Niverville
WHERE YOU BELONG

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Eric King

April 13, 2021

Ms. Shannon Kohler
Director, Environmental Approvals Branch
Manitoba Conservation and Climate
1007 Century Street
Winnipeg, MB
R3H 0W4

**Subject: Request for Removal of the Town of Niverville's Environment Act License #2712**

Dear Ms. Kohler,

On behalf of the Town of Niverville, please find enclosed a Request for Removal of Environment Act License #2712 for the Town's sewage decommissioned lagoon on SW 30-7-4 EPM in the Town of Niverville.

The Town of Niverville's long-term intention for the old lagoon site was to develop the area as a recreational and educational site for the community. The Town recognized early on during the onset of the project that opening the site to public access required decommissioning of the old lagoon in order to ensure all environmental and human health risks were mitigated, prior to the removal of the existing Environment Act License. The attached report outlines project results, how remediation targets have been met, and plans for site development including safety considerations. Justification for the removal of the Environmental License is that biosolids in the wetland cell area demonstrate a low risk to environmental or human health and are considered decommissioned.

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Current site conditions as noted in Table 10 of the report, in conjunction with risk mitigation strategies (Section C – 3.0), warrant the removal of the license from the site. License removal will allow the Town of Niverville to continue pursuing its progressive and sustainable vision for the Niverville Lagoon site as an interpretive and educational park site, central to its community.

Thank you for your consideration of this request. Should you require any further information or clarification of this request, please contact myself at 204-388-4600 or Lisette Ross, Senior Wetland/Upland Specialist, Native Plant Solutions at 204-953-8205.

Yours truly,
TOWN OF NIVERVILLE

[redacted]

Eric King CPA CGA
Chief Administrative Officer

Town of Niverville, Manitoba

# Request for licence removal on
# Environment Act Licence #2712

Prepared for:

Town of Niverville

Prepared by:

Native Plant Solutions/

Ducks Unlimited Canada

A-1238 Chevrier Boulevard

Winnipeg, Manitoba

R3T 1Y3

April 13th, 2021

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# A. Introduction

## 1.0 Project background

The use of wetland systems and plants to remove contaminants, both organic and inorganic, from soil and water is widely practiced in other parts of the world (Pilon-Smits, 2005). Plant-based remediation approaches, also known as phytoremediation, have long been used for the cleanup of sites contaminated with inorganic (e.g., metals, nutrients) and organic (e.g., petroleum hydrocarbons, polycyclic aromatic hydrocarbons, chlorinated solvents) substances. Although there is increasing interest in employing constructed wetlands for wastewater treatment, particularly to meet nutrient guidelines for release, little consideration has been given to employing the same natural systems at the "back end" of the process, for decommissioning a wastewater treatment lagoon.

In 2011, the Town of Niverville (also referred to as 'the Town' in this report) proposed to explore remediating its biosolids *in-situ* via phytoremediation, as an alternative to traditional lagoon decommissioning options (i.e., landfilling or spreading on agricultural land) for its old lagoon located on SW 30-7-4 EPM in the Town of Niverville. Reasoning for the Town exploring *in-situ* decommissioning was to consider an environmentally-friendly option, as the community prides itself on sustainability. Following extensive consultation with the Province of Manitoba and its expertise from Conservation and Climate (formerly Conservation and Water Stewardship), the Town of Niverville submitted a Notice of Alteration (NoA) to its existing Environmental Licence in order to obtain permission for pursuing this unique decommissioning option in a manner that posed no human or environmental health risks. Following approval of the proposed activities in September 2011, lagoon site decommissioning and research commenced in 2012.

Following two growing seasons in which the *in-situ* wetland and upland remediation systems had been operational (i.e., 2013 and 2014), as well as the completion of two graduate students conducting both laboratory and field research components of the project through the University of Manitoba, the project compiled sufficient data to demonstrate the success of the system and progress towards meeting remediation targets. Research data showed that soil materials from the dry cell area (i.e., former secondary cell) indicated that no potential environmental or public health risks associated with the previous operation of the wastewater treatment lagoon cell existed in the dry cell area. In October 2015 the Town submitted a NoA to the existing licence to have the dry cell removed from licence, as well as installing fencing inside of the lagoon berms to limit public access to those areas still under licence (i.e., wetland cell, control cell, and holding cell). Following approval of the NoA in December 2015, the Town commenced development of the interpretive site in the dry cell while allowing community members to walk the perimeter of the lagoon and view the research being undertaken in the wetland cell. Research continued on the wetland cell to gather more data on the progress of phytoremediation.

As the long-term goal for this site for the Town is to use the area as an interpretive/educational site and community park, the Town is requesting removal of the Environmental Licence to further this objective. A meeting was held at the Manitoba Conservation and Climate Steinbach's office in December 2019 with representatives from the Province (Robert Boswick, Curt Bueckert, and Asit Dey), Town of Niverville (Ryan Dyck and Eric King ), Native Plant Solutions (Lisette Ross, Bruce Friesen-Pankratz and Nicholson Jeke) to inform the Province of decommissioning results of the wetland cell and to be informed on the next steps to get the site off licence. The data showed the site had been remediated to levels that did not pose environmental risk. At the December 2019 meeting the Province recommended additional sampling to demonstrate the site did not pose a health risk if the site is opened for public access. As *in-situ* decommissioning has never been done before and no guidelines existed, the Province recommended using United States Environmental Protection Agency (USEPA) pathogen requirements for Class A biosolids as guidelines for assessing pathogen risk. A follow-up virtual meeting held in April 2020, with representatives from the Province (Robert Boswick and Curt Bueckert) and Native Plant Solutions (Lisette Ross, Bruce Friesen-Pankratz and Nicholson Jeke), finalized biosolids sampling requirements needed to assess the human health risks using USEPA Class A pathogen requirements.

After completion of the monitoring recommended by the Province in 2020, a meeting was held in February 2021 with representatives from the Province (Robert Boswick, Curt Bueckert, and Larry Markwart), Town of Niverville (Ryan Dyck and Eric King), Native Plant Solutions (Lisette Ross, Bruce Friesen-Pankratz and Nicholson Jeke) to present the results of the data gathered and to enquire on the process for removing the site from the licence. Representatives from the Province indicated their willingness to review a formal submission from the Town requesting removal from licence for those former lagoon locations remaining on licence (i.e., wetland cell, control cell and holding cell). This document serves as a formal request for removal of the site from Environment Act Licence #2712.

### 1.1 Document outline

This section describes the layout of the document. Section A – 2.0 describes the existing Environment Act Licence #271 on the former Niverville lagoon, including the two NoAs (2011 and 2015) under which research activities were approved. Section A – 3. 0 describes the project infrastructure which includes a description of the original lagoon structure and the remediation redesign of the site that was done to undertake phytoremediation research.

Section B describes the research that was conducted by researchers from the University of Manitoba from 2012 to 2018. After completion of the research that was done between 2013-2018, Manitoba Conservation and Climate recommended additional monitoring to demonstrate that the site does not pose health risks if opened for public access. Additional monitoring that was conducted in 2019 and 2020 as recommended is presented in Section C – 2.1 through 2.5.

Section C – 2.0 describes remediation targets that were adopted, including justification for their use. Sections C – 2.1 through 2.5 presents data and results that provides evidence for meeting targets for trace elements, nutrients and pathogens in biosolids and surface water. Section C – 3.0 outlines the steps the Town of Niverville is intending to take on site in order to mitigate future risks to environmental and human health. A summary of the justification for licence removal from the site is presented in Section C – 4.0.

## 2.0 Existing licence

On January 23, 2006, an Environment Act Licence #2712 was granted to the Town of Niverville to construct a new lagoon on SW 7-8-4 EPM, Rural Municipality of Richot to replace the existing lagoon on SW 30-7-4 EPM, Town of Niverville. The existing lagoon was no longer of sufficient capacity and its construction did not meet current standards.

The existing licence required that the Licencee follow conventional decommissioning protocols: removal of biosolids to a disposal site or spreading on agricultural land under environmental licence. However, in 2011 after the submission of a request for NoA by the Town of Niverville, the Province of Manitoba approved the activities under the NoA (i.e., undertaking a research project to assess contaminant reduction in lagoon biosolids using a wetland system and phytoremediation). On October 27, 2015 the Town submitted a formal request along with supporting documentation and research findings for the removal of the dry cell from Environment Act Licence #2712. On December 29, 2015 after submission of the NoA for partial removal of licence, the dry cell was removed from the licence while research activities continued on the wetland cell. Conditions under which the activities were approved included:

> *Clauses 38, 39 and 40 of Environment Act Licence No. 2712 are not required to be acted on by the Town at this time but remain enforceable for the control, holding, and wetland cells as identified on Figure 1 of the attachment;*
>
> *As indicated, a fence around the site of the old lagoon to limit access must be installed and maintained. The fence shall be a minimum of 1.2 meters high and have a locking gate;*
>
> *As indicated, a fence around the site of the control, holding, and wetland cells as identified on Figure 1 of the attachment to limit access must be installed and maintained. The fence shall be a minimum of 1.8 meters high, be effective at minimizing access to these cells to the satisfaction of the assigned Environment Officer, and have a locking gate which shall be locked at all times except to allow temporary access to these cells.*
>
> *Discharge of water from the control, holding, and wetland cells as identified on Figure 1 of the attachment shall only be via delivery to the Town of Niverville's new lagoon or to another wastewater treatment facility operating under a Licence issued pursuant to The Environment Act;*
>
> *Sludge solids shall not be removed from the control, holding, and wetland cells as identified on Figure 1 of the attachment unless otherwise authorized by an Environment Officer;*
>
> *Annual reports of the previous year's related activities shall be submitted to the Environmental Approvals Branch, Manitoba Conservation and Water Stewardship by January 31st of the following year; and*
>
> *This approval shall be revisited not later than five years after the date of this letter.*

## 3.0 Project infrastructure

This section describes the original lagoon structure and the remediation redesign of the site that was done in order to undertake phytoremediation research. In order to fulfill the research and remediation design of the project, the original lagoon structure composed of a primary cell and secondary cell, was redesigned (Figure 1).

The primary cell served as the wetland component of the research, where remediation occurred by vegetative and aquatic processes. The wetland cell was redesigned with benches to support the growth of wetland vegetation at their preferred growing depth, as the original depth of the cell was too deep for supporting plant growth (Figure 2). During construction in fall 2012, all biosolids in the primary cell and all biosolids within the footprint of the holding cell were stripped down to the underlying clay liner and temporarily stockpiled in the primary cell (Figure 3). After stripping the biosolids, the primary cell clay liner was excavated to a minimum depth of 15 cm followed by recompaction to a minimum density of 95% standard dry density. Soil embankments were constructed by placing excavated clay, followed by compaction to a minimum of 95% standard proctor dry density. The soil embarkments in the primary cell served as the foundation for wetland bench construction via the placement of biosolids to support plant establishment and growth. Biosolids were loosely placed on top of the constructed benches. The target biosolids depth after settling was 40 cm. The redesigned primary cell is hereafter referred to as the wetland cell. A center channel in the wetland cell of 1.5 m depth was left to limit the growth of wetland vegetation in this area. Note that no biosolids were placed in the center channel. Around the wetland cell, 1 metre of freeboard was maintained, for rain events.

Wetland plants (i.e., *Typha latifolia*; Broadleaved cattail) were established in the wetland cell using live propagules obtained and transplanted from donor sites in the area during the winter of 2012/2013. For research purposes, a control cell (Figure 1) was designed and built in the footprint of the original primary cell that contained no wetland plantings to determine the pathway of biosolids contaminants in the absence of wetland plants. However, cattail established in the control cell naturally within the first summer of wetland commissioning (i.e., 2013), and overtime it was naturally replaced by submerged rooted aquatic vegetation in its place. The vegetation that developed in the control cell is providing the same treatment capabilities as the cattails within its connected wetland cell. Note that the control cell is connected hydrologically to the wetland cell via an open pipe therefore both the wetland and control cells share the same surface water.

Wetland plants (i.e., *Typha latifolia*; Broadleaved cattail) were established in the wetland cell using live propagules obtained and transplanted from donor sites in the area during the winter of 2012. The wetland design included a water control structure to maintain a water depth of 45 cm on the wetland benches. In 2013 and 2014, as wetland plants were exposed to their first two growing seasons, commissioning of the water levels was important to establish a robust cattail community within a healthy, functioning wetland.

The original secondary cell was divided by a berm to form two separate cells; the holding cell and the dry cell (Figure 1). All biosolids that were existing in the holding cell area were removed during construction and placed in the wetland cell, as it was required for design of the wetland benches. With no biosolids remaining in the holding cell no biosolid samples were collected from the cell after reconstruction of the site. The holding cell is designed to allow for the commitment to the 2011 NoA to be met; that no water discharged from the lagoon would leave the site when water levels in the new wetland cell needed to be either lowered or raised to support the growth of young wetland plants. A weir manhole control structure with gate valve is installed between the wetland cell and the holding cell, controlling flow from the wetland cell to the holding cell. The wetland cell is not designed to discharge water to the environment; the wetland cell is connected to the control cell and holding cell.

The dry cell served as the dryland phytoremediation component of the research where remediation occurred by native plants. The dry cell was removed from the existing licence in December 2015. Berms separate the dry cell from the holding cell and the wetland cell. There are no pipes or other physical structures that connect the dry cell to the other cells. The dry cell was removed from licence in December 2015 and will not be the focus of this submission.

## 4.0 Formal request for licence removal

As presented at stakeholder meetings in December 2019 and February 2021, as well as in the NoA submitted to the Province of Manitoba in 2011 and 2015, the Town of Niverville's long-term intention for the old lagoon site is to develop the area as a recreational and educational site for the community. The Town recognized early on during the onset of the project that opening the site to public access required decommissioning of the old lagoon in order to ensure all environmental and human health risks are mitigated, prior to the removal of the existing Environment Act Licence. The Town partnered with both the University of Manitoba and Native Plant Solutions (NPS/Ducks Unlimited Canada (DUC) to complete a strong monitoring program that provides the results needed for the Province of Manitoba to make an informed decision on the environmental and health status of this site.

The remainder of this report outlines project results, how remediation targets have been met, and plans for site development including safety considerations.

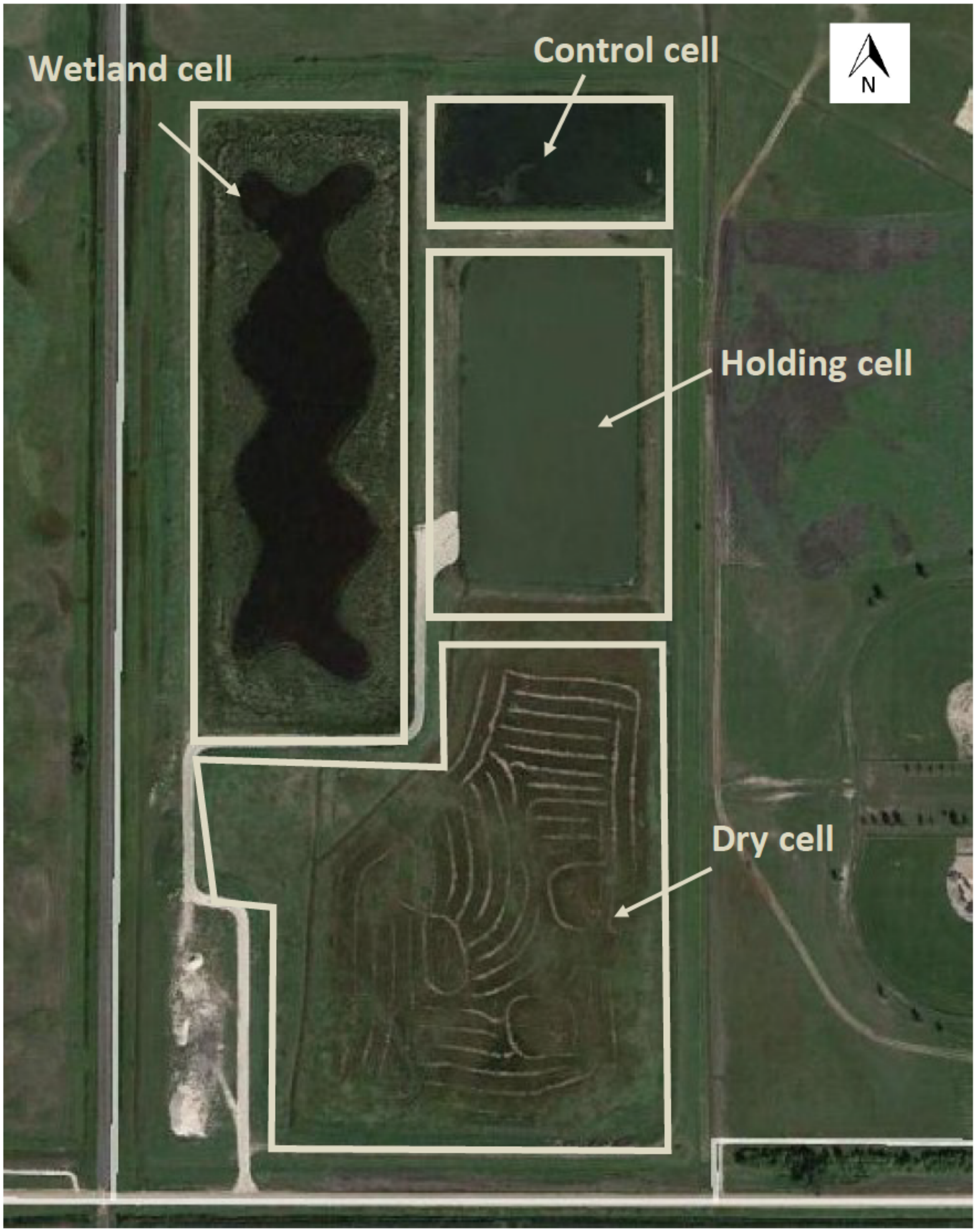

Figure 1. Niverville lagoon phytoremediation project site, including the wetland cell, control cell, holding cell and dry cell. Image courtesy of Google Earth (Imagery date: 2016).

Figure 2. Niverville lagoon on SW 30-7-4 EPM during operation in 2002 (left; Image courtesy of Google Earth; Imagery date: May, 2002) and in 2016 after redesign for the Niverville Lagoon Bioremediation Project (right; Image courtesy of Google Earth; Imagery date: 2016).

Figure 3. (a) Primary cell before construction of the wetland (September 7, 2011) (b) recontouring of the primary cell (October 16, 2012) (c) stockpiled biosolids and a constructed wetland bench (October 16, 2012) (d) spreading of biosolids on a wetland bench (October 16, 2012) (e) cattail plants placed within divots on wetland benches (November 28, 2012) (f) wetland vegetation in the second growing season (June 26, 2014).

# B. Research in Support of Licence Removal

This section describes the research that was conducted by researchers from the University of Manitoba from 2012 to 2018. Note that additional monitoring recommended by the Province in 2019 and 2020 for licence removal is presented in Section C – 2.1 through 2.5.

When the Town of Niverville decided to pursue *in-situ* wetland and phytoremediation as an alternative to conventional lagoon remediation it became apparent that research would provide, under both controlled and uncontrolled conditions (i.e., in growth chamber and field site conditions), the needed data to demonstrate the effect of *in-situ* remediation on lagoon decommissioning. In conjunction with researchers from the University of Manitoba and Native Plant Solutions/Ducks Unlimited Canada, a research design was developed to support testing of this decommissioning option. We believe it was the research-based focus of the *in-situ* remediation option that gave regulators within the Province of Manitoba the confidence to approve a Notice of Alteration to Niverville's existing lagoon Environmental Licence, as well as being an innovative approach that achieves nutrient reduction; a 2006 Lake Winnipeg Stewardship Board recommendation #20.1 (Lake Winnipeg Stewardship Board, 2006)

Research completed by the University of Manitoba supporting the justification for licence removal from the wetland cell is presented and described below. Additional data collected in 2019 and 2020 as requested by the Province is presented in Section C – 2.0. For abstracts of research and links to the full text research documents see Appendices A-K. The research resulted in 2 MSc theses, 1 PhD dissertation and 8 peer-reviewed publications in scientific journals such as the *Journal of Environmental Quality*, *Water, Air & Soil Pollution*, *International Journal of Phytoremediation*, and *Soil Science Society of America*.

## 1.0 Field sampling methodology

This section describes locations were biosolids, water and vegetation samples were collected. Before construction of the wetland cell, initial biosolid samples were collected in 2011 from 13 locations in the old lagoon to characterize nutrients and trace elements. Figure 4 shows biosolid sampling locations from 2013 to 2020. In the spring of 2013, 48 research plots (8 plots × 6 subplots) were established in the wetland by researchers from the University of Manitoba. Biosolids, vegetation samples and water samples were collected from the 48 plots from 2013 to 2018 by researchers from the University of Manitoba. After the research between 2013 and 2018 and in conversations with Manitoba Conservation and Climate, additional monitoring was recommended, biosolids sampling locations in 2019 and 2020 were spread across the entire wetland cell as shown in Figure 4. Results for data collected in 2019 and 2020 are presented in Section C – 2.1 through 2.5.

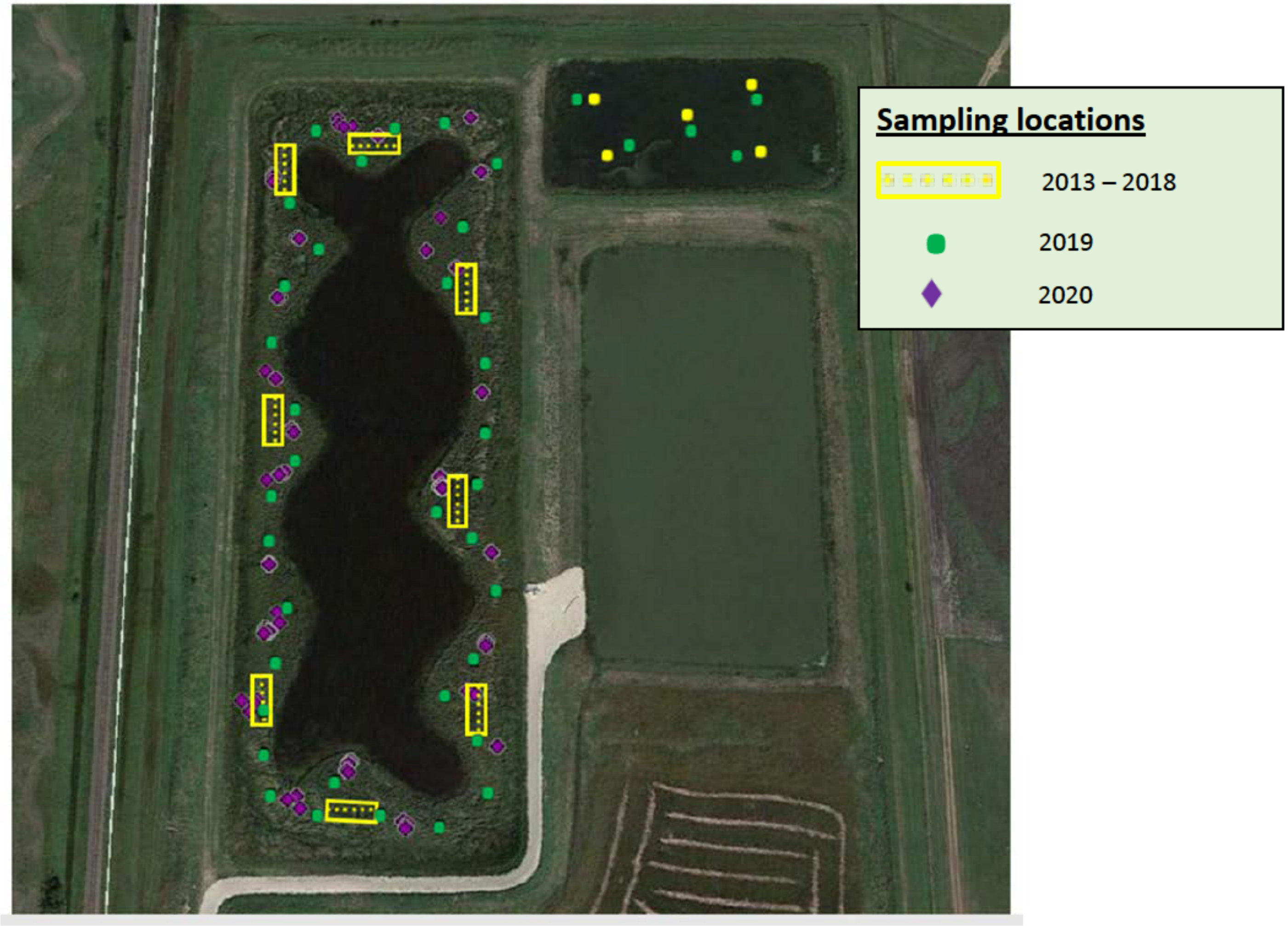

Figure 4. Biosolid sampling locations in the wetland cell and control cell from 2013 to 2020 (Image courtesy of Google Earth; Imagery date: 2016).

## 2.0 Plant growth and establishment

At the beginning of the study it was unknown whether biosolids alone (i.e., without soil amendments) could support plant growth necessary for phytoremediation. Growth room experiments demonstrated that the wetland plant, Cattail (*Typha* sp.) could grow in un-amended biosolids collected from the wetland cell (Hassan 2014; Appendix A). Cattail grown in biosolids alone produced more biomass and removed more nitrogen and phosphorus compared to cattails grown in a 50/50 mixture of biosolids and soil. The growth of cattail in biosolids alone was corroborated in the field as robust cattail plants established in the wetland cell within the first and second growing season after it was redesigned in 2012 (Figure 3f).

# 3.0 Nutrient availability in biosolids

Phosphorus and nitrogen occur in different fractions in biosolids. However, it is their bio-available inorganic forms that pose a risk to the health of aquatic environments. Mineralization is the process that transforms nutrients from organic N and P forms to inorganic forms. Inorganic P adsorbed to precipitates can become available through desorption. The availability of nutrients in the wetland cell biosolids was assessed using two methods:

- Sequential chemical fractionation of P to characterize forms of P in the biosolids, and
- Plant root simulators (PRS) probes to characterize available nutrients *in-situ*.

## 3.1 Sequential chemical fractionation study

Forms of P in the biosolids were extracted in a process modified from Hedley et al. (1982), which sequentially extracts P with solvents of increasing strength (Table 1). This method is widely used to characterize P availability in soils and organic materials such as biosolids and manure. Labile forms of P are removed with water and mild sodium bicarbonate solution.

Biosolids collected from the wetland cell in 2013 were subjected to a sequential chemical fraction as described in Table 1 to characterize the forms of P in the biosolids (Jeke et al., 2019). The readily available P fraction extracted with water, representing soluble orthophosphate, was only 6.7 mg/kg or <1% of total P (Table 2). This indicates low soluble orthophosphate in the biosolids. Potential available P extracted with sodium bicarbonate, representing weakly bound P was 141 mg/kg or 12% of total P, indicating low potentially available P in the biosolids. This potentially available P fraction represents phosphate that might be “rinsed out” of the biosolids when exposed to low phosphorus levels in the water column of the wetland. This labile P fraction represents P that is potentially available to the aquatic environment and is available for uptake by wetland plants, algae and microbiota. Research findings indicated that most of the P in the biosolids within the wetland is in the recalcitrant fractions which are not readily available (Table 2) for presenting a threat to the environment. This low availability of P in the biosolids shows that the biosolids pose a low risk to the health of aquatic environments.

Table 1. Description of sequential phosphorus extraction procedure and forms of phosphorus extracted.

| Order of Extraction | Extractant | Phosphorous form | Availability |
|---|---|---|---|
| 1 | Water ($H_2O$) | Soluble P | very high |
| 2 | Sodium bicarbonate ($NaHCO_3$) | Inorganic P weakly bound to aluminum and iron, and organic P weakly bound to soil organic matter. | high |
| 3 | Sodium hydroxide (NaOH) | Inorganic P tightly bound to aluminium and iron, and organic P tightly bound to soil organic matter. | moderate |
| 4 | Hydrochloric acid (HCl) | Inorganic P tightly bound to calcium and magnesium | very low |
| 5 | Sulphuric acid ($H_2SO_4$) and hydrogen peroxide ($H_2O_2$) | Residual P | unavailable |

Table 2. Phosphorus fractions (mg/kg) in biosolids from the wetland cell (2013) as measured by a modified Headily et al. (1982) chemical sequential fractionation (Jeke et al., 2019) (parentheses indicate standard deviations)$^A$.

|  | TP | $H_2O$-$P_i$ | $NaHCO_3$-$P_i$ | NaOH-$P_i$ | HCl-$P_i$ | Residual P |
|---|---|---|---|---|---|---|
| Availability |  | very high | high | moderate | very low | unavailable |
| 2013 | 1215 (226) | 6.7 (0.3) | 141 (2) | 171 (6) | 572 (24) | 228 (17) |

$^A$ TP, total phosphorus; $H_2O$-$P_i$, water extractable inorganic phosphorus; $NaHCO_3$–$P_i$, labile inorganic phosphorus; NaOH-Pi, Fe/Al-bound inorganic phosphorus; HCl-Pi, Ca/Mg-bound inorganic phosphorus.

## 3.2 Plant root simulator (PRS) probes study

Another study was completed in the wetland cell in 2014 to characterize the temporal changes in nutrient availability throughout a growing season using PRS probes (Jeke and Zvomuya, 2018). PRS probes are ion exchange membranes that adsorb ions at a rate dependent on ion activity and diffusion rate in solution. PRS probes measure available ions and also mimic uptake by plant roots. The PRS probes (15 cm by 3 cm by 0.5 cm; Western Ag, Saskatoon, SK) used in this study consisted of anion- and cation-exchange membranes that were enclosed in plastic supports (Figure 5). The anion-exchange membranes are positively charged and attract negatively charged ions while the negatively charged cation-exchange membranes attract and adsorb cations. The total number of pairs of probes deployed in the wetland cell over the study period was 84. Each pair of probes was inserted in the 0-15 cm biosolids layer in PVC cylinders (10-cm diam. by 45-cm height) in which plant roots had been removed to prevent root uptake of nutrients. Nutrient accumulation rates are expressed as microgram ($\mu$g) of nutrient absorbed per 10 cm$^2$ per burial period and are used as a measure of nutrient supply rate and bioavailability.

Very low available N was observed in the wetland (4 to 12 $\mu$g/cm$^2$/2 weeks; Figure 6c). For comparison, a study by Quaye et al. (2015) measured available nitrogen supply rates ranging from 30 to 120 $\mu$g/cm$^2$/2 weeks in agricultural soil amended with composted biosolids. In general, composted biosolids have low nutrient availability. In agricultural soils supplied with inorganic fertilizers, very high available N supply rates can be measured, e.g. 200 to >1100 $\mu$g/cm$^2$/2 weeks (Qian and Schoenau, 2005). Lower N supply rates measured in the Niverville wetland study is a result of low mineralizable N in the biosolids and the wetland environment, which reduce mineralization rates under anaerobic conditions. A laboratory study using the Niverville biosolids also demonstrated that the biosolids had low N mineralization rates (Jeke et al. 2015b; Appendix E).

Available P supply rate in the Niverville wetland cell was also low and remained relatively unchanged throughout the growing season, ranging from 17 to 24 µg/cm$^2$/2 weeks (Figure 6d). If P was readily available in the biosolids, a general increase in P supply rate would be expected under the saturated wetland environment, as available P bound to iron or aluminum is released under anaerobic conditions. The Niverville wetland biosolids had high available calcium (1700 to 1900 µg/cm$^2$/2 weeks; Figure 6f). In the presence of calcium, phosphate is readily bound to calcium forming insoluble calcium phosphate (apatite) which is stable and not readily available. This corroborates with the study on sequential chemical extraction described above (Section B – 3.1), which showed that 47% (572 mg/kg) of the total P (1215 mg/kg) was extracted with HCl, which extracts calcium or magnesium bound P (Table 2). The availability of P bound to calcium or magnesium is very low (Table 1).

Cumulative supply rates of the nutrients measured by PRS probes were highly correlated with measurements of N (correlation coefficient, r = 0.77) and P (r = 0.92) uptake by cattail uptake, indicating that PRS probes are effective in measuring availability of nutrients in biosolids sediments under wetland environments (Jeke and Zvomuya, 2018).

Figure 5. PRS probes retrieved from a research plot in the Niverville wetland cell, cleaned and combined to form a composite site for the plot.

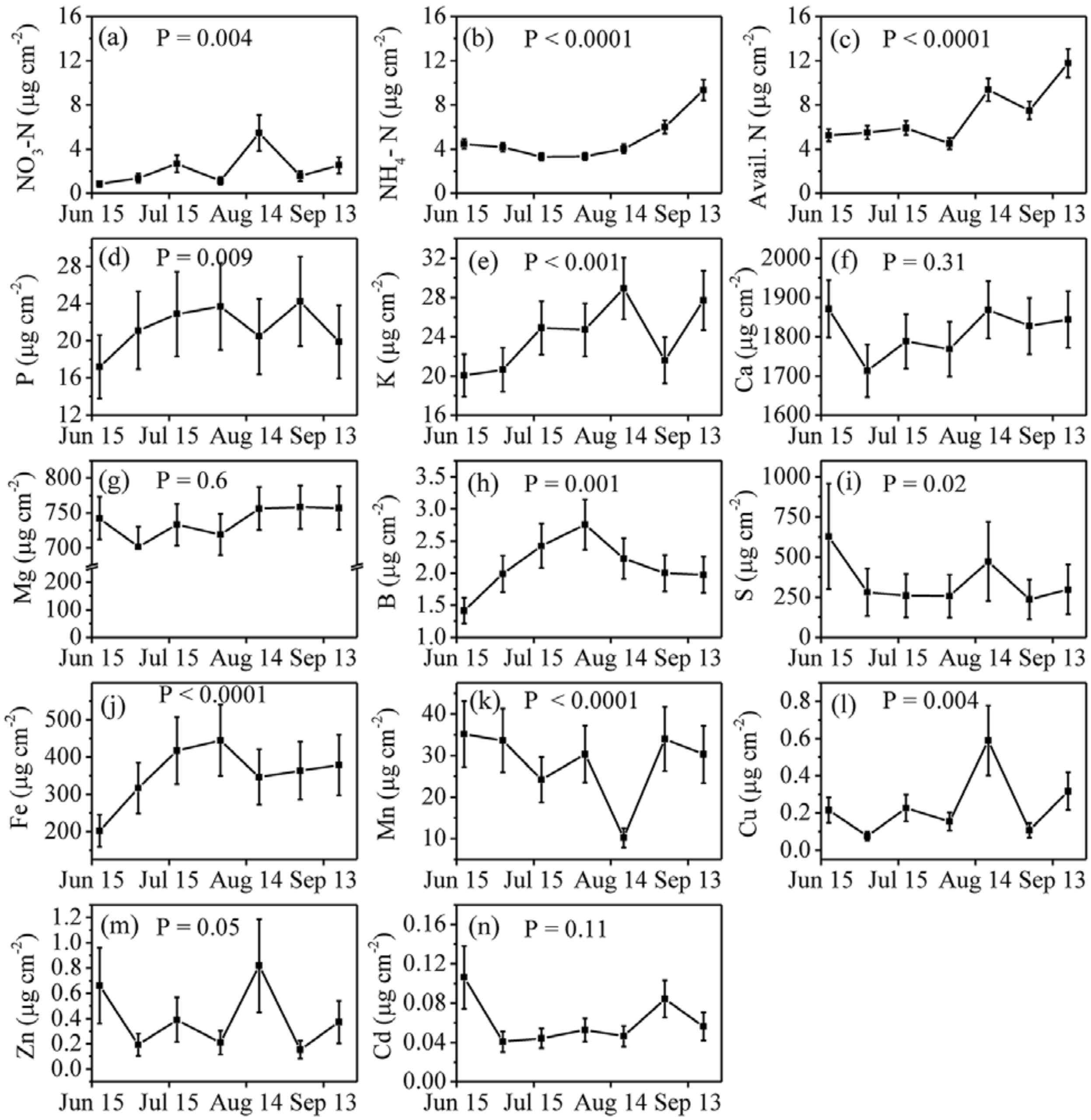

Figure 6. Temporal changes in nutrient and trace element supply rates (µg/cm$^2$/2 weeks) in biosolids in the wetland cell, measured by plant root simulators, as a function of time. Vertical bars represent standard errors of the mean (Jeke and Zvomuya, 2018).

## 4.0 Vegetation

A growth study by Jeke et al. (2015a) characterized nutrient and trace element accumulation and partitioning in cattails grown in biosolids. The study showed that a greater proportion of N and P absorbed by cattail was partitioned to the aboveground biomass of cattail, but this partition decreased after the onset of nutrient retranslocation to roots and rhizomes. Trace elements were mainly partitioned to the root biomass. This study provided insights on the timing of harvesting to optimize nutrient removal from harvesting plants.

A study was conducted in the wetland cell from 2013 to 2018 to quantify nutrient removal through uptake by cattail under field conditions. The study evaluated the effect of harvesting cattails once per growing season vs twice per season on removal of nutrients. Earlier growth room studies under controlled conditions had suggested that two harvests per season removed more in nutrient removal. However, harvesting cattail twice in the wetland cell per season resulted in a 50 to 60% decrease in removal of N and P relative to a single harvest per season. These results demonstrated that multiple harvesting per season reduces contaminant uptake and removal due to reduced plant growth resulting from multiple harvests under the climate (prairies) and environmental conditions (biosolids) tested.

Over the four years of vegetation study in the wetland cell (2013-2016), cattail removed 367 kg/ha of N and 56 kg/ha of P in the aboveground biomass (i.e., excluding amounts in the roots and rhizomes). A greater fraction of P (~ 73%) taken up by cattail was sequestered in the rhizomes, which reduced its mobility and transport to surface waters. The nutrient removal by cattail in the aboveground biomass accounted for 6.2% of initial N content and 2.2% of initial P content in the biosolids. Most of the P in the wetland cell biosolids are in the recalcitrant fractions and are not potentially available for plant uptake or for presenting a threat to the environment. Considering only the potentially available P (i.e., sum of $H_2O$-P and $NaHCO_3$-P), cattail aboveground biomass removed 19% of the initial potential available P. Overall, the study showed that cattail is effective in taking up large amounts of nutrient in biosolids in the wetland cell. Note that our research found that most of the P taken up by cattail remained partitioned in the roots and rhizomes indicating that harvesting cattails would not remove most of the P immobilized in the roots (Jeke et al., 2019; Kadlec and Wallace, 2009). Phosphorus immobilized in the roots is not available to cause a threat to the environment.

## 5.0 Surface water

Because the research study by the University of Manitoba in the wetland cell was aimed primarily at the removal of N and P from the primary source (i.e., the biosolid sediments), the study design did not allow for isolation of treatment effects on nutrient concentrations in the water column. Nevertheless, during the research, water samples were periodically taken from the wetland cell and analyzed for P concentrations. Total phosphorus concentrations in the water column in the wetland cell were close to 1 mg/L in most sampling dates (Table 3). The wetland cell and control cell are hydrologically connected with both cells sharing the same surface water. Therefore, the TP concentrations reported for the wetland cell represent the surface water quality of the entire system. Phosphorus concentrations in the holding cell were <1 mg/L (Table 3). The holding cell receives spring snowmelt and runoff from the adjacent Hespeler Park and no biosolids exist in the holding cell. The wetlands cell does not discharge water to the environment. Any water movement from the wetland cell is directed to/from the holding cell if the wetland cell water levels need to be lowered or raised.

Recent results for water sampling conducted in the wetland cell in 2020 are presented in Section C – 2.4 and 2.5.

Table 3. Total phosphorus (mg/L) in the wetland cell and holding cell from 2014 to 2018 (parentheses indicate standard deviations).

| Trace Element | Wetland Cell | Holding Cell |
|---:|:---:|:---:|
| August 8, 2014 | 0.83 (0.10) | 0.8 |
| April 29, 2015 | 0.37 (0.03) | 0.05 |
| May 15, 2015 | 0.45 (0.04) | - |
| June, 24 2015 | 0.71 (0.04) | 0.39 |
| July 14, 2015 | 1.0 (0.1) | 0.40 |
| July 28, 2015 | 1.0 (0.1) | 0.41 |
| August 11, 2015 | 1.2 (0.2) | - |
| October 02, 2015 | 1.1 (0.1) | - |
| June 15, 2016 | 1.2 (0.1) | - |
| September 9, 2016 | 2.0 (0.2) | 0.16 |

# C. Request for Licence Removal

## 1.0 Removal request description

This section provides the formal request for the removal of the Environmental Licence from the old Niverville lagoon (Figure 1). Justification for the removal of the Environmental Licence is that biosolids in the wetland cell area demonstrate a low risk to environmental or human health and are considered decommissioned. Since the method the Town of Niverville has selected for lagoon decommissioning has never been undertaken before in Manitoba or elsewhere, there is an absence of guidelines or precedence by which to compare the progress of this site. Therefore, project remediation targets used in both Canada and the United States, to which biosolid concentrations in the lagoon can be compared, were adopted based on recommendations and conversations with Manitoba Conservation and Climate. The Canadian Council of Ministers of the Environment (CCME) soil quality guidelines for residential/parkland use and the USEPA Exceptional Quality (EQ) and Class A biosolids limits were the guidelines adopted. Section C - 2.0 presents these remediation targets and provides justification for their use in evaluating the risk to environmental and human health. Sections C – 2.1 through 2.5 presents data and results that provides evidence for meeting targets for trace elements, nutrients and pathogens in biosolids and surface water. Section C – 3.0 outlines the steps the Town of Niverville is intending to take on site to mitigate future risks to environmental and human health. A summary of the justification for licence removal from the site is presented in Section C – 4.0.

## 2.0 Project phytoremediation findings and remediation targets

As this type of *in-situ* lagoon remediation has never before been undertaken in Manitoba or elsewhere, remediation targets for trace elements, nutrients and pathogens that determine when a lagoon has been 'decommissioned', or no longer requires an Environmental Licence, do not exist. With advice from experts from Manitoba Conservation and Climate, the CCME soil quality guidelines for residential/parkland use and the USEPA Exceptional Quality (EQ) and Class A biosolids limits were adopted to assess trace element concentration and pathogen risk status of the wetland for potential risks to human health.

CCME soil quality guidelines are derived for upland areas "specifically for the protection of ecological receptors in the environment or for the protection of human health associated with the identified land use" (CCME, 2007). Threshold values are determined on a chemical-by-chemical basis using toxicological data. The limiting pathway for environmental soil quality guidelines is soil contact and the limiting pathway for human health soil quality guidelines is soil ingestion. The lower threshold between the environmental soil quality guideline and the human health soil guideline is then used as the overall CCME soil quality guideline. CCME soil guidelines for residential/parklands use were used to assess trace elements at the Niverville site.

The USEPA developed their regulations (also known as Part 503 Rule) to protect public health and the environment from any reasonably anticipated adverse effects of pollutants that might be present in biosolids (USEPA, 1994a). The regulations are based on an extensive risk assessment and establish requirements for the final use or disposal of biosolids. USEPA categorizes biosolids based on levels of metals and pathogens. Exceptional Quality (EQ) biosolids meet requirements for EQ metal limits in the

USEPA regulations, and Class A biosolids meet pathogen reduction levels that are safe for human health. Biosolids characterized as both EQ and Class A can be used on any type of land without restrictions including as fertilizer in vegetable gardens and can be sold to homeowners as compost or fertilizer. EQ/Class A biosolids are considered virtually unregulated for use; therefore, meeting this classification would justify to the Province of Manitoba a removal of the Environmental Licence on the wetland cell.

The following sections compare established remediation targets to conditions in the wetland cell as well as, when available, to conditions in the control cell, holding cell, and comparable environments outside of the former lagoon's footprint.

### 2.1 Trace elements in biosolids

Trace element concentrations within the biosolids of the wetland cell were compared to the CCME soil guidelines for residential/parklands use and USEPA EQ limits (Table 4). Concentrations (mg/kg) were measured for eight trace elements in the biosolids within the wetland cell in 2011, 2013 and 2019. Cattails and submerged rooted aquatic vegetation that developed in the control cell are providing the same treatment capabilities that is occurring within its connected wetland cell. Trace element levels for 2011 represent trace element concentrations in the primary cell before construction of the wetland. Trace element levels measured in 2013 represent levels following wetland construction activities which included the spreading of biosolids on wetland benches. 2019 represents the biosolids 7 years after wetland construction was completed.

Copper, selenium and zinc were the only trace elements above the CCME soil guidelines in biosolids collected in 2011, before construction of the wetland (Table 4). Levels of these three trace elements met the CCME soil guidelines in biosolids collected in 2013 (i.e., after construction of the wetland cell) with further decreases in trace elements within biosolids sampled in 2019 (i.e., 7 years after phytoremediation began). All other trace elements met CCME soil quality guidelines across all the years (Table 4). Referring to the USEPA EQ limits, all trace element levels met the limits for biosolids sampled during all years. Note that the CCME soil guidelines are stricter than the USEPA EQ limits. Trace element concentrations in the biosolids were also compared to sediment collected from a natural wetland located 5 km NW of the old lagoon site (Figure 7). The trace element levels in the biosolids after 7 years of phytoremediation are comparable to levels found in sediments collected from the natural wetland.

Overall, the data showed that trace element concentrations in the biosolids in the wetland cell met all remediation targets and pose a low risk to the environment and human health (Table 4).

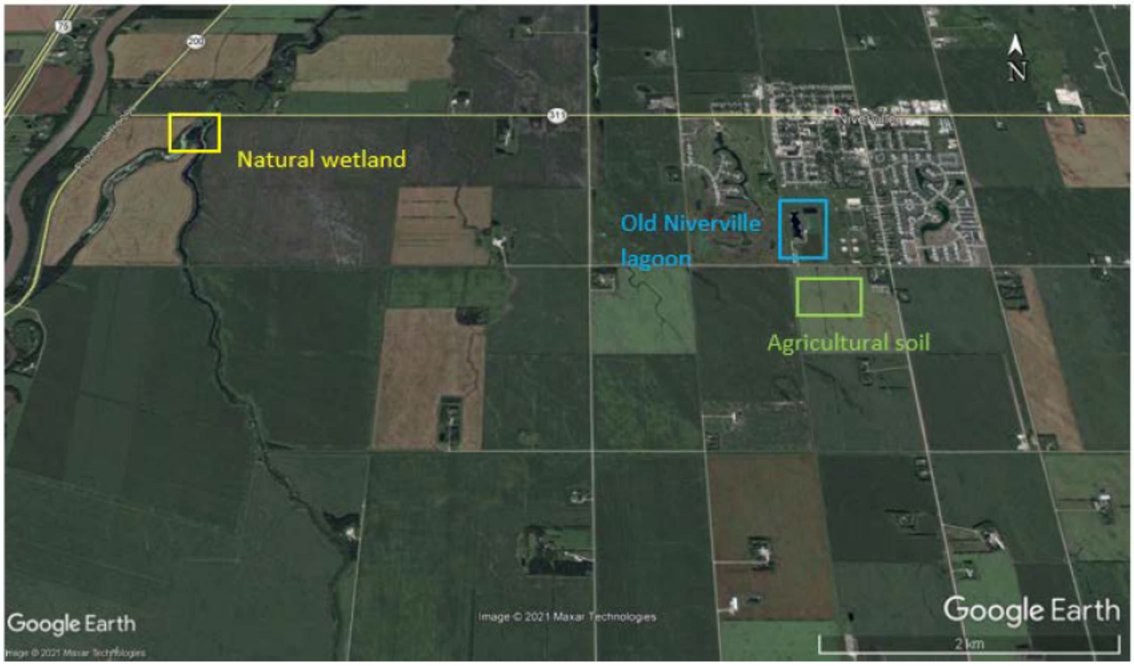

Figure 7. Location of the old Niverville lagoon, reference natural wetland and agricultural soil sampled.

Table 4. Trace element concentration (mg/kg) in wetland cell biosolid samples taken from 2011 to 2019 (parentheses indicate standard deviations). Red font indicates exceedance to the CCME soil guidelines.

| Trace Element | Wetland Cell[A] | | | CCME Soil Guideline[B] | USEPA EQ Limits[C] | Natural Wetland |
|---|---|---|---|---|---|---|
| | 2011 | 2013 | 2019 | | | 2015 |
| Arsenic | 8.0 (0.03) | 7.0 (0.4) | 6.7 (0.1) | 12 | 41 | 7.2 (1) |
| Cadmium | 1.2 (0.1) | 0.6 (0.2) | 0.5 (0.1) | 10 | 39 | 0.5 (0.02) |
| Chromium | 41 (1) | 48 (3) | 37 (1) | 64 | 1200 | 52 (2) |
| Copper | 115 (9) | 62 (22) | 42 (6) | 63 | 1500 | 34 (1) |
| Lead | 24 (3) | 18 (4) | 14 (1) | 140 | 300 | 15 (1) |
| Mercury | 0.5 (0.2) | 0.2 (0.2) | - | 6.6 | 17 | 0.07 (0.02) |
| Nickel | 33 (3) | 43 (3) | 32 (1) | 45 | 420 | 35 (2) |
| Selenium | 1.8 (0.05) | 0.7 (0.2) | 0.4 (0.04) | 1 | 100 | 0.3 (0.2) |
| Zinc | 273 (27) | 162 (50) | 106 (8) | 250 | 2800 | 121 (4) |

[A] Biosolids samples in 2011 were collected from the primary cell before redesign and construction of the wetland cell in 2012.
[B] CCME soil quality guidelines for the protection of environmental and human health in residential/parkland areas
[C] USEPA pollutant concentration limits for Exceptional Quality (EQ) biosolids.

## 2.2 Nutrients in biosolids

Similar to trace element concentrations in biosolids, as this type of *in-situ* lagoon remediation has never before been undertaken in Manitoba or elsewhere, remediation targets for nutrient concentrations that determine when a lagoon has been 'decommissioned', or no longer requires an Environmental Licence, do not exist. In addition, the CCME soil quality guidelines and USEPA guidelines have no limits set for phosphorus and nitrogen.

Total P and N levels in the Niverville wetland cell biosolids were compared to sediment collected from a nearby natural wetland and agricultural soils adjacent to the old lagoon site (Figure 7, Table 5). Total P and N levels declined from 2013 to 2019. Total nutrient levels in the wetland cell are below nutrient levels found in the nearby natural wetland. They are also comparable to soil collected from the agricultural soils across the lagoon. Phosphorus and N levels in the Niverville control cell biosolids were also comparable to sediment collected from the nearby natural wetland (Table 6). Biosolids in the control cell were left *in-situ* and represent biosolids that had not been moved around during construction of the wetland. Cattails and submerged rooted aquatic vegetation that developed in the control cell are providing the same treatment capabilities that is occurring within its connected wetland cell.

Overall, nutrient levels in the wetland biosolids are not different from ranges expected in natural wetlands or upland soils. The range of total P and N levels in upland and wetland soils in North America is as follows:

- Upland soils
    - TP: 50 - 1,500 mg/kg (Howard, 2006)
    - TN: 3.690 mg/kg - 6,664 mg/kg (Dunne et al., 2010)
- Wetland soils
    - TP: 30 - 500 mg/kg, but can be high as 10,000 mg/kg in human impacted systems (Dunne and Reddy, 2005).
    - TN: 4,390 - 12,560 mg/kg (Dunne et al., 2010)

Table 5. Phosphorus and nitrogen levels (mg/kg) in biosolid samples taken from the wetland cell from 2011 to 2019 (parentheses indicate standard deviations).

| Nutrients (mg/kg)$^{A}$ | 2011$^{B}$ | 2013 | 2014 | 2015 | 2016 | 2019 | Natural Wetland | Farmland Soil (0.5 km) |
|---|---|---|---|---|---|---|---|---|
| TP | 2705 (205) | 1215 (344) | 1046 (231) | 1194 (310) | 999 (254) | 904 (11) | 3684 (113) | 605 |
| Olsen P | 81 (1) | 79 (29) | 55 (31) | 84 (43) | 57 (19) | - | 51 (11) | 10.7 |
| $NH_4$-N | 13 (1) | 54 (12) | 30 (7) | 50 (13) | 36 (15) | 52 (15) | 278 (32) | 0.9 |
| $NO_3$-N | 366 (35) | 2.7 (0.2) | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | 33 |
| TN | 8191 (607) | 2131 (1050) | 2921 (577) | 2606 (580) | 2837 (578) | 2930 (99) | 6347 (724) | 2598 |

[A] TP-total phosphorus; $NH_4$-N – ammonium nitrogen, $NO_3$-N – nitrate nitrogen, and TN – total nitrogen.

[B] Biosolids samples in 2011 were collected from the primary cell before redesign and construction of the wetland cell in 2012.

Table 6. Phosphorus and nitrogen levels (mg/kg) in biosolid samples taken from the control cell from 2013 to 2019 (parentheses indicate standard deviations).

| Nutrients (mg/kg)[A] | 2013 | 2014 | 2019 | Natural Wetland | Farmland Soil (0.5 km) |
|---|---|---|---|---|---|
| TP | 1486 (349) | 1251 (384) | 1620 | 3684 (113) | 605 |
| Olsen P | 90 (28.3) | 74 (16) | - | 51 (11) | 10.7 |
| $NH_4$-N | 149 (46.7) | 44 (2) | 34 | 278 (32) | 0.9 |
| $NO_3$-N | <2.5 | <2.5 | <2.5 | <2.5 | 33 |
| TN | 5018 (2001) | 4837 (1283) | 5000 | 6347 (724) | 2598 |

[A] TP-total phosphorus; $NH_4$-N – ammonium nitrogen, $NO_3$-N – nitrate nitrogen, and TN – total nitrogen.

## 2.3 Pathogens in biosolids

To assess the risk of biosolids to human health, the Manitoba Conservation and Climate recommended consideration of USEPA's pathogen concentration requirements for Class A biosolids. Pathogen reduction requirements to meet Class A can either be met by certain specified technologies to treat biosolids or by showing that the quality of the biosolids meet established guidelines by testing key indicators of pathogens.

The USEPA definition for Class A biosolids relies on three key indicators of pathogens; (i) fecal coliforms or *Salmonella sp.* (do not require both), (ii) helminth ova, and (iii) enteric viruses. Fecal coliforms act as indicators of fecal bacteria, while helminths ova and enteric viruses act as indicators of human parasites and viruses. Identifying commercial laboratories in Canada that perform viable helminth ova and enteric virus testing proved to be difficult as these tests, as requested by the Province, are not routine tests done in commercial laboratories in Canada. One laboratory was identified in Ontario (A & L Canada Laboratories) that tests for helminth ova. No commercial laboratory was identified in Canada that tests for enteric viruses. Several laboratories in the US that test for enteric viruses in biosolids as part of the USEPA requirements for biosolids testing were identified.

Upon consultation with the Province (April 29, 2020 meeting), a decision was made to sample the biosolids for fecal coliforms and helminth ova. Helminth ova and enteric viruses do not regain viability once destroyed in the environment (outside the human body) (USEPA, 1994b). Helminth ova can survive in soil or biosolids for up to 7 years while enteric viruses survive up to 6 months (Table 7). The Niverville biosolids have been in the lagoon for almost 12 years without any addition of fresh biosolids or wastewater. Before re-construction and flooding of the cell in fall 2012 and spring 2013, the wetland cell and control cell sat dry for approximately 4-5 years from the time the cells stopped operating (2008) to the time of flooding (2013) after wetland construction. As a result it was agreed that enteric viruses would not have survived for these last 12 years. Therefore, helminth ova which survive for a longer time than viruses justified the sampling for helminth ova, given the short survivability of viruses (6 months) and the lack of testing capacity in Canada. Biosolid samples were sampled from several locations spread across the entire wetland cell in 2020 (purple symbols; Figure 4). The biosolid samples collected were thoroughly mixed and composited to form a single composite sample that was sent for helminth ova and fecal coliform testing. Fecal coliforms have a potential for regrowth if given the right conditions. Therefore, the biosolids in the wetland cell were tested for fecal coliforms 7 times in 2020 to sufficiently monitor levels and ensure that no additional regrowth occurs to levels above the safe limits.

Helminth ova were not detected in the biosolids (Table 8). This was not surprising given the length of time the biosolids had remained untouched in the old lagoon. Fecal coliforms were below the USEPA Class A fecal coliform guideline of <1000 MPN/g. The data and sample results demonstrate that the biosolids in the wetland cell and its connected control cell pose no risk to human health and supports removing the Environmental Act licence thereby allowing public access.

Table 7. Human pathogen survival in soil (Gerba and Smith, 2005).

| Pathogen | Absolute Maximum | Common Maximum |
|---|---|---|
| Bacteria | 1 year | 2 months |
| Viruses | 6 months | 3 months |
| Protozoa | 10 days | 2 days |
| Helminth | 7 years | 2 years |

Table 8. Fecal coliform bacteria and helminth ova in the wetland cell biosolids, 2020.

| | Fecal coliform (MPN/g)[A] | Helminth Ova |
|---|---|---|
| **USEPA Class A limits** | **<1000 MPN/g** | **<1/4g** |
| August 20, 2020 | 580 | None detected |
| September 9, 2020 | 269 | |
| September 23, 2020 | 153 | |
| October 14, 2020 | 23 | |
| October 21, 2020 | <2 | |
| October 27, 2020 | 56 | |
| November 3, 2020 | <2 | |

[A] MPN, most probable number; Detection limit < 2 MPN/g.

## 2.4 Nutrients in surface water

Although the Niverville site is not designed to discharge water to the environment, the 1 mg/L Provincial Tier I phosphorus target for wastewater discharge was used to assess the environmental health risk of the site's water quality (Government of Manitoba, 2011).

Water samples were collected from the wetland to determine TP concentrations in 2020. Water quality sub-samples were collected at 4 locations (Figure 8) within the wetland. The sub-samples were combined to form a single composite sample for each sampling date.

Total P levels fluctuated during the sampling season but remained close to 1 mg/L (Table 9). To account for natural variations in TP levels in treatment wetlands, the Province, when approving environmental releases, considers the rolling average based on the 3 most recent sampling events during a discharge period. Applying this rationale to the Niverville wetland the rolling average for the 3 most recent sampling dates (October 21, October 27, November 3) is 0.80 mg/L which is below the Provincial target of 1 mg/L

(Table 9). This provides the required evidence that, based on its TP level, the Niverville wetland demonstrates its ability to reduce concentration TP levels to below <1 mg/L.

It important to note that in 2020 the wetland was not managed at the normal operating level (NOL) of 30 cm on the wetland benches as cattail was being reestablished at some locations where cattails had been destroyed by muskrats (Appendix L). In future years when managed at NOL, the ability of the Niverville wetland to remove TP from the water column will be even greater than that seen in 2020 when water levels were lower than NOL. Managing the wetland at NOL maximizes the contact between water and cattail which provides optimal conditions for cattail to remove TP from the water column.

Figure 8. Niverville wetland cell water sampling locations in 2020 (Image courtesy of Google Earth; Imagery date: 2016 ).

Table 9. Niverville wetland total phosphorous (TP) concentrations and rolling average of consecutive sampling dates.

| Date (2020) | TP (mg/L) | Rolling average based on the 3 most recent consecutive sampling dates |
|---|---|---|
| May 11 | 0.95 | |
| June 25 | 1.45 | |
| July 28 | 1.29 | 1.23 (May 11, Jun 25, Jul 28) |
| August 20 | 1.16 | 1.30 (Jun 25, Jul 28, Aug 20) |
| September 9 | 1.06 | 1.17 (Jul 28, Aug 20, Sept 9) |
| September 23 | 1.18 | 1.13 (Aug 20, Sept 9, Sept 23) |
| October 14 | 0.96 | 1.07 (Sept 9, Sept 2, Oct 14) |
| October 21 | 0.93 | 1.02 (Sept 2, Oct 14, Oct 21) |
| October 27 | 0.92 | 0.94 (Oct 14, Oct 21, Oct 27) |
| November 3 | 0.55 | 0.80 (Oct 21, Oct 27, Nov 3) |

### 2.5 Pathogen levels in surface water

Although the Niverville wetland is not designed to discharge water to the environment, the 200 MPN/100 mL Provincial Tier I target for wastewater discharge was used to assess the human pathogen exposure risk of the site's surface water (Government of Manitoba 2011).

Fecal coliform counts in the water for most of the year were below the provincial limit of 200 MPN/100 mL for recreational waters (Figure 9). The reason for the high coliform counts on October 14 and October 27, 2020, was likely due to Canada goose activity on exposed wetland benches that were being reestablished with cattails after muskrat damage. The exposed benches provided areas for geese to loaf and to defecate upon (Figure 10). Following a rain event, fecal coliforms from geese feces on the benches can wash into the wetland. Once in the wetland fecal coliform numbers are reduced in the water column via natural processes including grazing by invertebrates and exposure to ultraviolet light.

At Niverville, the highest coliform count occurred on October 14 when the sampling event coincided with a rain event and surface water was observed flowing off the benches into the wetland. The second highest coliform count occurred on October 27, 2020, which coincided with heavy goose use of the wetland including loafing on the partial ice cover on the wetland (Figure 10). Goose feathers and droppings, which can be a source of fecal coliforms, were observed floating on the wetland surface in areas where water sub-samples were collected.

The direct relationship between coliform counts in October and goose activity clearly indicates that the source of the coliforms is external to the wetland and not from wetland soils. The consistently low coliform counts in the wetland soils (Section C – 2.3) also provide evidence that the source of the coliforms is external to the wetland.

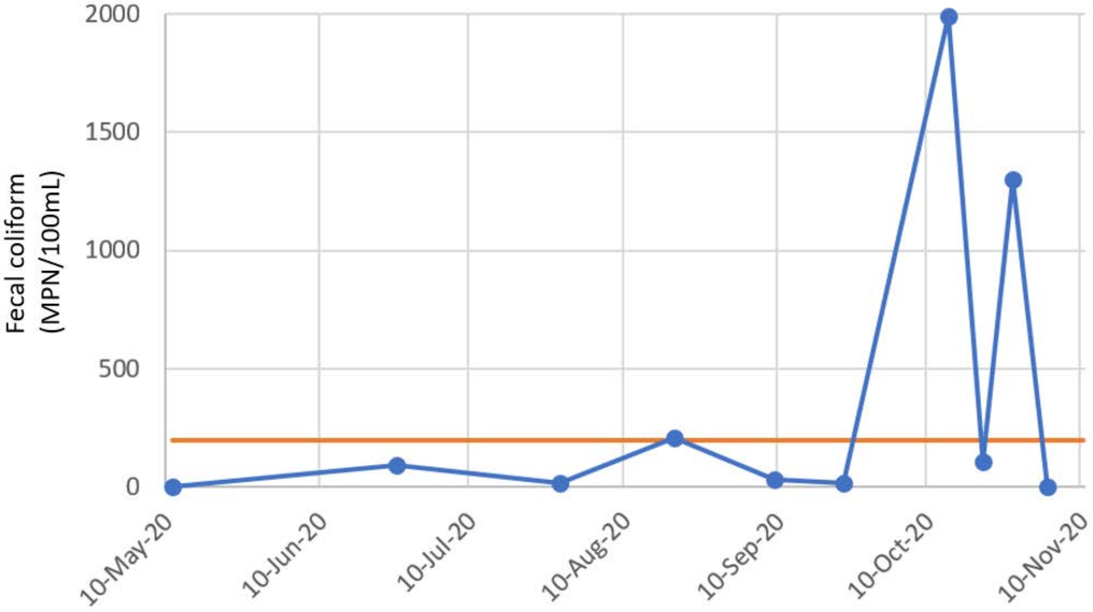

Figure 9. Niverville wetland cell water total fecal coliform counts. Orange line indicates Manitoba water quality target of 200 MPN/100mL for recreational waters.

Figure 10. Canada geese activity at the Niverville wetland. Note the goose feathers on the water surface in the foreground of the photo (October 27, 2020).

## 3.0 Risk mitigation

The Town has a mitigation strategy in place to limit the site's human and environmental health risks once the environmental license has been removed. The Town's risk mitigation strategy includes the following 3 components:

- Manage system as designed;
- Install and maintain safety signage and prescribed footpaths; and
- Zone site as park space.

### 3.1 Manage system as designed

The Town will continue to manage the holding, wetland and control cell as designed. The wetland is not designed to discharge water to the environment; the wetland is connected to the control cell and holding cell. The holding cell receives surface runoff from Hespeler Park. The holding cell will continue to be used to manage water levels within the wetland and connected control cell. Water levels in the wetland and connected control cell will be managed to provide optimum depths to support the continued growth of wetland plants. The wetland plant cover (cattail and submergent vegetation) in the wetland and connected control cell limit biosolid resuspension and remove nutrients from the water column.

Muskrats can destroy wetland plants and reduce the water quality function of wetlands. The town has a muskrat control program in place to remove muskrats from the site and reduce the risk of muskrat related vegetation damage. Appendix L presents a letter report prepared for the Town of Niverville describing activities undertaken in the wetland cell in 2020 which included reestablishment of vegetation in locations where the vegetation had been destroyed by muskrats. The letter report demonstrates the level of effort that the Town continues to put towards the health of this site.

The berms around the holding, wetland and control cells will be left intact. The system's cells were designed with 1 metre of freeboard. This limits the risk of run-off from the cells due to precipitation events and spring snowmelt. The cells also have a clay liner which will be left intact. The clay liner prevents leaching from the cells to the groundwater.

Although site signage (see Section C − 3.2) will instruct the public to keep out, there remains the possibility that individuals could enter the system cells. The biosolids were spread on the wetland benches constructed by heavy equipment and compacted to a minimum of 95% standard proctor dry density. Therefore, a person entering the wetland will not sink in the biosolids. In addition, the dense roots and rhizomes of cattail and vegetation material that accumulated over the years prevents one from sinking and hinders access to anyone attempting to enter into the wetland. This has been attested by researchers from the University of Manitoba and NPS staff who have been involved in collection of samples from the wetland cell over the years.

### 3.2 Install and maintain safety signage and prescribed footpaths

Once the environmental licence is removed from the site, the Town will develop the area as a public use space. This will include site signage and prescribed footpaths designed to address safety concerns related to public use of the site.

The holding, wetland, and control cells will be adequately signed (minimum of 2 signs per cell) warning the public of the risks related to entering the cells (e.g. deep water, potential contaminants, thin ice). These signs will be similar to the warning signs posted around the Town's conventional stormwater ponds.

Prescribed footpaths will be located at top of cell berms to provide optimal vantage of the open water area of the cells and the surrounding vegetation. These paths will guide the public on where to safely walk. There will also be signage instructing users to remain on the paths for the health of the vegetation in the surrounding environment.

### 3.3 Zone site as park space

The Town plans to merge titles of the former lagoon site with the Hespeler Park title once all provincial restrictions are removed. Zoned as park space the site will be off limits to incompatible land uses such as residential and commercial development (Government of Manitoba, 2015). This will help ensure that the site's biosolids continue to be vegetated for as long as the site is zoned a park.

## 4.0 Justification summary for licence removal

The work conducted over the past 9 years as presented in this report provides the evidence that the wetland, control and holding cells pose a low risk to human and environmental health and should be considered decommissioned.

In summary:

- Human pathogen concentrations meet targets in biosolids and surface waters.
- Trace element concentrations meet targets in biosolids.
- Nutrient concentrations in biosolids are comparable to nearby agricultural soils and natural wetland sediments.
- Low nutrient bioavailability within the biosolids constituents.
- Surface waters meet phosphorus target for protection of downstream environments.

Current site conditions (Table 10), in conjunction with risk mitigation strategies (Section C – 3.0), warrant the removal of the licence from the site. Licence removal will allow the Town of Niverville to continue pursuing its progressive and sustainable vision for the Niverville Lagoon site as an interpretive and educational park site, central to its community.

Table 10. Decommissioned status of the former Niverville lagoon site.

| Parameter | Decommission target | Site status |
|---|---|---|
| **BIOSOLIDS** | | |
| Pathogens | USEPA Class A Biosolid Target | Decommissioned:<br>- Wetland biosolids meet the target level. |
| Trace elements | CCME Soil Quality Guidelines and USEPA EQ Limits | Decommissioned:<br>- Wetland biosolids meet target levels for all trace elements. |
| Nutrient concentrations | Nutrient concentrations in biosolids comparable to wetland and upland soils | Decommissioned:<br>- Nutrient concentrations in biosolids comparable to wetland and upland soils. |
| Bioavailability of nutrients | Low bioavailability of biosolid nutrients | Decommissioned:<br>- Low bioavailability of nutrients due to low mineralization and high P fixation of nutrients in biosolids. |
| **SURFACE WATER** | | |
| Nutrient concentrations | Government of Manitoba<br>Tier I phosphorus target | Decommissioned:<br>- Rolling phosphorus average meets target level. |
| Pathogens | Government of Manitoba<br>Tier I fecal coliform target | Decommissioned:<br>- Fecal coliform counts meet target level. |

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# Appendix A. Phytoremediation of Municipal Biosolids: Terrestrial and Wetland Approaches

Hassan, Adenike Olabisi. M.Sc., University of Manitoba, August, 2014.
Advisor: Dr. Francis Zvomuya
Full text available at: https://mspace.lib.umanitoba.ca/xmlui/handle/1993/25170

## ABSTRACT

Growth room experiments were conducted to examine terrestrial and wetland-based phytoremediation approaches as alternatives to biosolids management. Results from both experiments show that biosolids do not need to be amended with soil to encourage plant growth and optimize biomass yields. In the terrestrial phytoremediation approach, two harvests per growth cycle produced greater switchgrass biomass yield than a single harvest but had no significant effect on cattail biomass yield during the first cycle. Repeated harvesting also significantly increased mean nutrient uptake in Cycle 1, reflecting the greater biomass yield from two harvests compared with a single harvest. In the wetland experiment, nutrient phytoextraction under two harvests was 4.25% of initial N content and 2.28% of initial P content compared with 2.9% and 1.58%, respectively, under a single harvest. Terrestrial phytoremediation could be beneficial to small communities that cannot afford the costly excavation, trucking, and eventual spreading of biosolids on agricultural land.

# Appendix B. Biomass, Nutrient and Trace Element Dynamics in Cattail and Switchgrass during Wetland and Terrestrial Phytoremediation of Municipal Biosolids

Jeke, Nicholson. M.Sc., University of Manitoba, January 8, 2015.
Advisor: Dr. Francis Zvomuya
Full text available at: https://mspace.lib.umanitoba.ca/xmlui/handle/1993/30172

Knowledge of nutrient accumulation and partitioning in plants is important to determine the optimum timing of harvesting during phytoremediation of biosolids. This research showed that a greater proportion of nitrogen (N) and phosphorus (P) absorbed by cattail and switchgrass was partitioned to the aboveground biomass (AGB), but this partition decreased after the onset of nutrient retranslocation to roots. Therefore, AGB should be harvested prior to retranslocation in order to optimize nutrient phytoextraction. Trace elements partitioned preferentially to the root biomass, indicating that AGB harvesting will have little impact on their phytoextraction. Net mineralized N concentration (Nmin) in biosolids from the primary lagoon cell was optimized near field capacity [60% water filled pore space (WFPS) but changed little under drier conditions (30% WFPS). Under near-saturation conditions (90% WFPS), net Nmin decreased with incubation time, likely due to reduced mineralization and denitrification. Available (Olsen) P concentration was not affected by moisture content.

# Appendix C. Wetland and Terrestrial Phytoremediation of an End-of-Life Municipal Lagoon using Cattail (*Typha spp*.)

Jeke, Nicholson. PhD, University of Manitoba, 2018.
Advisor: Dr. Francis Zvomuya
Full text available at: https://mspace.lib.umanitoba.ca/xmlui/handle/1993/33564

## ABSTRACT

Spreading biosolids on farmland is a common biosolids management practice in western Canada. Wetland and terrestrial-based phytoremediation approaches may be viable options for remediating biosolids in end-of-life municipal lagoons. Water depth is regulated during wetland phytoremediation whereas there is no control of water regime during terrestrial phytoremediation. Studies were conducted to quantify cattail (Typha spp.) biomass and nitrogen (N) and phosphorus (P) phytoextraction from biosolids in (i) a wetland constructed in the former primary cell and (ii) a dewatered secondary cell of an end-of-life municipal lagoon. Overall, the phytoextraction of N and P by cattail was lower with a single harvest than two harvests per year. The study also examined the effects of harvest timing (August, November, and April) on nutrient removal in the harvested cattail biomass. Compared to August, harvesting cattails in the wetland in November or April reduced N and P phytoextraction by 63-85%. In the wetland study, nutrient phytoextraction was 6.2% of initial N content and 2.2% of initial P content while the terrestrial-based approach removed 5.8% and 2.3% of the initial N and P content, respectively. A greater fraction of P (~ 73%) taken up by cattail was sequestered in the rhizomes, which reduced its mobility and transport to surface waters. A study examining nutrient availability using plant root simulator (PRS) probes during wetland-based phytoremediation showed that N supply rate increased with time after July whereas phosphate supply rate remained relatively unchanged. Cumulative nutrient supply rate was positively correlated with plant uptake. The effects of flooding on P release during terrestrial phytoremediation in the secondary cell was investigated using biosolids cores. Dissolved reactive P (DRP) was the major fraction of P in floodwater. Flooding for more than 3 d resulted in the release of >0.5 mg L-1 DRP to floodwater. Our results suggest that biosolids pose a risk of P loss to surface water bodies receiving floodwater from the lagoon. Releasing floodwater closer to the start of the flooding event minimizes P release to floodwater. Overall, this research shows that phytoremediation is a viable, low-cost option for managing biosolids from end-of-life municipal lagoons.

# Appendix D. Biomass, Nutrient, and Trace Element Accumulation and Partitioning in Cattail (*Typha latifolia L.*) during Wetland Phytoremediation of Municipal Biosolids

Jeke, N.N., Zvomuya, F., Cicek, N., Ross, L. and Badiou, P. 2015.
Journal of Environmental Quality 44:1541–1549.
Full text available at: https://doi.org/10.2134/jeq2015.02.0064

## ABSTRACT

Biomass and contaminant accumulation and partitioning in plants determine the harvest stage for optimum contaminant uptake during phytoremediation of municipal biosolids. This wetland microcosm bioassay characterized accumulation and partitioning of biomass, nutrients (N and P), and trace elements (Zn, Cu, Cr, and Cd) in cattail (*Typha latifolia* L.) in a growth room. Four cattail seedlings were transplanted into each 20-L plastic pail containing 3.9 kg (dry wt.) biosolids from an endof-life municipal lagoon. A 10-cm-deep water column was maintained above the 12-cm-thick biosolids layer. Plants were harvested every 14 d over a period of 126 d for determination of aboveground biomass (AGB) and belowground biomass (BGB) yields, along with contaminant concentrations in these plant tissues. Logistic model fits to biomass yield data indicated no significant difference in asymptotic yield between AGB and BGB. Aboveground biomass accumulated significantly greater amounts of N and P and lower amounts of trace elements than BGB. Maximum N accumulation in AGB occurred 83 d after transplanting (DAT), and peak P uptake occurred at 86 DAT. Harvesting at maximum aboveground accumulation removed (percent of the initial element concentration in the biosolids) 4% N, 3% P, 0.05% Zn, 0.6% Cu, 0.1% Cd, and 0.2% Cr. Therefore, under the conditions of this study, phytoremediation would be most effective if cattail is harvested at 86 DAT. These results contribute toward the identification of the harvest stage that will optimize contaminant uptake and enhance in situ phytoremediation of biosolids using cattail.

# Appendix E. Moisture Effects on Nitrogen Availability in Municipal Biosolid from End-of-Life Municipal Lagoons

Jeke, N.N., Zvomuya, and Ross, L. 2015.
Journal of Environmental Quality 44:1883–1891.
Full text available at: https://doi.org/10.2134/jeq2015.02.0084

## ABSTRACT

Nitrogen (N) availability affects plant biomass yield and, hence, phytoextraction of contaminants during phytoremediation of end-of-life municipal lagoons. End-of-life lagoons are characterized by fluctuating moisture conditions, but the effects on biosolid N dynamics have not been adequately characterized. This 130-d laboratory incubation investigated effects of three moisture levels (30, 60, and 90% water-filled pore space [WFPS]) on N mineralization (Nmin) in biosolids from a primary (PB) and a secondary (SB) municipal lagoon cell. Results showed a net increase in Nmin with time at 60% WFPS and a net decrease at 90% WFPS in PB, while Nmin at 30% WFPS did not change significantly. Moisture level and incubation time had no significant effect on Nmin in SB. Nitrogen mineralization rate in PB followed threehalf-order kinetics. Potentially mineralizable N (N0 ) in PB was significantly greater at 60% WFPS (222 mg kg−1) than at 30% WFPS (30 mg kg−1), but rate constants did not differ significantly between the moisture levels. Nitrogen mineralization in SB followed first-order kinetics, with N0 significantly greater at 60% WFPS (68.4 mg kg−1) and 90% WFPS (94.1 mg kg−1) than at 30% WFPS (32 mg kg−1). Low Nmin in SB suggests high-N-demanding plants may eventually have limited effectiveness to remediate biosolids in the secondary cell. While high Nmin in PB would provide sufficient N to support high biomass yield, phytoextraction potential is reduced under dry and near-saturated conditions. These results have important implications on the management of moisture during phytoextraction of contaminants in end-oflife municipal lagoons.

# Appendix F: Accumulation and Partitioning of Biomass, Nutrients, and Trace Elements in Switchgrass for Phytoremediation of Municipal Biosolids

Jeke, N.N., Zvomuya, and Ross, L. 2016.
International Journal of Phytoremediation 18: 892-899.
Full text available at: https://doi.org/10.1080/15226514.2016.1156634

## ABSTRACT

In situ phytoremediation of municipal biosolids is a promising alternative to the land spreading and landfilling of biosolids from end-of-life municipal lagoons. Accumulation and partitioning of dry matter, nitrogen (N), phosphorus (P), and trace elements were determined in aboveground biomass (AGB) and belowground biomass (BGB) of switchgrass (Panicum virgatum L.) to determine the harvest stage that maximizes phytoextraction of contaminants from municipal biosolids. Seedlings were transplanted into 15-L plastic pails containing 3.9 kg (dry wt.) biosolids. Biomass yield components and contaminant concentrations were assessed every 14 days for up to 161 days. Logistic model fits to biomass yield data indicated no significant differences in asymptotic yield between AGB and BGB. Switchgrass partitioned significantly more N and P to AGB than to BGB. Maximum uptake occurred 86 days after transplanting (DAT) for N and 102 DAT for P. Harvesting at peak aboveground element accumulation removed 5% of N, 1.6% of P, 0.2% of Zn, 0.05% of Cd, and 0.1% of Cr initially present in the biosolids. These results will contribute toward identification of the harvest stage that will optimize contaminant uptake and enhance in situ phytoremediation of biosolids using switchgrass.

# Appendix G: Phytoremediation of Biosolids from an End-of-Life Municipal Lagoon using Cattail (*Typha latifolia* L.) and Switchgrass (*Panicum virgatum* L.)

Jeke, N. A. Hassan, and N., Zvomuya. 2017.
International Journal of Phytoremediation. 19:270-280
Full text available at: https://doi.org/10.1080/15226514.2016.1225279

## ABSTRACT

Land spreading of biosolids as a disposal option is expensive and can disperse pathogens and contaminants in the environment. This growth room study examined phytoremediation using switchgrass (*Panicum virgatum* L.) and cattail (*Typha latifolia L.*) as an alternative to land spreading of biosolids. Seedlings were transplanted into pots containing 3.9 kg of biosolids (dry wt.). Aboveground biomass (AGB) was harvested either once or twice during each 90-day growth period. Switchgrass AGB yield was greater with two harvests than with one harvest during the first 90-day growth period, whereas cattail yield was not affected by harvest frequency. In the second growth period, harvesting frequency did not affect the yield of either plant species. However, repeated harvesting significantly improved nitrogen (N) and phosphorus (P) uptake by both plants in the first period. Phytoextraction of P was significantly greater for switchgrass (3.9% of initial biosolids P content) than for cattail (2.8%), while plant species did not have a significant effect on N phytoextraction. The trace element accumulation in the AGB of both plant species was negligible. Phytoextraction rates attained in this study suggest that phytoremediation can effectively remove P from biosolids and offers a potentially viable alternative to the disposal of biosolids on agricultural land.

# Appendix H: Nutrient Supply Rates and Phytoextraction by Cattail during Constructed-Wetland Phytoremediation of an End-of-Life Municipal Lagoon

Jeke, N. and N., Zvomuya. 2018.
Soil Science Society of America. 82:1004-1012
Full text available at: https://doi.org/10.2136/sssaj2018.02.0086

## ABSTRACT

In situ phytoremediation of municipal biosolids is a promising alternative to land spreading and landfilling during decommissioning of end-of-life municipal lagoons. Plant root simulator (PRS) probes can be used to examine nutrient availability during phytoremediation, but their use under wetland conditions is limited. This study examined nutrient availability using PRS probes during phytoremediation of biosolids vegetated with cattail. The probes were buried in the sediment for seven sequential 2-wk burial periods beginning in June 2014. Plants were harvested to determine biomass yield and nutrient content. Nitrogen supply rate did not change significantly with sampling period in June and July (4.5 to 5.9 μg $cm^{-2}$ $[2\ wk]^{-1}$) but increased thereafter to 11.8 μg $cm^{-2}$ $(2\ wk)^{-1}$. Phosphate supply rate (20.5 to 24.2 μg $cm^{-2}$ $[2\ wk]^{-1}$) did not differ significantly among sampling times. Cumulative supply rates of the macronutrients N, P, K, Ca and Mg ($r = 0.77–0.92$) and the micronutrients B, Fe, and Mn ($r = 0.7–0.81$) were highly correlated with cattail uptake, while the correlation was weaker for Cu ($r = 0.42$) and Zn ($r = 0.40$). Maximum attainable biomass yield (0.87 kg $m^{-2}$) coincided with the period of maximum nutrient uptake, indicating that harvesting cattail between late August and early September maximizes nutrient removal. In situ burial of PRS probes appears to be an effective method of measuring availability of macronutrients but may have limited effectiveness for Cu and Zn.

# Appendix I: Flooding Depth and Timing Effects on Phosphorus Release from Flooded Biosolids in an End-of-Life Municipal Lagoon

Jeke, N. and N., Zvomuya. 2018.
Water, Air, & Soil Pollution. 229.
Full text available at: https://link.springer.com/article/10.1007/s11270-018-3827-9

## ABSTRACT

Municipal biosolids in end-of-life lagoons can release phosphorus (P) to floodwater and contribute to P enrichment of receiving waters if the floodwater is released. Phosphorus release to floodwater is well-documented in agricultural and wetland soils, but information on flooding depth and timing effects on P release from flooded biosolids in end-of life municipal lagoons is currently lacking. This 42-day experiment utilized intact, cattail (*Typha latifolia L.*) vegetated biosolids cores (45.7-cm diameter by 60-cm height) to investigate the effects of flooding depth (5, 15, and 25 cm) on P release from biosolids and on P fractionation in pore water, floodwater, and biosolids upon flooding of municipal biosolids. Averaged across flooding depths, TP rapidly increased from the onset of flooding (0.45 mg $L^{-1}$) to day 14 (1.8 mg $L^{-1}$) and remained relatively constant thereafter (1.8–1.9 mg $L^{-1}$). Dissolved reactive P was the major fraction of P in pore water and floodwater. Flooding for more than 3 days resulted in the release of > 0.5 mg $L^{-1}$ dissolved reactive P (DRP) to floodwater. Phosphorus release was positively correlated with Fe and Mn concentrations in pore water and with water-extractable inorganic P, labile inorganic P, and Fe/Al-bound organic P concentrations in biosolids. Results indicate that P release to floodwater; hence, risk to receiving water bodies, is minimal during the first 3 days of flooding. This suggests that release of floodwater from the lagoon presents minimal adverse impact to receiving surface waters if done during the early stages (< 3 days) of flooding.

# Appendix J: A Field Bioassay of Nitrogen and Phosphorous Phytoextraction from Biosolids in a Seasonally-Frozen End-of-Life Municipal Lagoon Vegetated with Cattail

Jeke, N. and N., Zvomuya. 2018.
Journal of Environmental Quality. 47:1445-1452.
Full text available at: https://doi.org/10.2134/jeq2018.06.0230

## ABSTRACT

Managing biosolids from end-of-life municipal lagoons is a major challenge for many small communities where landfilling or spreading of biosolids on farmland is restricted. Contaminant removal via phytoextraction may be a viable remediation option for end-of-life lagoons in such communities. This study examined the effect of harvest frequency (once or twice per season) on cattail (*Typha latifolia L.*) biomass yield and N and P removal under a terrestrial phytoremediation system designed to treat the dewatered secondary cell of a municipal lagoon in Manitoba, Canada. Cattail was harvested once or twice per season from eight vegetation transects, each divided into two plots (2.5 × 2.5 m) to accommodate the two harvest frequencies. Biomass yields were greater for the single harvest (5.7 t $ha^{-1}$ $yr^{-1}$) than for two harvests per season (4.8 t $ha^{-1}$ $yr^{-1}$). This was mirrored by N phytoextraction, which was also greater for the single harvest (71 kg $ha^{-1}$ $yr^{-1}$) than the two-harvest frequency (58 kg $ha^{-1}$ $yr^{-1}$). Phosphorus phytoextraction varied with year of harvest and ranged from 8 to 14 kg $ha^{-1}$ $yr^{-1}$. Cumulative N and P phytoextraction amounts during the 5 yr were 330 kg N $ha^{-1}$ and 57 kg P $ha^{-1}$. A greater fraction of N (51–91 kg $ha^{-1}$ $yr^{-1}$) and P (23–40 kg $ha^{-1}$ $yr^{-1}$) was sequestered in the belowground biomass (11–17 t $ha^{-1}$ $yr^{-1}$) and therefore was not removed by harvesting. These results show that phytoremediation using cattail is a viable option for managing N and P in end-life lagoons.

# Appendix K: Nitrogen and Phosphorus Phytoextraction by Cattail (*Typha spp*.) during Wetland-Based Phytoremediation of an End-of-Life Municipal Lagoon

Jeke, N., F. Zvomuya, N. Cicek, L. Ross, and P. Badiou. 2019
Journal of Environmental Quality. 48:24-31.
Full text available at: https://doi.org/10.2134/jeq2018.05.0184

## ABSTRACT

Spreading biosolids on farmland can be an effective and beneficial option for managing end-of-life municipal lagoons. Where the spreading of biosolids on farmland is restricted or unavailable, in situ phytoremediation could be a sustainable alternative. This study examined nitrogen (N) and phosphorus (P) phytoextraction by cattail (*Typha spp.*) from biosolids in a wetland constructed within a lagoon cell previously used for primary treatment of municipal wastewater. The effect of harvesting season as well as harvest frequency on N and P removal were evaluated. Forty-eight 4m$^{-2}$ plots within the constructed wetland were used to determine the effect of cattail harvest frequency on plant N and P phytoextraction. Harvesting twice per season resulted in a 50 to 60% decrease in phytoextraction of N and P relative to a single harvest per season, which produced biomass yields of 0.58 to 0.6 kg m$^{-2}$ per year and accumulated 36.7 g N m−2 and 5.6 g P m−2 over the 4-yr period. Compared with August, harvesting cattails in November or April reduced N and P phytoextraction by 63 to 85%. These results demonstrate that phytoextraction of nutrients is more effective with a single harvest compared with two harvests per season. Additionally, we found that while harvesting in November and April is appealing logistically (since the wetland is frozen and provides easier access to harvest equipment), nutrient removal rates are significantly reduced.

# Appendix L. Letter Report Prepared for the Town of Niverville Summarizing 2020 Wetland Cell Activities

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**November 30, 2020**

**Attention: Eric King, CPA, CGA, Chief Administrative Officer, Town of Niverville.**

**RE: Summary of 2020 Niverville Wetland Activities**

Dear Mr. King,

The intent of this letter report is to summarize the 2020 wetland activities which involved the following:

- wetland vegetation restoration; and,
- wetland sampling in support of license removal.

In addition to providing a summary of our 2020 work this letter report also includes discussion on the next steps for removal of the environmental license from the wetland.

## 1. Wetland vegetation restoration

Since 2016, muskrat activity has removed cattail from a 6000 m$^2$ area within the wetland and reduced the wetland's treatment functions. In 2020, cattail restoration was undertaken in the area where the vegetation had been lost due to muskrat activity (Figure 1).

### 1.1 Cattail seed harvesting and processing

Cattail seed heads were harvested in the spring of 2020 from the St. Pierre-Jolys treatment wetland and the Niverville wetland (Figure 2). The seed heads were stored in cold storage until they were processed in May of 2020. Cattail seed processing involves subjecting the seed to physical stresses that mimic natural environmental conditions. The processed cattail seed had germination rates of $\geq$ 70% (Table 1).

### 1.2 Wetland bench preparation

In the spring of 2020, upslope areas of the wetland benches had dense curled dock (*Rumex crispus*) vegetation coverage. To prepare the benches for cattail seeding the curled dock was snipped with hedge clippers (Figure 3).

In preparation for seeding, wetland water levels were drawn down (Section 1.4). This resulted in the benches being covered by a thick algal mat. The algal mat was manually removed to expose the wetland soil (Figures 4 and 5) to increase cattail seed to soil contact at the time of seeding.

### 1.3 Cattail seeding

On June 25, backpack hydro-seeders were used to seed the wetland benches with processed cattail seed (Figure 6). To ensure success, the required seeding rate was doubled (1236 pure live seed/m$^2$).

In addition to the hydro-seeding, the left-over cattail chaff from seed processing was applied by hand to the exposed wetland soils (Figure 7).

### 1.4 Water level management

In the fall of 2019 wetland water levels were drawn down to expose the benches and create suitable conditions for cattail seedling emergence from the existing wetland seedbank in the spring of 2020. However, despite ideal soil moisture conditions few cattail seedlings emerged from the existing seedbank. Instead the exposed benches were dominated by upland weeds such as curled dock. To drown out the weeds, water was pumped into the wetland from the holding cell using a 6-inch pump (Table 2) and held at the normal operating level (NOL) until June 17 (Figure 8). Then from June 17 to June 19, the connection between the wetland and the holding cell was opened and a gravity draw down of wetland water level occurred to expose the benches for seeding (Figure 9). By the end of July, the exposed wetland benches had below optimum moisture levels for cattail establishment. On July 29 water was pumped into the wetland from the holding cell using an 8-inch pump. Water levels were brought up to a depth of 5 cm at Location A (Figure 10) on the upslope edge of bench 4 and held there until August 10. A depth of 5 cm at Location A was determined by NPS at the time to represent the optimum water level for cattail growth for all the seeded benches.

However, it was discovered in 2020 that the wetland benches are not all at the same elevation. Consequently, holding water level at 5 cm at Location A resulted in deeper water levels at other bench locations (Figure 10). Cattail seedlings in areas where the water level was above 15 cm were becoming stressed by the second week of August (Figure 11). To relieve the stress caused by high water levels the connection between the wetland and the holding cell was again opened from August 10 to August 11 (Figure 12) and water levels were lowered to expose the wet soil on the wetland benches. From August 11 into freeze up the wetland soils on the benches remained wet but had no standing water. These are ideal conditions for the health of the young cattail going into the spring of 2021.

### 1.5 Cattail establishment

On July 2, one week after seeding, cattail seedlings were first observed emerging from the wetland soil (Figure 13). New cattail seedlings continued to emerge throughout the 2020 growing season (Figure 14).

In July grazing of the young cattail by geese was noted (Figure 15). To deter geese from the site plastic eagles were installed at benches 2 and 4 (Figure 16). The eagles worked to deter geese for the first 2 weeks after they were installed. When geese returned to the site later in the year much of the cattail had already reached heights that were no longer desirable for the geese to graze upon (Figure 17).

The Town of Niverville had two colonial muskrat traps (Figure 18) in the wetland during the 2020 growing season and removed 8 muskrats from the wetland. This trapping effort helped limit muskrat damage to the cattail seedlings.

On October 6, 2020 cattail cover was determined by conducting stem counts along eight, $1m^2$ transects that extended across the seeded wetland benches (Figures 19, 20; Table 3). The average stem count of 85/m$^2$ was above the minimum recommended range (40 to 60/m$^2$) to achieve optimum phosphorus removal from wetland water columns[1]. Because of the success of the spring seeding, no further remedial seeding in 2020 was required.

### 1.6. Future wetland monitoring and management

The 2020 revegetation of cattail at the Niverville wetland was good with excellent coverage on all the benches that were seeded (Table 3). To ensure cattail success in 2021 water levels need to be further managed so as to provide optimum conditions for cattail growth. To manage water levels more effectively at least 2 permanent water level gauges (Figure 21) that clearly show the NOL should be installed in the wetland.

The cattail that emerged in July 2020 will, in the spring of 2021, have stem growth originating from below ground rhizomes. In the early spring, prior to the growth of stems, below ground rhizomes are supplied with oxygen via a “snorkelling” action through the above ground standing dead stems. Thus, there is not a great risk of drowning out cattail in the spring like there was in the first year of growth when the cattail was growing from seed and the young seedlings, if flooded over ,would not have had an oxygen supply.

NPS will monitor water levels in 2021, starting in late April, and will advise the Town of Niverville on how to manage levels for optimum cattail growth. Based on NPS’s experience we anticipate that by mid-summer water levels could be raised and held at NOL. Raising water levels to NOL will cover the benches and limit geese activity which in turn will reduce fecal coliform contamination of the wetland. The NOL will also maximize water contact with the cattail and improve the wetland’s ability to remove phosphorus from the water column.

In 2021 biweekly site visits from late April to July and monthly visits from August through October 2021 will be conducted to monitor the continued cattail establishment at the site. At the end of the 2021 growing season, stem counts should be conducted at the 8 transects established in 2021 (Figure 19).

Muskrat control needs to continue within the wetland in 2021 to prevent significant cattail damage and subsequent loss of the wetland’s water quality function.

## 2. Wetland sampling in support of license removal

On December 16, 2019 and April 29, 2020 discussions were held between the Town of Niverville, the Province of Manitoba and NPS to determine what steps are required to remove the current environmental license from the wetland. In these meetings it was decided that another year of sampling should be undertaken in 2020 to demonstrate that the wetland met the criteria for license removal (Table 4). The sampling effort that was agreed to by the Province and the Town included both wetland water and biosolid sampling (Table 4).

[1] *Native Plant Solutions 2020. Operations and maintenance manual for the St. Pierre-Jolys treatment wetland. Submitted to the Village of St. Pierre-Jolys: April 2020.*

### 2.1 Water quality

During the 2020 growing season water quality sub-samples were collected at 4 locations (Figure 22) within the wetland. The sub-samples were combined to form a single composite sample for each sampling date. The composite samples were sent to the ALS Environmental Laboratory in Winnipeg for total phosphorus (TP) and fecal coliform analysis.

#### 2.1.1 Water column total phosphorus

TP levels fluctuated during the sampling season but remained close to the Provincial target of 1 mg/L (Table 5). To account for natural variations in TP levels in treatment wetlands, the Province, when approving environmental releases, considers the rolling average based on the 3 most recent sampling events. Applying this rationale to the Niverville wetland we see that the rolling average for the 3 most recent sampling dates (Oct 21, Oct 27, Nov 3) is 0.80 mg/L which is below the Provincial target of 1 mg/L (Table 5). This provides the required evidence that, based on its TP level, the Niverville wetland meets the requirements for environmental license removal.

In future years when managed at NOL, the ability of the Niverville wetland to remove TP from the water column will be even greater than that seen in 2020 when water levels were lower than NOL. Managing the wetland at NOL maximizes the contact between water and cattail which provides optimal conditions for cattail to remove TP from the water column.

#### 2.1.2 Water column fecal coliforms

Fecal coliform counts, for most of the year were below the provincial limit of 200 MPN/100 mL for recreational waters (Figure 23).

The reason for the high coliform counts on October 14 and October 27 was likely due to geese activity on the exposed wetland benches. The exposed benches provided areas for geese to laze and defecate upon. Following a rain event or snow melt, fecal coliforms from geese feces on the benches can wash into the wetland. Once in the wetland fecal coliform numbers are reduced in the water column via natural processes including grazing by invertebrates and exposure to ultraviolet light.

At Niverville, the highest coliform count occurred on October 14 when the sampling event coincided with a rain event and surface water was observed flowing off the benches into the wetland (Figure 24). The second highest coliform count occurred on October 27 which coincided with heavy geese use of the wetland including loafing on the partial ice cover on the wetland (Figure 25). Goose feathers, which can be a source of fecal coliforms, were observed floating on the wetland surface in areas where water sub-samples were collected.

The direct relationship between coliform counts and geese activity clearly indicates that the source of the coliforms is external to the wetland and not from the wetland soils. The consistently low coliform counts in the wetland soils (See section 2.2) also provides evidence that the source of the coliforms is external to the wetland.

The 2020 sampling demonstrated that the coliform source to the wetland water is external loading and not the wetland soils. This provides the required evidence that based on its coliform characteristics the Niverville wetland meets the requirements for license removal.

In future years, the wetland will be managed at NOL and there will be no exposed benches for geese to defecate upon. This will greatly reduce fecal coliform contamination of the wetland.

## 2.2. Biosolid quality

On August 20 wetland biosolid sub-samples were collected from 164 locations for fecal coliform and helminth ova analyses (Figure 26). The sub-samples were combined to form a single composite sample. The composite sample was divided into two portions. One portion of the composite sample was sent to A & L Laboratories in Ontario for helminth ova counts. The other portion of the August 20 biosolid sample was sent to ALS Environmental Laboratory in Winnipeg for fecal coliform analysis. Additional biosolid composite samples were collected from the wetland in September and October from 4 locations upslope of the 4 water sampling locations (Figure 4) and sent to ALS Environmental Laboratories in Winnipeg for fecal coliform analysis.

### 2.2.2 Biosolid fecal coliforms

In 2020 fecal coliform counts in the biosolids were below the USEPA Class A target during each sampling event (Table 6). On the last sampling event of 2020 (November 3), fecal coliform counts were below detection limits. The 2020 sampling campaign provides the required evidence that the Niverville wetland meets the biosolid fecal coliform requirements for license removal.

### 2.2.3 Biosolid helminth ova

Helminth are the longest surviving group of human pathogens in soils (Table 7). It is for this reason that they were selected to assess the human health risk of the Niverville wetland biosolids.

Helminth ova were not detected in the Niverville biosolids in 2020. This provides the required evidence that the Niverville wetland meets the biosolid human pathogen requirements for license removal.

## 3. Next steps for removal of environmental licence from wetland

The Niverville wetland's water and biosolid conditions, based on the most recent sampling campaigns, meet the provincial requirements for the removal of the environmental license (see table below). In January 2021 the Town of Niverville along with NPS should schedule a meeting with the Province to present the 2020 data and request that the environmental license be removed from the wetland.

| | Parameter | Target | Niverville | Target met |
|---|---|---|---|---|
| **Water quality** | Total phosphorus (mg/L) | 1 | 0.55[A] | YES |
| | Fecal coliforms (MPN/100 mL) | 200 | 4[A] | YES |
| **Biosolid quality** | Fecal coliforms (MPN/g) | < 1000 | < 2[A] | YES |
| | Helminth ova (ova/4g) | < 1 | None detected[B] | YES |

[A] November 3, 2020 sampling date

[B] August 20, 2020 sampling date

## 4. Closing and Corporate Authorization

This letter report, *Summary of 2020 Niverville Wetland Activities*, is prepared by Ducks Unlimited Canada operating as Native Plant Solutions for the Town of Niverville. The material herein reflects the best judgment of Native Plant Solutions based on the information available at the time of preparation. Any use, which a third party makes of this report, or reliance on or decisions made based on it, is the responsibility of the third party. Native Plant Solutions accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

Sincerely,

[redacted]

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Native Plant Solutions – Ducks Unlimited Canada

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Native Plant Solutions – Ducks Unlimited Canada

# Figures and Tables

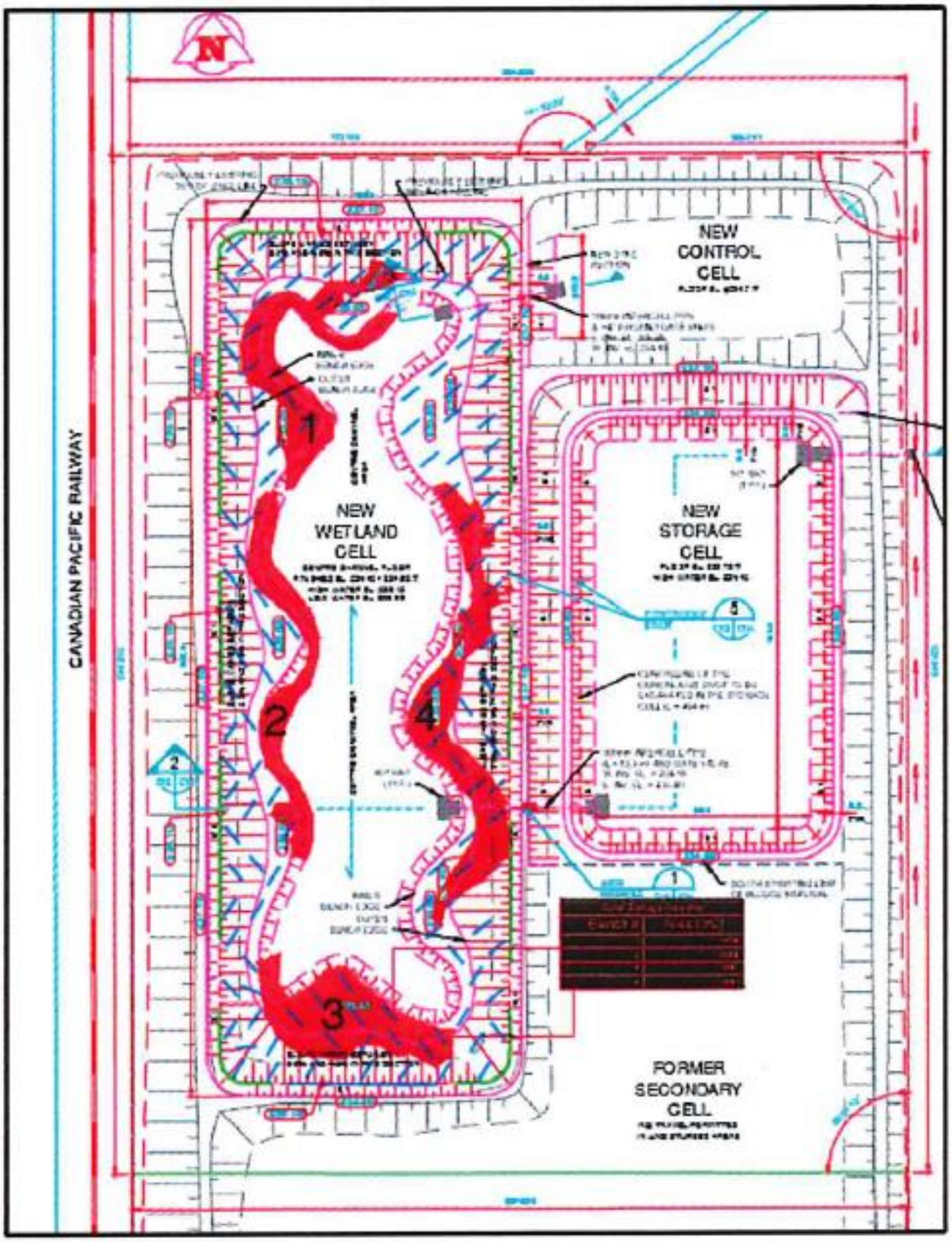


**Figure 1.** Areas highlighted in red indicate wetland benches (numbered 1 to 4) where cattail has been lost due to muskrat activity.

**Figure 2.** Cattail seed heads in the Niverville wetland at time of harvest (May 21, 2020).

**Figure 3.** Before and after photos at a location within the Niverville wetland where curled dock was clipped (June 10, 2020).

**Figure 4.** Manually removing algal mat to expose wetland soils in preparation for seeding (June 24, 2020).

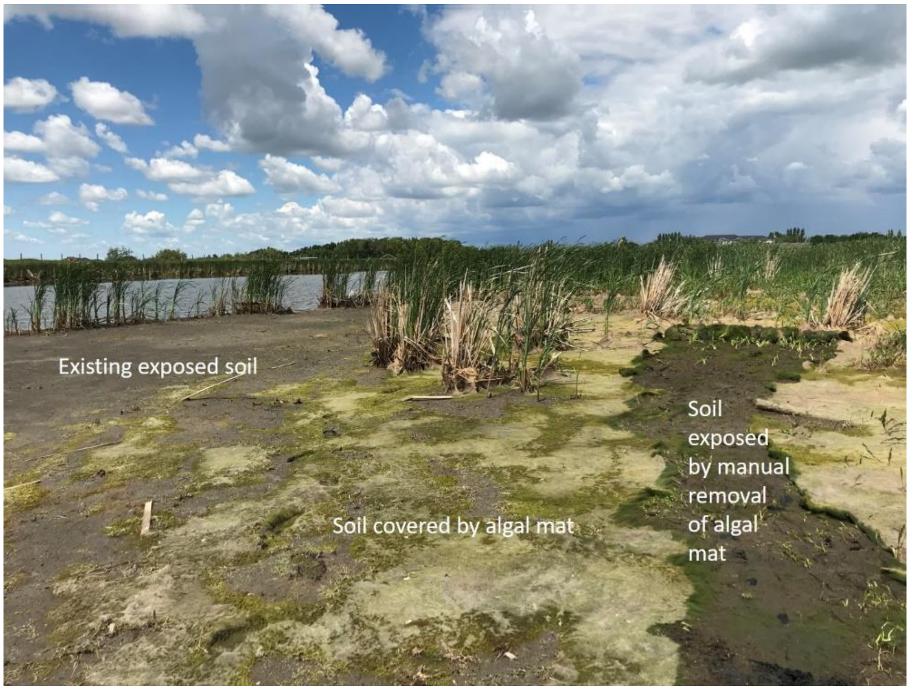


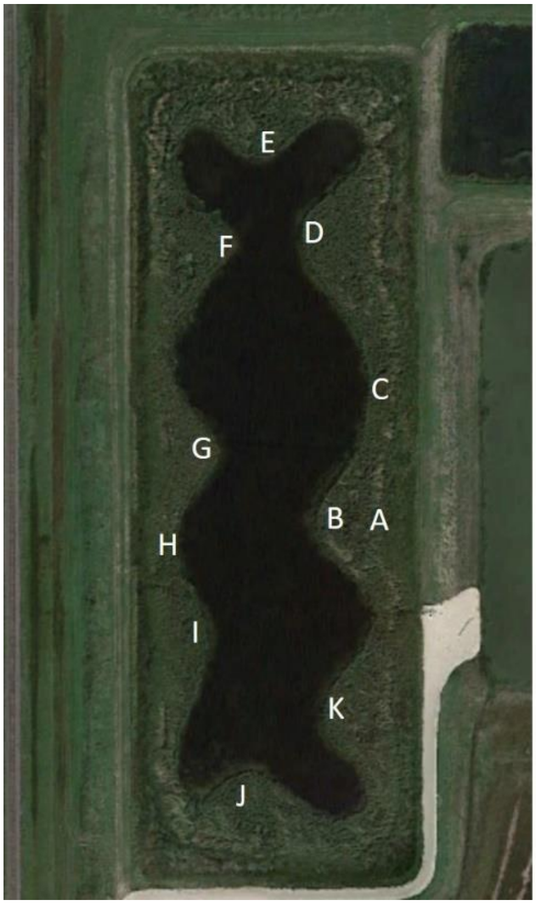
**Figure 5.** Wetland bench showing the difference in soil exposure between areas covered by algal mat and areas where the algal mat has been removed (June 24, 2020).

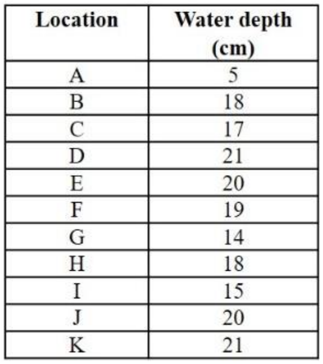
**Figure 6.** Cattail hydroseeding of Niverville wetland (June 25, 2020).

**Figure 7.** Cattail chaff hand deposited on exposed soil at the Niverville wetland (June 25, 2020).

**Figure 8.** Water level on wetland benches at NOL to drown out upland vegetation (May 21, 2020).

**Figure 9.** Exposed wetland soils following wetland drawdown (June 24, 2020).





| Location | Water depth (cm) |
|---|---|
| A | 5 |
| B | 18 |
| C | 17 |
| D | 21 |
| E | 20 |
| F | 19 |
| G | 14 |
| H | 18 |
| I | 15 |
| J | 20 |
| K | 21 |

**Figure 10.** Wetland bench water levels, August 10, 2020.

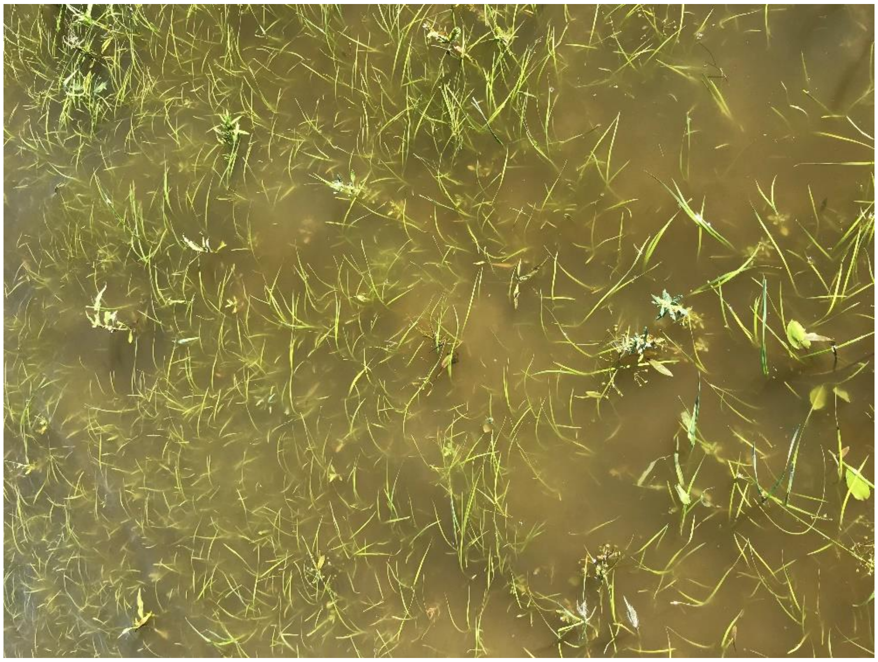


**Figure 11.** Stressed cattail seedlings due to water levels > 15 cm (August 10, 2020).

**Figure 12.** Town of Niverville employee Andrew Rempel opening connection between wetland and holding cell (August 10, 2020).

**Figure 13.** Cattail seedlings emerging from wetland soil July 2, 2020.

**Figure 14.** Cattail seedlings emerging from wetland soil September 23, 2020.

**Figure 15.** Cattail seedlings damaged by geese grazing (July 21, 2020).

**Figure 16.** Plastic eagle installed on 2 bench (July 17, 2020).

**Figure 17.** Tall cattail seedlings no longer at risk of grazing by geese (August 10, 2020).

**Figure 18.** Colonial muskrat trap ready for deployment in wetland (August 10, 2020).

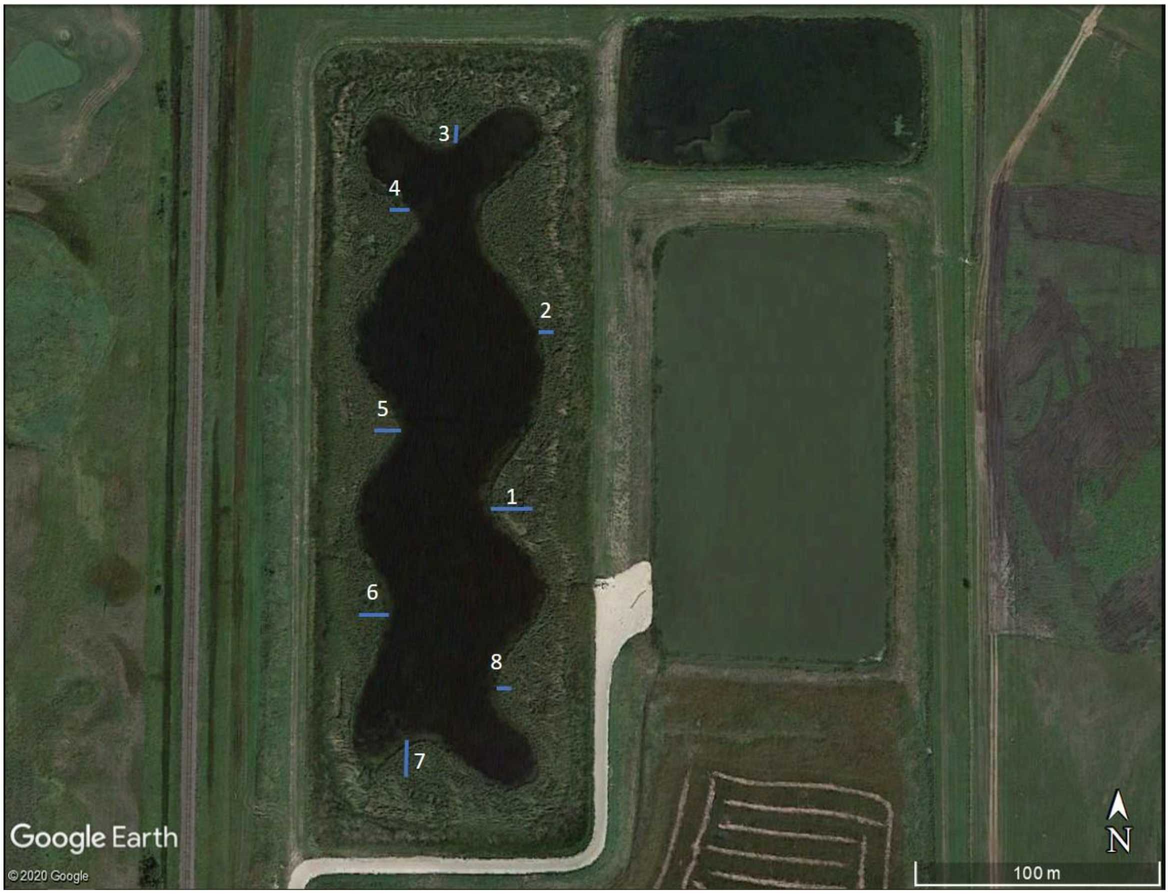


**Figure 19.** Location of cattail stem count transects.

**Figure 20.** Cattail stem count quadrat located along Transect 1 (October 6, 2020).

**Figure 21.** Example of the type of water level gauge that should be installed at the Niverville wetland in the spring of 2021.

**Figure 22.** Niverville wetland water sampling locations.

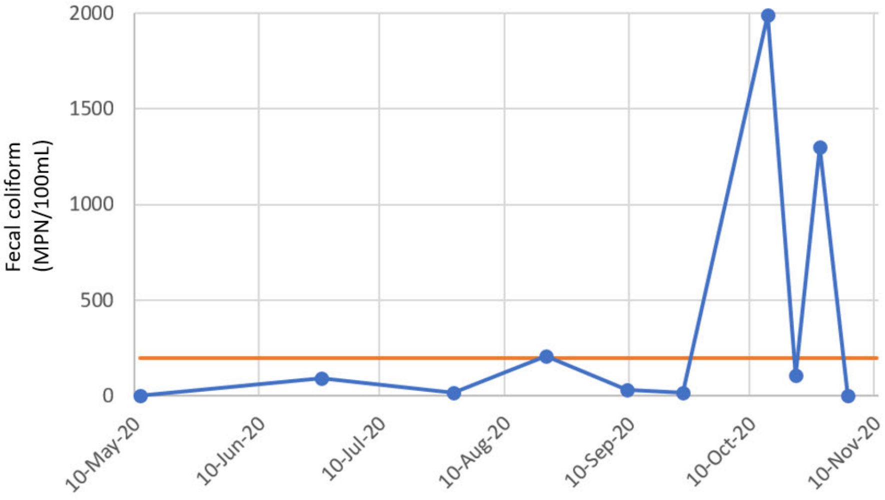


**Figure 23.** Niverville wetland water total fecal coliform counts. Orange line indicates Manitoba water quality target of 200 MPN/100mL for recreational waters.

**Figure 24.** Surface flow into the wetland over wetland Bench 4 during the October 14 water sampling campaign which occurred during a precipitation event (October 14, 2020).

**Figure 25.** Canada geese activity at the Niverville wetland. Note goose feathers on the water surface in the foreground of the photo (October 27, 2020).

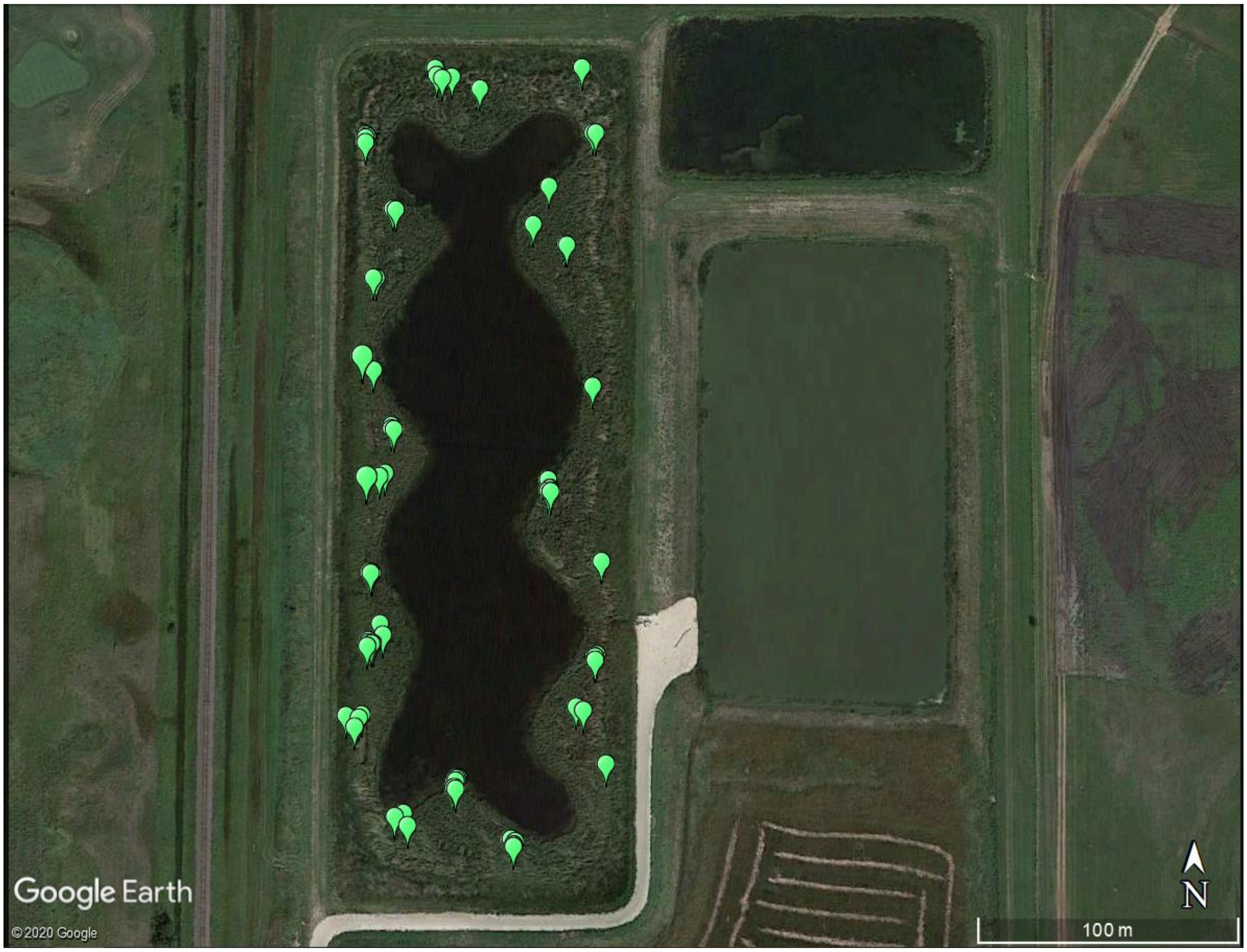


**Figure 26.** Niverville wetland biosolid sampling locations.

**Table 1.** Germination test results for cattail seeds from the Niverville and St. Pierre-Jolys wetlands.

| **Seed collection location** | **Lot#** | **Percent germination (%)** |
|---|---|---|
| Niverville wetland | 1 | 73 |
| | 2 | 70 |
| | 3 | 85 |
| St. Pierre-Jolys treatment wetland | 1 | 91 |
| | 2 | 93 |
| | 3 | 81 |

**Table 2.** Run times for pumping water from the holding cell to the wetland (6 inch PTO driven pump).

| Date | Pump run time (hours) |
|---|---|
| May 15 | 6 |
| May 19 | 8 |
| May 20 | 8 |
| May 21 | 8 |
| May 22 | 8 |
| May 25 | 8 |

**Table. 3.** Cattail stem counts (October 6, 2020) in $1x1m^2$ quadrats. Transects extend across seeded bench with quadrat #1 being closest to the open water edge.

| | Transect # | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Quadrat #** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 113 | 72 | 113 | 133 | 156 | 140 | 47 | 78 |
| 2 | 83 | 78 | 112 | 118 | 168 | 84 | 60 | 102 |
| 3 | 63 | 56 | 41 | 120 | 169 | 56 | 78 | 120 |
| 4 | 143 | 68 | 45 | 87 | 68 | 88 | 74 | 78 |
| 5 | 167 | 76 | | | 95 | 126 | 65 | 73 |
| 6 | 86 | | | | | 81 | 86 | 58 |
| 7 | 48 | | | | | 86 | 43 | 83 |
| 8 | 38 | | | | | 71 | 36 | |
| 9 | 33 | | | | | 41 | 38 | |
| 10 | | | | | | | 46 | |
| 11 | | | | | | | 52 | |

**Table 4.** Wetland criteria for license removal.

| | Parameter | Guideline | 2020 Sampling frequency |
|---|---|---|---|
| Water quality | Total Phosphorous | 1 mg/L[A] | 10 |
| | Fecal coliforms | 200 MPN/100 mL[A] | 6 |
| Biosolids | Helminth ova | 1 per 4 g[B] | 1 |
| | Fecal coliforms | 1000 MPN/g[B] | 6 |

[A] Manitoba target

[B] USEPA target for Class A biosolids

**Table 5.** Niverville wetland total phosphorous concentrations and rolling average consecutive sampling dates.

| **Date (2020)** | **TP (mg/L)** | **Rolling average based on the 3 most recent consecutive sampling dates** |
|---|---|---|
| May 11 | 0.95 | |
| June 25 | 1.45 | |
| July 28 | 1.29 | 1.23 (May 11, Jun 25, Jul 28) |
| August 20 | 1.16 | 1.30 (Jun 25, Jul 28, Aug 20) |
| September 9 | 1.06 | 1.17 (Jul 28, Aug 20, Sept 9) |
| September 23 | 1.18 | 1.13 (Aug 20, Sept 9, Sept 23) |
| October 14 | 0.96 | 1.07 (Sept 9, Sept 2, Oct 14) |
| October 21 | 0.93 | 1.02 (Sept 2, Oct 14, Oct 21) |
| October 27 | 0.92 | 0.94 (Oct 14, Oct 21, Oct 27) |
| November 3 | 0.55 | 0.80 (Oct 21, Oct 27, Nov 3) |

**Table 6.** Fecal coliform counts in Niverville wetland biosolids.

| **Date 2020** | **Fecal coliform MPN/g** | **Helminth ova** |
|---|---|---|
| August 20 | 580 | None detected |
| September 9 | 269 | |
| September 23 | 153 | |
| October 14 | 23 | |
| October 21 | < 2 | |
| October 27 | 56 | |
| November 3 | < 2 | |

**Table 7.** Human pathogen survival in soil (From: Gerba, C.P. and J.E. Smith. 2005. Sources of pathogenic microorganisms and their fate during land application of wastes. Journal of environmental quality. 34:42-48.).

| **Pathogen** | **Absolute Maximum** | **Common Maximum** |
|---|---|---|
| Bacteria | 1 year | 2 months |
| Viruses | 6 months | 3 months |
| Protozoa | 10 days | 2 days |
| Helminth | 7 years | 2 years |