Liquid Waste Management Plan

Technical Memorandum

LWMP Technical Memorandum #4

TO: Wastewater Advisory Committee

SUBJECT: Lagoon System Performance

DATE: October 26, 2017

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1.0 WASTEWATER TREATMENT SYSTEM DESCRIPTION

The Village of Cumberland has operated and maintained a lagoon wastewater treatment system since 1967 consisting of influent screens, a smaller surface aerated lagoon and a larger facultative lagoon. The aerated lagoon includes 4 surface aerators which provide oxygen to enable the biological process. This is not too different to adding air to a fish tank to keep the fish healthy. The aerators also provide mixing of the water so the oxygen can be distributed throughout the lagoon thus using more of the lagoon area for biological treatment. The larger lagoon does not have mixing thus solids can settle. It relies on passive diffusion of oxygen from the atmosphere to provide oxygen to support aerobic biological treatment within the lagoon. The water from the facultative lagoon flows into Maple Lake Creek (a man-made channel), and downstream through a natural wetland along Maple Lake Creek to a confluence point with the Trent River.

The aerated lagoon has a surface area of about 9,300 m^2, and a depth of 1.5 m, resulting in a volume of about 14,000 m^3. At a nominal summer flow (including stormwater flows from rain events), the hydraulic retention time is about 14 days. When constructed in 1968, both lagoons were facultative, with aeration added to the smaller lagoon in 1973 to increase the oxidation capacity.

The facultative or stabilization lagoon has a surface area of about 25,700 m^2, and a depth of 1.5 m, resulting in a volume of about 39,000 m^3, with a nominal summer wastewater flow hydraulic retention time of about 39 days.

No effluent disinfection nor phosphorus removal is provided prior to release from the facultative lagoon to Maple Lake Creek; however, the long retention time within the lagoons results in natural attenuation and reduction of pathogens. Water quality data collected from within Maple Lake Creek prior to the confluence with Trent River shows there is a high degree of natural phosphorus attenuation and removal occurring within the wetlands along Maple Lake Creek between the lagoons and the confluence with the Trent River.

2.0 COMBINED SEWER FLOW IMPACTS ON TREATMENT

The community's combined sewer and stormwater collection system causes the wastewater flows entering the lagoon treatment system to increase dramatically during rainfall events, with recorded discharge flows to Maple Lake Creek exceeding 20,000 m^3/d. The average dry weather wastewater flows (flows without rain water and ground water infiltration) during the summer of around 900 m^3/d. The high stormwater influenced wastewater flows entering the lagoon system results in reduced hydraulic retention time – less time for treatment. A flow increase from 1,000 m^3/d to 10,000 m^3/d reduces the overall hydraulic retention time from just over 50 days to about 5 days.

The primary water quality parameter affected by the reduced hydraulic retention time is the Biochemical Oxygen Demand (BOD) which reflects the amount of oxygen required by bacteria over 5 days to consume the biodegradable organic contaminants in the wastewater. Any BOD not removed by the treatment process will enter the receiving environment (Maple lake Creek and Trent River), where bacteria in the environment will continue to consume and digest the residual BOD not removed during treatment. The oxygen required by bacteria in the receiving environment can exceed the amount of oxygen that is naturally made available through diffusion from the atmosphere which can deplete the dissolved oxygen (DO) in the receiving environment. When the BOD loading is too great, the dissolved oxygen concentration in Maple Lake Creek or the Trent River could drop to a level that would not support aquatic life in those streams. This effect is referred to as DO sag.

Taking the above into consideration, one of the reasons a lagoon system is generally a superior wastewater treatment process in comparison to a mechanical treatment facility under conditions with extremely large flow variations, is that it a lagoon system is generally less affected by wide variations in flow and hydraulic retention time. While under the scenario of a 10:1 increase in wastewater flows will reduce the hydraulic retention time in the Cumberland lagoons from 50 to 5 days, the comparable change in a mechanical treatment process would be from 10 hours to 1 hour. Further, mechanical solids liquid separation processes are even more susceptible to hydraulic fluctuations than lagoon systems. Generally, a settling time of about 2 hours allows settling of suspended solid particles (grown bacteria). The settling is done in clarifiers that are included in mechanical treatment processes are often designed with nominal retention times between 2 to 4 hours. The impact of a 10:1 variation in flow on a clarifier serving a mechanical treatment process would be to reduce the hydraulic retention time from 2 to 4 hours down to 12 to 24 minutes while creating turbulence within what needs to be a quiescent zone; resulting in poor solids separation and high effluent TSS. The clarifiers can handle occasional peaks but with the large peaking factors, clarifiers must be designed with larger storage volume and thus become more expensive to meet the peak flow events. In contrast the solids settling capabilities of a lagoon system with hydraulic capacity measured in days is relatively unaffected as the proportion of the quiescent time within the lagoon is still in the order of days.

Major storm flow events also tend to “flush out” the sewer lines, washing grit and grease/scum off the pipes. This can lead to large loadings of grit, rags and Fats, Oils and Grease (“FOG’s”) reaching the headworks during storm events. The headworks consists of two parallel channels with a “Muffin Monster” macerator and screen in one of them (and designed for future screen installation in the second channel). During storm events, excess flow bypasses the screen and goes through the empty channel, carrying some of the grit, rags and FOG’s into the lagoons.

3.0 SUMMER 2017 WATER QUALITY MONITORING PROGRAM

Review of the previous studies on water quality in the lagoons and Maple Lake Creek revealed some “data gaps” to be filled as part of the summer 2017 monitoring program. Specifically, it was desired to collect data from;

1. The influent to the lagoons and the effluent from the aerated lagoon to the facultative lagoon, to assess the performance of the aerated system, and
2. Locations within Maple Lake Creek, to investigate the behaviour of phosphorus during the lowest flow (lowest dilution) periods.

Table 1 illustrates the results of a water quality survey carried out at various locations within the treatment process during the summer period (higher level of treatment required) and receiving environment within Maple Lake Creek and the Trent River between April 25 and September 26, 2017. Samples were collected from various locations to determine the degree of reduction in key contaminants as the wastewater flowed through the lagoons and along Maple Lake Creek to the Trent River.

Table 1 presents the average water quality parameter concentration at specific strategic locations for samples collected over a five-month period from April 25 to September 25

Table 1 Average Water Quality Parameter Concentrations (April 25 to September 25, 2017)

LOCATION	Total BOD (mg/L)	Soluble BOD (mg/L)	TSS (mg/L)	Total Phosphorus (mg-P/L)	Ortho-Phosphorus (mg-P/L)	Ammonia (mg-N/L)	E. coli (pathogen) CFU/100mL	Fecal Coliform (pathogen). CFU/100mL
Influent	292	175	282	6.8	4.08	41.4	1,350,000	2,176,750
Aerated Lagoon	38	8	100	6.4	4.46	43.2	16,100	115,500
Facultative Lagoon	17	< 6	49	4.7	3.50	24.6	2,692	12,618
Wetland Treatment	< 6	< 6	< 4	0.2	0.231	0.366	48	398
Trent 100 m U/S	< 6	< 6	<4	< 0.005	< 0.005	0.235	3	34
Trent 100 m D/S	< 6	< 6	< 4	0.035	0.024	0.132	10	55

With respect to BOD, the monitoring data shows the aerated lagoon alone achieves an advanced secondary treatment level with an average soluble BOD of less than 10 mg/L. While the average BOD values of 38 mg/L exceeds the Permit limit of 30 mg/L at that stage of treatment, the average filtered (soluble) BOD concentration of 8 mg/L which indicates that 30 mg/L is associated with suspended solids. The majority of the solids in the lagoon system appear to be algae (algae are also visible on surface and with colour of water samples). The influence of algae growth is also reflected in the average total suspended solids concentration in the aerated lagoon effluent of 100 mg/L. What this indicates is that if the suspended solids were removed through sedimentation and/or filtration, the water quality after the aerated lagoon would be well within the current Permit and federal WSER BOD requirements. Further, not shown in Table 1, is that the soluble (filtered) BOD concentrations from the aerated lagoon were all less than 12 mg/L, which is almost sufficient to meet the Greater Exposure Potential (GEP) water reuse criteria of BOD less than or equal to 10 mg/L. With filtration, the TSS concentration would also be less than the GEP water reuse criteria of less than 10 mg/L.

After additional aerobic treatment through the facultative lagoon, the average BOD concentration of 17 mg/L is well below the Permit and WSER criterion and the soluble BOD was consistently less than the BOD analytical detection limit of 6 mg/L. This indicates the BOD concentrations recorded were primarily due to suspended solids (i.e. algae) which were as high as 85 mg/L. Again, with adequate solids separation (e.g. filtration) both the BOD and TSS concentrations would be expected to meet the GEP water reuse criteria.

The summer 2017 monitoring data also illustrates the lagoons have little effect in removing or reducing the wastewater phosphorus concentrations, as well as negligible nitrification (i.e. bacterial conversion of ammonia to nitrate), as evidenced by the high ammonia concentrations in the discharge from the facultative (larger) lagoon and the relative absence of nitrate in the discharge. This is an important observation as the federal WSER water quality criteria requires low unionized ammonia concentrations. While some ammonia uptake is evident, particularly during period of rapid algal growth, there is no evidence to support a significant degree of nitrification is occurring. Accordingly, any upgrade plans for the lagoon system must include a nitrification stage to reduce potential ammonia toxicity.

Although the lagoons have limited effect on reducing either total or ortho phosphorus concentrations, even during periods of rapid algal growth, there is evidence that phosphorus is rapidly taken up and/or adsorbed as the effluent from the lagoons travels along Maple Lake Creek towards the Trent River. By the time the water reaches the Trent River, approximately 95 percent of the phosphorus leaving the lagoons is removed, with the average total-phosphorus concentration in Maple Lake Creek (after passing through natural wetlands) of 0.20 mg-P/L.

Similarly, while the median fecal colifom and E.coli levels in the discharge from the lagoons into Maple Lake Creek are 12,600 MPN/100 mL and 2,700 MPN/100 mL, respectively, prior to the confluence with the Trent River the median levels in Maple Lake Creek drop to about 400 and 50 MPN/100 mL, respectively (i.e. indicating a 4-Log reduction in potential pathogens without a disinfection treatment stage).

Overall, the data collected indicates that following treatment through the lagoon and natural wetland systems along Maple Lake Creek, the following treatment performance is being achieved just before reaching the Trent River:

- Biochemical Oxygen Demand (BOD_5): maximum < 6 mg/L (98% removal)
- Total Suspended Solids (TSS): maximum < 4 mg/L (99% removal)
- Total Phosphorus (TP): average 0.20 mg-P/L (97% removal)
- Ammonia (NH_4^+): average 0.37 mg-N/L (99% removal)
- E. coli: median 48 MPN/100mL (4.4-Log removal)
- Fecal Coliform: median 398 MPN/100mL (3.7-Log removal)

While the existing Discharge Permit defines the point of discharge as the release of water from the facultative lagoon into Maple Lake Creek, treatment continues as the water flows along Maple Lake Creek to the Trent River. The development of wetlands along Maple Lake Creek is a natural occurrence and response to the nutrients being released to the creek and serves as a buffer or polishing stage to protect water quality in the Trent River.

4.0 WASTEWATER TREATMENT BEING ACHIEVED

The water quality within Maple Lake Creek is of particular importance during the summer months as the flow contribution from Maple Lake Creek represents a significant portion of the water flowing within the Trent River downstream of the confluence point, and the flow in Maple Lake Creek is almost entirely due to the water flowing from the Cumberland lagoon system.

Although the water from the lagoon system is not disinfected, the data shows that the lagoon system achieves a 2 to 3-Log reduction in indicator bacteria, which increases to a 3 to 5-Log reduction after the water has passed through the downstream wetlands along Maple Lake Creek. Again, noting the water flowing in the Trent River downstream of the confluence is comprised primarily of flows originating from Maple Lake Creek during the summer months, the fecal coliform and E. coli levels measured in the Trent River 100 metres below the confluence of the two streams indicates a net reduction in indicator bacteria (and associated potential pathogens that could be present of 5-Logs.

The level of treatment achieved by the lagoon and natural wetland systems combined is superior to most mechanical tertiary treatment processes. They reduce BOD and TSS to below their analytical detection limits, reduce the ammonia and phosphorus concentrations to levels that compare to the best-in-class nutrient removal processes, and achieve 3-5-Log-reductions in indicator bacteria. By association, this is a 3-5-Log reduction in potential disease causing viruses, bacteria and parasites that could be present in the influent wastewater – comparable to what would be expected for a disinfection treatment process.

The water quality data shows that, with the combination of the lagoons and the Maple lake Creek wetlands, the Village of Cumberland is achieving a remarkable level of treatment with this passive wastewater treatment process during the summer months. Monitoring over many years demonstrates the indicated water quality levels are also maintained throughout the winter months when the flows in the Trent River are significantly greater than the discharge from Maple Lake Creek, despite a dramatic increase in wastewater flows due to the combined sewer system serving the community. Although the Permitted average dry weather flow (ADWF) discharge is 910 m3/d, peak wet weather flows can exceed 20,000 m^3/d. It is believed that the resulting reduction in treatment time through the lagoons and wetlands due to the higher flows is off-set by the reduced influent contaminant concentrations as a result of a dilution-effect from the stormwater flows.

While the overall water quality released from Maple Lake Creek to the Trent River represents a remarkable level of treatment for all constituents of concern, it is important to note that the current Discharge Permit is for the release of treated wastewater from the lagoons to Maple Lake Creek. It is considered unlikely that the Ministry of Environment would consider the natural wetlands along Maple Lake Creek to be a formal extension of the Village of Cumberland wastewater treatment process. While the Village could attempt to make a case for that inclusion, it is very likely the Ministry will continue to consider the discharge point to be where effluent enters Maple Lake Creek as a point discharge, and require the Village to meet water quality requirements at that location.

5.0 IMPLICATIONS FOR TREATMENT UPGRADES

Because there is less than 10:1 dilution with ambient water in Maple Lake Creek or Trent River during the dry summer months, the current regulations – the MWR –would require that GEP water reuse water quality be met for discharge into Maple Lake Creek.

To meet the GEP quality, the treatment will need to be upgraded to include:

- Filtration to remove BOD and TSS to less than 10 mg/L and turbidity to less than 2 NTU;
- Nitrification to meet un-ionized ammonia and effluent toxicity requirements,
- Total phosphorus reduction to achieve a maximum total phosphorus concentration of 1 mg-P/L; and
- Disinfection to meet non-detect fecal coliform water reuse indicator bacteria requirements; and

Although the number of indicator bacteria in Maple Lake Creek following passage through the wetlands system is comparable to that expected for UV or a chemical disinfection process, it is expected that disinfection of the water leaving the lagoon system would be the first incremental change to the treatment process, to meet the Discharge Permit requirement for disinfection. This would address concerns that the reduction in indicator bacteria due to natural processes may not necessarily reflect reductions in pathogens of concern. Ultraviolet transmissivity testing carried out during the summer concluded that UV disinfection is not a feasible option for disinfection due to extremely low UV transmissivity levels determined in filtered wastewater and water samples collected through the lagoon system and along Maple Lake Creek. As it is generally agreed that chlorination is undesirable due to the chlorinated hydrocarbon by-products produced and toxicity of chlorine to aquatic organisms, it is recommended that Peracetic Acid (PAA) disinfection be considered instead. This will be discussed further in a separate Technical Memo.

The second incremental change to meet the current Discharge Permit upgrade requirements is to add a “nutrient removal” process to reduce effluent total phosphorus concentrations to less than 1 mg-P/L. This could be done in several ways, including the use of chemicals to precipitate phosphorus (e.g. lanthanum chloride, alum or ferric chloride), or by incorporating a reed bed filtration system into the treatment process with media designed to adsorb toxic and complex organic and inorganic contaminants of concern – including emerging contaminants such as pharmaceuticals and endocrine disrupting chemicals, as well as phosphorus using zero valent iron.

Any change from the Permit to an MWR registration will trigger the requirement to achieve GEP reuse quality. As discussed in TM#1 Regulatory Framework, the major trigger for an MWR registration will be when the ADWF exceeds the Permit limit of 910 cu.m/day, or, if a minor 10% increase is granted, when it exceeds 1001 cu.m/day.