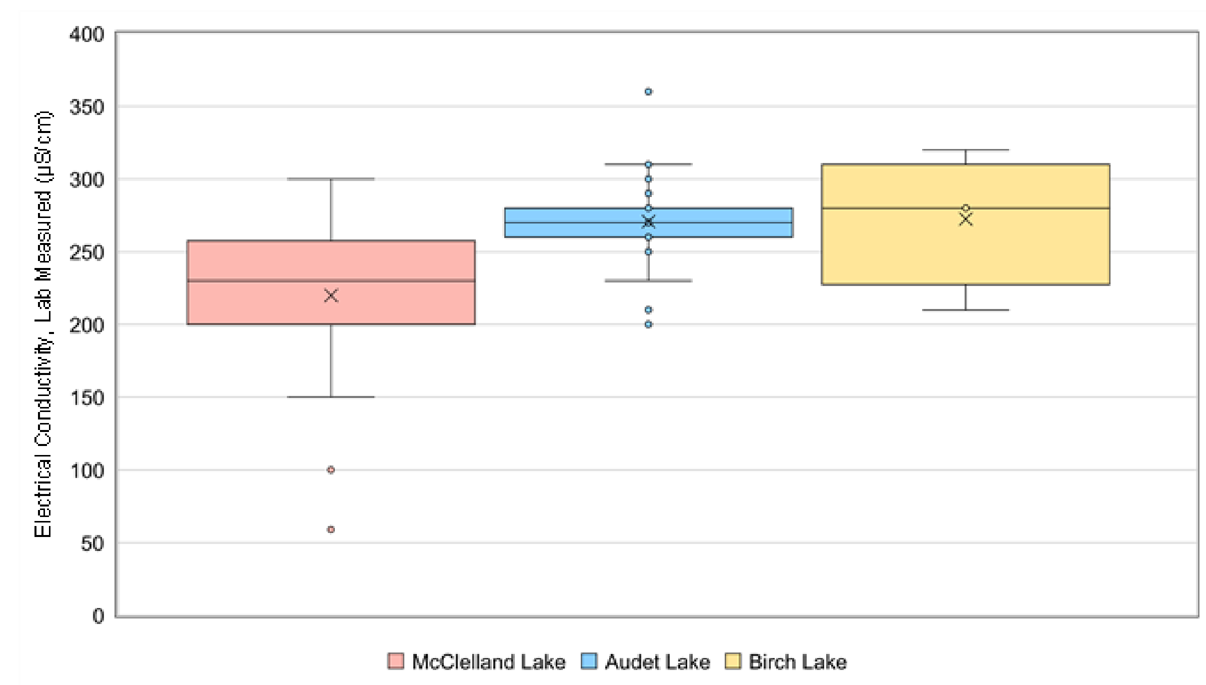


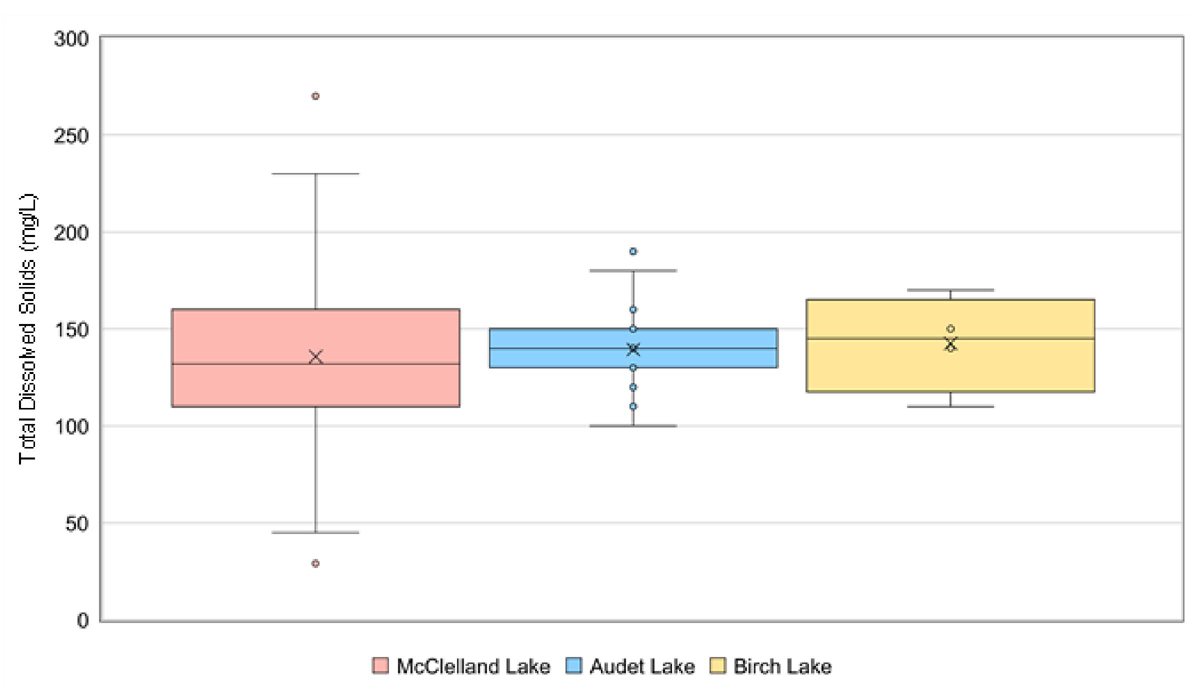
Note: The length of the boxplot represent the inter-quartile range (25th and 75th interquartiles) with the median denoted by the horizontal line and mean by the x symbol. The whiskers represent the minimum and maximum values of the dataset unless outliers are present, in which case the whiskers extend to a maximum of the 1.5 times the inter-quartiles range. Outliers (circles) are values greater than 1.5 times the inter-quartiles range.

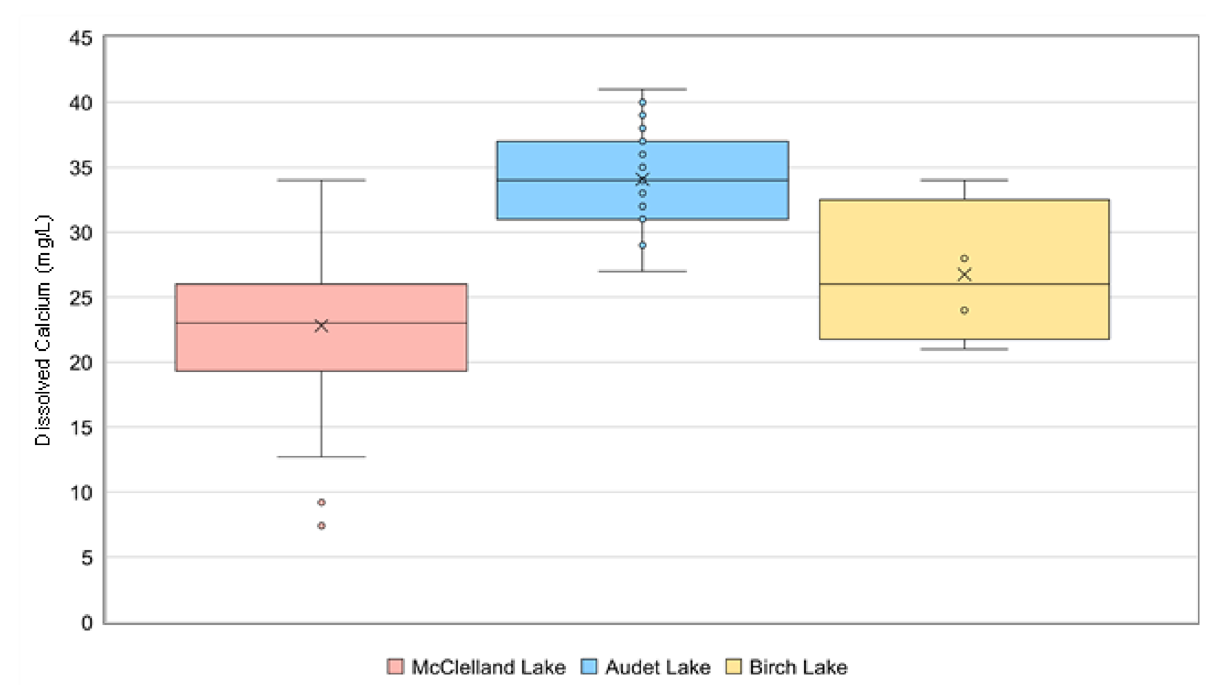
$CaCO_3$ = calcium carbonate; EHZ = Ecohydrology Zone; mg/L = milligrams per litre; µS/cm = microSiemens per centimetre.

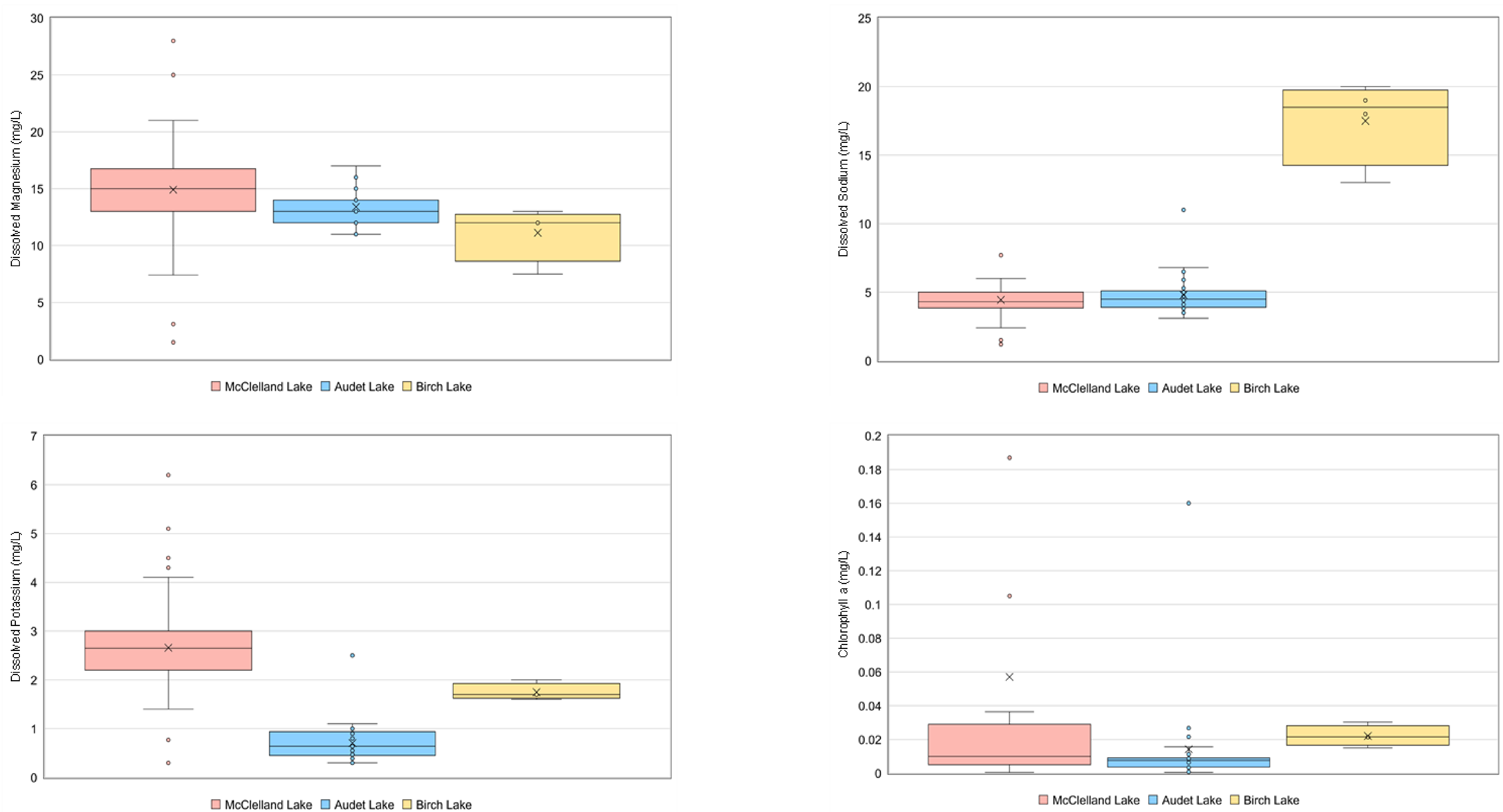
Figure 2.5-37: Comparison of Surface Water Quality Indicators in ALWC and GGWC to MLWC


pH, field + lab
10
9
8
7
6
5
4
McClelland Lake
Audet Lake
Birch Lake


Electrical Conductivity, Lab Measured (µS/cm)
400
350
300
250
200
150
100
50
0
McClelland Lake
Audet Lake
Birch Lake


Total Dissolved Solids (mg/L)
300
250
200
150
100
50
0
McClelland Lake
Audet Lake
Birch Lake


Dissolved Calcium (mg/L)
45
40
35
30
25
20
15
10
5
0
McClelland Lake
Audet Lake
Birch Lake



Note: The length of the boxplot represent the inter-quartile range (25th and 75th interquartiles) with the median denoted by the horizontal line and mean by the x symbol. The whiskers represent the minimum and maximum values of the dataset unless outliers are present, in which case the whiskers extend to a maximum of the 1.5 times the inter-quartiles range. Outliers (circles) are values greater than 1.5 times the inter-quartiles range.

mg/L = milligrams per litre; µS/cm = microSiemens per centimetre.

Figure 2.5-38: Comparison of Surface Water Quality Indicators in McClelland Lake, Audet Lake, and Birch Lake

2.5.7. Aquatic Resources

2.5.7.1. Introduction

McClelland Lake, and the surrounding waterbodies, is an important habitat for aquatic species harvested by Indigenous Peoples, and ITK holders have indicated that it was used extensively for fishing and shellfish gathering activities prior to industrial development. Fishing at McClelland Lake was an important part of the seasonal round in recent history. One ITK holder remembers:

> *"When I was twenty something years old, I was born in 1952, so them days in the seventies, earlier seventies, maybe '74 or '76… we used to come hunting all the way from Fort Chip with a dog team sometimes you know, come all the way down there just to come hunting for moose or something in that area [Muskeg River and Kearl Lake area]… and sometimes when it was summer time, when we used to come up from Fort Chip, we'd come to McMurray, September before school starts, we used to go hunting, used to make some dried fish, some of those areas, down a creek and you'd come to a big lake [McClelland Lake], spent our time picking berries and my mum, all our family used to spend all our time making dried fish and dried meat if we killed a moose, see a lot of moose some days."* (MCFN ITK holder, MCFN 2019)

Pickerel and jackfish were fished from the area in the past, however with lowering water levels in recent years, it is now less likely that fishing for such species in the lake is possible as freeze-up makes overwintering of large fish unlikely. Grayling have been harvested in clean clear waters such as those of the Firebag River (FCM ITK holder, FMC 2019). Clams are also collected from the rocky bottoms of watercourses such as the Firebag (FCM ITK holder, FCM 2019). The presence of water striders on top of the water, or birds (for example hawks and eagles) flying overhead, was often a good indication of the presence of fish in a waterbody (MCFN ITK holders, MCFN 2019).

The quality of fished and gathered aquatic species is tied to water quality conditions in waterbodies, but the fish themselves are also an indication of clean, good water conditions. To some ITK holders, the presence of minnows and fish jumping are indicative of a health fen and lake (MCFN ITK holders, MFCN 2019).

2.5.7.1.1. Aquatic Invertebrates

Aquatic invertebrates were sampled in MLWC to understand variability within the MLWC, and to assess whether aquatic invertebrates should be included as an indicator in the OP. A summary of the sampling programs, timing, and sampling methods used throughout the pre-mining baseline studies is provided in Table 2.5-18.

Sixteen sampling programs were carried out between 2009 and 2017 and varied in sampling and sorting methods, timing of sampling (i.e., spring [early June], summer [July and August], and late summer/fall [September]), and habitat sampled (i.e., lakeshore, flark, and pool). The first four years of sampling were reviewed (Armada 2013a) and recommendations to the most effective sampling and sorting methods (i.e., dip nets with hand sorting) and sampling habitat (i.e., lakeshore sites) were proposed and used in future sampling programs.

The method used during most pre-mining baseline sampling events was dip net sampling. From 2013 to 2017, samples were collected using a 500 micrometres (µm) mesh net, which was knifed into the water at a 45-degree angle to the bottom and pulled out straight. Samples were then sorted by hand in a white tray, by picking out the live aquatic invertebrates, which were preserved in formalin and sent to a qualified taxonomist for identification.

Table 2.5-18: Summary of Aquatic Invertebrate Sampling in McClelland Lake Wetland Complex and Reference Areas

Visit #	Year	Date	Sampling Method	Sorting Method	Survey Area
1	2009	Aug 25	dip net	hand sorting	MLWC
2	2010	Jun 08	dip net	floatation	MLWC
3	2010	Aug 12	dip net	hand sorting	MLWC
4	2011	July 12	funnel / activity trap	hand sorting	MLWC and ALWC
5	2011	Aug 18	funnel / activity trap	hand sorting	MLWC and ALWC
6	2011	Sep 11	funnel / activity trap	hand sorting	MLWC and ALWC
7	2012	Jun 29	artificial substrates	hand sorting	MLWC and ALWC
8	2012	Aug 21	artificial substrates	hand sorting	MLWC and ALWC
9	2013	Jun 26	dip net	hand sorting	MLWC and ALWC
10	2013	Sep 05	dip net	hand sorting	MLWC and ALWC
11	2014	July 01	dip net	hand sorting	MLWC and ALWC
12	2014	Aug 19	dip net	hand sorting	MLWC and ALWC
13	2015	Jun 23	dip net	hand sorting	MLWC and ALWC
14	2015	Aug 25	dip net	hand sorting	MLWC and ALWC
15	2016	Aug 16	dip net	hand sorting	MLWC, ALWC, and GGWC
16	2017	Aug 11 and 12	dip net	hand sorting	MLWC, ALWC, and GGWC

ALWC = Audet Lake Wetland Complex; GGWC = Gipsy-Gordon Wetland Complex; MLWC = McClelland Lake Wetland Complex.

Sampling locations within MLWC varied among programs due to the changes in standing water between sampling events. To reduce variability due to different sampling locations, sampling events from 2014 to 2017 prioritized sampling at locations most sampled in prior programs. Between 2009 and 2017, a total of 30 locations were sampled in MLWC, of which four were sampled seven to eight times, 10 were sampled four to six times, and 16 were sampled less than four times throughout the pre-mining baseline sampling period.

2.5.7.1.2. Fish Populations and Health

As part of the Aquatic Resources component, available fish population and health pre-mining baseline/monitoring data for the McClelland Lake watershed were compiled and evaluated for its suitability to define the MRV of various population parameters and thereby support a future fish population monitoring program.

The available data were examined for the following population parameters:

- fish species composition/diversity – number of fish per species
- fish abundance – catch-per-unit-effort per species
- fish size – length, weight, and condition factor per species

Available data were also examined for fish health information, including frequency of abnormalities and fish tissue chemical concentrations.

Data were available from the following sources:

- The 2000-2001 Fort Hills Baseline Study (TrueNorth 2001).
- The 2012 fish population monitoring survey for the McClelland and Audet wetland complexes (Armada 2013b).
- The 2011 Laboratory Report for analysis of fish tissues from McClelland Lake and Audet Lake (Maxxam 2011)
- The 2020 Fort Hills Baseline Survey (Golder 2020).
- Data for various years from 2002 to 2008 located in the Alberta Environment and Parks (AEP) Fish and Wildlife Management Information System (FWMIS) database (AEP 2020).

Data were compiled for the following components of the watershed:

- MLWC
- Tributaries to the MLWC
- pothole lakes within the MLWC
- pothole lakes adjacent to the MLWC
- McClelland Lake
- The McClelland Lake inlet channel
- The McClelland Lake outlet channel (McClelland Creek)

A summary of the available fish population data is provided in Table 2.5-19, which identifies the data sources, survey locations and types of data available. Available fish health data were limited to collection of one fish tissue sample from McClelland Lake in 2011 for laboratory determination of chemical concentrations; no fish abnormality data were collected. The tissue sample was analyzed for concentrations of 30 metals and 18 PAHs.

Table 2.5-19: Summary of Available Fish Population Pre-Mining Baseline Data for the McClelland Lake Watershed

Survey Year	Seasons	Study Name	Survey Area	Fish Sampling Method			Survey Data Collected			
				Gill Net	Minnow Trap	Electrofishing	No. Fish per Species	CPUE	Length	Weight
2000	Spring, Summer, Fall	Fort Hills Baseline Study	McClelland Lake	Yes	Yes	No	Yes	Yes	No	No
2000	Spring, Summer, Fall		Pothole lakes within MLWC	Yes	Yes	No	Yes	Yes	No	No
2000	Spring, Summer, Fall		Pothole lakes adjacent to MLWC	Yes	No	No	Yes	No	No	No
2001	Winter		Pothole lakes adjacent to MLWC	No	Yes	No	Yes	No	No	No
2002	Spring, Summer	FWMIS Data	McClelland Lake	Yes	Yes	Yes	Yes	Yes[(a)]	No	No
2003	Summer		McClelland Lake Outlet	No	No	Yes	Yes	Yes	No	No
2003	Summer		MLWC Tributary	No	No	Yes	Yes	Yes	No	No
2005	Fall		McClelland Lake Inlet	No	No	Yes	Yes	Yes	No	No
2005	Fall		McClelland Lake Outlet	No	Yes	Yes	Yes	Yes[(a)]	No	No
2008	Summer, Fall		McClelland Lake Inlet	No	Yes	Yes	Yes	Yes[(a)]	No	No
2008	Summer		McClelland Lake	Yes	Yes	No	Yes	No	No	No
2008	Fall		MLWC Tributary	No	Yes	No	Yes	No	No	No
2012	Fall	McClelland/Audet Monitoring Survey	McClelland Lake and Audet Lake	No	Yes	Yes	Yes	Yes[(a)]	No	No
2020	Spring, Fall	Additional Fort Hills Baseline Study	McClelland Lake	Yes	Yes	No	Yes	Yes	Yes	No
	Spring		MLWC	No	Yes	No	Yes	Yes	Yes	Yes
	Spring, Fall		MLWC Tributaries	No	Yes	Yes	Yes	Yes	Yes	Yes

(a) Electrofishing CPUE only – CPUE for minnow trapping is not available.

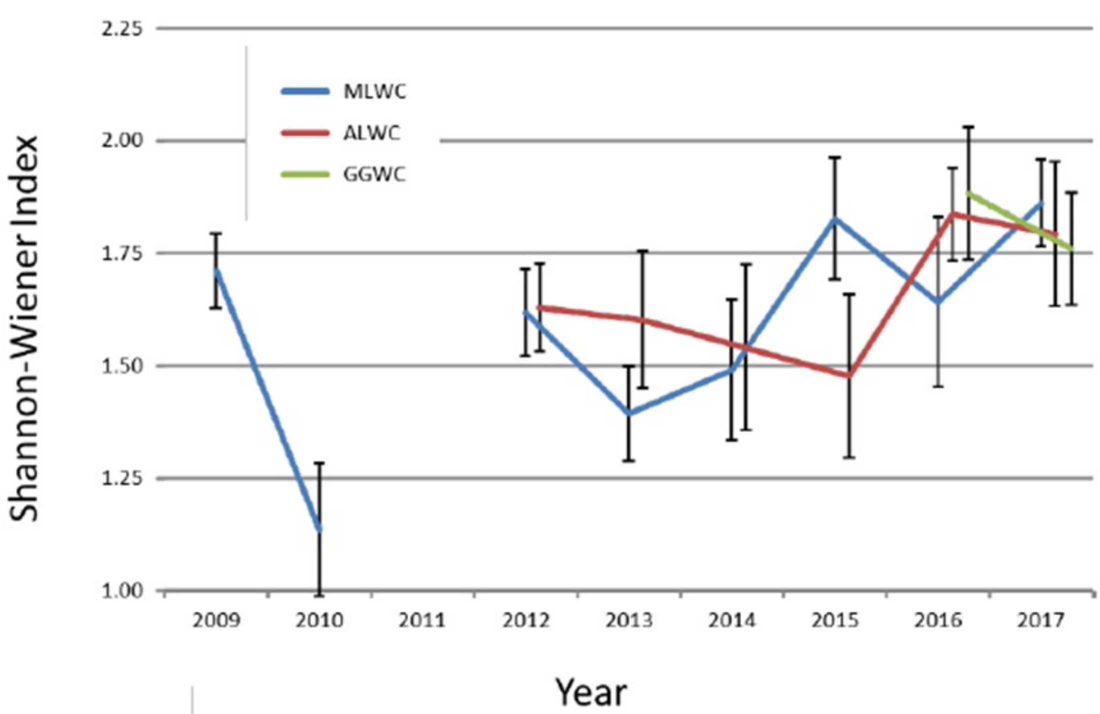
CPUE = catch-per-unit-effort; FWMIS = Fish and Wildlife Management Information System; MLWC = McClelland Lake Wetland Complex; No. = number

2.5.7.2. Aquatic Resources Pre-Mining Baseline Conditions

2.5.7.2.1. Aquatic Invertebrates

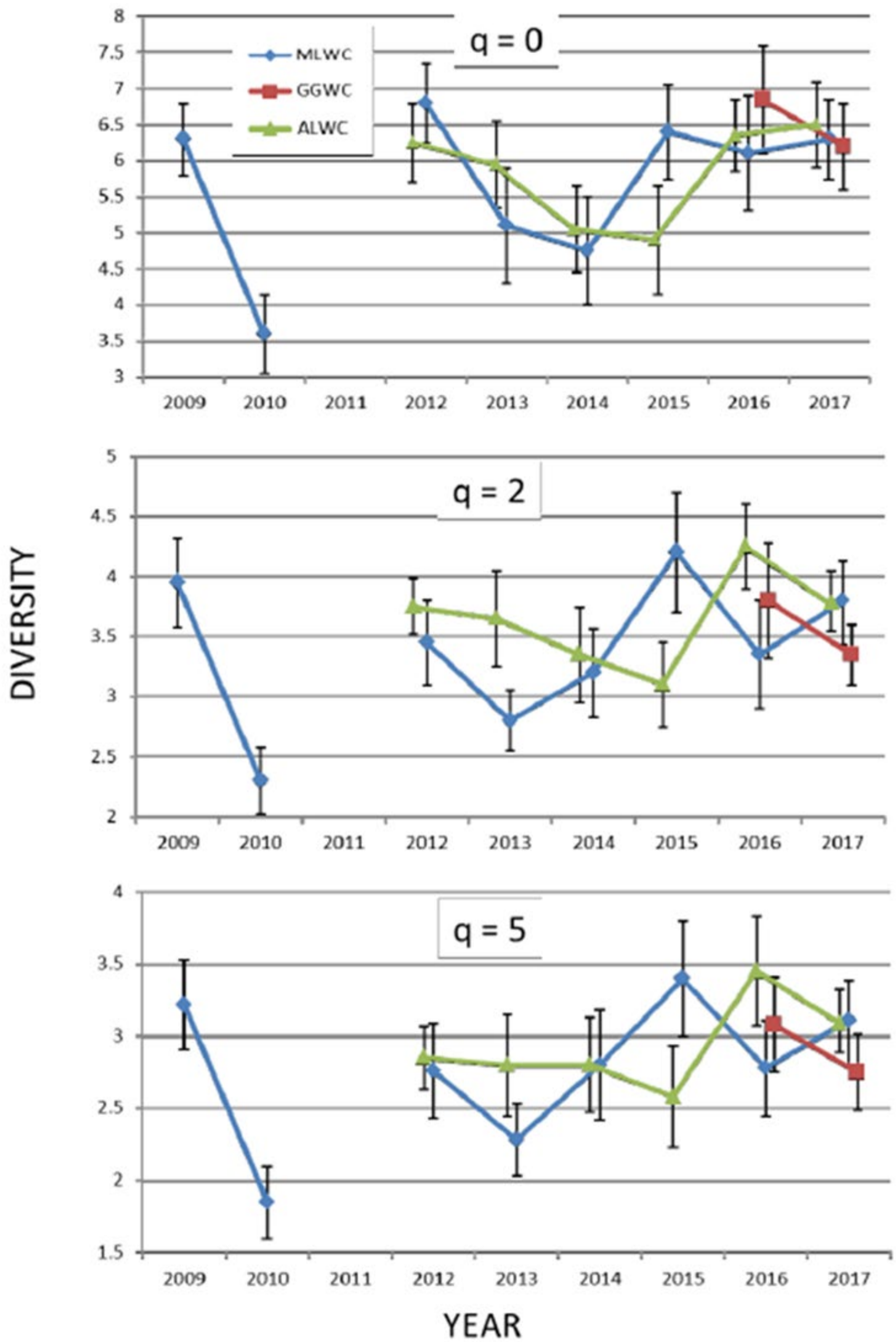
Aquatic invertebrate data from MLWC, ALWC, and GGWC were used to calculate community variables (i.e., diversity and community composition) and statistical power for BACI analysis under various scenarios. Results from the 2009 to 2012 sampling programs were reported in a summary report (Armada 2013a), and thereafter annually (Armada 2014, 2015, 2017, 2018), with the latter two reports also presenting historical summaries of species diversity.

Analyses of species diversity, reported as the Shannon-Weiner Index and diversity profiles, suggest that diversity did not differ between wetland complexes throughout the sampling period, although there was a significant increase in mean Shannon-Weiner Index at MLWC over time (2009 to 2016; Figure 2.5-39). The diversity profiles are presented for various q index values which control the weight given to species abundance in addition to grouping species that are functionally similar. The value of q ranges from 0 to infinity; when q=0, the diversity profile measures the number of all species equally, but as q increases, less weight is given to rare species and similar species are grouped. The resulting diversity profiles shown here can be interpreted as follows: a q index of zero is representative of species richness, a q index of 1 provides a diversity profile that is related to the Shannon-Weiner Index, a q index of 2, provides a diversity profile that is related to the Simpson's Diversity Index, and a q index of 5 represents a diversity profile of the effective number of species (i.e., number of equally common species) (Figure 2.5-40).



Note: Error bars represent one standard error.
Source: Armada (2018).

Figure 2.5-39: Average Shannon-Weiner Diversity for Each Fen Complex through Time



Note: Each plot represents a different q index; a q index of zero is representative of species richness, a q index of 1 provides a diversity profile that is related to the Shannon-Weiner Index, a q index of 2 provides a diversity profile that is related to the Simpson's Diversity Index, and a q index of 5 provides a diversity profile of the effective number of species. Error bars represent one standard error.

Source: Armada (2018).

ALWC = Audet Lake Wetland Complex; GGWC = Gipsy-Gordon Wetland Complex; MLWC = McClelland Lake Wetland Complex.

Figure 2.5-40: Diversity Profiles Compared among Fen Complexes Over the Life of the Aquatic Invertebrate Pre-Mining Baseline Program

Invertebrate community composition was compared between wetland complexes using ordination plots, following Peck (2010), and statistically, using the Multi-Response Permutation Procedure based on a Bray-Curtis distance measure. The community composition at MLWC was not statistically different from that at ALWC in 2014 and 2015, but ALWC differed from MLWC and GGWC in 2016, and MLWC differed from the two reference complexes in 2017. Although the BACI experimental design does not require community composition at exposure and reference areas to be the same, differences from one year to another in which fen's community composition differs from others suggest that community composition at reference and exposure fens does not vary similarly over time.

Power analyses were performed on comparable data following the 2012, 2014, 2016, and 2017 sampling programs using alpha 0.05 and an acceptable power of 0.8 for various scenarios using the method by Stroup (1999). Slight changes in power analysis methods complicated direct comparisons between reports; however, the suggested power of the program to detect changes in aquatic invertebrate community variables (i.e., species diversity) declined through the pre-mining baseline sampling period.

Following the 2012 sampling program, power analyses suggested that detection of the loss or gain of one species within the MLWC would be possible if 8 to 10 years of pre-impact data were obtained (Armada 2013a). Following the 2014 sampling program, power analyses suggested that the detection of the loss or gain of 3 species within the MLWC would be possible if 8 years of pre-impact data were obtained and that the detection of a 5% change in the diversity profile (q index set to 5) would be possible with as little as two years of post-impact monitoring (Armada 2015). Following the 2016 and 2017 sampling programs, power analyses suggested that detection of the loss or gain of 2 and 7 species, respectively, within the MLWC would be possible if 10 years of pre-impact data were obtained (Armada 2017, 2018). The best scenario following sampling in MLWC, ALWC, and GGWC in 2017 was that the program would be capable of detecting a 20% change in diversity profile after an additional 5 years of sampling prior to and 10 years following the initial impact to MLWC. The decrease in statistical power throughout the sampling period was attributed to the high variability of the data at each site throughout the sampling period.

2.5.7.2.2. Fish Populations and Health

The available fish population and health dataset for the McClelland Lake watershed and Audet Lake was examined to determine if it would support a future monitoring program for either the MLWC or McClelland Lake itself, using Audet Lake as a reference area.

Fish population data for the McClelland Lake watershed are available from eight years over the period of 2000 to 2020. However, these data are limited and most of the studies are too old to be considered current. The data are also limited in scope, in that a small amount of effort was undertaken at most of the sites (aside from McClelland Lake). For the tributaries that are a part of or flow into the MLWC, most of the previous studies selected a single site and used one type of fishing method (i.e., electrofishing). McClelland Lake, including its inlet and outlet, have the most complete data record, with studies having applied a higher level of sampling effort there compared to other survey areas. Fish health data are available from McClelland Lake only and are limited to fish tissue data obtained from analysis of a single sample.

The available data show that the McClelland Lake watershed supports four species of small-bodied forage fish (i.e., sticklebacks and minnows), with no large-bodied species (i.e., sport fish or suckers) present (Table 2.5-20). The four species consist of Brook Stickleback (*Culaea inconstans*), Lake Chub (*Couesius plumbeus*), Finescale Dace (*Chrosomus neogaeus*) and Northern Pearl Dace (*Margariscus nachtriebi*).

Table 2.5-20: Summary of Fish Population Sampling Results for the McClelland Lake Watershed

Survey Area	Fish Species CPUE							
	Brook Stickleback		Lake Chub		Northern Pearl Dace		Finescale Dace	
	Minnow Trap [fish/trap-hour]	Electro-fishing [fish/100 s]	Minnow Trap [fish/trap-hour]	Electro-fishing [fish/100 s]	Minnow Trap [fish/trap-hour]	Electro-fishing [fish/100 s]	Minnow Trap [fish/trap-hour]	Electro-fishing [fish/100 s]
McClelland Lake	0.17 to 2.2	19.1	0.12 to 0.15	0	0	3.8	0.02	0
McClelland Lake Inlet	0.10	2.7 to 3.6	0	0	0.10	1.0	0	0
McClelland Lake Outlet	-	1.9 to 4.6	-	0	-	3.5 to 5.7	0	-
MLWC	0.78	-	0	-	0	-	0	-
MLWC Tributaries	-	0.33 to 1.8	-	0	-	0	-	0
Pothole Lakes within the MLWC	0.04 to 0.83	-	0	-	0	-	0	0
Pothole Lakes adjacent to the MLWC	0	-	0	-	0	-	0	-

CPUE = catch-per-unit-effort; s = second; - = no sampling effort; MLWC = McClelland Lake Wetland Complex.

All four species are present in McClelland Lake, but only Brook Stickleback have been recorded upstream of the lake, with this species present in a watercourse in the MLWC, several tributaries to the MLWC, and in some of the pothole lakes. The analytical results for the one fish tissue sample collected from McClelland Lake (Maxxam 2011) showed detectable concentrations of 13 of the 30 metals tested, and 2 of the 18 PAHs tested (Table 2.5-21).

Table 2.5-21: Summary of Fish Tissue Analytical Results for McClelland and Audet Lakes

Parameter	Units	Audet Lake Sample 1	Audet Lake Sample 2	McClelland Lake Sample 1
Metals				
Aluminium	µg/g	0.9	1.7	1.2
Barium	µg/g	1.7	3.0	2.4
Calcium	µg/g	7,300	8,900	6,100
Cobalt	µg/g	bdl	bdl	0.01
Copper	µg/g	1.2	1.2	1.3
Iron	µg/g	17	28	34
Magnesium	µg/g	290	420	560
Manganese	µg/g	9.1	11	11
Phosphorus	µg/g	5,100	5,800	4,500
Potassium	µg/g	2,000	1,700	2,800
Sodium	µg/g	520	590	1,000
Strontium	µg/g	17	20	13
Zinc	µg/g	29	47	48

Table 2.5-21: Summary of Fish Tissue Analytical Results for McClelland and Audet Lakes

Parameter	Units	Audet Lake Sample 1	Audet Lake Sample 2	McClelland Lake Sample 1
Arsenic, Antimony, Beryllium, Bismuth, Boron, Cadmium, Chromium, Lead, Molybdenum, Nickel, Selenium, Silver, Strontium, Thallium, Tin, Titanium, Uranium, Vanadium	µg/g	bdl		
Polyaromatic Hydrocarbons				
2-Methylnaphthalene	µg/g	bdl	bdl	0.04
Naphthalene	µg/g	bdl	bdl	0.03
Acenaphthene, Acenaphthylene, Anthracene, Benzo(a)anthracene, Benoz(a)pyrene, Benzo(b/j)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, 1-Methylnaphthalene, Phenanthrene, Pyrene	µg/g	bdl		

bdl = below detection limit; µg/g = micrograms per gram.

Although pre-mining baseline data for McClelland Lake includes numbers of fish per species from all studies for assessing species composition, catch-per-unit-effort (CPUE) data for assessing fish abundance are limited and absent for some species. In addition, length and weight data to determine fish size and condition factor are largely absent. Fish health data are also absent, except for tissue chemistry data for one sample.

Only one survey has been conducted in watercourses in the MLWC, with only one site surveyed. Although this survey was recent (2020) and collected fish composition, fish abundance and fish measurement data, this single dataset is insufficient to define the MRV or to support a monitoring program.

Overall, the available baseline dataset for McClelland Lake and the MLWC is insufficient to support a monitoring program for fish populations or fish health. Although numbers of fish per species data are available from all studies for assessing species composition, CPUE data for assessing fish abundance are limited and absent for some species. In addition, length and weight data to determine fish size and condition factor are largely absent and only one sample was collected for fish health analysis (tissue chemistry only, no abnormalities). Therefore, the dataset is not sufficient to define the MRV for any parameter. In addition, fish populations consist only of small-bodied forage fish species with no large-bodied fish (i.e., sport fish or suckers) present and, therefore, no species used in traditional or recreational fish harvest or for human consumption. In general, forage fish species are small and short-lived and do not bioaccumulate contaminants to the same extent as longer-lived large-bodied species, particularly predatory (piscivorous) species. Forage fish are also less likely to exhibit a wide variety of abnormalities. For these reasons, fish populations and fish health are not suitable for selection as indicators for the OP.

The proposed reference lake, Audet Lake, has a limited historical data record with surveys from only three years over the period 2000 to 2012. Fish health data from Audet Lake are limited to fish tissue data from two samples. No fish surveys have been conducted in the ALWC.

The available data show that Audet Lake supports four species of small-bodied forage fish (i.e., sticklebacks and minnows), with no large-bodied species (i.e., sport fish or suckers) present (Table 2.5-22). The four species consist of Brook Stickleback (*Culaea inconstans*), Lake Chub (*Couesius* *plumbeus*), Northern Pearl Dace (*Margariscus nachtriebi*), and Spottail Shiner (*Notropis hudsonius*). The analytical results for the two fish tissue samples collected from Audet Lake consist of detectable concentrations of 11 of the 30 metals tested and none of the PAHs tested.

Table 2.5-22: Summary of Fish Population Sampling Results for Audet Lake

Survey Area	Fish Species CPUE[(a)]			
	Brook Stickleback	**Lake Chub**	**Northern Pearl Dace**	**Spottail Shiner**
Audet Lake	0.16	0.03	0.0	0.04

(a) Minnow trap sampling only; units are fish/trap-hour.
CPUE = catch-per-unit-effort.

Although pre-mining baseline data in Audet Lake include numbers of fish per species for assessing species composition from the few studies conducted, CPUE data for assessing fish abundance, and length/weight data to determine fish size and condition factor, were collected by only one survey. Fish health data are also largely absent, except for tissue chemistry data for two samples.

2.5.7.3. Reference Site Baseline Conditions

2.5.7.3.1. Aquatic Invertebrates

Consistent with the Before-After Control-Impact study design, aquatic invertebrates were sampled in reference areas unimpacted by mine activities. Aquatic invertebrates were sampled in the ALWC annually, from 2011 to 2017 and the GGWC in August 2016 and 2017. Sampling dates, methods, and sorting methods at ALWC and GGWC are presented in Table 2.5-18.

Between 2011 and 2017, a total of 26 locations were sampled in ALWC of which eight were sampled five to six times, and 18 were sampled less than four times; a total of 19 locations were sampled in GGWC between 2016 and 2017 of which 10 were sampled in both years.

2.5.7.3.2. Fish Populations and Health

Available fish population and health pre-mining baseline/monitoring data for the ALWC and GGWC, the candidate reference sites for the monitoring program, were compiled and evaluated.

The available data were examined for the following population parameters:

- fish species composition/diversity – number of fish per species
- fish abundance – catch-per-unit-effort per species
- fish size – length, weight and condition factor per species

Available data were also examined for fish health information, including frequency of abnormalities and fish tissue chemical concentrations.

Data were available from the following sources:

- The 2012 fish population monitoring survey for the McClelland and Audet wetland complexes (Armada 2013b).
- Data from 2000 and 2004 located in the AEP FWMIS database (AEP 2020).

Fish population data were available for Audet Lake only; no baseline data were collected in the ALWC or GGWC.

A summary of the available fish population data is provided in Table 2.5-23, which identifies the data sources, survey locations and types of data available. Available fish health data were limited to collection of two fish tissue samples from Audet Lake in 2012 for laboratory determination of chemical concentrations; no fish abnormality data were collected. The tissue samples were analyzed for concentrations of 30 metals and 18 PAHs, with detectable concentrations found for 12 of the metals and none of the PAHs tested.

Table 2.5-23: Summary of Available Fish Population Data for the Audet Lake Reference Site

Survey Year	Season	Study Name	Survey Area	Fish Sampling Method		Survey Data Collected			
				Gill Net	Minnow Trap	No. Fish per Species	CPUE	Length	Weight
2000	Fall	FWMIS Data	Audet Lake	Yes	Yes	Yes	No	No	No
2004	Summer		Audet Lake	No	Yes	Yes	No	No	No
2012	Fall	McClelland/Audet Monitoring Survey	Audet Lake	Yes	Yes	Yes	Yes	Yes	No

CPUE = catch-per-unit-effort; FWMIS = Fish and Wildlife Management Information System.

Similar to McClelland Lake watershed, the data for Audet Lake are not sufficient to define the MRV for any parameter and the fish populations consist only of small-bodied forage fish species, further indicating that fish populations and fish health are not suitable for selection as indicators for the OP.

2.5.8. Soils

ITK holders have characterized the soils in the area as a mixture of sand bars, and muskeg underlain by clay. In some places, the muskeg hangs over areas of open ground water, creating dangerous shelves. In some shallow waterbodies, conditions have been likened to those of quicksand. Both hanging muskeg shelves and quicksand-like conditions have been noted as safety concerns by some ITK holders. In more recent years, such conditions have persisted for longer into the winter seasons as the ground has been observed to freeze later and later as seasonal temperatures remain warmer (IEG 2021).

2.5.8.1. Overview of Pre-Mining Baseline Data

Available soil datasets associated with the MLWC include:

- soil survey inspections, laboratory analysis and geospatial database (Paragon 2017)
- soil temperature string data
- soil volumetric water content and temperature profile (Hatfield 2018)
- soil infiltration and hydraulic conductivity tests (Hatfield 2018)

Based on the soil survey inspections, soils in the MLWC are developed on non-saline, non-calcareous sandy ice contact glaciofluvial (Firebag series) and glaciofluvial outwash (Mildred series) parent materials in uplands. The dominant upland soils include the coarse-textured Firebag series and its variants (3,575 ha or 18% of the MLWC watershed) occupying the majority of the Fort Hills area, and the coarse-textured Mildred series and its variants (6,778 ha or 33% of the MLWC watershed) occupying the majority of the area north and east of the central fen and McClelland Lake.

The peatlands of the MLWC are predominantly fen peat (sedge-dominated McClelland series), accounting for 21% of the total MLWC watershed area. Twelve percent (12%) of the MLWC watershed consists of other map units, including medium-textured and other coarse-textured uplands, transitional areas, permafrost, and bog peatlands. The remaining 16% of the MLWC watershed includes McClelland Lake and associated small waterbodies.

Soil temperature in the patterned fen peaks between 15 and 25°C in the summer months (late July to mid-August) at the 10 cm soil depth, and at about 15°C at depths below 50 cm. When freeze up occurs (generally end of October to mid-December), the upper 20 cm freezes much sooner than at the 50 cm depth, which may stay unfrozen through most of the winter, and only freezing in March or early April just before the thaw begins, between mid-April and the first week of May. Soil temperatures for Mildred and Firebag soils were below the freezing point over much of the winter. The frozen period near the ground surface extended from November to mid-March but was shorter for deeper soil (i.e., from late January to early-March at soil depths greater than a metre).

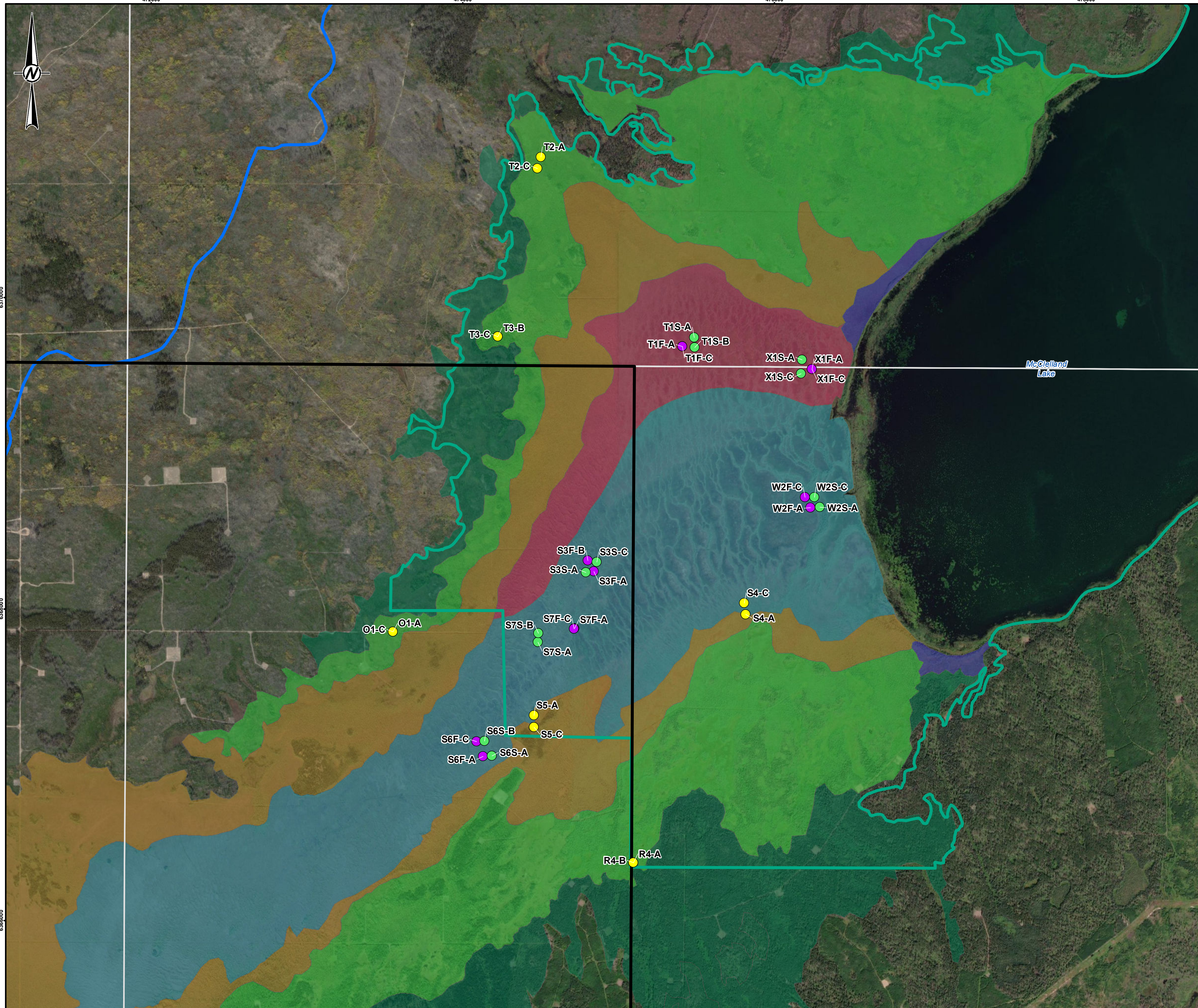
The Mildred soil series is very rapidly drained. Through 2018, soil moisture rarely reached 15%; the maximum volumetric water content corresponded with large precipitation events and moisture progressively moved downwards through time in response to these events. The soils within the patterned fen area are mainly associated with the McClelland soil series. The moisture content of the McClelland soil series was generally high (greater than 50%) and did not respond to precipitation events since it is primarily saturated and typically poorly drained. The Firebag soil series is moderately-well drained and soil moisture conditions are similar to the Mildred soil series; however, moisture is generally more slowly attenuated. Volumetric water content at the well and moderately-well drained Mildred and Firebag soil stations generally declined over autumn, was low during winter, and rapidly increased in March/April in response to snowmelt.

The soil infiltration rate was approximately four times greater for Mildred soils than Firebag soils, while the hydraulic conductivity was about three times greater in Mildred soils than Firebag soils, correlating with soil type descriptions. Field observation of soils indicated sand dominated soil types at Mildred locations, and mixed soil types containing sand/silt/clay at Firebag locations. Of the two peat/organics locations tested, there is large variance in soil infiltration rate which is attributable to underlying clay at relatively shallow depths.

2.5.9. Vegetation

2.5.9.1. Introduction

A vegetation monitoring program was initiated at the MLWC in 2008 (Jacques Whitford AXYS 2008), and vegetation monitoring was carried out every year except 2011 from 2008 to 2018 (Golder 2010, 2011; Armada 2013a, 2014, 2015, 2017, 2018). The MLWC plot locations are shown in Figure 2.5-41. The vegetation monitoring program described in the most recent report (i.e., Armada 2019) includes two plots within six sites each for string, flark, and wooded fen vegetation types at the MLWC. Each plot includes one 400 square metres (m^2) tree plot, three 16 m^2 nested shrub subplots, and ten 1 m^2 nested ground subplots. Within each tree plot, vigour was assessed using a qualitative five-point scale for ten permanently marked trees. Within shrub and ground subplots, percent cover was assessed for each vascular and non-vascular plant taxon. In addition, mean depth to water table, electrical conductivity, and pH were measured at each plot (Armada 2019).



LEGEND

- FORT HILLS *OIL SANDS CONSERVATION ACT AND WATER ACT* BOUNDARY
- NON-MINED PORTION OF THE MLWC
- WATERSHED BOUNDARY

WETLAND TYPES

- FLARK VEGETATION PLOT
- STRING VEGETATION PLOT
- WOODED FEN VEGETATION PLOT

ECOHYDROLOGY ZONES

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

0 0.5 1

1:25,000 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
McCLELLAND LAKE WETLAND COMPLEX VEGETATION MONITORING LOCATIONS

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
DESIGNED	GB
PREPARED	LB
REVIEWED	ZG
APPROVED	JH

PROJECT NO.	CONTROL	REV.	FIGURE
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Vegetation data collected at the MLWC from 2008 to 2017 were synthesized in 2018 to identify temporal trends and data gaps to focus subsequent efforts (Golder 2018). Concerns with changing species identification and inter-annual variation in percent cover values were identified, but similarity in ordination results generated using percent cover and absolute frequency datasets suggested a high level of uniqueness in plant community composition for MLWC monitoring sites not necessarily attributable to data collection inconsistencies (Golder 2018). ITK holders have identified that the condition and location of plants within an area does naturally change over time; however, the changes they have observed in the past few decades are beyond their expectations (IEG 2021). Possible refinements to the vegetation monitoring program will be discussed at upcoming SC workshops planned for 2022 (see Table 1.7-1 in the Introduction).

Land cover classification within the MLWC watershed was assessed using remote sensing techniques (Hatfield 2018). Wetland classification followed the Alberta Wetland Classification System (GOA 2015) and included wetland classes (i.e., bog, fen, marsh, shallow open water, and swamp) and forms (wooded deciduous, wooded coniferous, wooded mixedwood, shrubby, graminoid, and bare). The same forms were applied within the non-wetland (i.e., upland) class for upland areas outside the MLWC (Hatfield 2018). Wetland class and form were evaluated at both the stand and sub-stand level, which provided a meaningful way to aggregate finer-scale results to a stand level (Figure 2.5-42). Of the vegetated wetland forms documented within the MLWC watershed, shrubby fens (F-S) had the highest total area (2,590 ha; Table 10 from Hatfield [2018]).

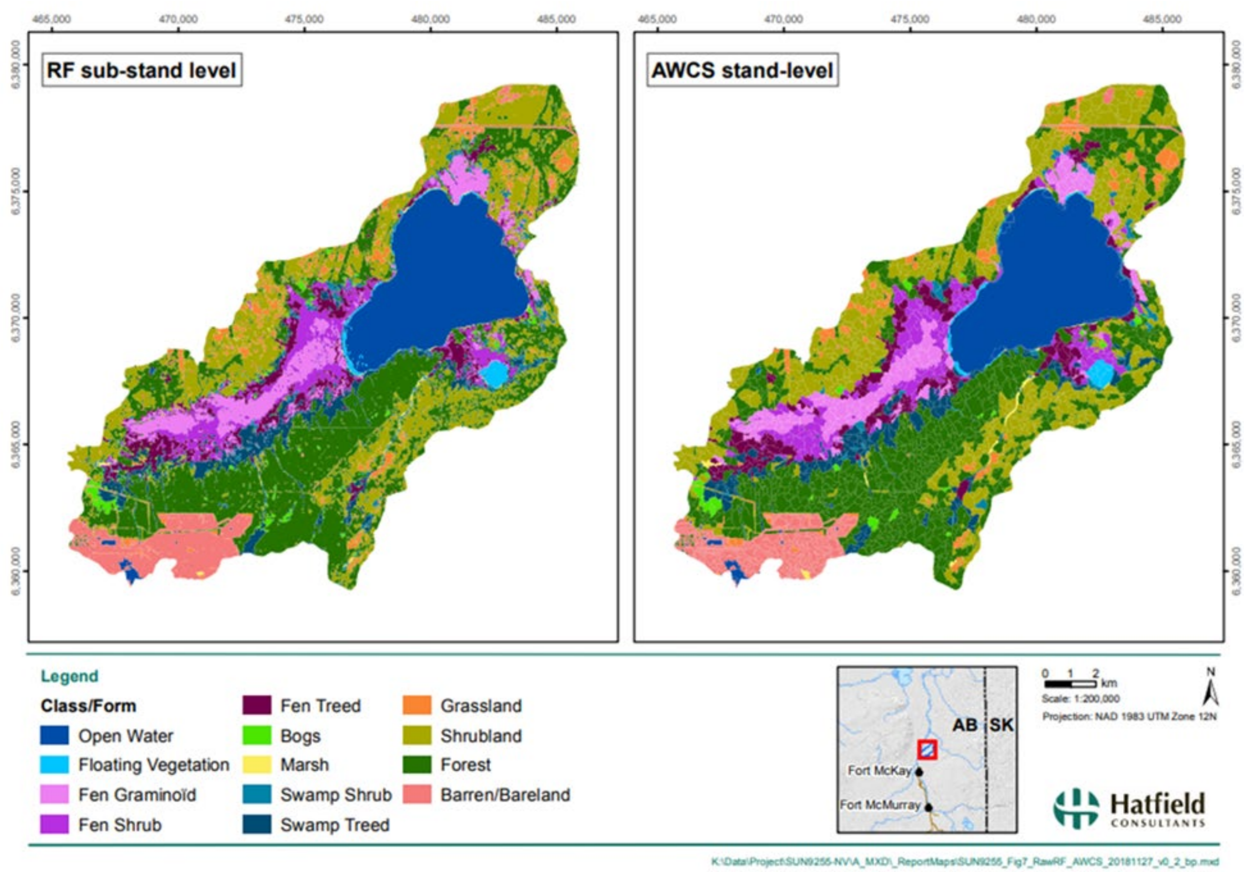


Figure 2.5-42: Random Forest Sub-Stand Object and Stand-Level Aggregation

2.5.9.2. McClelland Lake Wetland Complex Pre-Mining Baseline Conditions

The MLWC area has been and continues to be an important site for the harvest of plants for food and medicine. Plant gathering is often carried out from spring until winter. Some important plant species harvested by Indigenous Peoples in the area include wild mint, sweetgrass, red willow, diamond willow fungus, saskatoon betties, pin cherries, blueberries, and low-bush cranberries/mooseberries. Sweetgrass, blueberries, pitcher plant cranberries, mint, chokecherries, muskeg tea, rat root, and diamond willow fungus are, in particular, important species that continue to be harvested in the MLWC area as a source of food and medicine each year (ITK from several communities, IEG 2021).

Harvesting of such plants is not only important for food and medicine, but as a part of community and cultural identity, and in the transmission of knowledge between generations. Maintaining a connection to the land in and around the MLWC is important for the people that harvest there, and for future generations. In addition to the presence of plants, plant health has been identified by ITK holders as an important quality for harvesting and use. Two plants that have been highlighted as being sensitive to change include bear berries, and bulrush (FMFN and FMMN ITK holders, IEG 2020).

Balsam, Tamarac and Birch are important tree species, and their bark is harvested for its medicinal properties. Specific trees may act as bark harvesting sites for multiple generations. Some ITK holders have noted that the bark today appears different, and drier, from in the past despite its roots growing near rivers. Some will no longer harvest balsam bark from the area. An ITK holder noted that the area around the Eight Lakes appears to have been logged in recent years, removing balsam and birch stands. The encroachment of very young blueberry plants in burned areas suggests that this change is recent (FCM ITK holder, FCM 2019). One ITK holder remembers:

> *"At that time the balsam trees weren't big, as I could remember. Now they were—they're growing, they're big ones. But the bark looks dry. Don't look like the way a balsam bark should look. Balsam bark is kind of smooth and then there's bumps, pebbles where the pitch is in, eh. I looked at it and I said, well, the roots reach the river, so they can't be dry, like with no water. But what was in the water that made the tree like that, is what I thought. Those trees didn't look right. They just looked like they were—I didn't take the bark because it didn't look healthy. Who knows where I got to go now for balsam bark."* (FMFN ITK holder about a visit in 2009, IEG 2021)

Harebell is another important medicinal plant harvested by Indigenous Peoples that is tied to water availability. It is found on higher ground and in sandy soil. The roots of the plant are harvested and are a good indicator of water table height. As the water table changes, so too do the medicinal plants that rely on it (IEG 2021). The presence of grasses and cattails along the shore in new locations not observed in the past suggests to some ITK holders that the areas in and around McClelland Lake are drying in recent years. Similarly, willows act as a good indicator of water level, growing along the shoreline. In recent years, fewer willows have been present around the shore of McClelland Lake, which some ITK holders have attributed to water level drawdown and overall drying of the site. ITK holders have noted that sphagnum moss is important for water retention during the drier summer months, and acts as a natural deterrent for fires. There is concern that, should the wetlands begin to dry up, that the moss will die and the area will become a fire hazard (IEG 2021). One ITK holder remembers:

> *"You know, water doesn't do any good unless there's something there to bind it together to keep it moist during the dry periods, you know? Because we probably all have things growing in our garden or outside. Well, you let it dry out, it's dead. That's it. So that moss gives it a buffer zone. Not a buffer zone, but a slow release of moisture over dry periods. So you drain the stuff out, it*

dies. Then you have one—peat moss, it's—when it's dry, it's a bad fire hazard, but when it's wet, keep it wet, you got a natural fire barrier." (FCM ITK holder, FCM 2019)

An excerpt from IEG 2021 summarizes observations from ITK holders regarding the current state of many of the plant species harvested:

> *"Since the 1960s, participants have noticed many negative changes to culturally important plant species. For example, some medicinal plants are now very rare or are no longer available within the McClelland Lake Wetland Complex and surrounding area. Other plants that are available have changed. For example, some plants ripen at abnormal times of the year and may have different textures, or taste. When participants observe these changes, they question the plant's health and purity. One member described how many of her family's historic berry patches are now gone due to industry and that her children and that her children will not have the opportunity to experience and visit them. Members have also observed that the cranberries and blueberries are smaller and drier than in the past. Members are concerned about the safety of berries for consumption, and whether they are contaminated by chemicals. Members identified that the condition and location of plants within an area does naturally change over time; however, the changes they have observed in the past few decades are beyond their expectations"* (FMFN ITK holder, IEG 2021).

ITK holders have noted the rich biodiversity found in the MLWC during the pre-development baseline. Some ITK holders continue to harvest plants, although they have stated there has been a decline in quality observed since the onset of industry. One ITK holder noted that she does not collect and eat any berries anymore from around McClelland Lake because of concerns around emissions and contaminants, or collect medicinal balsam bark blisters because they look unhealthy and dry. The reduction in biodiversity of plants includes some rare medicinal plants that are now very rare or no longer available within the MLWC and adjacent areas (FCM ITK Holder, FCM 2019). Once culturally important plants disappear, it is difficult to bring them back (IEG 2021).

2.5.9.2.1. Methods

String, Flark, and Wooded Fen Vegetation Data

Data from 36 permanent plots (18 different sites) in string, flark, and wooded fen site types were included in the pre-mining baseline vegetation analysis for MLWC. Prior to data analysis, potential issues of changing or incorrect species identification were recognized in the dataset and species were standardized between years within sites, when applicable (Table B1 in Golder 2018). Additional species identification issues not included in Golder (2018) were also updated in the dataset and are shown in Table 2.5-24. During future vegetation monitoring events, efforts will be made to calibrate field survey crews as described by U.S. EPA (2019) to minimize similar issues in the vegetation dataset moving forward.

Prior to calculating species richness or diversity, taxa identified to the genus level (e.g., *Carex* sp.) were removed from the dataset if other taxa within the genus had been identified to species. Percent cover was averaged for each site and year combination to avoid pseudoreplication at the subplot level. Means are reported at the site type level (i.e., string, flark, or wooded fen type).

Species richness refers to the number of species within a sample unit and provides a metric for assessing relative differences in species composition among sample units and through time, independent of abundance (percent cover). Presence/absence data were used to calculate species richness. Species diversity is a description of the number of different species in a community, and incorporates both the number of species and the evenness of the species' abundances. Shannon's diversity index is defined as the proportion of species relative to the total number of species, whereas Simpson's diversity index is defined as the probability of selecting two organisms at random that are different species (Magurran 1988) and it places less emphasis on rare species than Shannon's diversity index.

Table 2.5-24: Additional Changes to Species Names in the McClelland Lake Wetland Complex Vegetation Dataset

Initial Name	Updated Name	Number of Occurrences	Rationale
Calamagrostis canadensis	*Calamagrostis* sp.	32	Identification often alternated between years; if identifications are confirmed in the field, the correct ID could be assigned to all years.
Calamagrostis purpurascens		2	
Calamagrostis stricta		59	
Calamagrostis stricta ssp. inexpansa		27	
Carex retrorsa	*Carex diandra*	16	Species was only identified in 2008; ID for remaining years for those plots was *Carex diandra* across all years.
Epilobium glaberrimum	*Epilobium palustre*	4	Species was only identified in 2009; ID for remaining years for those plots was *Epilobium palustre* across all years.
Polytrichum juniperinum	*Polytrichum strictum*	1	Species was only identified in 2013; ID for remaining years for that plot was *Polytrichum strictum* across all years.
Sparganium natans	*Sparganium angustifolium*	7	Based on subplot data from other years.
Sparganium sp.		8	
Sparganium fluctuans	*Sparganium angustifolium*	1	
Sparganium fluctuans	*Sparganium natans*	7	
Sphagnum balticum	*Sphagnum angustifolium*	1	Species was only identified in 2018; ID for remaining years for that plot was *Sphagnum angustifolium* across all years.
Sphagnum cf. *isoviitae*	*Sphagnum angustifolium*	2	Based on subplot data from other years; species was only identified in 2018.
Sphagnum cf. *isoviitae*	*Sphagnum warnstorfii*	2	
Sphagnum cf. *isoviitae*	*Sphagnum* sp.	2	
Sphagnum fuscum	*Sphagnum warnstorfii*	1	Based on subplot data from other years.
Sphagnum squarrosum	*Sphagnum warnstorfii*	1	Based on subplot data from other years.
Sphagnum teres	*Sphagnum warnstorfii*	3	Based on subplot data from other years.
Stellaria calycantha	*Stellaria* sp.	1	Identification often alternated between years; if identifications are confirmed in the field, the correct ID could be assigned to all years.

ID = identification.

Species diversity metrics were calculated using the Vegan package (Oksanen et al. 2020) in R version 4.0.3 (R Core Team 2020). Diversity metrics included species richness at the site scale (i.e., alpha [α] diversity) and the landscape scale (i.e., gamma [γ] diversity), Shannon's diversity index, and Simpson's diversity index. Site-scale diversity was calculated as the mean number of species within each site type for each year, and landscape-scale diversity was calculated as the total number of species recorded each year for each site type. Additionally, a suite of diversity metrics was calculated using a similar method to diversity analyses reported by Armada (2019), as outlined in Section 2.5.1.

Four indicator species groups were identified based on known species habitat preferences and EHZ fidelity (Vitt and House 2020), and communications with Dale Vitt (Vitt 2020, pers. comm.). The four plant indicator species groups are defined as follows:

- string indicators (i.e., *Betula pumila* [dwarf birch], *Larix laricina* [larch], *Tomentypnum nitens*)
- moderate-rich fen water chemistry indicators (i.e., *Hamatocaulis vernicosus*, *Epilobium palustre* [marsh willowherb], *Carex diandra* [two-stamened sedge])
- extreme-rich fen water chemistry indicators (i.e., *Scorpidium scorpioides*, *Meesia triquetra*, *Triglochin maritima* [seaside arrow-grass])
- eutrophication indicators (i.e., *Typha latifolia* [cattail])

Percent cover for each indicator species group within each plot was estimated by summing cover values for each species within each group. Mean cover values were calculated for each site-year combination for comparison to normal ranges.

Normal ranges were calculated for each of the fen types (i.e., wooded fen, string, and flark) across all years using R version 4.0.3 (R Core Team 2020), following the methods outlined in Section 2.5.1. Mean values were calculated for the four diversity indices (i.e., site-scale species richness [α], landscape-scale species richness [γ], Shannon's diversity index, and Simpson's diversity index), three additional diversity values (i.e., diversity profile using q values of 0, 2, and 5), and cover of the four indicator species groups for each fen type in each year (2008-2018). Mean values for all parameters were compared to the normal range for each parameter within each fen type.

String and Flark Vegetation Data Stratified by Ecohydrology Zone

Data were stratified by EHZ and were analysed using similar methodology to those described above. Vegetation data from string and flark site types were included in the analysis, and these were separated into sites located in EHZ 1 (i.e., T1F/T1S and X1F/X1S) and EHZ 2 (i.e., W2F/W2S, S3F/S3S, S7F/S7S, and S6F/S6S). Normal ranges were calculated for string and flark fen types across all years using R version 4.0.3 (R Core Team 2020) following the methods outlined at the beginning of Section 2.5. Mean values were calculated for the four diversity indices, three additional diversity values, and cover of the four indicator species groups for each fen type in each year (2008-2018). Mean values for all parameters were compared to the normal range for each parameter within each fen type.

2.5.9.2.2. Results and Discussion

Overview of MLWC Ecohydrology Zone 1 and 2 Vegetation Patterns

Unless otherwise noted, results in Section "Overview of MLWC Ecohydrology Zone 1 and 2 Vegetation Patterns" are derived from Vitt and House (2020) or Birks et al. (2019). As a component of Phase 2 of the MLWC Paleoenvironmental Study, a grid of 64 evenly spaced points was utilized to locate string and flark plots where water chemistry, water height, and species abundance data were measured. Both plant species and surface water chemistry were variable across the lower fen (i.e., the future non-mined area in EHZs 1 and 2), mostly varying across a north-south direction, with dominant plant species following distributions that are closely linked to meso-wetness (strings versus flarks) and/or base cation concentrations.

Chemistry varied from base cation rich waters in the south (i.e., EHZ 2) with lower concentrations northward (i.e., EHZ 1). Specifically, Ca^{+2} concentrations were 63-74 mg/L in EHZ 2 vs. 31-34 mg/L in EHZ 1; Mg^{+2} concentrations were 29-37 mg/L in EHZ 2 vs. 9-13 mg/L in EHZ 1; Na^{+} concentrations were 7-9 mg/L in EHZ 2 vs. 3-4 mg/L in EHZ 1; and K^{+} concentrations were 4-7 mg/L in EHZ 2 vs. 2-3 mg/L in EHZ 1. Areas to the south had double the specific conductance as those farther north (i.e., 393-448 µS/cm in EHZ 2 vs. 153-189 µS/cm in EHZ 1). Although pH had little variation, there was a significant downward gradient to the north (i.e., 7.7-7.9 in EHZ 2 vs. 7.2-7.3 in EHZ 1). Likewise, plant species had distributions along a north/south gradient, with species characteristic of extreme-rich fens dominating to the south, while those with high abundance in moderate-rich fens dominated to the north. For example, *Carex diandra* (two-stamened sedge), *Comarum palustris* (marsh cinquefoil), *Epilobium palustre* (marsh willowherb), *Hamatocaulis vernicosus*, and species of *Sphagnum* were more abundant where base cations were found at low concentrations (i.e., EHZ 1), while *Triglochin maritima* (seaside arrow-grass), *Meesia triquetra*, *Scorpidium scorpioides,* and alkaline sentinel species of bryophytes (*Aneura pinguis, Meesia triquetra, Pseudocalliergon trifarium, Scorpidium cossonii, Scorpidium revolvens,* and *Scorpidium scorpioides*) were more abundant where base cations were found at higher concentrations (i.e., EHZ 2). In general, the area along the northern edge of EHZ 2 along with EHZ 1 were considerably different from the remainder of EHZ 2. There was little variation along the east/west direction of the southern fen, while some species distributions varied along this direction in the northern fen.

Water chemistry changes in the direction of lower pH and lower base cation concentrations may create conditions unfavourable for the extreme-rich fen species currently predominating in the southern portion of the fen and absent from the northern areas. Conversely, changes that increase pH and base cation concentrations would have less effect on the northern species, as they currently also occur in the southern area where higher concentrations of base cations are found.

Vegetation assemblages also varied between flarks and strings. Species diversity was higher in strings at both the plot (alpha) and landscape (gamma) level, likely due to higher structural and elevational complexity in these habitats compared to flarks. For example, *Tomentypnum nitens, Larix laricina*, and species of *Sphagnum* were abundant when water levels were below the ground layer surface, while *Scorpidium scorpioides*, alkaline bryophytes, and *Menyanthes trifoliata* occurred where water levels were between 8 cm below to 5 cm above the ground layer. A rise in the fen water table could negatively impact some of the species on strings, as these species do not inhabit flarks; however, a lowered water table may not have as much of a negative effect on plant diversity. Thus, changes in vegetation species assemblages can indicate changes in either base cation concentrations or water levels.

String, Flark, and Wooded Fen Vegetation Data

Vegetation datasets collected at MLWC from 2008 to 2018 were used to characterize pre-mining baseline conditions and define the MRV. Results of seven vegetation diversity metrics and four indicator species groups for pre-mining baseline conditions are presented in Table 2.5-25, Table 2.5-26, and Table 2.5-27.

Table 2.5-25: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for Wooded Fen Sites from 2008 to 2018

Parameter	2008 (2)	2009 (6)	2010 (6)	2011 (-)	2012 (6)	2013 (6)	2014 (6)	2015 (-)	2016 (6)	2017 (6)	2018 (6)
	Year[a] (sample size)[b]										
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)										
Species Richness [α][c]	Normal Range Lower Bound: 36.7; Normal Range Upper Bound: 55.0										
	48.5 (5.5)	50.2 (2.4)	47.2 (4.0)	-	43.0 (2.1)	44.2 (2.9)	42.2 (3.1)	-	48.0 (3.1)	44.8 (2.6)	46.3 (2.5)
Species Richness [γ][d]	Normal Range Lower Bound: 76; Normal Range Upper Bound: 118										
	66	115	108	-	101	92	87	-	107	95	101
Shannon's Diversity Index	Normal Range Lower Bound: 16.5; Normal Range Upper Bound: 26.5										
	24.5 (2.2)	22.0 (1.4)	19.2 (1.9)	-	19.9 (1.0)	23.7 (2.0)	20.4 (1.6)	-	23.7 (1.5)	21.2 (1.1)	21.0 (1.6)
Simpson's Diversity Index	Normal Range Lower Bound: 0.87; Normal Range Upper Bound: 0.95										
	0.94 (0.01)	0.93 (0.01)	0.91 (0.01)	-	0.92 (0.01)	0.93 (0.01)	0.92 (0.01)	-	0.93 (0.01)	0.93 (0.00)	0.92 (0.01)
Diversity Profile q=0	Normal Range Lower Bound: 7.2; Normal Range Upper Bound: 11.9										
	10.1 (0.7)	10.3 (0.3)	10.0 (0.4)	-	9.1 (0.4)	8.9 (0.5)	9.0 (0.6)	-	9.7 (0.5)	10.0 (0.5)	9.5 (0.4)
Diversity Profile q=2	Normal Range Lower Bound: 1.8; Normal Range Upper Bound: 6.0										
	4.2 (0.3)	3.7 (0.3)	3.4 (0.2)	-	3.2 (0.3)	4.4 (0.5)	4.5 (0.6)	-	3.6 (0.4)	4.1 (0.5)	4.1 (0.4)
Diversity Profile q=5	Normal Range Lower Bound: 1.5; Normal Range Upper Bound: 4.7										
	3.2 (0.2)	2.9 (0.3)	2.7 (0.2)	-	2.6 (0.2)	3.5 (0.4)	3.6 (0.5)	-	2.8 (0.3)	3.2 (0.3)	3.4 (0.3)
String Indicator Species (% cover)	Normal Range Lower Bound: 13.4; Normal Range Upper Bound: 71.4										
	74.4 (10.8)	47.3 (10.6)	41.1 (8.9)	-	36.7 (10.8)	31.7 (8.4)	38.1 (10.1)	-	44.9 (10.8)	38.8 (10.0)	42.4 (12.0)
Moderate-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 45.1										
	21.3 (3.2)	15.4 (5.1)	21.9 (7.3)	-	23.0 (10.3)	17.6 (5.6)	6.0 (3.1)	-	25.2 (8.9)	28.7 (9.3)	21.1 (7.4)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 12.0										
	13.9 (3.4)	3.2 (1.7)	***14.0 (12.7)***	-	10.0 (6.9)	7.2 (4.4)	1.9 (0.9)	-	2.7 (1.1)	1.7 (0.7)	3.4 (1.7)
Eutrophication Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 3.1										
	3.2 (3.2)	0.5 (0.5)	0.5 (0.5)	-	0.4 (0.4)	1.1 (1.1)	1.0 (1.0)	-	0.9 (0.9)	0.6 (0.6)	0.5 (0.5)

(a) Data were not collected at wooded fen sites in 2011 or 2015.

(b) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(c) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(d) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

Note: **Bolded** and *italicized* numbers were outside the normal range bounds.

\- = no data; EHZ = Ecohydrology Zone.

Table 2.5-26: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for String Fen Sites from 2008 to 2018

Parameter	2008 (4)	2009 (6)	2010 (6)	2011 (-)	2012 (6)	2013 (6)	2014 (6)	2015 (-)	2016 (6)	2017 (6)	2018 (6)
	Year[a] (sample size)[b]										
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)										
Species Richness [α][c]	Normal Range Lower Bound: 32.7; Normal Range Upper Bound: 55.9										
	40.5 (2.4)	45.0 (3.6)	46.5 (4.5)	-	45.7 (3.3)	44.2 (4.3)	40.8 (3.4)	-	45.2 (2.9)	44.0 (4.7)	45.2 (4.4)
Species Richness [γ][d]	Normal Range Lower Bound:77; Normal Range Upper Bound: 97										
	74	***98***	89	-	89	90	78	-	86	89	89
Shannon's Diversity Index	Normal Range Lower Bound: 14.1; Normal Range Upper Bound: 30.5										
	18.6 (1.1)	20.2 (2.4)	18.1 (2.3)	-	21.9 (2.6)	23.6 (3.7)	22.3 (3.2)	-	23.8 (2.0)	21.4 (3.2)	22.3 (3.4)
Simpson's Diversity Index	Normal Range Lower Bound: 0.87; Normal Range Upper Bound: 0.97										
	0.92 (0.00)	0.92 (0.01)	0.90 (0.01)	-	0.92 (0.01)	0.93 (0.01)	0.93 (0.01)	-	0.93 (0.01)	0.93 (0.01)	0.92 (0.01)
Diversity Profile q=0	Normal Range Lower Bound: 7.5; Normal Range Upper Bound: 11.0										
	8.7 (0.1)	9.3 (0.3)	9.4 (0.4)	-	8.9 (0.3)	8.4 (0.5)	7.6 (1.1)	-	9.0 (0.5)	9.0 (0.4)	8.5 (0.3)
Diversity Profile q=2	Normal Range Lower Bound: 2.6; Normal Range Upper Bound: 6.1										
	3.8 (0.1)	4.1 (0.1)	4.1 (0.3)	-	3.8 (0.2)	5.0 (0.3)	4.6 (0.5)	-	4.8 (0.2)	4.6 (0.3)	4.8 (0.4)
Diversity Profile q=5	Normal Range Lower Bound: 2.2; Normal Range Upper Bound: 5.0										
	3.1 (0.1)	3.3 (0.1)	3.3 (0.2)	-	3.1 (0.2)	4.1 (0.2)	3.9 (0.4)	-	3.9 (0.2)	3.7 (0.2)	3.8 (0.4)
String Indicator Species (% cover)	Normal Range Lower Bound: 57.4; Normal Range Upper Bound: 91.4										
	65.1 (4.4)	74.1 (3.8)	74.0 (4.9)	-	65.0 (4.7)	67.3 (4.3)	84.3 (4.6)	-	76.2 (5.6)	76.6 (7.1)	81.9 (5.7)
Moderate-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 11.6; Normal Range Upper Bound: 54.0										
	20.2 (4.8)	27.9 (9.3)	41.1 (8.8)	-	35.5 (5.8)	22.6 (4.6)	21.8 (9.7)	-	31.6 (5.1)	38.9 (5.3)	29.7 (4.5)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 1.7; Normal Range Upper Bound: 19.7										
	22.1 (17.1)	6.8 (3.0)	10.9 (4.0)	-	9.8 (3.2)	6.2 (1.9)	9.9 (4.9)	-	7.1 (1.8)	7.4 (2.3)	5.0 (0.8)
Eutrophication Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 9.5										
	1.3 (1.3)	0.6 (0.5)	1.2 (0.6)	-	1.1 (0.8)	4.8 (1.5)	5.7 (2.3)	-	7.8 (3.0)	5.0 (1.9)	4.8 (1.6)

(a) Data were not collected at string fen sites in 2011 or 2015.

(b) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(c) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(d) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

Note: **Bolded** and *italicized* numbers were outside the normal range bounds.

\- = no data; EHZ = Ecohydrology Zone.

Table 2.5-27: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for Flark Fen Sites from 2008 to 2018

Parameter	2008 (4)	2009 (6)	2010 (6)	2011 (-)	2012 (6)	2013 (-)	2014 (-)	2015 (6)	2016 (6)	2017 (6)	2018 (6)
	Year[a] (sample size)[b]										
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)										
Species Richness [α][c]	Normal Range Lower Bound: 20.0; Normal Range Upper Bound: 37.2										
	22.5 (3.2)	27.7 (3.6)	28.8 (3.1)	-	31.3 (3.2)	-	-	31.0 (3.0)	30.0 (2.7)	29.0 (3.1)	30.7 (2.7)
Species Richness [γ][d]	Normal Range Lower Bound:44; Normal Range Upper Bound: 60										
	40	53	54	-	57	-	-	56	54	48	52
Shannon's Diversity Index	Normal Range Lower Bound: 6.7; Normal Range Upper Bound: 17.0										
	10.1 (2.2)	12.7 (1.9)	10.0 (1.4)	-	11.4 (1.9)	-	-	15.5 (1.3)	11.8 (1.2)	10.9 (1.6)	11.9 (1.6)
Simpson's Diversity Index	Normal Range Lower Bound: 0.64; Normal Range Upper Bound: 0.91										
	0.81 (0.06)	0.85 (0.04)	0.80 (0.06)	-	0.79 (0.05)	-	-	0.90 (0.01)	0.85 (0.02)	0.82 (0.03)	0.82 (0.04)
Diversity Profile q=0	Normal Range Lower Bound: 5.5; Normal Range Upper Bound: 8.1										
	7.4 (0.3)	7.3 (0.5)	7.0 (0.3)	-	6.3 (0.9)	-	-	7.0 (0.3)	7.0 (0.4)	7.3 (0.3)	7.2 (0.3)
Diversity Profile q=2	Normal Range Lower Bound: 2.1; Normal Range Upper Bound: 4.4										
	3.8 (0.3)	3.8 (0.2)	3.6 (0.2)	-	2.8 (0.3)	-	-	3.9 (0.2)	3.4 (0.2)	3.4 (0.1)	3.6 (0.2)
Diversity Profile q=5	Normal Range Lower Bound: 1.9; Normal Range Upper Bound: 4.1										
	3.3 (0.3)	3.3 (0.2)	3.2 (0.2)	-	2.4 (0.2)	-	-	3.5 (0.2)	2.9 (0.1)	2.9 (0.2)	2.9 (0.2)
String Indicator Species (% cover)	Normal Range Lower Bound: 1.5; Normal Range Upper Bound: 27.3										
	10.4 (7.7)	11.4 (6.3)	11.5 (4.8)	-	8.1 (4.1)	-	-	17.8 (7.5)	10.8 (4.2)	10.2 (4.3)	9.6 (2.9)
Moderate-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 9.4; Normal Range Upper Bound: 97.8										
	34.8 (24.8)	41.2 (15.2)	51.9 (15.0)	-	46.0 (10.7)	-	-	43.8 (15.6)	43.5 (15.6)	57.3 (14.7)	47.9 (13.5)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 2.3; Normal Range Upper Bound: 86.5										
	50.4 (17.8)	38.3 (11.1)	46.6 (13.6)	-	49.9 (13.8)	-	-	78.0 (14.9)	50.8 (14.5)	42.1 (13.4)	42.5 (13.3)
Eutrophication Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 2.0										
	0.1 (0.1)	0.2 (0.2)	0.2 (0.2)	-	0.5 (0.2)	-	-	1.4 (0.9)	1.1 (0.4)	1.4 (0.5)	0.6 (0.3)

(a) Data were not collected at flark fen sites in 2011, 2013 or 2014.

(b) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(c) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(d) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

Note: **Bolded** and *italicized* numbers were outside the normal range bounds.

\- = no data; EHZ = Ecohydrology Zone.

Four key vegetation diversity metrics were evaluated to assess plant species diversity: species richness at the site (α) and landscape (γ) scales, Shannon's diversity index, and Simpson's diversity index. While there was variation among years, site-scale (α) species richness, Shannon's diversity index, and Simpson's diversity index did not exceed the bounds of the normal range calculated for all fen types and years (Table 2.5-25, Table 2.5-26, and Table 2.5-27). Landscape-scale (γ) diversity for all fen types was below the lower bound of the normal range in 2008 and above the upper bound of the normal range for string fen types in 2009. The relatively low values from 2008 may be attributable to detection of fewer inconspicuous species compared to other years. Species richness at the site scale and diversity have remained within the normal range throughout the past ten years, which is useful for determining pre-mining baseline levels within wooded fens, flarks, and strings within the MLWC.

Three additional diversity measures were evaluated, following Armada (2019), to assess plant species diversity when accounting for species similarity; diversity was evaluated at q=0, q=2, and q=5. Similar to the other diversity metrics, there was variation among years, but diversity values for q=0, q=2, and q=5 were within the bounds of the normal range calculated for all fen types and years (Table 2.5-25 Table 2.5-26, and Table 2.5-27).

Normal ranges were used to assess total percent cover of species within the following indicator groups: string indicators, moderate-rich fen water chemistry indicators, extreme-rich fen water chemistry indicators, and eutrophication indicators. While there was variation among years, most of the percent cover values for these indicator groups were within calculated normal ranges (Table 2.5-25, Table 2.5-26, and Table 2.5-27) with a few exceptions. String indicator species exceeded the upper bound of the normal range in wooded fen types in 2008 Table 2.5-25), possibly because there was slightly higher cover of *Tomentypnum nitens* in 2008 in this fen type. Eutrophication indicator species exceeded the upper bound of the normal range in wooded fens in 2008 (Table 2.5-25); while *Typha latifolia* cover was similar at one site over multiple years, fewer plots were surveyed in 2008, which resulted in the overall mean appearing higher in 2008. Extreme-rich fen water chemistry indicators were above the upper bound of the normal range in wooded fens in 2008 and 2010 (Table 2.5-25) and strings in 2008 (Table 2.5-26). These high values appeared to be associated with higher values of *Meesia triquetra* and *Scorpidium scorpioides* cover in 2008 and 2010 (for wooded fens) relative to other years, possibly due to observer variability. No indicator groups exceeded the bounds of the normal range in flark fen types in any year (Table 2.5-27).

String fen types had wider normal ranges for Shannon's diversity indices compared to wooded fen and flark fen types, indicating that there is more natural variation in Shannon's diversity index for this fen type and it may not be as sensitive to changes in Shannon's diversity index as the other two fen types. However, wooded fen types had wider normal ranges for q=0, 2, and 5 compared to string and flark fen types, indicating that there is more natural variation in this fen type and it may not be as sensitive to changes in diversity as the other two fen types. In both cases, flark fen types appear to be more sensitive to changes in diversity. In all fen types, the normal ranges for eutrophication indicator species were relatively narrow and the upper limits were between 2.0 and 9.5% cover; this indicator group will likely be sensitive to increases in cover.

A few metrics had large standard errors due to differences in species cover between plots within fen types. In wooded fens, there were large standard errors for string indicator species in all years, and for extreme-rich fen water chemistry indicators in 2010. One string indicator, *Tomentypnum nitens*, and one extreme-rich fen water chemistry indicator, *Scorpidium scorpioides*, had relatively high cover in one plot and relatively low cover in the other plots in the years that had high standard errors. However, inclusion of the string indicator group and the extreme-rich fen water chemistry indicator group was intended for contrast with the moderate-rich fen water chemistry indicator group in strings and flarks, and changes in abundance of extreme-rich fen water chemistry indicators within wooded fens is not expected to be a sensitive indicator of change for the effects monitoring program.

In string fen types, extreme-rich fen water chemistry indicators had a large standard error in 2008, likely due to high cover of *Meesia triquetra* and *Scorpidium scorpioides* in only one plot each. In flark fen types, there were large standard errors for both moderate-rich and extreme-rich fen water chemistry indicators in all years. One moderate-rich fen water chemistry indicator, *Hamatocaulis vernicosus*, and one extreme-rich fen water chemistry indicator, *Scorpidium scorpioides*, had relatively high cover in one plot and relatively low cover in the other plots that had high standard errors. The variation among plots is greater than the affinity of a species to a particular assigned indicator grouping. Variation in cover of species in moderate-rich and extreme-rich fen water chemistry indicator groups among plots may indicate that stratification by EHZ may need to be taken into consideration, in addition to fen type (i.e., wooded, string, flark), during analyses.

String and Flark Vegetation Data Stratified by Ecohydrology Zone

Results for seven vegetation diversity metrics and four indicator species groups, stratified by EHZ for string and flark sites, are presented in Table 2.5-28, Table 2.5-29, Table 2.5-30, and Table 2.5-31, below. Four key vegetation diversity metrics and three additional vegetation diversity values were evaluated to assess plant species diversity: species richness at the site (α) and landscape (γ) scales, Shannon's diversity index, Simpson's diversity index, and diversity at q=0, q=2, and q=5. Similar to results for the unstratified vegetation dataset (described in the previous section), there was variation among years, but diversity values did not exceed the bounds of the normal range calculated for the fen types in EHZ 1 and 2 (Table 2.5-28, Table 2.5-29, Table 2.5-30, and Table 2.5-31).

Normal ranges were used to assess total percent cover of species within the following indicator groups: string indicators, moderate-rich fen water chemistry indicators, extreme-rich fen water chemistry indicators, and eutrophication indicators. While there was variation among years, most of the percent cover values for these indicator groups were within calculated normal ranges (Table 2.5-28, Table 2.5-29, Table 2.5-30, and Table 2.5-31) with a few exceptions. Extreme-rich fen water chemistry indicators exceeded the upper bound of the normal range in string fen types in EHZ 2 in 2008 (Table 2.5-30), which was also noted in the unstratified vegetation dataset. Eutrophication indicators exceeded the upper bound of the normal range in string fen types in EHZ 2 in 2016 (Table 2.5-30), likely due to observer variability, as cover of *Typha latifolia* was relatively constant in years preceding and following 2016. String indicator species were below the lower bound of the normal range in flark fen types in EHZ 1 in 2008 (Table 2.5-29), likely because only one site was surveyed in this fen type in this EHZ in 2008. This site had low cover of string indicator species in all years, resulting in the overall mean appearing higher in subsequent years when an additional site was surveyed. This was likely not captured in the unstratified vegetation dataset as more sites were included, likely resulting in the mean cover of string indicator species appearing higher in 2008. Overall, stratifying the dataset into EHZ had minimal impacts on exceedances of the normal ranges, which is not surprising since these data represent pre-mining conditions.

Table 2.5-28: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for String Fen Sites from 2008 to 2018 in Ecohydrology Zone 1

Parameter	Year[a] (sample size)[b]										
	2008 (1)	**2009 (2)**	**2010 (2)**	**2011 (-)**	**2012 (2)**	**2013 (2)**	**2014 (2)**	**2015 (-)**	**2016 (2)**	**2017 (2)**	**2018 (2)**
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)										
Species Richness [α][c]	Normal Range Lower Bound: 27.3; Normal Range Upper Bound: 42.5										
	34.0 (NA)	34.5 (1.5)	33.0 (1.0)	-	38.5 (2.5)	32.5 (1.5)	31.0 (1.0)	-	39.0 (2.0)	35.0 (4.0)	36.0 (3.0)
Species Richness [γ][d]	Normal Range Lower Bound: 30; Normal Range Upper Bound: 58										
	34	44	41	-	54	42	41	-	50	45	46
Shannon's Diversity Index	Normal Range Lower Bound: 9.5; Normal Range Upper Bound: 21.9										
	15.8 (NA)	14.4 (1.0)	11.6 (1.3)	-	17.3 (3.6)	13.9 (0.4)	14.9 (0.7)	-	19.0 (1.1)	17.7 (1.0)	16.7 (2.2)
Simpson's Diversity Index	Normal Range Lower Bound: 0.85; Normal Range Upper Bound: 0.95										
	0.91 (NA)	0.89 (0.01)	0.86 (0.02)	-	0.90 (0.03)	0.89 (0.01)	0.90 (0.01)	-	0.92 (0.01)	0.92 (0.01)	0.91 (0.01)
Diversity Profile q=0	Normal Range Lower Bound: 7.0; Normal Range Upper Bound: 9.5										
	8.4 (NA)	9.0 (0.5)	8.4 (0.1)	-	8.0 (0.3)	7.9 (0.4)	8.0 (0.5)	-	8.3 (0.5)	8.5 (0.6)	7.8 (0.3)
Diversity Profile q=2	Normal Range Lower Bound: 3.0; Normal Range Upper Bound: 6.0										
	3.7 (NA)	4.4 (0.3)	4.1 (0.4)	-	3.9 (0.6)	4.6 (0.6)	5.0 (0.2)	-	5.2 (0.6)	5.0 (0.3)	4.1 (0.4)
Diversity Profile q=5	Normal Range Lower Bound: 2.2; Normal Range Upper Bound: 5.2										
	3.0 (NA)	3.6 (0.2)	3.3 (0.3)	-	3.2 (0.5)	3.9 (0.6)	4.3 (0.3)	-	4.3 (0.7)	4.2 (0.3)	3.2 (0.5)
String Indicator Species (% cover)	Normal Range Lower Bound: 50.0; Normal Range Upper Bound: 91.4										
	72.7 (NA)	68.3 (4.6)	66.3 (5.1)	-	63.2 (4.4)	63.3 (11.7)	77.2 (6.8)	-	85.3 (1.4)	68.1 (4.9)	73.0 (6.5)
Moderate-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 4.8; Normal Range Upper Bound: 84.4										
	22.9 (NA)	52.9 (15.3)	66.7 (12.5)	-	47.5 (6.7)	30.3 (13.5)	42.4 (27.6)	-	42.3 (3.2)	50.3 (3.5)	35.0 (11.1)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 0.7; Normal Range Upper Bound: 5.5										
	0.8 (NA)	1.9 (0.7)	1.3 (0.7)	-	4.2 (2.2)	2.4 (0.1)	5.5 (1.0)	-	3.5 (0.8)	3.8 (1.0)	3.4 (0.6)
Eutrophication Indicator Species (% cover)	Normal Range could not be calculated										
	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

(a) Data were not collected at string fen sites in 2011 or 2015.

(b) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(c) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(d) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

\- = no data; EHZ = Ecohydrology Zone.

Table 2.5-29: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for Flark Fen Sites from 2008 to 2018 in Ecohydrology Zone 1

Parameter	Year[a] (sample size)[b]										
	2008 (1)	**2009 (2)**	**2010 (2)**	**2011 (-)**	**2012 (2)**	**2013 (-)**	**2014 (-)**	**2015 (2)**	**2016 (2)**	**2017 (2)**	**2018 (2)**
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)										
Species Richness [α][c]	Normal Range Lower Bound: 5.3; Normal Range Upper Bound: 39.6										
	13.0 (NA)	18.0 (6.0)	21.0 (6.0)	-	25.0 (7.0)	-	-	23.5 (5.5)	26.5 (7.5)	22.5 (7.5)	25.5 (7.5)
Species Richness [γ][d]	Normal Range Lower Bound: 10; Normal Range Upper Bound: 51										
	13	27	29	-	36	-	-	32	39	33	35
Shannon's Diversity Index	Normal Range Lower Bound: 0.1; Normal Range Upper Bound: 17.8										
	3.8 (NA)	7.5 (3.3)	7.1 (3.4)	-	9.5 (4.5)	-	-	13.2 (2.8)	9.7 (2.8)	9.3 (2.5)	8.7 (3.1)
Simpson's Diversity Index	Normal Range Lower Bound: 0.50; Normal Range Upper Bound: 1.0										
	0.63 (NA)	0.74 (0.10)	0.68 (0.16)	-	0.74 (0.13)	-	-	0.89 (0.02)	0.81 (0.04)	0.80 (0.06)	0.74 (0.08)
Diversity Profile q=0	Normal Range Lower Bound: 5.0; Normal Range Upper Bound: 7.5										
	6.5 (NA)	5.9 (0.4)	6.0 (0.3)	-	6.3 (0.5)	-	-	6.1 (0.3)	5.9 (0.4)	6.5 (0.7)	6.6 (0.7)
Diversity Profile q=2	Normal Range Lower Bound: 2.5; Normal Range Upper Bound: 4.5										
	3.2 (NA)	3.7 (0.4)	3.5 (0.3)	-	3.2 (0.1)	-	-	3.6 (0.6)	3.4 (0.5)	3.7 (0.1)	3.3 (0.2)
Diversity Profile q=5	Normal Range Lower Bound: 2.1; Normal Range Upper Bound: 4.0										
	3.0 (NA)	3.4 (0.3)	3.1 (0.2)	-	2.8 (0.1)	-	-	3.2 (0.7)	3.0 (0.4)	3.3 (0.0)	2.5 (0.1)
String Indicator Species (% cover)	Normal Range Lower Bound: 0.8; Normal Range Upper Bound: 15.2										
	0.5 (NA)	4.8 (3.8)	8.8 (7.3)	-	3.8 (2.8)	-	-	6.8 (1.8)	9.4 (7.4)	6.9 (3.9)	5.3 (1.3)
Moderate-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 48.2; Normal Range Upper Bound: 100.0										
	100.0 (NA)	83.1 (26.2)	96.7 (5.7)	-	72.7 (8.5)	-	-	88.5 (25.0)	88.8 (15.1)	92.9 (9.4)	87.7 (5.4)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 0.8; Normal Range Upper Bound: 28.3										
	2.7 (NA)	3.7 (2.7)	5.5 (5.0)	-	8.0 (7.0)	-	-	42.9 (36.4)	5.8 (3.5)	5.0 (1.8)	4.8 (3.8)
Eutrophication Indicator Species (% cover)	Normal Range could not be calculated										
	0.0 (NA)	0.0 (0.0)	0.0 (0.0)	-	0.0 (0.0)	-	-	0.0 (0.0)	0.5 (0.5)	1.0 (1.0)	0.3 (0.3)

(a) Data were not collected at flark fen sites in 2011, 2013 or 2014.

(b) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(c) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(d) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

Note: **Bolded** and *italicized* numbers were outside the normal range bounds.

- = no data; EHZ = Ecohydrology Zone.

Table 2.5-30: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for String Fen Sites from 2008 to 2018 in Ecohydrology Zone 2

Parameter	2008 (3)	2009 (4)	2010 (4)	2011 (-)	2012 (4)	2013 (4)	2014 (4)	2015 (-)	2016 (4)	2017 (4)	2018 (4)
	Year[a] (sample size)[b]										
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)										
Species Richness [α][c]	Normal Range Lower Bound: 41.1; Normal Range Upper Bound: 58.2										
	41.7 (1.5)	50.0 (2.3)	53.3 (2.3)	-	49.3 (3.6)	50.0 (3.5)	45.8 (1.9)	-	48.3 (3.2)	48.5 (5.7)	50.5 (4.9)
Species Richness [γ][d]	Normal Range Lower Bound: 62; Normal Range Upper Bound: 99										
	64	89	86	-	82	85	74	-	78	83	83
Shannon's Diversity Index	Normal Range Lower Bound: 17.9; Normal Range Upper Bound: 32.5										
	19.2 (0.8)	23.1 (2.4)	24.1 (1.3)	-	24.2 (3.0)	28.4 (3.4)	26.1 (3.3)	-	26.1 (2.1)	23.2 (4.7)	25.3 (4.5)
Simpson's Diversity Index	Normal Range Lower Bound: 0.90; Normal Range Upper Bound: 0.97										
	0.92 (0.00)	0.93 (0.01)	0.92 (0.01)	-	0.93 (0.01)	0.94 (0.01)	0.94 (0.01)	-	0.94 (0.01)	0.93 (0.01)	0.93 (0.01)
Diversity Profile q=0	Normal Range Lower Bound: 7.6; Normal Range Upper Bound: 11.9										
	8.8 (0.1)	9.5 (0.4)	9.8 (0.4)	-	9.4 (0.3)	8.7 (0.8)	8.9 (0.8)	-	9.3 (0.6)	9.2 (0.5)	8.9 (0.4)
Diversity Profile q=2	Normal Range Lower Bound: 3.3; Normal Range Upper Bound: 6.7										
	3.9 (0.2)	4.0 (0.1)	4.0 (0.4)	-	3.8 (0.2)	5.2 (0.4)	5.2 (0.2)	-	4.6 (0.1)	4.4 (0.4)	5.1 (0.5)
Diversity Profile q=5	Normal Range Lower Bound: 2.7; Normal Range Upper Bound: 5.4										
	3.2 (0.1)	3.2 (0.1)	3.3 (0.3)	-	3.1 (0.2)	4.2 (0.2)	4.3 (0.2)	-	3.7 (0.1)	3.4 (0.2)	4.2 (0.4)
String Indicator Species (% cover)	Normal Range Lower Bound: 46.2; Normal Range Upper Bound: 100.0										
	62.6 (5.0)	77.0 (5.0)	77.9 (6.4)	-	65.8 (7.1)	69.3 (4.4)	87.9 (5.7)	-	71.7 (7.5)	80.8 (10.2)	86.3 (7.3)
Moderate-Rich Fen Indicator Species (% cover)	Normal Range Lower Bound: 1.0; Normal Range Upper Bound: 45.7										
	19.3 (6.7)	15.3 (4.4)	28.4 (2.1)	-	29.6 (6.4)	18.7 (2.7)	11.5 (2.0)	-	26.2 (5.8)	33.2 (6.0)	27.0 (4.9)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 3.1; Normal Range Upper Bound: 24.8										
	29.2 (22.0)	9.3 (4.0)	15.6 (4.2)	-	12.6 (4.0)	8.1 (2.3)	12.1 (7.4)	-	8.9 (2.2)	9.2 (3.2)	5.9 (1.0)
Eutrophication Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 10.4										
	1.7 (1.7)	0.8 (0.7)	1.8 (0.6)	-	1.7 (1.1)	7.2 (0.5)	8.5 (2.3)	-	***11.8 (2.6)***	7.4 (1.7)	7.2 (0.9)

(a) Data were not collected at string fen sites in 2011 or 2015.

(b) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(c) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(d) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

Note: **Bolded** and *italicized* numbers were outside the normal range bounds.

\- = no data; EHZ = Ecohydrology Zone.

Table 2.5-31: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for Flark Fen Sites from 2008 to 2018 in Ecohydrology Zone 2

Parameter	Year[a] (sample size)[b]										
	2008 (3)	2009 (4)	2010 (4)	2011 (-)	2012 (4)	2013 (-)	2014 (-)	2015 (6)	2016 (4)	2017 (4)	2018 (4)
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)										
Species Richness [α][c]	Normal Range Lower Bound: 23.9; Normal Range Upper Bound: 40.9										
	25.7 (0.3)	32.5 (1.5)	32.8 (1.5)	-	34.5 (2.6)	-	-	34.8 (1.9)	31.8 (2.3)	32.3 (2.1)	33.3 (1.3)
Species Richness [γ][d]	Normal Range Lower Bound: 33; Normal Range Upper Bound: 60										
	37	49	51	-	51	-	-	52	45	42	44
Shannon's Diversity Index	Normal Range Lower Bound: 6.9; Normal Range Upper Bound: 19.7										
	12.2 (0.7)	15.4 (0.8)	11.4 (1.0)	-	12.3 (2.2)	-	-	16.6 (1.2)	12.9 (1.0)	11.7 (2.2)	13.4 (1.4)
Simpson's Diversity Index	Normal Range Lower Bound: 0.81; Normal Range Upper Bound: 0.91										
	0.87 (0.01)	0.90 (0.01)	0.85 (0.02)	-	0.82 (0.06)	-	-	0.90 (0.01)	0.86 (0.02)	0.83 (0.04)	0.86 (0.02)
Diversity Profile q=0	Normal Range Lower Bound: 1.3; Normal Range Upper Bound: 8.5										
	7.7 (0.2)	8.0 (0.2)	7.5 (0.1)	-	6.4 (1.3)	-	-	7.5 (0.2)	7.5 (0.3)	7.6 (0.2)	7.6 (0.1)
Diversity Profile q=2	Normal Range Lower Bound: 1.9; Normal Range Upper Bound: 4.5										
	4.0 (0.2)	3.8 (0.2)	3.6 (0.2)	-	2.7 (0.4)	-	-	4.1 (0.1)	3.4 (0.1)	3.2 (0.1)	3.7 (0.2)
Diversity Profile q=5	Normal Range Lower Bound: 1.8; Normal Range Upper Bound: 4.2										
	3.4 (0.3)	3.3 (0.2)	3.2 (0.2)	-	2.3 (0.3)	-	-	3.7 (0.1)	2.9 (0.1)	2.6 (0.1)	3.1 (0.3)
String Indicator Species (% cover)	Normal Range Lower Bound: 2.1; Normal Range Upper Bound: 33.7										
	13.7 (9.8)	14.7 (9.2)	12.9 (6.9)	-	10.3 (6.0)	-	-	23.3 (10.5)	11.5 (5.9)	11.9 (6.3)	11.8 (4.1)
Moderate-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 7.4; Normal Range Upper Bound: 49.6										
	10.2 (4.9)	20.2 (4.8)	29.5 (7.4)	-	32.7 (9.9)	-	-	21.4 (2.5)	20.9 (7.7)	39.6 (14.4)	28.0 (7.3)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 33.7; Normal Range Upper Bound: 100.0										
	66.3 (11.3)	55.6 (3.3)	67.1 (6.0)	-	70.9 (5.3)	-	-	95.5 (4.9)	73.2 (4.4)	60.7 (10.2)	61.3 (9.3)
Eutrophication Indicator Species (% cover)	Normal Range could not be calculated										
	0.2 (0.2)	0.3 (0.3)	0.3 (0.3)	-	0.8 (0.3)	-	-	2.2 (1.3)	1.4 (0.6)	1.5 (0.7)	0.8 (0.4)

(a) Data were not collected at flark fen sites in 2011, 2013 or 2014.

(b) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(c) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(d) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

\- = no data; EHZ = Ecohydrology Zone.

Flark fen types in EHZ 1 had wider normal ranges for richness (α and γ) and both Shannon's and Simpson's diversity, indicating that flark fen types in EHZ 1 may not be as sensitive to changes in diversity compared to string fen types in EHZ 1 and both fen types in EHZ 2. While there was no consistent pattern among widths of normal ranges for the seven diversity indices, results from the first four diversity indices indicate that strings may be more sensitive to changes in diversity, which is opposite of the results from the unstratified vegetation data. In contrast, results from the additional three diversity indices, were similar for stratified and unstratified vegetation data and suggest that flarks may be more sensitive to changes in diversity. In both cases, results varied by EHZ, indicating that natural variation between string and flark fen types likely varies by EHZ, and thus, it is important to consider EHZ in future monitoring programs.

String fen types in EHZ 1 and 2 had wider normal ranges for percent cover of string indicator species than flark fen types, indicating that there is more natural variation in string indicator species in string fen types compared to flark fen types. Additionally, normal ranges for string fen types in EHZ 1 and 2 were 50% to 91% and 46% to 100%, respectively, compared to 1% to 15% and 2% to 34% in flark fen types in EHZ 1 and 2, respectively. These results support this indicator species grouping, in which cover of string indicator species is higher in string fen types. There appears to be more natural variation in EHZ 2, indicating that there is also variation between the EHZs.

String and flark fen types in EHZ 1 had approximately double the width of the normal range for percent cover of moderate-rich fen water chemistry indicator species (5% to 84% and 48% to 100%, respectively) compared to string and flark fen types in EHZ 2 (1% to 46% and 7% to 50%). These results support this indicator species grouping, in which cover of moderate-rich fen water chemistry indicator species is higher in EHZ 1 compared to EHZ 2.

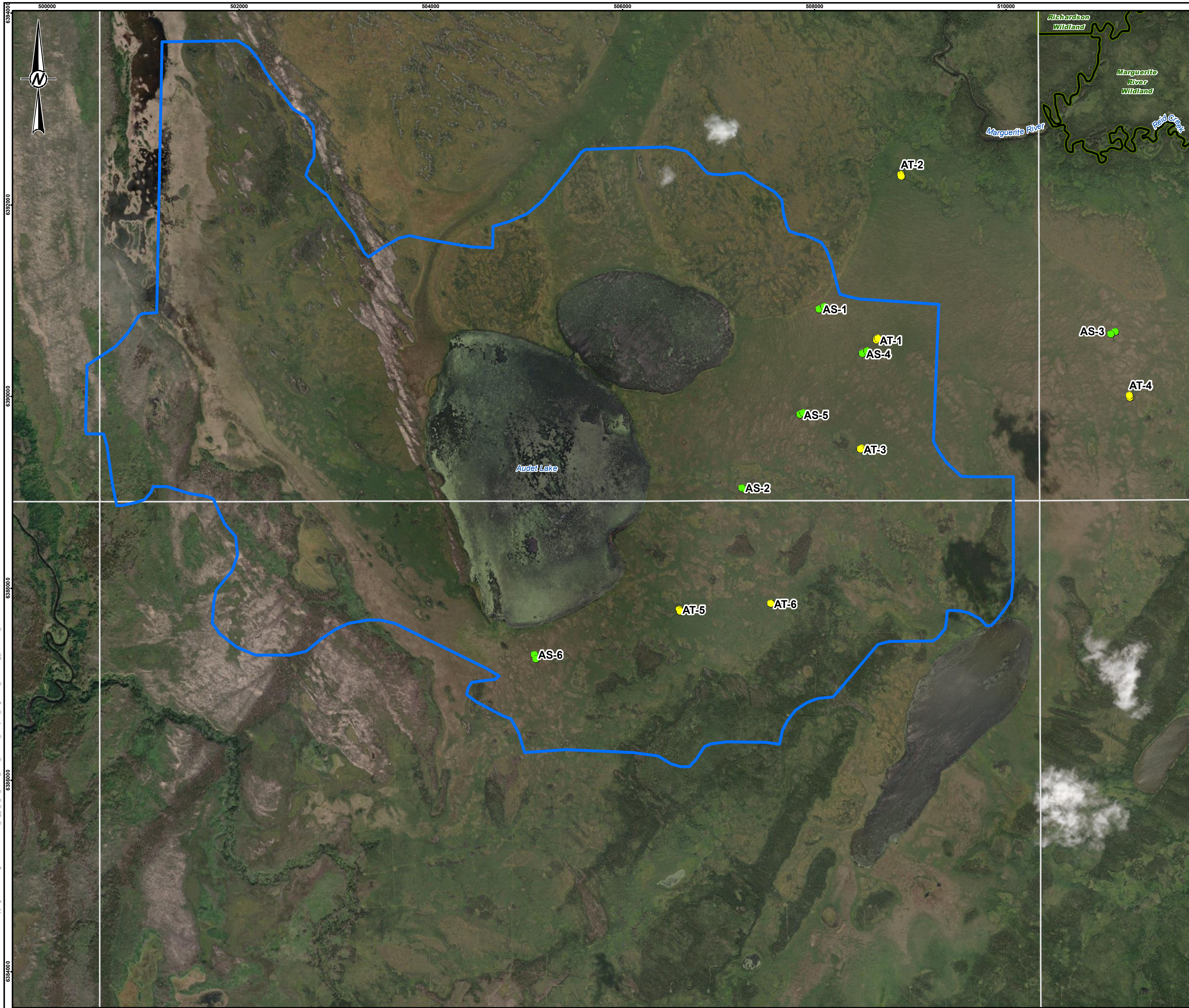
Flark fen types in EHZ 2 had a wider normal range for percent cover of extreme-rich fen water chemistry indicator species (34% to 100%) compared to string fen types in EHZ 2 (3% to 25%) or string or flark fen types in EHZ 1 (1% to 6% and 1% to 28%, respectively). These results support this indicator grouping for flark fen types in EHZ 2. However, there were similar levels of extreme-rich fen water chemistry indicator species in string fens types in EHZ 2 and flark fen types in EHZ 1, indicating differences in EHZs between the fen types.

Most sites in both fen types and EHZs had either no or limited cover of eutrophication indicator species; similar to results from the unstratified vegetation dataset, both fen types and EHZs will likely be sensitive to increases in cover for this indicator species group.

Additionally, a few metrics had large standard errors due to limited sample sizes and/or differences in species cover between plots within the fen types in each EHZ. Both string and flark fen types in EHZ 1 only included one site sampled in 2008 and two sites sampled in subsequent years. This limited the amount of variation captured and resulted in large standard errors, particularly for the indicator species groups. There were some additional large standard errors that were explained in the previous paragraph (e.g., extreme-rich fen water chemistry indicators in string fen types and moderate- rich and extreme-rich fen water chemistry indicators in flark fen types). While variation among plots can account for some differences within the indicator species groups, the cover of moderate- rich and extreme-rich fen water chemistry indicator species observed within each of the EHZ, as described above, indicate that the affinity of a species to its assigned indicator grouping is, for the most part, a good indicator within the respective fen types within each EHZ, particularly in EHZ 1.

2.5.9.3. Reference Site Baseline Conditions

Two potential reference wetland complexes were surveyed to evaluate their suitability as reference sites for the MLWC as a component of the BACI experimental design. Vegetation monitoring plots were added at the ALWC in 2012 (Figure 2.5-43); these plots were surveyed in 2012, 2013, 2014, 2017, and 2018 in addition to the plots at MLWC (Armada 2013a, 2014, 2015, 2018). Additional vegetation monitoring plots were added at the GGWC in 2015 (Figure 2.5-44); these plots were surveyed in 2015, 2016, 2017, and 2018 in addition to the plots at MLWC (Armada 2015, 2017, 2018).



LEGEND

PARK / PROTECTED AREA

WATERSHED BOUNDARY

WETLAND TYPES

WOODED FEN VEGETATION PLOT

STRING VEGETATION PLOT

0 1 2

1:40,000 KILOMETRES

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

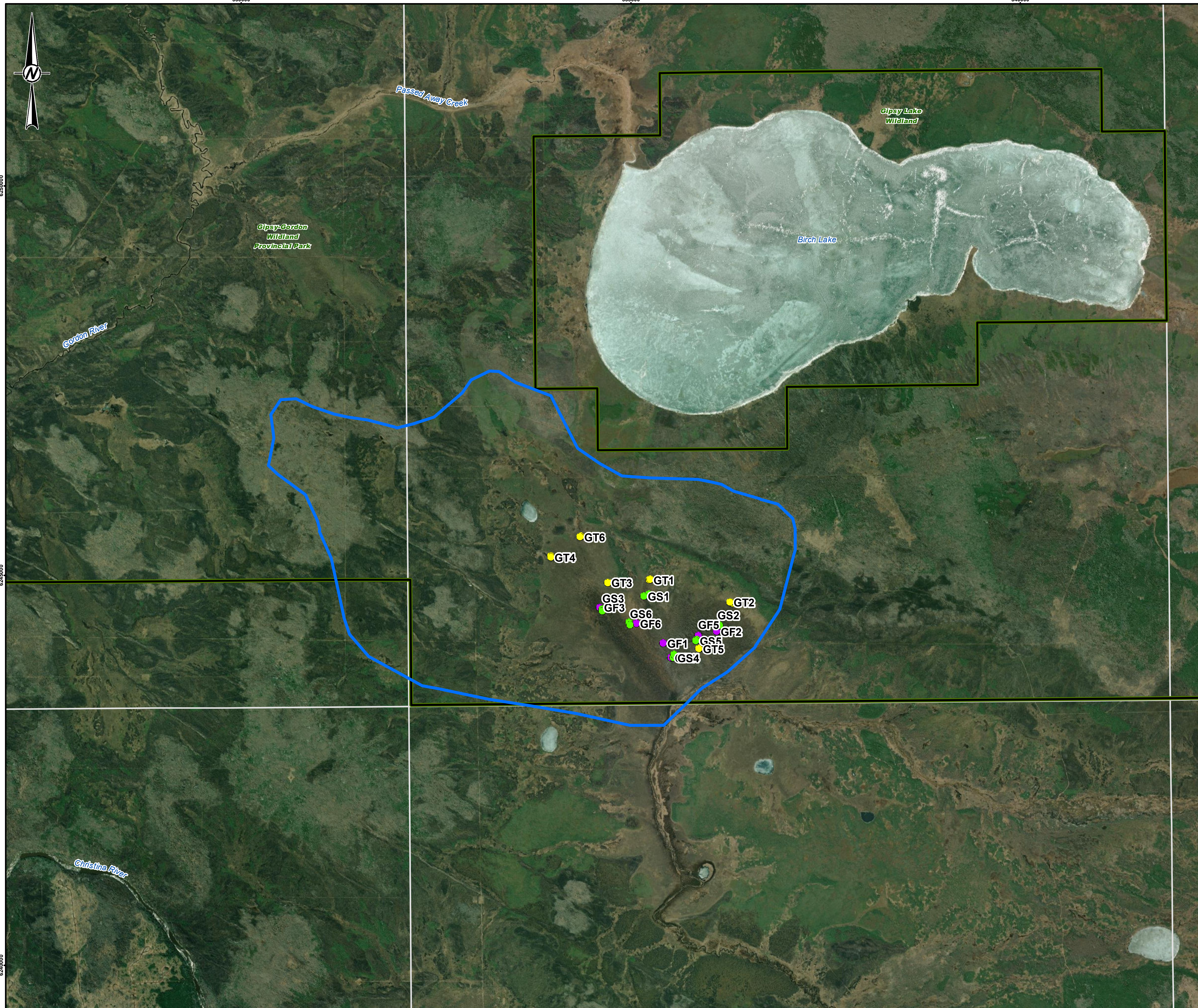
TITLE

AUDET LAKE WETLAND COMPLEX VEGETATION MONITORING LOCATIONS

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
DESIGNED	CZ
PREPARED	LB
REVIEWED	ZG
APPROVED	JH

PROJECT NO.	CONTROL	REV.	FIGURE
20140450		0	2.5-43



LEGEND

PARK / PROTECTED AREA

WATERSHED BOUNDARY

WETLAND TYPES

WOODED FEN VEGETATION PLOT

FLARK VEGETATION PLOT

STRING VEGETATION PLOT

0 1 2

1:50,000 KILOMETRES

REFERENCE(S)

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CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

McCLELLAND LAKE WETLAND COMPLEX - OPERATIONAL PLAN

TITLE

GIPSY GORDON WETLAND COMPLEX VEGETATION MONITORING LOCATIONS

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
DESIGNED	CZ
PREPARED	LB
REVIEWED	ZG
APPROVED	JH

PROJECT NO.	CONTROL	REV.	FIGURE
20140450		0	2.5-44

2.5.9.3.1. Methods

Parameters measured at all plots include:

- tree vigour
- percent cover of shrub species
- percent cover of forbs, graminoids, ferns/fern allies, dwarf woody plants, hepatics, bryophytes, and lichens
- physical characteristics including mean depth to water table, water conductivity, and pH

Data were analysed using similar methodology to those described in Section 2.5.1. Vegetation data from 24 permanent plots (12 different sites) in string and wooded fen types at ALWC, and from 36 permanent plots (18 different sites) in string, flark, and wooded fen types at GGWC were included in the reference site analyses. Prior to data analysis, potential issues of changing or incorrect species identification were recognized in the dataset and species were standardized between years within sites, when applicable (Table 2.5-32 and Table 2.5-33).

Plant community composition was assessed for each fen type within each wetland complex. Multivariate statistical procedures can be used to simultaneously examine the responses of many variables (e.g., species in a plant community) to multiple environmental gradients. Multi-response Permutation Procedure (MRPP) tests for significant differences between two or more groups for univariate or multivariate response variables and is similar mathematically to analysis of variance. The MRPP was used to assess differences among wetland complexes for each fen type separately, followed by post-hoc pairwise comparisons, using a Holm's adjustment.

Ordination is a type of multivariate analysis that provides a graphical means of assessing patterns in relationships between plant species and the underlying environmental gradients that may be influencing these patterns. Sample units that are similar to each other are grouped closer together on ordination axes, while those that are less similar appear farther apart. Non-metric Multidimensional Scaling (NMDS) 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 was used to visualize relationships among the plant communities surveyed in string, flark, and wooded fen types at MLWC, ALWC, and GGWC.

The MRPP was performed using the Bray-Curtis distance measure, with weight assigned based on group size (n), and with 999 permutations. The NMDS was performed using the Bray-Curtis distance measure with a random starting configuration, 250 runs with real data, and a maximum of 500 iterations. A Wisconsin double standardization was performed on the data to account for values larger than common abundance class scales. All MRPP analyses and NMDS ordinations were performed in the vegan package (Oksanen et al. 2020) using R (Version 4.0.3; R Core Team 2020).

Table 2.5-32: Changes to Species Names in the Audet Lake Wetland Complex Vegetation Dataset

Initial Name	Updated Name	Number of Occurrences	Rationale
Arboreal lichens *(Bryoria simplicior, Bryoria fuscescens, Ramalina pollinaria, Usnea lapponica, Vulpicida pinastri)*	Not applicable	8	Arboreal lichens were not intended for inclusion in the dataset and were not recorded consistently; they were removed from the dataset.
Brachythecium sp.	*Brachythecium acutum*	7	Based on subplot data from other years
Carex lacustris	*Carex lasiocarpa*	174	
Carex raynoldsii	*Carex* sp.	48	Based on habitat preferences.
Carex rossii		3	
Cladonia (all species)	*Cladonia* sp.	110	Not recorded to a consistent level of detail throughout monitoring period; this maintains consistency between MLWC and reference sites.
Dicranum sp.	*Dicranum undulatum*	1	
Drepanocladus aduncus	*Hamatocaulis vernicosus*	14	
Equisetum arvense	*Equisetum fluviatile*	1	
Equisetum hyemale		2	
Equisetum pratense		6	
Eriophorum angustifolium	*Eriophorum vaginatum*	1	
Eriophorum sp.	*Eriophorum angustifolium*	2	
Eriophorum vaginatum		1	
Galium labradoricum	*Galium trifidum*	1	
Grass species	*Eriophorum angustifolium*	2	
	Muhlenbergia glomerata	11	
Hypnum lindbergii	*Hypnum pratense*	13	
Hypnum sp.		2	
Hypnum pratense	*Hypnum lindbergii*	1	
Meesia longiseta	*Meesia triquetra*	3	
Meesia uliginosa		11	
Pellia neesiana	*Mylia anomala*	1	
Ptilium crista-castrensis	*Helodium blandowii*	13	Based on habitat preferences
Rubus arcticus	*Rubus arcticus* ssp. *acaulis*	13	Based on subplot data from other years
Rubus pubescens		12	
Rumex brittanica	*Rumex occidentalis*	5	
Salix candida	*Salix pedicellaris*	3	
Sparganium sp.	*Sparganium angustifolium*	2	
Sphagnum angustifolium	*Sphagnum warnstorfii*	1	
Sphagnum fuscum	*Sphagnum angustifolium*	1	
	Sphagnum warnstorfii	1	
Sphagnum girgensohnii	*Sphagnum warnstorfii*	1	
Sphagnum magellanicum	*Sphagnum fuscum*	2	
Sphagnum sp.	*Sphagnum squarrosum*	1	
Stellaria sp.	*Stellaria crassifolia*	2	
	Stellaria longifolia	8	
Utricularia sp.	*Utricularia intermedia*	11	

Table 2.5-33: Changes to Species Names in the Gipsy Gordon Wetland Complex Vegetation Dataset

Initial Name	Updated Name	Number of Occurrences	Rationale
Brachythecium sp.	*Brachythecium acutum*	11	Based on subplot data from other years.
Calamagrostis (all species)	*Calamagrostis* sp.	35	Identification often alternated between years; if identifications are confirmed in the field, the correct ID could be assigned to all years.
Calliergon richardsonii	*Calliergon giganteum*	1	Based on subplot data from other years.
Carex limosa	*Carex leptalea*	1	
Carex livida	*Carex diandra*	1	
	Carex limosa	9	
Carex paupercula	*Carex limosa*	16	
Carex pseudocyperus	*Carex utriculata*	8	
Carex sp.	*Carex chordorrhiza*	2	
	Carex diandra	4	
	Carex interior	1	
	Carex leptalea	1	
	Carex limosa	33	
	Carex livida	1	
Cladonia (all species)	*Cladonia* sp.	6	Not recorded to a consistent level of detail throughout monitoring period; this maintains consistency between MLWC and reference sites.
Drepanocladus aduncus	*Hamatocaulis vernicosus*	47	Based on cover values and dominance in subplots over time; changes should be re-evaluated when species identities are confirmed following the next field season.
Drepanocladus sp.	*Hamatocaulis vernicosus*	20	
Eriophorum sp.	*Eriophorum angustifolium*	9	Based on subplot data from other years.
Grass species	*Muhlenbergia glomerata*	1	
Hamatocaulis vernicosus	*Drepanocladus aduncus*	18	Based on cover values and dominance in subplots over time; changes should be re-evaluated when species identities are confirmed following the next field season.
Peltigera sp.	*Peltigera neopolydactyla*	4	Based on subplot data from other years.
Plagiomnium sp.	*Plagiomnium ellipticum*	1	
Ptilium crista-castrensis	*Helodium blandowii*	8	Based on habitat preferences.
Ptychostomum cyclophyllum	*Ptychostomum pseudotriquetrum*	1	Based on subplot data from other years.
Rumex sp.	*Rumex occidentalis*	2	
Salix candida	*Salix pedicellaris*	1	
Sphagnum angustifolium	*Sphagnum warnstorfii*	2	
Sphagnum fallax	*Sphagnum warnstorfii*	2	
Sphagnum sp.	*Sphagnum angustifolium*	2	
	Sphagnum warnstorfii	1	
Sphagnum warnstorfii	*Sphagnum angustifolium*	3	
	Sphagnum fuscum	3	
	Sphagnum teres	1	
Stellaria crassifolia	*Stellaria* sp.	95	Identification often alternated between years; if identifications are confirmed in the field, the correct ID could be assigned to all years.
Stellaria longifolia		112	

Table 2.5-33: Changes to Species Names in the Gipsy Gordon Wetland Complex Vegetation Dataset

Initial Name	Updated Name	Number of Occurrences	Rationale
Triglochin sp.	*Triglochin maritima*	1	Based on subplot data from other years.
Utricularia sp.	*Utricularia intermedia*	2	
Vaccinium vitis-idaea	*Vaccinium oxycoccos*	3	

ID = identification; MLWC = McClelland Lake Wetland Complex.

Methods used to determine species richness, species diversity, species diversity metrics, indicator species groups, and to calculate normal ranges were similar to those used for the MLWC vegetation dataset (Section 2.5.1).

Normal ranges were calculated for string, flark, and wooded fen site types in each wetland complex across all years using R version 4.0.3 (R Core Team 2020) following methods outlined in Section 2.5.1. Mean values were calculated for the four diversity indices, three additional diversity values, and cover of the four indicator species groups for each fen type in each wetland complex in each year. Mean values for all parameters were compared to the normal range for each parameter within each fen type in each wetland complex.

2.5.9.3.2. Results and Discussion

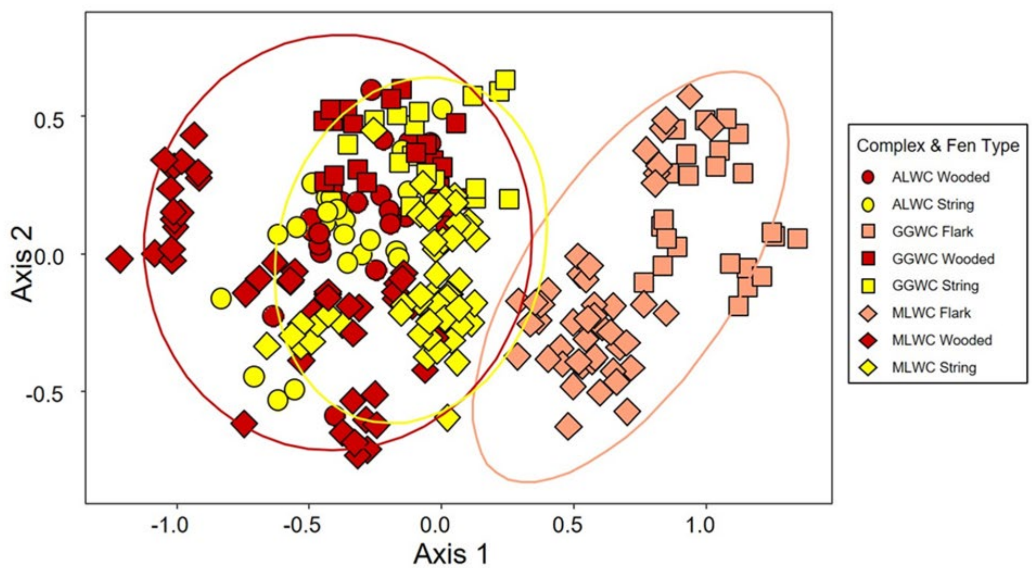
Plant Community Composition

Ordination of vegetation data was completed to provide a visual overview of plant community composition for string, flark, and wooded fen types at MLWC, ALWC, and GGWC. Data from all sites were combined on the same set of ordination axes to examine differences among fen types (Figure 2.5-45) and wetland complexes (Figure 2.5-46, Figure 2.5-47, Figure 2.5-48, Figure 2.5-49). Each point on the ordination represents a vegetation site in each year a survey was completed.

When string, flark, and wooded fen data were shown on the same set of ordination axes, differences in plant community composition of fen types were readily apparent. String and wooded fen types were similar to each other and were grouped separately from flark fen types along the first ordination axis, which is illustrated with 95% confidence ellipses in Figure 2.5-45.

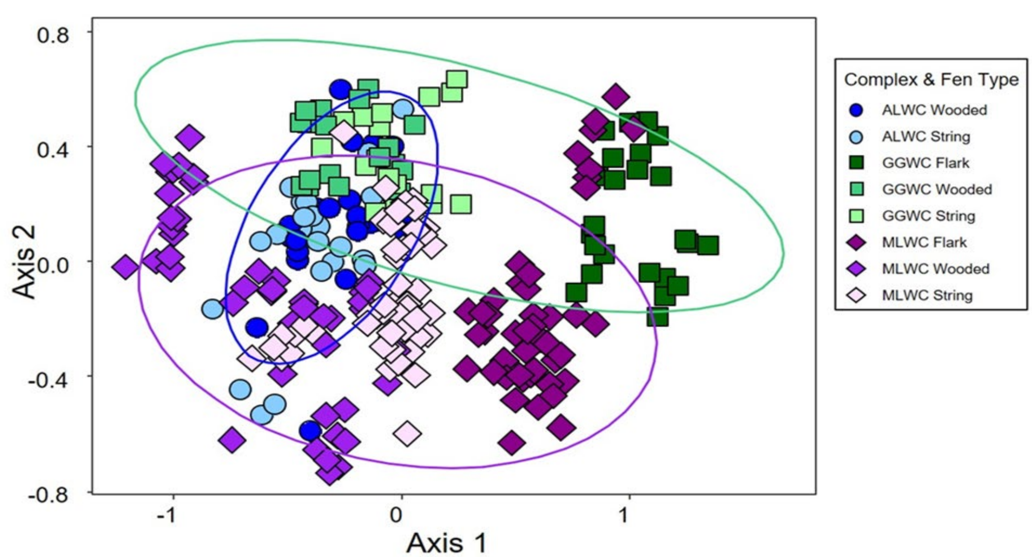
The ordination from Figure 2.5-45 was re-symbolized to show differences among wetland complexes in Figure 2.5-46, and 95% confidence ellipses were drawn around wetland complexes instead of around wetland types, as was done in Figure 2.5-45. The MLWC and GGWC overlapped along the first ordination axis, which was driven by the flark fen type occupying the right side of the ordination and string and wooded fen types occupying the left side of the ordination. These two wetland complexes were somewhat separated along the second ordination axis (Figure 2.5-46). Because ALWC did not have plots in flark fen types, ALWC plant communities were restricted to the left side of the ordination space, where they overlapped almost completely with MLWC along the second ordination axis (Figure 2.5-46).

The final stress for the ordination shown in Figure 2.5-45 and Figure 2.5-46 was 0.17 for a two-dimensional solution, which is considered acceptable.



Note: There were no plots in flark fen types surveyed at ALWC. Each point represents a vegetation site in each year a survey was completed. Ellipses represent the 95% confidence interval associated with plant communities found within each wetland complex.

Figure 2.5-45: Non-Metric Multidimensional Scaling Ordination of String, Flark, and Wooded Fen Types at MLWC, ALWC, and GGWC



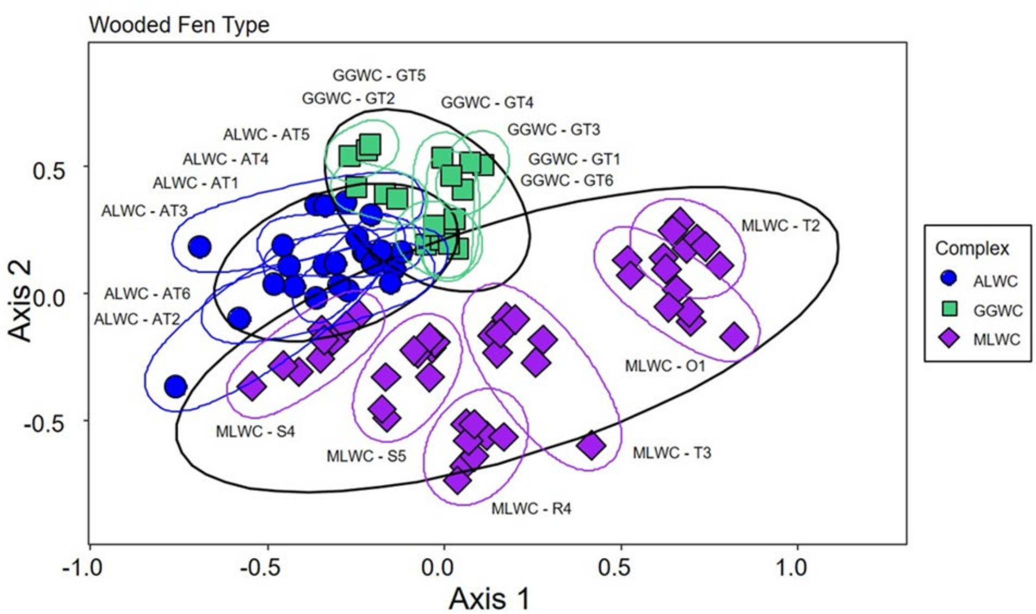
Note: There were no plots in flark fen types surveyed at ALWC. Each point represents a vegetation site in each year a survey was completed. Ellipses represent the 95% confidence interval associated with plant communities found within each wetland complex.

Figure 2.5-46: Non-Metric Multidimensional Scaling Ordination of Plant Communities at MLWC, ALWC, and GGWC, separated into String, Flark, and Wooded Fen Types

In addition to the NMDS ordinations completed for all fen types and wetland complexes together (Figure 2.5-45 and Figure 2.5-46), ordinations were also carried out separately for each fen type (Figure 2.5-47, Figure 2.5-48, and Figure 2.5-49). The MRPP found significant differences among wetland complexes within string (A = 0.1873; p = 0.001), flark (A = 0.0511; p = 0.001), and wooded (A = 0.1318; p = 0.001) fen types. Results of pair-wise comparisons are provided along with the description for each fen type in the following paragraphs.

Wooded Fen Type

Within the wooded fen type, plant communities at MLWC were widely spread out along the first ordination axis compared to either ALWC or GGWC, which were both grouped closely together and located on the left side of the ordination. MLWC and ALWC overlapped to some extent along the second ordination axis, while GGWC was located in the upper portion of the ordination plot where it had little overlap with MLWC (Figure 2.5-47). Pair-wise comparisons between wetland complexes show that MLWC wooded fen types differed significantly from wooded fen types at both ALWC and GGWC (p<0.001). The ALWC and GGWC also differed significantly from each other (p<0.001).



Note: Each point represents a vegetation site in each year a survey was completed. Ellipses represent the 95% confidence interval associated with plant communities found within each site and wetland complex.

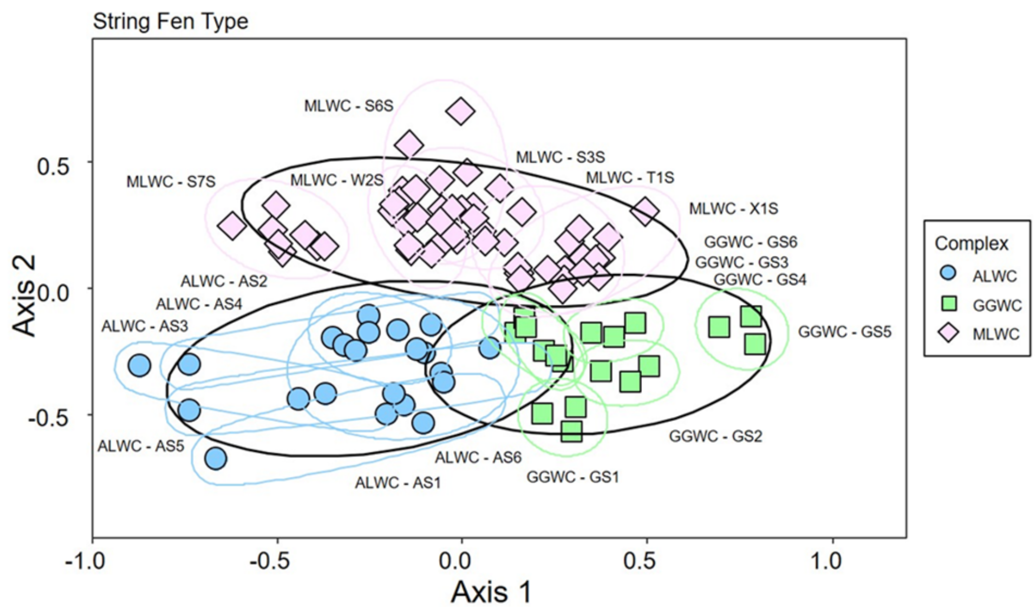
Figure 2.5-47: Non-Metric Multidimensional Scaling Ordination of the Wooded Fen Type at MLWC, ALWC, and GGWC

Several species were associated with the upper portion of the second ordination axis and help explain the location of the wooded fen reference sites in the ordination plot. *Peltigera neopolydactyla, Liparis loeselii, Cypripedium parviflorum,* and *Paludella squarrosa* were associated with the uppermost portions of the ordination space, and within wooded fens, were only recorded at ALWC and/or GGWC. *Paludella squarrosa* was the one exception as it was also found at MLWC site T3, which appeared closest to the GGWC plots on the ordination (Figure 2.5-47). MLWC sites T2 and O1 were the most different from the reference sites and they contained several species that were only found at one or both of those sites, and which were associated with the farthest right portion of the first ordination axis. Species that drove the location of MLWC sites T2 and O1 included *Sphagnum riparium, Warnstorfia exannulata*, *Rubus arcticus*, and *Chamaedaphne calyculata*. Separation of MLWC sites O1 and T2, and the high-level of within-wetland complex variation for MLWC is consistent with results presented by Golder (2018).

The final stress for the ordination shown in Figure 2.5-47 was 0.21 for a two-dimensional solution, which is considered acceptable.

String Fen Type

Within the string fen type, plant communities at MLWC overlapped with those of ALWC and GGWC along the first ordination axis; however, MLWC plant communities were separated from those of both reference wetland complexes, which were similar to each other, along the second ordination axis (Figure 2.5-48). This separation along ordination axis 2 was driven primarily by species that were not as commonly recorded within the string fen type. The location of MLWC sites in the upper portion of the ordination plot was driven by occurrences of *Anastrophyllum helleranum, Maianthemum canadense, Rhizommium* cf. gracile, and *Viola nephrophylla*, which within strings, were only recorded at MLWC. The location of ALWC and GGWC in the lower portion of the ordination plot was driven by occurrences of *Dicranum species, Sphagnum riparium*, and *Lophozia ventricosa at ALWC*, and *Plagiochila asplenioides* at GGWC.



Note: Each point represents a vegetation site in each year a survey was completed. Ellipses represent the 95% confidence interval associated with plant communities found within each site and wetland complex.

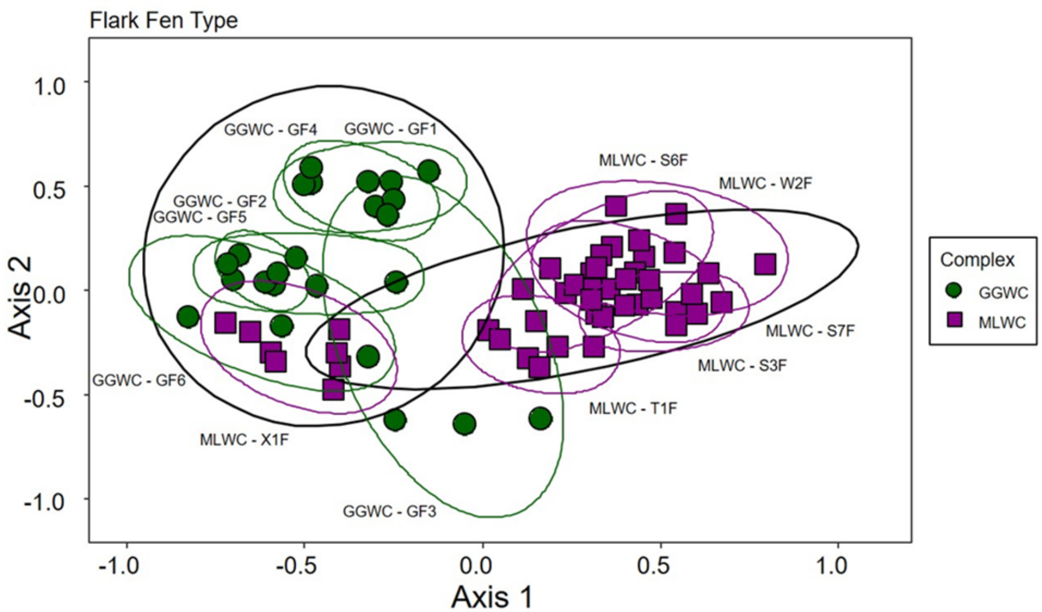
Figure 2.5-48: Non-Metric Multidimensional Scaling Ordination of the String Fen Type at MLWC, ALWC, and GGWC

Plant communities within MLWC EHZ 1 (i.e., T1S and X1S) occurred at the periphery of the MLWC group closest to GGWC, and plant communities within MLWC EHZ 2 (i.e., all other MLWC string sites) occurred closer to ALWC than GGWC. Therefore, EHZ 1 string plant communities may have more in common with GGWC string plant communities. Similarly, MLWC EHZ 2 string plant communities appear to have more in common with ALWC string plant communities. Further discussion of similarities and differences between reference sites and the MLWC is provided in Section 2.6.2.

Pair-wise comparisons between wetland complexes showed that MLWC string fen types differed significantly from string types at both ALWC and GGWC ($p<0.001$). Similarly, ALWC and GGWC string plant communities differed significantly from each other ($p<0.001$). The final ordination stress was 0.19 for a two-dimensional solution, which is considered acceptable.

Flark Fen Type

Within the flark fen type, plant communities at MLWC and GGWC were generally grouped separately along the first ordination axis, with the exception of MLWC site X1F, which overlapped completely with GGWC flark sites. Otherwise, MLWC sites were located on the right side of the ordination plot, and GGWC sites were located on the left side of the ordination plot (Figure 2.5-49). MLWC and GGWC overlapped almost completely along the second ordination axis. Overall, MLWC and GGWC plant communities were significantly different ($A = 0.0511$; $p = 0.001$). Flark plant community data have not been collected from the ALWC; thus, ALWC flark sites are not included on the ordination plot.



Note: There were no plots in flark fen types surveyed at ALWC. Each point represents a vegetation site in each year a survey was completed. Ellipses represent the 95% confidence interval associated with plant communities found within each site and wetland complex.

Figure 2.5-49: Non-Metric Multidimensional Scaling Ordination of the Flark Fen Type at MLWC, ALWC, and GGWC

The separation of MLWC and GGWC flark plant communities along ordination axis 1 was driven by species that were not commonly recorded within the flark fen type. The location of MLWC on the right portion of the ordination plot was driven by occurrences of *Carex gynocrates, Helodium blandowii, Salix pyrifolia*, and *Malaxis paludosa*, which in flarks, were only recorded at MLWC. The location of GGWC on the left portion of the ordination was driven by *Cicuta maculata* and *Triantha glutinosa*, which within flarks, were only recorded at GGWC.

MLWC site X1F was the only site which overlapped fully with plots at GGWC; this was driven by the presence of *Eriophorum vaginatum*, which was associated with the left portion of the ordination and was only recorded at MLWC at site X1F. Additionally, GGWC appears more similar to MLWC EHZ 1 sites (i.e., X1F and T1F), which were located the furthest left, closest to the GGWC sites on the ordination plot (Figure 2.5-49). One EHZ 2 indicator species, *Scorpidium scorpioides*, was also commonly found at MLWC sites X1F and T1F and GGWC sites GF3 and GF6, which were located closer to the centre of the ordination plot, in close proximity to each other.

The final ordination stress was 0.17 for a two-dimensional solution, which is considered acceptable.

Diversity Metrics and Indicator Species Groups

Results of seven vegetation diversity metrics and four indicator species groups for reference sites are presented in Table 2.5-34, Table 2.5-35, and Table 2.5-36. Vegetation datasets collected at ALWC from 2012 to 2018 and at GGWC from 2015 to 2018 were used to characterize reference site conditions and define the MRV for these metrics.

Plant Species Diversity Metrics

Four key vegetation diversity metrics were evaluated to assess plant species diversity: species richness at the site (α) and landscape (γ) scales, Shannon's diversity index, and Simpson's diversity index. While there was variation among years, values for these parameters did not exceed the bounds of the normal range calculated for all fen types, years, and reference wetland complexes (Table 2.5-34, Table 2.5-35, and Table 2.5-36). In wooded fens, species richness at the site (α) and landscape (γ) scales, and Shannon's diversity index had wider normal range bounds at ALWC and GGWC compared to MLWC, and the bounds had higher values at MLWC compared to either reference site (Table 2.5-34). This indicates that in wooded fens, not only do ALWC and GGWC have lower species richness and diversity compared to MLWC, but they are also less sensitive to changes in these parameters compared to MLWC. Similarly, Simpson's diversity index had wider normal range bounds at GGWC and ALWC compared to MLWC in wooded fens.

Species richness at the site scale in strings had similar widths of ranges and values for the bounds at GGWC and MLWC (Table 2.5-35). While the widths of ranges between strings in these wetland complexes were also similar for richness at the landscape scale, lower and upper bounds had higher values at MLWC. Shannon's diversity index had similar widths of ranges for strings in all three wetland complexes, although values for the bounds were higher at MLWC compared to the reference sites. Simpson's diversity index was similar among strings in the three wetland complexes.

Species richness at the site (α) and landscape (γ) scales, Shannon's diversity index, and Simpson's diversity index in flarks had a much wider range at GGWC, and the bounds for those parameters at MLWC fell within those of GGWC for all parameters (Table 2.5-36). Overall, for these vegetation diversity metrics, ALWC and GGWC tended to have wider normal ranges compared to MLWC, indicating more variability in reference site datasets, and potentially lower sensitivity to changes. Furthermore, values of the bounds of the normal range tended to be higher at MLWC than at either of the reference sites, indicating higher overall diversity in flarks at MLWC.

Table 2.5-34: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for Wooded Fen Sites at Reference Wetland Complexes

Parameter	Audet Lake Wetland Complex					Gipsy Gordon Wetland Complex		
	Year (sample size)[a]							
	2012 (6)	**2013 (3)**	**2014 (3)**	**2017 (6)**	**2018 (6)**	**2016 (6)**	**2017 (6)**	**2018 (6)**
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)							
Species Richness [α][b]	Normal Range Lower Bound: 9.5; Normal Range Upper Bound: 42.9					Normal Range Lower Bound: 11.0; Normal Range Upper Bound: 37.0		
	24.7 (2.7)	24.0 (7.0)	25.3 (3.4)	26.3 (3.7)	29.0 (3.5)	24.2 (3.8)	21.8 (3.6)	28.0 (3.5)
Species Richness [γ][c]	Normal Range Lower Bound: 64; Normal Range Upper Bound: 95					Normal Range Lower Bound: 41; Normal Range Upper Bound: 77		
	95	70	***64***	69	70	58	63	56
Shannon's Diversity Index	Normal Range Lower Bound: 0.2; Normal Range Upper Bound: 15.9					Normal Range Lower Bound: 1.1; Normal Range Upper Bound: 18.2		
	6.9 (0.9)	7.7 (2.5)	8.4 (2.7)	7.7 (1.7)	9.7 (1.8)	7.9 (1.9)	4.5 (0.8)	9.5 (1.3)
Simpson's Diversity Index	Normal Range Lower Bound: 0.33; Normal Range Upper Bound: 0.96					Normal Range Lower Bound: 0.00; Normal Range Upper Bound: 1.00		
	0.74 (0.03)	0.74 (0.06)	0.73 (0.13)	0.72 (0.06)	0.78 (0.07)	0.69 (0.09)	0.54 (0.07)	0.81 (0.03)
Diversity Profile q=0	Normal Range Lower Bound: 7.2; Normal Range Upper Bound: 11.4					Normal Range Lower Bound: 5.2; Normal Range Upper Bound: 10.4		
	9.8 (0.4)	9.2 (0.9)	8.4 (0.6)	9.5 (0.3)	9.1 (0.3)	7.8 (0.5)	8.0 (0.6)	7.6 (0.4)
Diversity Profile q=2	Normal Range Lower Bound: 2.8; Normal Range Upper Bound: 6.0					Normal Range Lower Bound: 3.3; Normal Range Upper Bound: 5.4		
	4.0 (0.2)	5.0 (0.4)	4.5 (0.1)	4.4 (0.4)	4.5 (0.3)	4.3 (0.2)	4.5 (0.2)	4.2 (0.2)
Diversity Profile q=5	Normal Range Lower Bound: 2.1; Normal Range Upper Bound: 5.1					Normal Range Lower Bound: 2.4; Normal Range Upper Bound: 4.7		
	3.3 (0.2)	4.3 (0.5)	3.6 (0.1)	3.5 (0.3)	3.7 (0.3)	3.7 (0.3)	3.6 (0.2)	3.4 (0.2)
String Indicator Species (% cover)	Normal Range Lower Bound: 10.2; Normal Range Upper Bound: 58.1					Normal Range Lower Bound: 9.8; Normal Range Upper Bound: 120.9		
	30.6 (4.7)	26.5 (7.3)	31.0 (5.9)	37.1 (3.8)	40.3 (5.1)	38.9 (8.6)	34.7 (8.9)	38.7 (9.7)
Moderate-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 0.3; Normal Range Upper Bound: 61.6					Normal Range Lower Bound: 0.3; Normal Range Upper Bound: 19.9		
	6.2 (3.6)	17.5 (10.5)	14.4 (11.3)	18.0 (5.4)	17.8 (5.9)	3.1 (1.0)	5.2 (1.7)	2.1 (0.9)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 2.7					Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 2.3		
	1.4 (0.2)	1.1 (0.5)	0.7 (0.4)	0.9 (0.3)	1.1 (0.4)	0.6 (0.3)	0.6 (0.3)	0.6 (0.2)
Eutrophication Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 0.2					Normal Range Bounds could not be calculated as no species in this group were recorded.		
	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

(a) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(b) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(c) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

Note: **Bolded** and *italicized* numbers were outside the normal range bounds.

EHZ = Ecohydrology Zone.

Table 2.5-35: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for String Fen Sites at Reference Wetland Complexes

Parameter	Audet Lake Wetland Complex					Gipsy Gordon Wetland Complex		
	Year (sample size)[a]							
	2012 (6)	2013 (2)	2014 (2)	2017 (6)	2018 (6)	2016 (6)	2017 (6)	2018 (6)
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)							
Species Richness [α][b]	Normal Range Lower Bound: 29.0; Normal Range Upper Bound: 68.2					Normal Range Lower Bound: 25.0; Normal Range Upper Bound: 54.3		
	54.3 (2.9)	57.5 (8.5)	50.0 (4.0)	44.0 (1.7)	44.0 (4.7)	40.3 (2.7)	41.8 (3.8)	36.8 (1.3)
Species Richness [γ][c]	Normal Range Lower Bound: 15; Normal Range Upper Bound: 138					Normal Range Lower Bound: 54; Normal Range Upper Bound: 69		
	108	56	62	78	78	60	61	63
Shannon's Diversity Index	Normal Range Lower Bound: 7.0; Normal Range Upper Bound: 22.5					Normal Range Lower Bound: 4.4; Normal Range Upper Bound: 20.8		
	15.5 (1.3)	20.1 (3.5)	15.1 (2.8)	14.4 (1.6)	12.5 (0.7)	13.1 (1.1)	13.1 (2.4)	11.5 (0.9)
Simpson's Diversity Index	Normal Range Lower Bound: 0.71; Normal Range Upper Bound: 0.93					Normal Range Lower Bound: 0.73; Normal Range Upper Bound: 0.96		
	0.86 (0.02)	0.91 (0.00)	0.88 (0.02)	0.86 (0.02)	0.86 (0.02)	0.86 (0.01)	0.83 (0.04)	0.85 (0.01)
Diversity Profile q=0	Normal Range Lower Bound: 8.2; Normal Range Upper Bound: 11.6					Normal Range Lower Bound: 6.0; Normal Range Upper Bound: 9.1		
	10.1 (0.3)	8.9 (0.1)	9.5 (0.7)	10.4 (0.3)	9.7 (0.4)	7.4 (0.3)	7.7 (0.3)	7.6 (0.3)
Diversity Profile q=2	Normal Range Lower Bound: 2.3; Normal Range Upper Bound: 7.0					Normal Range Lower Bound: 1.8; Normal Range Upper Bound: 5.1		
	4.1 (0.5)	5.7 (0.1)	6.0 (0.7)	4.4 (0.4)	4.5 (0.4)	3.3 (0.2)	3.8 (0.4)	3.2 (0.3)
Diversity Profile q=5	Normal Range Lower Bound: 1.5; Normal Range Upper Bound: 6.3					Normal Range Lower Bound: 1.9; Normal Range Upper Bound: 5.6		
	3.4 (0.5)	5.2 (0.0)	5.4 (0.8)	3.6 (0.4)	3.8 (0.4)	2.6 (0.1)	3.0 (0.3)	2.6 (0.3)
String Indicator Species (% cover)	Normal Range Lower Bound: 18.7; Normal Range Upper Bound: 42.8					Normal Range Lower Bound: 21.9; Normal Range Upper Bound: 83.5		
	28.4 (2.2)	24.4 (2.7)	30.8 (2.4)	32.1 (2.6)	34.0 (1.9)	55.9 (5.7)	51.5 (6.4)	50.8 (6.2)
Moderate-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 0.1; Normal Range Upper Bound: 32.8					Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 30.4		
	1.6 (0.5)	13.9 (5.5)	7.3 (4.3)	10.3 (3.8)	8.6 (1.9)	14.3 (3.9)	14.3 (3.5)	11.6 (2.5)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 4.6					Normal Range Lower Bound: 0.1; Normal Range Upper Bound: 16.7		
	1.6 (0.4)	0.3 (0.1)	1.4 (1.2)	0.5 (0.1)	0.8 (0.3)	2.6 (1.0)	2.5 (1.1)	1.1 (0.4)
Eutrophication Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 1.3					Normal Range Bounds could not be calculated as no species in this group were recorded.		
	0.0 (0.0)	0.1 (0.1)	0.1 (0.1)	0.2 (0.1)	0.2 (0.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

(a) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(b) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(c) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

EHZ = Ecohydrology Zone.

Table 2.5-36: Species Diversity and Indicator Group Metrics in Comparison to Normal Ranges for Flark Fen Sites at Gipsy Gordon Wetland Complexes

Parameter	Year (sample size)[a]			
	2016 (6)	2016 (6)	2017 (6)	2018 (6)
	Normal Range (Lower Bound, Upper Bound) of Inter-Annual Variation Mean (± Standard Error)			
Species Richness [α][b]	Normal Range Lower Bound: 13.0; Normal Range Upper Bound: 50.0			
	34.2 (6.2)	32.5 (6.5)	32.8 (3.9)	34.8 (3.9)
Species Richness [γ][c]	Normal Range Lower Bound: 18; Normal Range Upper Bound: 59			
	46	39	34	34
Shannon's Diversity Index	Normal Range Lower Bound: 0.7; Normal Range Upper Bound: 20.6			
	10.5 (2.5)	9.5 (2.3)	11.2 (1.6)	11.3 (1.6)
Simpson's Diversity Index	Normal Range Lower Bound: 0.43; Normal Range Upper Bound: 0.91			
	0.76 (0.07)	0.74 (0.08)	0.83 (0.04)	0.84 (0.02)
Diversity Profile q=0	Normal Range Lower Bound: 4.1; Normal Range Upper Bound: 8.7			
	5.7 (0.5)	5.4 (0.3)	5.8 (0.5)	5.2 (0.3)
Diversity Profile q=2	Normal Range Lower Bound: 1.2; Normal Range Upper Bound: 3.8			
	3.0 (0.2)	2.6 (0.2)	2.5 (0.3)	2.0 (0.2)
Diversity Profile q=5	Normal Range Lower Bound: 0.9; Normal Range Upper Bound: 3.3			
	2.6 (0.2)	2.1 (0.2)	2.0 (0.2)	1.7 (0.2)
String Indicator Species (% cover)	Normal Range Lower Bound: 0.0; Normal Range Upper Bound: 1.0			
	0.2 (0.1)	0.1 (0.0)	0.1 (0.1)	0.2 (0.2)
Moderate-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 1.9; Normal Range Upper Bound: 96.4			
	42.4 (13.4)	49.6 (17.1)	47.6 (16.9)	44.2 (15.3)
Extreme-Rich Fen Water Chemistry Indicator Species (% cover)	Normal Range Lower Bound: 0.4; Normal Range Upper Bound: 97.4			
	34.8 (15.5)	30.8 (16.8)	28.6 (15.4)	35.3 (18.3)
Eutrophication Indicator Species (% cover)	Normal Range Bounds could not be calculated as no species in this group were recorded			
	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

(a) Sample size reflects the number of sites, not the number of subplots; percent cover values were averaged together into one value per species per site.

(b) Alpha diversity was calculated as the total number of species documented within each site; each site was represented by 20 1 m^2 subplots, thus, each alpha diversity value represents 20 m^2.

(c) Gamma diversity reflects the total number of species in each fen type in each year; thus the sum, rather than mean and standard error, are provided.

EHZ = Ecohydrology Zone.

Three additional diversity measures were evaluated, following Armada (2019), to assess plant species diversity when accounting for species similarity; diversity was evaluated at q=0, q=2, and q=5. Similar to the other diversity metrics, there was variation among years, but diversity values for q=0, q=2, and q=5 were within the bounds of the normal range calculated for all fen types, years, and reference wetland complexes (Table 2.5-34, Table 2.5-35, and Table 2.5-36). Widths of normal ranges varied among q values and sites (Table 2.5-34, Table 2.5-35, and Table 2.5-36).

Overall, for these vegetation diversity metrics, ALWC and MLWC tended to be more similar in wooded fens, GGWC and MLWC tended to more similar in strings, and MLWC tended to have slightly higher values for the upper bound in flarks, compared to GGWC. Further discussion of similarities and differences between reference sites and the MLWC is provided in Section 2.6.2.

Indicator Species Group Metrics

Normal ranges were used to assess total percent cover of species within the following indicator groups: string indicators, moderate-rich fen water chemistry indicators, extreme-rich fen water chemistry indicators, and eutrophication indicators. While there was variation among years, percent cover values for these indicator groups were within calculated normal ranges for all fen types, years, and reference wetland complexes (Table 2.5-34, Table 2.5-35, and Table 2.5-36).

In wooded fens, widths of normal ranges and values of the bounds for percent cover of string indicator species and moderate-rich fen water chemistry indicator species were similar between ALWC and MLWC, while there were very few extreme-rich fen water chemistry indicator species present in any of the wetland complexes (Table 2.5-34). As wooded fens were not sampled as part of the EHZs, these indicator species groupings are not particularly useful for wooded fens. In strings, values for bounds of percent cover of string indicator species did not overlap between ALWC and MLWC (MLWC was higher), and the width of the normal range was much wider for GGWC compared to MLWC. With higher variability inherent in the GGWC string dataset, the strings at MLWC are expected to be more sensitive to changes for these species compared with GGWC, and similar to ALWC (Table 2.5-35).

Values for bounds of percent cover of moderate-rich fen water chemistry indicator species in strings were similar between ALWC and GGWC, both of which had lower values compared to MLWC, likely due to differences in plant communities among wetland complexes. Both the width of normal ranges and values for percent cover of extreme-rich fen water chemistry indicator species in strings were similar between GGWC and MLWC. While there were some string indicator species in flarks at MLWC, there were few at GGWC, indicating this indicator group may not be an ideal indicator of changes for flark reference sites (Table 2.5-36). The width of the normal ranges in flarks for percent cover of moderate-rich and extreme-rich fen water chemistry indicator species were relatively wide for both GGWC and MLWC, indicating that this group may not be sensitive to changes and therefore may not be an ideal indicator of changes in flarks. EHZ 1 and 2 in flarks also had high standard errors, reflecting relatively high variation in species presence and abundance among plots.

Eutrophic indicator species were recorded with relatively low abundance at ALWC, were not recorded at GGWC, and were recorded with slightly higher abundances at MLWC; thus, this is an important group to monitor for changes over time. Eutrophic indicator species are present with low abundance during pre-mining baseline conditions at MLWC; any changes should be readily detected

2.5.10. Wildlife

2.5.10.1. Wildlife Pre-Mining Baseline Conditions

2.5.10.1.1. Birds

ITK holders described birds in the MLWC area as “plentiful and that the fen side of the lake was a ‘haven’ for waterfowl prior to industrial development”. The number of eggs members found during a typical trip was 10-15 eggs, one member even described that early on, it was possible to find a single nest with 16 eggs in it. Members expressed that there were always enough harvested birds and eggs to share with their family and friends (IEG 2021).

Chickens (grouse), ducks, and geese are some commonly harvested species in the MLWC area. ITK holders have observed a lower number of birds as in recent years, suggesting changes to bird populations outside the natural range. Members of Indigenous communities have observed that bird populations have decreased since the 1960s, especially during the last couple of decades. Members have indicated there has been reduced sightings, or absence, of specific bird species, such as grey jay, and have indicated that nesting and habitat areas for birds have also been eliminated or disturbed by industry. The ITK holders from one Indigenous community have noted that one of the reasons that fewer birds have been seen is that, due to lower water levels in the fen and the surrounding area, birds are less likely to stop during migration (IEG 2021).

> *"Maybe we seen a few ducks but not as much as long ago. … Chickadees always, been there before, and they're gone. Even a robin or whatever, it's all gone."* (MCFN ITK holder, MCFN 2019).
>
> *"You don't see no cranes there or nothing, cranes usually eat the frogs."* (MCFN ITK holder, MCFN 2019)

FMFN and FMMN ITK holders have indicated other reasons that there are fewer birds in the area. For example, Fort McKay members shared that disturbances can impact how birds behave. Using a Cree phrase, they described a specific bird behaviour, namely, the nervous or jittery behaviour of ducks reacting to disturbances. FMFN Members also explained that project disturbances such as tree removal can push birds out of the area, for example, the disappearance of the culturally important and sensitive grey jay is predicted if it experiences more disturbance from development' (IEG 2020). Similarly, ITK holders described disturbances from industrial activities such as human activities, noise, odors, and visual also impact animal behaviour. For example, participants explained that birds and other wildlife are sensitive to disturbances from industrial noise. Disturbances degrade the quality of habitat resulting in changes in animal behaviour and migration patterns' (IEG 2020).

FMMN and FMFN ITK holders recalled they used to see many ducks when they travelled between McClelland Lake and Saline Lake, but now the area is dry and they see fewer ducks. However, ducks continue to be harvested from the McClelland Lake area by members each year. Numerous ducks are harvested during Métis Days and at the annual harvest camp to distribute to community members, with approximately 20 to 40 ducks harvested each year, typically two or three times during the fall months (IEG 2021).

During a field visit in August 2019, an FCM ITK Holder noted that they didn't observe whiskey jack or songbirds during the visit, but that pelicans had been seen recently and are new to the area (FCM 2019).

The presence of birds has been cited by ITK holders as an indicator of the health of the overall ecosystem:

> *"You can tell it's healthy, everything is on that lake, especially … you see crows ... you see these hawks. You see a lot of hawks there, and you see a lot of eagles flying around, means there's fish in the lake. …When I see blue herons I'm pretty sure it's a healthy spot because he eats frogs and he eats snakes. As far as I know, wherever I see nice clean water to drink, I always see blue herons around all the time."* (MCFN ITK holder, MCFN 2019)

Breeding bird point count surveys have been completed at the MLWC from 2010 to 2018 , with the exception of 2015 (Hawkes et al. 2019). Data from surveys completed in 2011 are excluded from analyses because these surveys were completed in July; surveys in all other years were completed in June. A total of 312 point counts have been completed in the MLWC from 2010 to 2018 (excluding 2011 and 2015).

Autonomous recording units (ARUs) were deployed in the MLWC in 2017 and 2018 to survey for four bird species at risk: yellow rail (*Coturnicops noveboracensis*), olive-sided flycatcher (*Contopus cooperi*), common nighthawk (*Chordeiles minor*), and rusty blackbird (*Euphagus carolinus*) (Hawkes et al. 2019).

Five ARUs were deployed in the wetland complex in both years. The ARUs were deployed during the migratory bird breeding season in both years.

A total of 69 bird species have been recorded in the MLWC during point count surveys from 2010 to 2018 (excluding 2011 and 2015) (Hawkes et al. 2019). All four bird species at risk (yellow rail, common nighthawk, olive-sided flycatcher, and rusty blackbird) have been recorded on ARUs that were deployed in the MLWC in 2017 and 2018. Yellow rails are commonly observed in the wetland complex with calls detected on 188 days (113 days in 2017 and 75 days in 2018) over all 5 ARUs in both survey years (range 0 to 39 days with detections over both years). Common nighthawk calls were detected on 66 days (27 days in 2017 and 39 days in 2018) over all ARUs in both survey years (range 2 to 12 days with detections over both years) and rusty blackbirds were detected on 91 days in 2017 and 2018 (4 days in 2017 and 87 days in 2018; range 0 to 33 days with detections over both years). Olive-sided flycatchers are the least commonly detected bird species at risk in the wetland complex with detections on a total of seven days in 2017 and 2018 (1 day in 2017 and 6 days in 2018; range 0 to 3 days with detections over both years).

Although there was a higher detection rate for birds in 2018 compared to 2017, this is likely due to the ARUs being deployed for a much longer period in 2018 (average 88 detection days [range 88 to 89 days]) versus 2017 (average 49 detection days [range 45 to 54 days]) (Hawkes et al. 2019). Bird abundance commonly fluctuates from year to year in response to variables such as resource abundance, weather, habitat availability on breeding and wintering grounds, and population processes (Holmes et al. 1986; Holmes and Sherry 1988; Hutto 1989; Blake et al. 1994). According to the North American Breeding Bird Survey, rusty blackbird, common nighthawk, and olive-sided flycatcher populations in Bird Conservations Region 6 (Alberta – Boreal Taiga Plains) have decreased by 2.46% to 4.82% annually from 1970 through 2019, which has resulted in a total population decreases for these species of 70.6% to 91.1% over this period (ECCC 2021). No population trends are available for yellow rail.

2.5.10.1.2. Amphibians

Frogs and leeches are a food source for fish, and their presence helps to indicate a healthy aquatic environment. One ITK holder remembers from her childhood during the early years of the pre-mining baseline:

> *"Yeah, McClelland Creek, all the way—you could hear frogs for a long ways. Because one time we were going home out to the river and passed Moose Creek, going closer to McClelland. We were going to camp at McClelland Creek. And it was, like—I think it was in the—I don't know if it was more towards in the afternoon. Oh, you could hear frogs, creek, creek, he said. My dad said, probably lots of water. Well yeah, sure enough, because we had to—now he had to make a trail around to take the dogs, the dog team. Me and my mother—well, it wasn't—it's not too wide. It's right on the cut line too and it's got a hard bottom. Plus we hauled stuff across; [the water] was about up to here. Sure, my mum said, see, that frog said, 'creek, creek'. [laughs]"* (FCM ITK holder, FCM 2019)

Two types of amphibian surveys have been completed at the MLWC from 2011 to 2018: wood frog egg mass surveys (2011 to 2018, excluding 2016) and ARUs (2017 and 2018) (Hawkes et al. 2019).

Wood frog egg mass surveys have been completed at 20 locations in the wetland complex over all survey years. A maximum of 222 egg masses have been reported in all survey ponds over all survey years. Total egg mass counts from all survey ponds range from 362 to 2,268 over all survey years.

Five ARUs were deployed in the MLWC in 2017 and 2018 to survey for Canadian toad (*Anaxyrus hemiophrys*), which is a species at risk (Hawkes et al. 2019). The ARUs were deployed during the amphibian breeding season in both survey years. Three Canadian toad calls were recorded at a total of two locations in 2017. Five Canadian toad calls were recorded at a total of two locations in 2018.

Amphibian populations can vary from year to year due to several factors such as resource abundance, habitat availability, and population processes (Gómez-Rodríguez et al. 2010). Although Canadian toad populations started declining in the mid-1980s and this trend appears to be continuing. However, historical information on population size is limited and so accurate estimates of the rate of decline are not available (GOA 2002).

2.5.10.1.3. Mammals

Prior to industrial development, hunting was a primary activity for ensuring they had enough food throughout the year. Species like moose, bear, caribou were plentiful in the MLWC and surrounding area as well as more predictable. Fur bearers were trapped as an important source of food and income. Local Indigenous Knowledge was used to predict the location of species to successfully harvest. For families, hunting and trapping was part of everyday survival prior to the 1960s.

Bear and moose hunting in the MLWC area has occurred in the years since industrial development began. In recent years, concern has been expressed over the health and abundance of hunted species. ITK holders have observed that animal populations range naturally over time; however, the changes that they have observed in moose and caribou over the last few decades differ from what participants have observed in the past. Participants have observed decreased populations of culturally important animal species, such as moose, caribou and bear, making it difficult to find and harvest animals. Habitat areas have been eliminated or disturbed. ITK holders have indicated that moose and bear populations are lower than in the past, which they attribute to reduced availability of berries and overall poorer quality of habitat areas. Some ITK holders have observed bears infested with tapeworms, and moose meat that appears to be contaminated, resulting in less culturally important food available for consumption and sharing with friends and family. One ITK holder remembers:

> *"Like, I'm up there [Firebag River] bear hunting, is what I'm doing, and there is bear. I mean, there's not—it's any kind—any time you find water, you're going to come across bear. You know, that's just—that's why you hunt along rivers. Bear, you know, they take bear out—they say they're out after the moose. No, they're looking for berries, and in the springtime they're looking for 'weeds'. Well, they eat a lot of what I call joint grass. We call it joint grass. It grows in a muskeg, and it's just grass, and call it—because you can pull it apart in little joints. And they love it in the spring, and that's all they eat. They eat it before the berries, you know." "it's sort of [in] a slough, and that's where that grass—the bears hang out in these areas in the spring before the berries are out." "one of the reasons why the Firebag is good for hunting are these sloughs on each—on the sides. Old riverbeds."* (FCM ITK holder, FCM 2019)

> *"... a lot of people maybe kill a moose, they make meat, they harvest ... for the winter, and you make moose hide ... whatever you want, mukluks or any kind of bead work on it and stuff like that, that's where they get all that stuff from. … One of the signs that [is] good is, when you see a moose, even all the insects, you see some of these birds, they're on top of the moose eating the insects from the moose. … In the [moose] meat, when you open up between his guts and his ribs, [there are white spots] there, or sometimes maybe you'll see it on his liver, like his liver is kind of like when you have an infection, full of little spots there inside. Even the hide sometimes you get that, when you skin him, the hide is something like, it got an infection, there's bubbles on them or something, like sores, you know? Not healthy."* (MCFN ITK holder, MCFN 2019)

Since industrial development began in the MLWC area, ITK holders have noticed decreased fur bearer populations and diversity. A reduction in beaver activity has been credited with changes in water quality in the area, as beavers play an important role in maintaining the health and water levels of McClelland Lake and the surrounding wetlands. Prior to the 1950s, a beaver dam across McClelland Creek helped to maintain high water levels in McClelland Lake.

ITK holders have stated that the presence of beaver and muskrat are also an indicator of the overall health of the wetland. In recent years, muskrat have been absent from McClelland Lake, possibly due to the lower water levels. Beaver are not found in the pothole lakes in the area today. One ITK holder remembers:

> *"Yeah animal signs is more different, we used to see some moose crossing, by the lake, you see signs of that when we're paddling around like I said, and there was more beavers and less beavers now."* (MCFN ITK holder, MCFN 2019)
>
> *"I seen all that and no rat signs, whatever, there's beavers but not that much. And it looks good, should be rats, there's not one rat to be seen."* (MCFN ITK holder, MCFN 2019)
>
> *"No rats, used to be rats before. No rat sign along the shore, nothing, no rat shacks, nothing."* (MCFN ITK holder, MCFN 2019)
>
> *"I wouldn't say muskrat because they're too, muskrats, they need the water, and if they, and if that water freezes right to the bottom every winter, well they can't live around there either."* (MCFN ITK holder, MCFN 2019)
>
> *"The only places that water is still good is when beavers damming, cause beaver controls the water, right?"* (MCFN ITK holder, MCFN 2019)

ITK holders have suggested that beaver populations and activities should be monitored in addition to water quality in the MLWC.

Remote cameras have been deployed at the MLWC from 2009 to 2018 (Hawkes et al. 2019). A total of 255 remote cameras have been deployed over all survey years, with a range of 3 to 8 cameras deployed per habitat type per year. Cameras are deployed year-round.

Fifteen mammal species have been detected on cameras deployed at the MLWC from 2009 to 2018, and data were analysed for the eight most commonly detected species: American black bear (*Ursus americanus*), Canada lynx (*Lynx canadensis*), grey wolf (*Canis lupus*), marten (*Martes americana*), moose (*Alces alces*), red fox (*Vulpes vulpes*), showshoe hare (*Lepus americanus*), and white-tailed deer (*Odocoileus virginianus*) (Hawkes et al. 2019). For most species, there was an increase in sighting events in 2012 followed by a decline and relatively stable sightings per year from 2013 to 2018 (Hawkes et al. 2019). No federally listed mammal species at risk have been detected on the cameras, however, Canada lynx, which is considered a sensitive species in Alberta (GOA 2020), has been recorded eight times over all survey years and cameras.

2.5.10.2. Reference Site Wildlife Pre-Mining Baseline Conditions

2.5.10.2.1. Birds

Breeding bird point count surveys have been completed at Audet Lake from 2012 to 2018, with the exception of 2015 (Hawkes et al. 2019). A total of 272 point counts have been surveyed at Audet Lake from 2012 to 2018 (excluding 2015).

A total of 96 breeding bird point count surveys were completed at Gipsy-Gordon in 2017 and 2018 (Hawkes et al. 2019).

Five ARUs were deployed at both Audet Lake and Gipsy-Gordon (total 10 units) in 2017 and 2018 to survey for four bird species at risk: yellow rail, olive-sided flycatcher, common nighthawk, and rusty blackbird (Hawkes et al. 2019). The ARUs were deployed during the migratory bird breeding season in both survey years.

A total of 59 bird species have been detected during point counts at Audet Lake from 2012 to 2018 (excluding 2015) (Hawkes et al. 2019). Rusty blackbird and olive-sided flycatcher are the two most common bird species at risk detected on ARUs at Audet Lake in 2017 and 2018 with detections on 69 nights and 96 nights, respectively. Common nighthawks were detected on 26 nights and yellow rails were detected on 22 nights over all ARUs and survey years.

A total of 43 bird species have been recorded during point count surveys at Gipsy-Gordon in 2017 and 2018 (Hawkes et al. 2019). Olive-sided flycatchers were detected on 127 nights over all detectors placed in Gipsy-Gordon in 2017 and 2018. Yellow rails were also frequently detected, with calls recorded on 108 nights over both survey years. Common nighthawks and rusty blackbirds were also detected in Gipsy-Gordon, with calls recorded on 84 and 20 nights, respectively.

Bird abundance commonly fluctuates from year to year in response to variables such as resource abundance, weather, habitat availability on breeding and wintering grounds, and population processes (Holmes et al. 1986; Holmes and Sherry 1988; Hutto 1989; Blake et al. 1994) (see Section 2.5.10.1.1 for more details).

2.5.10.2.2. Amphibians

Wood frog egg mass surveys have been completed at Audet Lake from 2012 to 2018 (excluding 2016) and at Gipsy-Gordon in 2017 and 2018 (Hawkes et al. 2019). Egg mass surveys have been completed at 22 locations at Audet Lake and 20 locations at Gipsy Gordon over all survey years. Although sampling has only been completed at Gipsy-Gordon for two years, the number of egg masses recorded at Gipsy-Gordon (maximum 134 egg masses at all survey locations) are dramatically lower than those reported at Audet Lake (maximum 272 egg masses at all survey locations over all survey years). A total of 259 and 165 egg masses were recorded for all survey locations at Gipsy-Gordon in 2017 and 2018, respectively. The total number of egg masses recorded over all survey locations at Audet Lake ranges from 459 to 3,309 over all survey years.

Five ARUs were deployed at both Audet Lake and Gipsy-Gordon (total 10 units) in 2017 and 2018 to survey for Canadian toad, which is a species at risk (Hawkes et al. 2019). The ARUs were deployed during the amphibian breeding season in both survey years. Two Canadian toad calls were recorded at one location in Gipsy-Gordon in 2017; no Canadian toad calls were recorded here in 2018. Ten Canadian toad calls were recorded at one location at Audet Lake in 2018; no Canadian toad calls were recorded at Audet Lake in 2017.

Amphibian populations can vary from year to year due to several factors such as resource abundance, habitat availability, and population processes (Gómez-Rodríguez et al. 2010) (see Section 2.5.10.1.2 for more details).

2.5.10.2.3. Mammals

Remote cameras have been deployed at Audet Lake from 2011 to 2018 (Hawkes et al. 2019). A total of 152 remote cameras have been deployed over all survey years, with a range of 3 to 8 cameras deployed per habitat type per year. Cameras are deployed year-round.

Sixteen mammal species have been detected on cameras from 2011 to 2018 (Hawkes et al. 2019). Two federally listed mammal species at risk have been recorded on the cameras. Woodland caribou, which is listed as a threatened species (SARA 2021), has been recorded eight times over all survey years and cameras, while wolverine, which is listed as a species of special concern (SARA 2021), has been detected once. Canada lynx, which is considered a sensitive species in Alberta (GOA 2015), has been recorded 17 times over all survey years and cameras.

2.5.11. Aerial Invertebrates

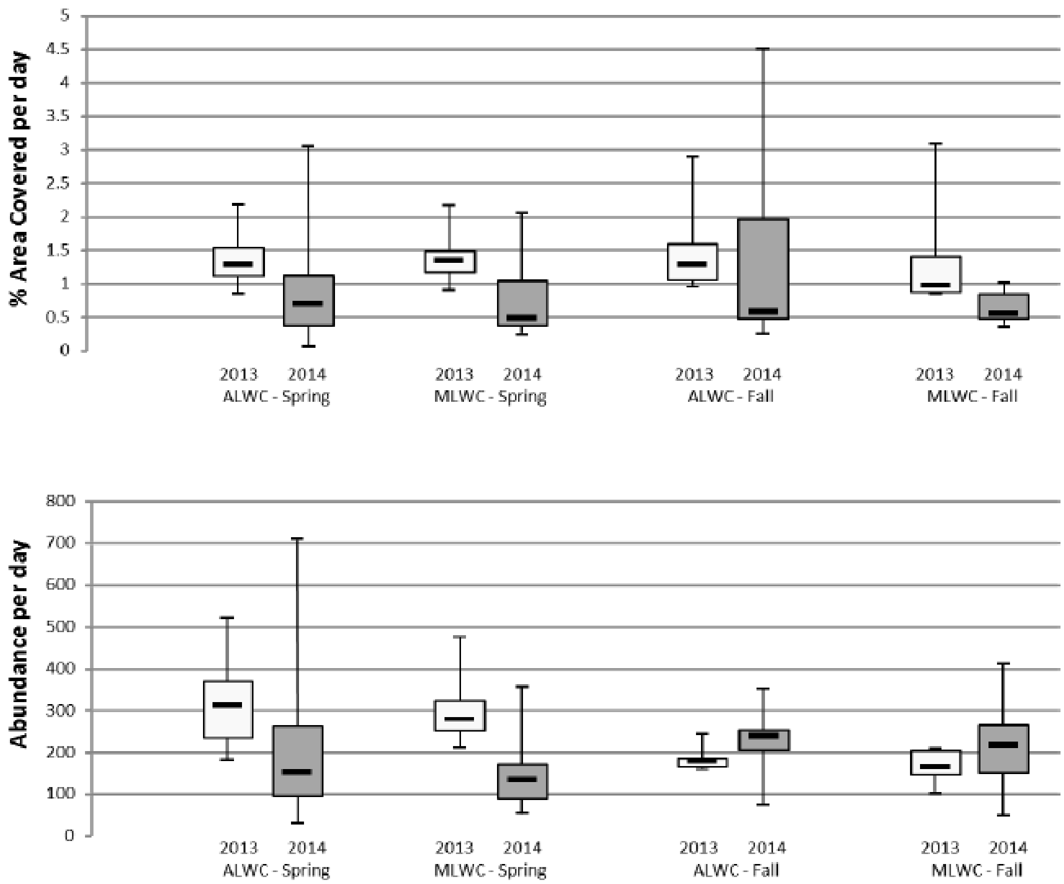
2.5.11.1. Overview of Pre-Mining Baseline Data

ITK holders have noted the presence of aerial invertebrates (bugs such as butterflies, bees, dragonflies, mosquitoes, horseflies, damselflies, and water beetles) as being indicative of good conditions for other forms of life in the MLWC area:

> *"Well as long as you can see the mosquitos when you first get there, you know you're gonna see the birds or whatever, that's what's really important for the birds, that's what they live on. Same thing as us would live on food, same thing too, you live on insects."* (MCFN ITK holder, MCFN 2019).

Aerial (flying) invertebrates were monitored at the MLWC during June/July and September 2013, and July and August 2014. Aerial invertebrates were caught with sticky traps and enumerated with computer software (ImageJ) to calculate percent area of the scanned image covered with insects (as a proxy for biomass) and count the number of individuals (abundance).

In 2013, abundance of aerial invertebrates differed between seasons ($p < 0.001$), but there were no differences in percent area between seasons ($p = 0.95$). There were no differences in abundance or percent area of aerial invertebrates between MLWC and ALWC fens ($p = 0.49$ and $p = 0.76$, respectively) and the ordination analysis revealed that the aerial invertebrates in MLWC and ALWC fens were compositionally similar ($p = 0.078$). In 2014, there were no differences in abundance or percent area ($p = 0.59$ and $p = 0.22$, respectively; Figure 2.5-50) and the ordination analysis revealed that the aerial invertebrates in MLWC and ALWC fens were compositionally similar ($p = 0.177$).



Source: Armada (2015).
% = percent; ALWC = Audet Lake Wetland Complex; MLWC = McClelland Lake Wetland Complex.

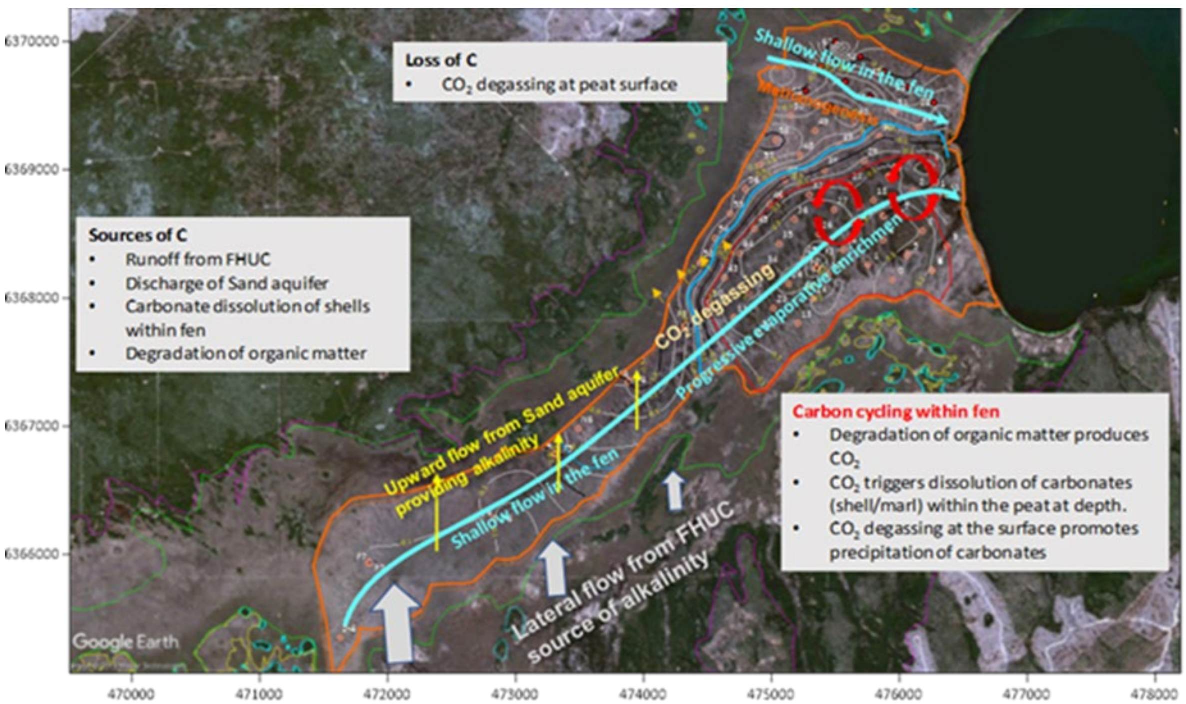
Figure 2.5-50: Boxplots of the Percent Area and the Abundance of Flying Invertebrates for Each Round of Sampling, Separated by Wetland Complex

Recommendations were made to either discontinue aerial invertebrate sampling or to reduce sampling to include only pre-mining baseline sampling (two to three years pre-impact). Aerial invertebrate sampling was initially included to supplement aquatic invertebrate data during dry years, as sticky traps do not rely on the presence of open water; however, as the approach selected for the aquatic invertebrate program has increased flexibility to select sites with access to open water, aerial invertebrate sampling was deemed redundant. Additionally, there was no correlation between aerial sticky trap and aquatic invertebrate results. Therefore, the use of sticky traps is not a suitable substitute for aquatic invertebrate sampling.

2.6. Interdisciplinary Analysis

2.6.1. Integration of Pre-Mining Baseline Condition

The following section is integrates the western science data from the baseline information presented in Sections 2.5.4 through 2.5.7, as well as findings from the hydrochemical model presented in InnoTech (2021). Similarly, ITK references to pre-mining baseline water quality and levels are included for comparison and temporal trend over time. InnoTech (2021) used geochemical and isotope data to develop a modern water balance of McClelland Lake and to identify key water sources, pathways, and reactions occurring along flowpaths, for the MLWC. The InnoTech (2021) conceptual model is illustrated in Figure 2.6-1.



FHUC = Fort Hills Upland Complex; C = carbon; CO2 = carbon dioxide.

Figure 2.6-1: Summary of Main Water flow Paths and Geochemical Processes in the McClelland Lake Wetland Complex

Groundwater data from the MLWC showed a relatively narrow range in groundwater levels in most of the wells in the fen and detectable seasonal responses (higher in the spring). The exception is the EHZ 2 wells which showed an overall range of 5.6 m, though the variability within each individual well dataset was smaller. The vertical gradients within the fen were variable, with some showing upward gradients, and others downward gradients. In contrast, groundwater data from the NOP showed rapid changes in groundwater levels in response to precipitation events and a strong downward vertical gradient, suggesting rapid infiltration in this area. In the FHUC there is limited groundwater data, but from the limited data it appears the range in groundwater levels is similar to the fen.

Surface water datasets from the fen showed consistent water levels that reflect surface topography. The sources of water to the fen include: precipitation, surface runoff originating from the south and southwest, permafrost meltwater, and groundwater originating from the FHUC and NOP. The primary loss of water in the fen is through evaporation. The relative amount of inflow from each source, as well as loss due to evaporation, is different in the different EHZs. For example, the oxygen isotope, major ion concentrations and their stoichiometry, and the radon isotope (^{222}Rn) data suggest the sources of water to EHZ 1 and EHZ 2 are different, and that there is little mixing of waters between the two zones (Section 2.5.6 and InnoTech 2021). The source of water to EHZ 1 appears to be from north of the fen and is more dilute compared to EHZ 2 (lower major ion concentrations, source is likely surface runoff and/or dilute groundwater from the NOP). The chemistry of water in EHZ 2 shows evidence of multiple sources including groundwater originating from the FHUC, upward migration of groundwater from the sand aquifer, and runoff originating from the FHUC and from the western part of the fen that is impacted by evaporation as it flows toward the lake (InnoTech 2021). The different mix of water sources appear to influence the vegetation within these EHZs. Seasonal variability in chemistry is observed, though the seasonal differences are relatively small.

There are several reactions occurring within the fen that control the chemistry and pH of fen water. The reactions include carbon dioxide (CO_2) generation via the degradation of organic matter, CO2 degassing and/or utilization by vegetation, precipitation and dissolution of carbonate minerals, methanogenesis, and evaporation (MacDonald et al. 1987; InnoTech 2021).

The lake water levels fluctuated by less than 1 m in the 1997 to 2020 dataset. However, air photo evidence and ITK present differing water levels in the past, (lower for a short period during the pre-development baseline) and higher levels prior to the 1990s. Water level data shows that generally higher water levels are observed in winter, which may be due to ice jamming at the outlet, or a combination of lower evaporative losses and steady groundwater discharge over the winter. However, lake water chemistry is dilute relative to most of the groundwater in the area which suggests most of the inflow to the lake is surface or shallow flow from the fen and surrounding watersheds. This is further supported by the baseline modelling which showed groundwater likely accounts for less than 10% of the lake inflows. The primary inflows to the lake are surface runoff from the south and southwest and precipitation. Also, in the patterned fen the strings act as small dams and the flarks as pools and together these control the storage and discharge of water to the lake from the fen (InnoTech 2021). The isotopic composition of McClelland Lake indicates that most water loss is due to evaporation (InnoTech 2021). The main outflow is through a depression at the east end for the lake as non-channelized flow. Further details on the conceptual models for MLWC is provided in Appendices D and E.

2.6.2. Regional Reference Sites

Characteristics of the ALWC and GGWC were compared with those of the MLWC to assess their utility as reference sites to support a BACI experimental design. Both reference sites include a lake near a patterned fen. McClelland Lake (approximately 3,020 ha) is the largest of the three lakes, followed by Birch Lake (associated with the GGWC and approximately 1,750 ha) and Audet Lake (approximately 700 ha). Preliminary analysis of coarse-scale topographical and hydrological data shows that at both the MLWC and ALWC, water flows from the patterned fen into the lake. However, while all the water within the MLWC patterned fen appears to drain into McClelland Lake, at the ALWC, a drainage divide appears to occur within the patterned fen, and a portion of the patterned fen appears to drain away from Audet Lake towards the Marguerite River to the north (Figure 2.5-42). Similarly, at GGWC, a hydrological divide separates the patterned fen from nearby Birch Lake, and water flows away from the lake and drains into a watercourse to the south (Figure 2.5-15); thus, the GGWC and Birch Lake are not hydrologically connected.

String and flark patterning is apparent at all three sites, although the prominence of the strings and flarks is more pronounced at the MLWC than at the ALWC or the GGWC. Areas with closely spaced, narrow, linear strings and flarks interspersed with areas with more rounded, lenticular patterning at both reference sites (Figure 2.5-42 and Figure 2.5-43) suggest that each site is influenced by unique, site-specific hydrogeological and hydrological processes. Evidence for the drainage divide within the ALWC is apparent in the orientation of the string and flark patterning (Figure 2.5-42).

Patterns of water level fluctuations at Audet Lake are similar to those observed at McClelland Lake and the MLWC based on water level data from 2017 to 2020 (Figure 2.5-42). Climate data analysis shows similarities between the ALWC and the MLWC, whereas a high-level analysis of climate data from the Gordon Lake Lookout climate station (near the GGWC) suggests wetter climate conditions at the GGWC than at the ALWC or MLWC.

Water quality and vegetation data from the MLWC were stratified into EHZ for comparison with the ALWC and the GGWC. In general, EHZ 1 had lower concentrations for key water quality indicators (e.g., pH, electrical conductivity, TDS, calcium, magnesium, potassium, and sodium) than EHZ 2 (Section 2.5.6). Water quality characteristics of the GGWC were closest to those of MLWC EHZ 1, and water quality characteristics of the ALWC were closest to those of MLWC EHZ 2 (Section 2.5.6). Plant communities in MLWC EHZ 1 and 2 reflect these differences in water quality (Section 2.5.9). Plant communities in EHZ 1 (i.e., vegetation plots T1F and X1F) were similar to GGWC plant communities for both strings and flarks, and plant communities in EHZ 2 were similar to ALWC string plant communities (shown on ordinations in Section 2.5.9), which is consistent with water quality results. To account for differences in plant community composition between reference sites and MLWC, stratification of plots by dominant species and water quality characteristics may be considered in future analyses focused on detecting change as mining progresses within the MLWC watershed.

Overall, water quality and vegetation results show that the ALWC and GGWC together represent the full range of conditions documented at the MLWC; neither reference site alone encompasses the full MRV that characterizes the MLWC. Therefore, both reference sites will be included in the effects monitoring program and response framework described under Objectives 5 and 6, respectively, to achieve a BACI design.

2.7. Objective 1 Summary

The purpose of Objective 1 is to define baseline conditions for the MLWC, including those prior to industrial development (pre-development), and during the years between early industrial activities and today (pre-mining). The Indigenous Peoples using the MLWC area, both in the past and today, value the site as an important “grocery store” ecosystem that provides clean water, berries and medicinal plants, fish, game, and furs integral to their sustainable life on the land. Since industrial activities began in the area, Indigenous Peoples have observed changes to the ecosystem. According to ITK, water levels are lower, and water quality has left some land users unable to trust the safety of water for consumption. The abundance and health of plants and animals harvested for consumption, medicinal use, and culturally important practices including the transfer of knowledge between generations has also changed. While some are now wary of consuming water, plants, or animals from the area due to concerns over industrial contamination, the MLWC and surrounding area still represents a culturally importance subsistence landscape for the Indigenous Peoples who have, and continue to access it.

Pre-development baseline conditions are conditions occurring before the influence of oil sands development, defined temporally as 1960 or earlier. In addition to ITK holders knowledge and observations before the onset of oil sands industrial activity informing the pre-development baseline conditions, pre-development baseline was also characterized through investigation of paleo-ecology within the peatland, and paleolimnology within McClelland Lake. Reconstruction of post-glacial vegetation up to 13,000 cal yr BP was used to characterize changes throughout the Holocene, and initiation and development of the MLWC, peat accumulation, string stability, and reconstructed water quality and hydrology characteristics were included in the discussion. The paleolimnological investigation of McClelland Lake included sediment core age-depth relations, paleohydrology, phototrophic and diatom community analyses, analysis of polycyclic aromatic compounds, and a summary of the paleoenvironmental history of McClelland Lake. The EHZ conceptual model was developed based on this work, and continues to inform our understanding of the MLWC.

Pre-mining baseline conditions (i.e., conditions including existing anthropogenic disturbances and effects on the natural environment, prior to mining in the MLWC watershed, defined temporally by the timelines captured in monitoring or modelling data) were informed by ITK, MLWC monitoring program data, historical imagery, and model predictions. Pre-mining baseline conditions were characterized for geology and hydrostratigraphy, topography, hydrogeology, surface water hydrology, surface water and groundwater quality, aquatic resources, soils, vegetation, wildlife, and aerial invertebrates. A distinction was drawn between the NRV (i.e., the spectrum of ecosystems states and processes encountered over a long time period) and the MRV (i.e., variability quantified during the pre-mining baseline period). The MRV was summarized for the MLWC, and also for two reference sites (i.e., ALWC and GGWC) for select components (i.e., surface water hydrology, surface water quality, vegetation, and wildlife) so that a BACI statistical model can be implemented following commencement of ditching and draining activities in the MLWC watershed.

Overall, the characterization of physical, hydrological, chemical and biological processes performed by the MLWC provided in the pre-development and pre-mining baseline sections of Objective 1 will be used to inform discussions of functionality and indicator selection in Objective 2.

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ABBREVIATIONS, ACRONYMS, AND UNITS

Abbreviations and Acronyms

Abbreviation/Acronym	Definition
2020 MLWC HGS model	HydroGeoSphere Model
AAG	Aboriginal Advisory Group
ACFN	Athabasca Chipewyan First Nation
AEP	Alberta Environment and Parks
AER	Alberta Energy Regulator
AET	actual evapotranspiration
ALWC	Audet Lake Wetland Complex
AQ1/AQ2/AQ4	silty sand aquifer material
Aquanty	Aquanty Inc.
Armada	Armada Environmental Inc.
ARU	Autonomous recording unit
AT2	patchy sandy silt aquitard
AT4	sandy silt aquitard material
BACI	Before-after-control-impact
BCMWLAP	British Columbia Ministry of Water, Land, and Air Protection
C	carbon
ca.	circa
CCME	Canadian Council of Ministers of the Environment
Clay Till 1	clay till layer
Clay Till 2	Clay till aquitard
CO_2	carbon dioxide
CPUE	Catch-per-unit-effort
DOC	dissolved organic carbon
E	evaporation
ET	evapotranspiration
ECCC	Environment and Climate Change Canada
e.g.,	for example
EHZ	Ecohydrology Zone
FCN	Fort Chipewyan Métis
FHEC	Fort Hills Energy Corporation
FHUC	Fort Hills Upland Complex
FMFN	Fort McKay First Nation
FMMN	Fort McKay Métis Nation
Fort Hills Project	Fort Hills Oil Sands Project
FWMIS	Fish and Wildlife Management Information System
GGWC	Gipsy Gordon Wetland Complex
GOA	Government of Alberta

Abbreviation/Acronym	Definition
Golder	Golder Associates Ltd.
HEG	Human Environment Group
ID	identification
i.e.,	that is
IEG	Integral Ecology Group
IRC	Industry Relations Corporation
ITK	Indigenous Traditional Knowledge
JOSM	Joint Oil Sands Monitoring
LiDAR	Light Detection and Ranging
Matrix	Matrix Solutions Inc.
MCFN	Mikisew Cree First Nation
MLWC	McClelland Lake Wetland Complex
MRPP	Multi-response Permutation Procedure
MRV	Measured range of variability
NMDS	Non-metric Multidimensional Scaling
NOP	North Outwash Plain
NRV	natural range of variability
OP	Operational Plan
OSM	Oil Sands Monitoring
PAC	polycyclic aromatic compounds
PAH	polycyclic aromatic hydrocarbons
PET	potential evapotranspiration
PGKM	Rafted McMurray
QA/QC	quality assurance and quality control
RAMP	Regional Aquatics Monitoring Program
SC	Sustainability Committee
TDS	total dissolved solids
TLU	Traditional land use
U.S. EPA	United States Environmental Protection Agency
UV	ultraviolet
VW	vibrating wire
VWP	vibrating wire piezometer

Units

Unit	Definition
%	percent
<	Less than
°C	degree Celsius
cal yr BP	calendar years before present
cm	centimetre
g/cm^3	grams per cubic centimetre
ha	hectare
km	kilometre
km^2	square kilometre
km/hr	kilometres per hour
masl	metres above sea level
mbgs	metres below ground surface
m	metre
m^2	square metre
m/m	metres per metre
m/s	metres per second
mg/L	milligrams per litre
mm/yr	millimetres per year
MPa	megapascal
s	second
W/m^2	watts per square metre
µm	micrometre
µS/cm	microSiemens per centimetre