Risk Assessment at a Wastewater Treatment Lagoon Managed by the Canadian Armed Forces (CAF)

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ABSTRACT

The use of lagoons is one of the most cost-effective wastewater treatment (WWT) options for rural communities in Canada. This type of wastewater treatment is also used at several military bases of the Canadian Armed Forces. Lagoons are low-maintenance systems that use natural and energy-efficient processes. This paper presents a monitoring programme that will be used to conduct an investigation of a two stage aerobic lagoon system, at a military base in Central Canada, originally constructed in 1988. The proposed programme includes the use of in-situ instrumentation for the analysis of parameters indicative of treatment performance and sampling for detailed analysis of wastewater characteristics. It also includes the assessment of the lagoon's ability to contain the wastewater using a variety of methods including a LiDAR survey. The proposed monitoring programme should allow a quantitative assessment of the WWT lagoon with the view of determining its impact on the surrounding environment and the base's source water.

RÉSUMÉ

L'utilisation de lagunes est parmi les méthodes les moins dispendieuses pour le traitement des eaux usées pour les communautés rurales au Canada. Ce type de traitement des eaux usées est aussi employé à plusieurs bases militaires des Forces armées canadiennes. Les lagunes utilisent des processus naturel, écoénergétique et ainsi nécessite peux d'entretien. Cet article présente un programme de surveillance qui sera utilisé pour évaluer une lagune à deux étang aérobic utilisé a une base militaire situé dans la région central du Canada, originalement construis en 1988. Le programme proposé incluse l'utilisation d'instrument in-situ pour l'analyse sur place de paramètres indicatif de l'efficacité du trainement ainsi que de l'échantillonnage pour effectuer une analyse détailler des caractéristiques de l'eau usée. De plus, ce programme inclue une étude de l'efficacité de l'infrastructure à contenir l'eau usée en utilisant une variété de méthode qui inclut l'arpentage au LiDAR. Le programme de surveillance proposé devrait permettre une évaluation quantitative de la lagune dans le but de déterminer son impact sur son environnement et sur la source d'approvisionnement en eau de la base.

1 INTRODUCTION

The use of lagoons is one of the most simplistic and cost-effective wastewater treatment options for rural communities in Canada. According to the Federation of Canadian Municipalities and National Research Council (2004), 48% (868 facilities) of treatment facilities are lagoon systems. Lagoons are particularly favoured in the prairie provinces with Manitoba, Saskatchewan, and Alberta at 85% (127 facilities), 92% (129 facilities), and 83% (278 facilities) respectively. This type of wastewater treatment is also used at several military bases of the Canadian Armed Forces (CAF). As wastewater treatment (WWT) lagoons rely on providing optimal conditions for naturally occurring processes to stabilize the wastewater, they do not require the complex infrastructure and chemical additives of typical wastewater treatment plants. This simplicity results in low-energy and low-maintenance requirements for the treatment of wastewater. Despite their mechanical simplicity, there are complex chemical, biological, and physical processes taking place in lagoons that can be further burdened by site-specific factors including hydrogeological parameters and inflow volume.

The two (2) main forms of biological reactions taking place in WWT lagoons are aerobic stabilization and anaerobic fermentation and are produced via algae and bacterial activity. Aerobic stabilization occurs in the upper layer of the facultative lagoons and throughout the water column in aerobic lagoons. Oxygen is introduced to the wastewater via algae photosynthesis and surface reaeration. In contrast, anaerobic fermentation occurs in zones where dissolved oxygen (DO) is absent from the wastewater. In this environment, bacterial acid creation and methane fermentation provide effective treatment (Federation of Canadian Municipalities and National Research Council, 2004; Metcalf & Eddy, 2013; USEPA, 2011). Due to the higher reaction rate of aerobic stabilization and the objectionable odour emissions from anaerobic fermentation, facultative and aerobic lagoons are more frequently used for the treatment of municipal wastewater.

As the stabilization of wastewater within lagoons is conducted via biological processes, the rate and efficiency of the treatment will vary in accordance to three (3) main factors: light, temperature, and pH (Metcalf & Eddy, 2013; Tilsworth & Smith, 1984; USEPA, 2011). These factors are further influenced by the total suspended solids (TSS) levels, loading rate (i.e. BOD_5/$CBOD_5$), and wind action. A schematic representation of the wastewater stabilization within a WWT lagoon is presented in Figure 1. To assess

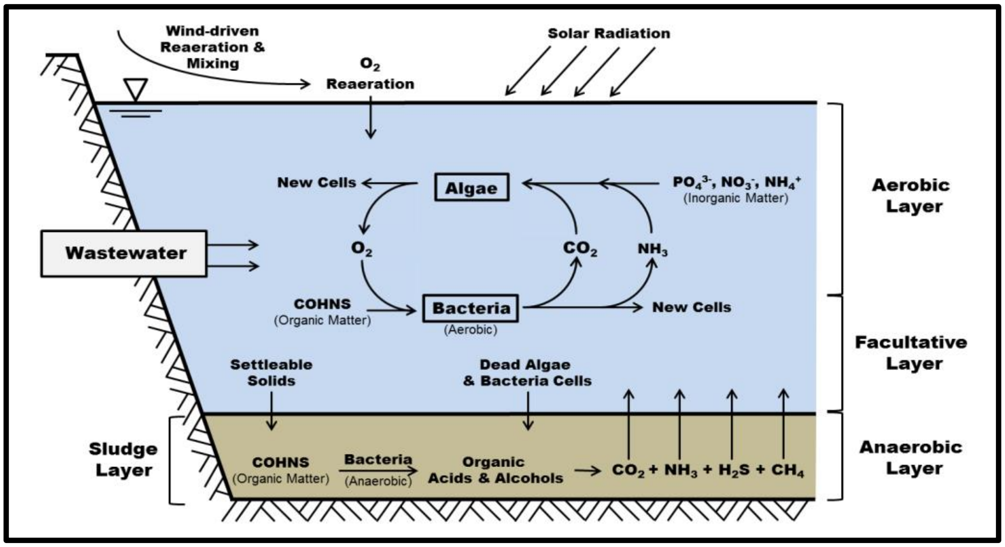


Figure 1. Schematic of the stabilization of wastewater in lagoon systems (Adapted from Tchobanoglous & Schoeder, 1985)

the performance of a WWT lagoon, all the factors presented above need to be known along with their spatial variation within the wastewater cells and their temporal variation, both diurnal and annual variation.

WWT lagoons located on CAF bases are under federal jurisdiction and thus must follow the effluent quality standards stipulated by the Government of Canada (2016). These regulations are intended for the protection of the receiving ecosystem and as such regulate the concentration of biochemical oxygen demand (BOD), carbonaceous biochemical oxygen demand (CBOD), total suspended solids (TSS), nutrients (such as ammonia and nitrate), and residual chlorine which are known to have deleterious effects.

WWT lagoons are also regulated for air emissions based on the Canadian Ambient Air Emission Standards (Canadian Council of Ministers of the Environment, n.d.) for various chemical emissions.

2 OBJECTIVES

The aim of the project is to quantify and assess the effectiveness of the treatment and operational performance of the WWT lagoon with a view to determine its effect, influence, and risk with regards to the drinking water supply (i.e. source water vulnerability). This paper will focus on the development of the monitoring programme that will be used for the assessment of the WWT lagoon.

The proposed monitoring programme will look at both the WWT lagoon system's treatment performance and its ability to effectively contain the wastewater. This programme was designed based on the possible failure mechanisms of the WWT lagoon. These failure mechanisms can be divided into two (2) main categories: containment failure and treatment failure.

2.1 Failure to Contain the Wastewater

Containment failure is defined as the involuntary discharge of wastewater in sufficiently large quantities to have deleterious effects on the surrounding environment. As the majority of the treatment is undertaken in two (2) cut-and-fill reservoirs, the primary focus is placed on the support structure (i.e. berms) and the lining system of the lagoons. The berms and the lining system are the two (2) principal elements that compose the structural health of the WWT lagoon. In addition, containment failure may be caused by human actions (operation problems) such as excessive hydraulic loading, improper maintenance cleaning, or even vandalism. This failure mechanism was obtained from the USEPA's municipal wastewater stabilization pond design manual (USEPA, 1983).

2.2 Failure to Provide Sufficient Treatment

Treatment failure is defined by the voluntary release of water that has not met the regulatory quality standards. Additionally, treatment failure can occur if air emissions from the WWT lagoon exceed the Canadian Ambient Air Quality Standards (CAAGS) (Canadian Council of Ministers of the Environment, n.d.) or if objectionable odours are impacting the neighbours of the lagoon facilities. The considered treatment failure mechanisms used for this monitoring programme are listed in Table 1.

2.3 Scope Limitation

The investigation of the WWT lagoon will exclude an assessment of the infrastructural appurtenances (e.g. septic tank access housing, pump house, and chlorination chamber housing). In addition, the state of the electrical and mechanical equipment will also not be included in the investigation.

Table 1. Principal behaviour leading to treatment failure of WWT lagoons (Barlet, 2017; Metcalf & Eddy, 2013; Tilsworth & Smith, 1984; USEPA, 2011)

Treatment Problems	Odour & Emissions Problems
Insufficient in cell light	Overloading of cells
Insufficient DO	Excessive accumulation of surface scum
Water temperature too low	
Excessive nutrient concentration	Uncontrolled aquatic and embankment vegetation
Excessive SS concentration	

3 METHODOLOGY

To quantify and assess the effectiveness of the treatment and operational performance of the WWT lagoon along with its impact on the surrounding environment and its potential risk to the base's source water, the following methodology will be followed.

An analysis of the lagoon's effluent will be conducted to identify its quality and the nature of contaminants that are a concern. The WWT lagoon system will be assessed to ensure that it operates adequately based on its intended design and operating condition.

Groundwater sampling will be carried out to assess the WWT lagoon for possible leaks. This will be done by analysing the groundwater for the key contaminants previously identified in the effluent. Monitoring wells (MW) located up gradient from the WWT lagoon will be used to determine the background of the groundwater quality.

The WWT lagoon will then be instrumented using a variety of in-situ sensors that will measure and record the parameters that affect the quality of the wastewater. Each cell will receive their own set of instruments in order to understand their specific behaviours. In addition, the septic tank will be instrumented in order to ascertain the initial condition of the influent and to assess the septic tank's contribution to the overall treatment of the wastewater. By having instruments in multiple locations throughout the WWT lagoon systems, the assessment of the contribution of each component of the WWT lagoon system will be possible. Periodic sampling of the wastewater will augment the in-situ instrumentation. The samples will then be analysed for a series of parameters that cannot be captured with on-line sensors. In addition, regular sludge cores will be taken to measure its accumulation at the bottom of each cell. Air emission will also be measured periodically. The instrumentation will confirm the effectiveness of the wastewater treatment, track its seasonal variations, and confirm the effectiveness of the WWT lagoon's design.

Based on the knowledge that will be obtained from the monitoring programme, the impact of the WWT lagoon on the surrounding environment and its risk to the base's source water will then be determined.

4 SITE DESCRIPTION

The site of interest is located in central Canada and more specifically within the Canadian Prairies. The daily average temperature for the warm months (June to August) is below 20ºC and cold months (November to March) are below the freezing mark (0ºC). On average, the site receives an annual rainfall of 263.8 mm and snowfall of 76.6 mm. The yearly cumulative hours of sunshine are approximately 2268 hrs in accordance to the historical climate data available online through the Government of Canada (Government of Canada, n.d.). The historical climate data did not include data on the wind direction or speed. The meteorological data for the site was estimated based on the closest weather station for which historical climate norms were available through the Government of Canada (Government of Canada, n.d.). This weather station was located approximately 40 km north of the site.

The WWT lagoon (Figure 2) is located approximately 900 m away from the closest production well that supplies the base's drinking water. The soil at the base consists of silty sand with an average hydraulic conductivity ranging from 5e^{-5} to 3.9e^{-4} cm/s. The groundwater at the site is considered to be under the direct influence of surface water and is located 6.5 to 9.5 m below grade. The proximity of the WWT lagoon to the production wells along with the surface water's influence on the groundwater leaves the base's drinking water source vulnerable to possible leaks or breaches of the WWT lagoon system. This risk is further increased by the lack of a formal wellhead protection programme.

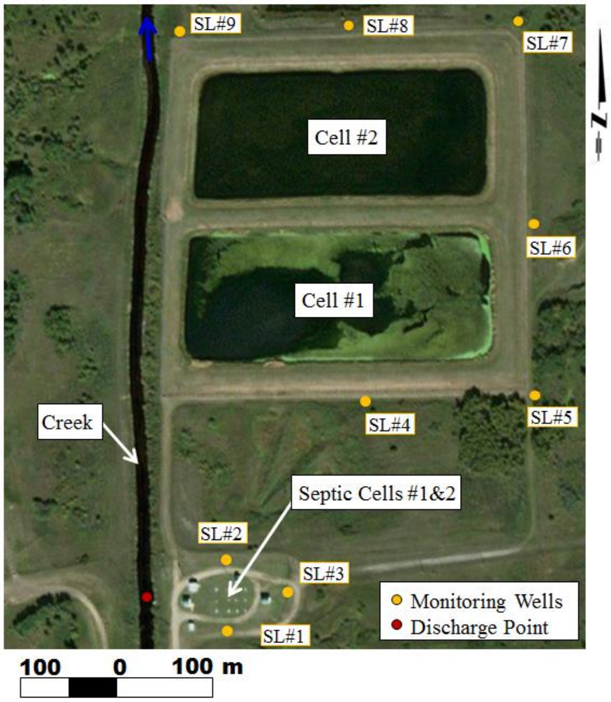


Figure 2. Site layout. The nomenclature SL# is used by the base staff to differentiate the monitoring wells located near the Sewage Lagoon from the remainder of the monitoring wells located on the base. (imagery provided by Microsoft Bing Map)

The only major surface water body in the vicinity of the WWT lagoon is a creek which serves as the effluent's receiving ecosystem. This creek was realigned and straightened in 1941 and is 30–50 m away from the Western border of the WWT lagoon. The flow rate of the creek was measured by a previous study to be approximately 0.009 m^3/s. The study, conducted by the local watershed authority, focused on fish habitats and was conducted approximately 20 km upstream for the WWT lagoon. The effluent travels approximately 35 km along the creek before reaching the northern boundary of the base and entering provincial jurisdiction.

A series of nine (9) MW surrounds the WWT lagoon and were installed as part of the base's groundwater monitoring programme as seen in Figure 2.

4.1 Infrastructure Description

The WWT lagoon is managed by the Real Property Operations (RP Ops) detachment of the base. The RP Ops section is responsible for the management of all buildings and the exploitation of utilities located on the base. The WWT lagoon is operated by three (3) operators, which include one (1) supervisor, and two (2) journeyman operators. The same three (3) operators are also responsible for the operation of the base's water treatment plant and conducting the water quality control sampling across the base.

The WWT lagoon was originally constructed in 1988 and currently serves a population of 150–230 people with a seasonal surge of 450 people. This surge is due to increase in military training exercises that take place in the mid to late summer. This surge results in approximate 100% increase in loading rates to the WWT lagoon. This significant variation in loading rate is unlike all WWT lagoon system of typical municipalities of similar sizes.

The WWT lagoon system consists of two (2) aerobic cells, 1.1 m and 2.0 m deep for cell #1 and cell #2 respectively (Figure 2). Each cell holds approximately 22000 m^3 of wastewater (Table 2). The wastewater is contained in the cells using a high-density polyethylene (HDPE) liner superimposed with 600 mm of compacted clay till on the berms and 150 mm of native sand in the beds. The HDPE liner is anchored at the top of the berms using the trench cut and backfill method. The HDPE liner has not been replaced and is now 30 years old.

Table 2. Basic properties of the WWT lagoon's cells (all values correspond to the max operating water quantity based on the original construction drawing)

Cell #	Water Column (m)	Cell Surface Area (m^2)	Cell Volume (m^3)
1	1.1	22017	30214
2	2.0	22121	41062

The influent is pretreated in two (2) septic tanks operating in parallel in order to settle out large solids prior to entering cell #1. Discharge is controlled and occurs once annually (mid to late May) for a period of approximately 1-10 days. Prior to its discharge (discharge point indicated on Figure 3), the effluent undergoes chlorination.

5 CURRENT MONITORING PRACTICES AT THE BASE

A monitoring programme is already in place as part of the regular operation of the WWT lagoon by base staff. In its current form, pH and wastewater temperature measurements are taken from grab samples of cell #1 and #2 (for as long as no ice cover is present) and within the septic tank on a daily basis. All readings are taken using handheld devices and manually recorded in log books on site. Wastewater volumes are obtained by recording a volume meter at each pump and subtracting the previous day's reading. The runtime of each pump is also recorded daily (in hours). All logbooks are digitized in bulk at the end of each month.

In addition to the daily monitoring, sampling is carried out prior, during, and after discharge. Prior to discharge, samples are taken in the receiving creek at locations upstream and downstream near the discharge point and two (2) locations where the creek reaches the boundary of the base. Additionally, samples from the septic tank and each cell are collected. During discharge, samples are taken on a daily basis from the effluent. At the mid-point in the discharge face, samples are taken from the receiving creek upstream and downstream from the discharge point. Once discharge has been completed, final samples are taken from the two (2) locations at the boundary of the base. Lastly, nine (9) monitoring wells were installed as part of the base's groundwater monitoring programme as seen in Figure 2. Each of these wells is sampled once

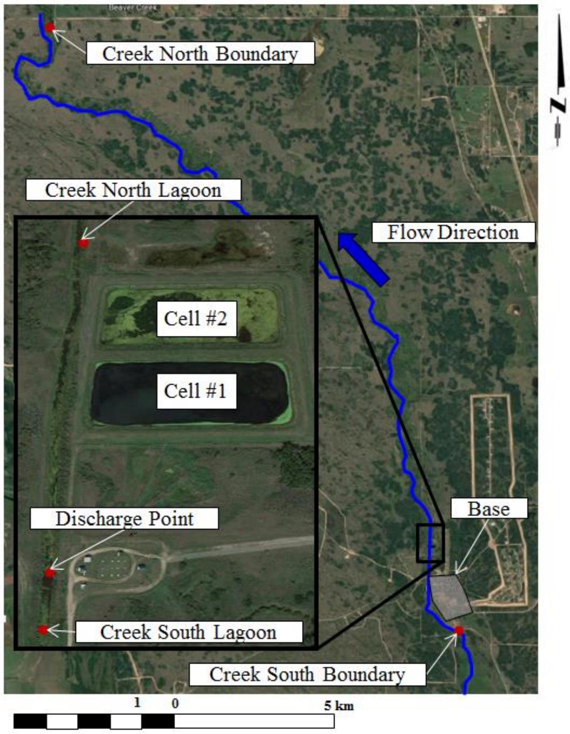


Figure 3. Sampling location as part of the current monitoring programme. (imagery provided by Microsoft Bing Map)

annually. All samples are analysed for approximately 92 parameters.

Although the current monitoring practice meets the requirements as dictated by the Wastewater Systems Effluent Regulations (Government of Canada, 2016), the data collected are insufficient to thoroughly assess the mechanism that controls the treatment of the wastewater. In addition, in its current form, the monitoring programme does not monitor for air emissions or monitor the condition of the infrastructure with the noted exception of the annual testing of the groundwater. The current methodology is reactive in nature and remedial actions are only taken once an issue has been identified. This results in a situation that can place additional risk on the local environment and the base's source water.

The proposed monitoring programme will need to monitor all parameters that influence the effectives of the treatment over the entirety of the effective treatment period. Additionally, the monitoring programme will need to assess for leaks.

6 SELECTED MONITORING PARAMETERS

In order to monitor and quantify the complex chemical, biological, and physical processes that take place in WWT lagoons, key environmental and wastewater quality parameters have been selected for in-situ monitoring using a variety of instruments in both cells and in the septic tank. These parameters include the minimum parameter necessary for the adequate evaluation of a WWT lagoon as described by Pearson et al. (1987). These parameters include: wastewater temperature, algal biomass (chlorophyll-a), algal genera, sludge depth, sulphates, DO, and pH. Additional parameters (e.g. meteorological parameters, loading rate, and wastewater levels) have also been selected to fully understand the operating condition of the WWT lagoon. Several of these parameters require grab and composite samples to be taken for analysis in the laboratory. The parameters are listed in Table 3.

The WWT lagoon's ability to retain the wastewater will be assessed using several methods. Additionally, groundwater samples will be taken from pre-existing monitoring wells (MW) located around the WWT lagoon system (Figure 2). The samples will be analysed for various parameters including parameters indicative of contamination by wastewater (Table 4).

Table 3. Treatment Monitoring Parameters

Environmental (Meteorological) Parameters	
Air Temperature	Wind Speed/Direction
Daily Sunshine Hours	Solar Radiation Intensity
	Evaporation
Precipitation	
Wastewater Parameters	
Temperature	pH
Dissolved Oxygen (DO)	Total Suspended Solids (TSS)
5 Day Biochemical O_2 Demand (BOD_5)	5 Day Carbonaceous Biochemical O_2 Demand ($CBOD_5$)
Algal Biomass	Nitrogen Forms
Phosphorus	Air Emissions
Pathogens	Metals
Anions and Nutrients	Hydrocarbons
Operational Parameters	
Cell Wastewater Levels	Sludge Levels
Loading Rate	

Table 4. Groundwater monitoring parameters

Physical Parameters	
Groundwater Elevation	pH
Conductivity	Dissolved Oxygen (DO)
Alkalinity	Fluoride
Hardness	Total Dissolved Solids (TDS)
Nutrients Parameters	
Nitrate	Nitrite
Ammonia	Phosphorus
Biological Parameters	
E. Coli	Total Coliform
Additional Parameters	
Anions	Dissolved Metals
Hydrocarbons	

7 PROPOSED INSTRUMENTATION STRATEGY

7.1 Weather Station Instrument Set

The monitoring programme includes the installation of a weather station to be placed immediately adjacent to both cells. The weather station would include the instruments listed in Table 5. This weather station will allow the study to obtain more precise and timely weather data then the closest station (~40 km away). In addition, the solar radiation intensity and effective daylight sunshine hours data will be collected. Such data was previously unavailable.

The collected data from the thermometer will be used to assess the correlation between the air temperature with the wastewater under various weather and hydraulic loading conditions. The anemometer will be used to assess the effectiveness of wind induced oxygen injection. The pyranometer will assess effectiveness of photosynthesis occurring in the wastewater.

Table 5. Weather station instruments set and their respective reading frequencies.

Instrument	Reading Frequency
Thermometer	1 / min

Hydrometer	1 / hour
Rotational anemometer	1 / min
Pyranometer	1 / min
Rain and snow gauge	1 / day
Atmometer	1 / day

7.2 Continuous Wastewater Quality Sensor Sets

Several essential wastewater quality parameters identified by Pearson et al. (1987) will be recorded using a variety of in-situ sensors listed in Table 6. These sensors will be deployed at several locations in the wastewater cells to capture spatial variations and provide redundancy in case of instrument failure. Additional DO sensors and thermistors will be used to capture variation within the wastewater column. This will allow to identify if and when an anaerobic zone is being developed within the cells. The reading frequency for each instrument is also presented in Table 6. The relatively high reading frequency was established in order to capture the diurnal variations at each cell exhibit.

The instruments will be installed on purpose-built floating platforms fabricated in-house for this study. The platforms will be held in place using a tether wire anchored to the berms and guide lines. The tether wire will also serve to support the data cable relaying the instruments to the data acquisition unit. GPS trackers will be installed on each platform to more accurately (± 5 m) position the reading from the platforms and an alert will be sent if one of the platform floats out of position.

7.3 Piezometers

Vibrating wire piezometers are to be installed in each of the cells to measure the wastewater elevations. These piezometers will be located as close to the edge as possible while still remaining above the bed and in opposite corners from each other to minimize the influence of wind-driven waves. The piezometers are to be sampled at a frequency of 1 / hour. To provide redundancy and to ensure reading correctness, an incremented rod is to be installed in each cell. Manual reading from these rods will be taken at a frequency of 1 / week.

Table 6. In-situ wastewater quality instruments set and their respective reading frequencies.

Instrument	Reading Frequency
DO sensors	1 / hour
pH sensors	1 / hour
Oxidation reduction potential (ORP) sensors	1 / hour
Thermistors	1 / hour
Conductivity electrodes	1 / hour
Total Algae (Chlorophyll a & blue-green algae) sensors	1 / hour
Turbidity sensors	1 / hour
Ammonium, nitrate Ion selective electrodes	1 / hour

The data collected from the piezometers will allow the measurement of the rate at which the wastewater column increases and its effect on the treatment of the wastewater.

7.4 Flow Sensor

Flow entering cell #1 will be recorded using the readouts on the pumps following the current procedure. However, a flow meter will also be installed in the connection pipe between cell #1 and #2 to record the wastewater flow between the two cells. This data will help to ascertain the retention time of the wastewater in cell #1.

7.5 Wastewater Sampling

Wastewater will be sampled using an automated composite sampler. Composite samples of equal sizes will be obtained for a period of 24 h in each of the cells. The sampling frequency from those composite samplers will be set to 1 / week during the period estimated to have the highest biological activity (July – August) and 1 / 2 weeks for the remainder of the year with temperatures above 0ºC. The samples will them be promptly sent to a qualified third party laboratory for analysis of the parameters presented in Table 3. The sampling days will rotate with regards to the day of the week in order to capture possible weekly variations. This methodology was modified from the methodology recommended by Pearson et al. (1987).

7.6 Sludge Level Measurements

Manual sludge measurements will be taken using an incremented clear walled sludge sampler off a floating platform (i.e. a boat). Sludge measurements will be taken at 10 locations within each of the cell at a frequency of 1 / 2 weeks. This procedure should ensure that spatial and temporal variations in sludge accumulations are captured. To facilitate locating the intended measurement points repeatedly, a handheld GPS will be used.

7.7 Air Emissions Measurements

Air emissions will be measured using chemical emission analysers. Air emissions will be analysed for typical odour causing compounds such as ammonia (NH_3) and sulphur dioxide (SO_2) along with greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2). Emissions concentrations will be compared with typical detection thresholds for human detection as described by Metcalf & Eddy (2013) and the Canadian Ambient Air Quality Standards where standards exist (Canadian Council of Ministers of the Environment, n.d.).

7.8 Monitoring Well Sampling

Grab samples from the monitoring wells will be taken manually for the pre-existing MWs surrounding the WWT lagoon (**Error! Reference source not found.**). Samples will be taken from all MWs at a frequency of 1 / 2 weeks.

The MWs: SL#3, #5, #6, and #7 are up-gradient of the WWT lagoon and will be used to obtain the background groundwater quality. The samples from MWs: SL#1, #2, #4, #8, and #9 will be compared to those MWs: SL#3, #5, #6, and #7to ascertain the exact impact of the WWT lagoon on the surrounding environment.

7.9 Creek Water Sampling

The current sampling practices conducted prior, during, and after discharge, as described in section 3, will be maintained. In addition regular sampling of stagnant water ponds and the unnamed meandering creek located immediately to the North of cell #2 will be taken to assess for contamination from the WWT lagoon (Figure 4). These water features are thought to be relics from the discharge creek's original path prior to its straightening.

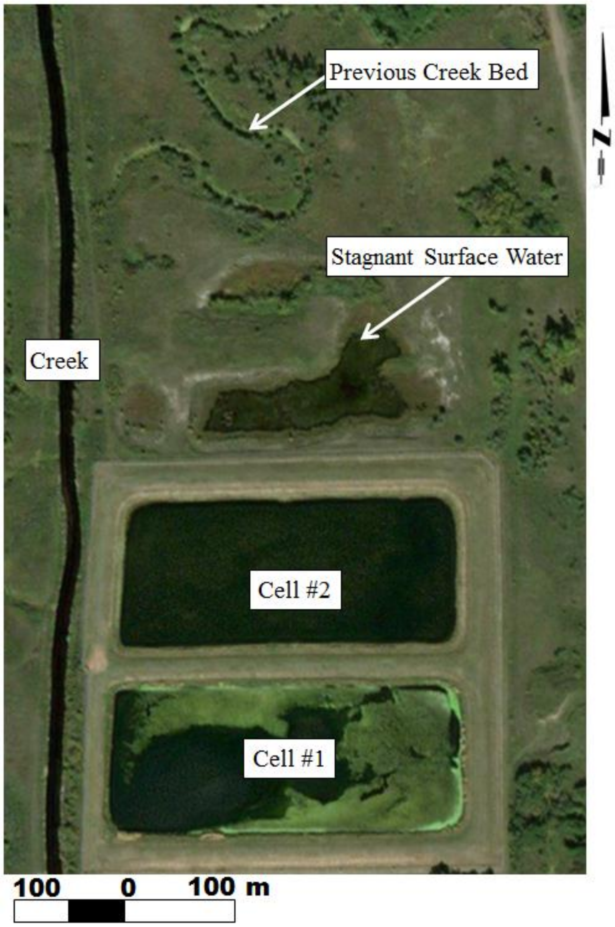


Figure 4. Surface water features located north of the WWT lagoon (imagery provided by Microsoft Bing Map).

7.10 Infrastructure Survey

The berms geometry and structural health will be assessed using visual inspection. This inspection will assess the:

a. Berms' cover and vegetation grown for signs of deterioration
b. Possible deterioration of the liner anchors
c. Rodent and other animal activity
d. Deterioration of the perimeter fence

In addition to the visual inspection, a LiDAR survey will be undertaken to provide a quantitative assessment of the berms' geometry. The resulting 3D model from the LiDAR survey will to be compared to the original construction drawings. This will allow identification of any gradual reduction in slopes and decreases in height that may have occurred since 1988 and could alter the structural stability of the WWT lagoon or its design volume.

7.11 Data Acquisition System

A data acquisition system will be required to obtain and manage the relatively large amount of data this instrumentation programme will generate. The system will require a variety of multiplexers and data acquisition units to obtain the data generated by the sensors. An on-site computer will be required to record the data and remotely transmit it to Royal Military College of Canada, Kingston, ON where the data will be interpreted. Power is available on-site. However, a power supply unit will be required to provide the instrumentation with clean power.

8 FUTURE ACTIVITIES

Once the monitoring programme has been initiated and data is being collected, the data will be assessed for validity and adjustment to the instrumentation will be carried out as needed. Once the data has been determined to be representative, the assessment of the treatment's effectiveness will be undertaken. The seasonal variation will be tracked and the effectiveness of the WWT lagoon's design will be completed. A leak assessment based on the wastewater quality and groundwater sampling data will also be undertaken.

9 CONCLUSION

The WWT lagoon of interest was constructed in 1988 and has seen no major upgrades since. Given its age, it poses a potential risk to the surrounding environment and more specifically the base's source water. A proper impact and risk assessment should be made.

The proposed monitoring programme laid out in this paper will provide adequate data to fully assess and understand the complex mechanisms that determine the wastewater's treatment effectives by the base's WWT lagoon system. The data should also be sufficient to capture both spatial and temporal variation of the various treatment parameters. This programme surpasses the minimum guidelines as set by Pearson et al. (1987).

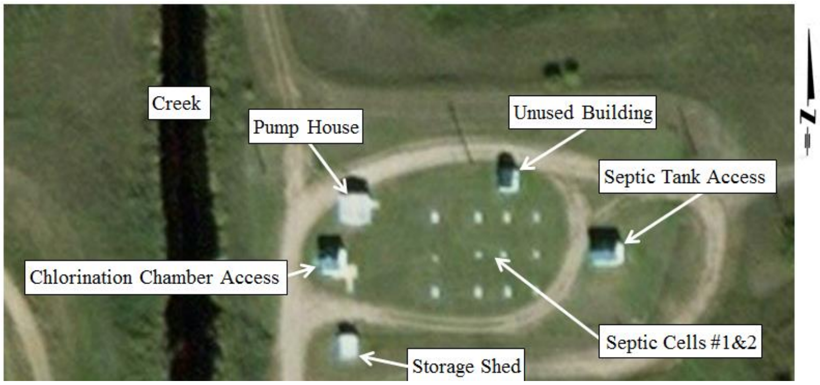
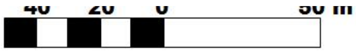


Figure 5. Close-up of the septic tank and surrounding infrastructure (imagery provided by Microsoft Bing Map)



In addition, the monitoring programme will assess both qualitatively and quantitatively the structural health of the containment infrastructure (i.e. the berms and liner) and assess for wastewater seepage.

The assessment that will be conducted with the data acquired from the programme will be used to determine the impact of the WWT lagoon on the surrounding environment and the risk it poses to the base's source waster. The results of the study should prove useful for the Real Property Operation Section of the base to minimize the risk associated with the continued operation of this WWT lagoon.

10 ACKNOWLEDGEMENTS

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