Municipality of the County of Kings

Waste to Energy Feasibility Study

Final Report

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December 7, 2020

Tim Bouter, P.Eng.
Manager of Engineering Services
Municipality of the County of Kings
181 Coldbrook Village Park Drive
Coldbrook, NS B4R 1B9

Dear Mr. Bouter:

RE: Waste to Energy Feasibility Study

Please find enclosed a Final Report containing the findings of the Waste to Energy Feasibility Study. Thank you for the opportunity to work with the Municipality of the County of Kings.

Yours very truly,

CBCL Limited

Prepared by:
Sarah Ensslin, M.Sc., P.Eng.
Process Engineer
Telephone: 902-421-7241 Ext. 2238
E-Mail: sensslin@cbcl.ca

Reviewed by:
Mike Abbott, M.Eng., P.Eng.
VP, Water Treatment

CC: Scott Quinn, P.Eng.
Jim Doody, P.Eng.

Project No: 200801.01

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Chapter 1 Introduction

1.1 Objectives

The Municipality of the County of Kings ("the Municipality") commissioned CBCL to prepare a feasibility study to investigate the options for sludge management at two of their existing sewage treatment plants, with three main objectives in mind:

1. To produce Green energy from the waste, if possible;
2. To recommend cost-effective sludge handling and disposal methods for sludge not suitable for Green energy production; and
3. To consider possible partnerships for the Municipality in achieving each of the other objectives.

These objectives are discussed in more detail below:

1.1.1 Green Energy Production

The Municipality's primary objective in commissioning this study was to determine if it was feasible to produce Green energy from the existing waste sources, by using anaerobic digestion. Anaerobic digestion is the primary way in which wastewater sludges can be converted into Green energy, with the possibility of beneficial use. Anaerobic digestion is breaking down the wastewater solids using anaerobic bacteria, which thrive in the absence of oxygen. They produce a mixture of methane (2/3) and carbon dioxide (1/3), called biogas, which can be burned to produce heat and/or electricity, with suitable equipment. The bacterial breakdown takes place in a heated concrete tank which serves as a digester. The amount of wastewater solids is reduced, and they are changed into a stabilized form which can be more easily used in a beneficial way (for soil conditioning or environmental site remediation). Anaerobic digestion produces the most biogas when the feedstock has a high energy value to begin with (fresh, undigested sludge, for example), and when the conditions in the bioreactor are kept steady and consistently favourable to the necessary bacterial populations.

In order to determine if the Municipality could use anaerobic digestion to produce biogas from the wastewater solids, all three available Municipality feedstocks were sampled, tested and evaluated for anaerobic digestibility using a bench-scale anaerobic digester apparatus at the Verschuren Centre. The option of anaerobic digestion followed by burning biogas for Green energy was then considered in more detail for all available feedstocks, including those of potential partners.

1.1.2 Cost-Effective Sludge Handling and Disposal

The Municipality identified the risk that the Regional STP lagoon sludge might not be suitable for digestion. If some of the available feedstocks were found to not be digestible following testing, then other options for handling and disposal of this sludge were to be considered, with economic and environmental benefits as the primary measures for evaluation.

1.1.3 Possible Partners

In order to increase the possibility that the feedstock volumes available would be feasible, and to share costs, the Municipality was also interested in identifying possible partners. Partners could have either feedstock or facilities that could be used to increase the scale and the cost-effectiveness of anaerobic digestion or other methods of sludge handling and disposal. Partners with these resources could include other municipalities, Valley Waste Management, and local businesses such as farms.

1.2 Background

The Municipality has two existing sewage treatment plants (STPs) that were included in this study: the Regional STP, which serves the region of New Minas and Kentville, and the Greenwood STP, which treats wastewater from the Village of Greenwood, including CFB Greenwood. Each of these is described in more detail below.

1.2.1 Regional STP Overview

The Regional STP is a partially mixed, aerated lagoon, located on dykeland just outside of New Minas. It receives wastewater from the surrounding region, including New Minas, the Town of Kentville, and North Kentville. This area includes some food processing industry which contributes heavy loads at times. Some of the wastewater types are pre-treated at the industrial facility which produced them. The influent is pumped to the plant from a number of pump stations. The average day flow to the plant has been about 6,500 m^3/day (1.72 MGD) over the past three years.

1.2.1.1 Headworks

Flow initially enters the headworks, where it is screened. Due to the strength of the incoming wastewater, the influent is screened using four rotary drum screens that contain fine mesh, to remove solids and organic matter to a higher degree than is typical for aerated lagoon sewage treatment plants.

1.2.1.2 Lagoon Cells

After screening in the headworks, the sewage then flows to the first cell in a series of five aerated lagoon cells. The five lagoon cells are intended to be aerated to varying degrees, highest at first, and then decreasing as the water is progressively treated. Aeration equipment replacement was carried out in some cells in 2020 because the old system of in-cell aerators was at the end of its useful life and was no longer performing acceptably. Some of the cells had too much sludge built up to allow new aerators to be installed.

The approximate area of each cell as well as some notes are listed in the table below:

Table 1.1: Regional STP Cell Data

Cell	Area (approximate)	Notes
1	32,000 m²	• Significant sludge build-up: measured volume of 33,000 m³. • Aerators could not be replaced in 2020.
2	30,000 m²	• Significant sludge build-up: measured volume of 30,000 m³. • Aerators could not be replaced in 2020.
3	30,000 m²	• Estimated volume of sludge is 20,000 m³. • New aeration system installed in 2020.
4	30,000 m²	• Estimated volume of sludge is 15,000 m³. • New aeration system installed in 2020.
5	30,000 m²	• Estimated volume of sludge is 10,000 m³. • New aeration system installed in 2020.

1.2.1.3 Disinfection

Following biological treatment in the aerated lagoon, the effluent is disinfected by ultraviolet (UV) disinfection and released to the Cornwallis River.

1.2.1.4 Sludge Handling

Typically, in an aerated lagoon, sludge settles to the bottom and digests in place. Sludge slowly accumulates over a period of years until it builds up to levels that noticeably reduce treatment capacity. Sludge has been building up in the Regional STP for upwards of twenty years at this point.

1.2.1.5 Performance and Outlook

Over the past three years, the plant has sometimes struggled to meet the provincial effluent requirement of 20 mg/L Carbonaceous Biochemical Oxygen Demand (CBOD), and frequently does not meet provincial requirements for Total Suspended Solids (TSS). Although the new aeration system in Cells 3 to 5 is anticipated to improve effluent results, and initial testing shows some improvement, there is very limited spare capacity in the Regional STP to accept more load.

1.2.2 Greenwood STP Overview

The Greenwood STP is an extended aeration sewage treatment plant located on the South Mountain above Greenwood. It accepts flow from the Village of Greenwood and CFB Greenwood. All flow is pumped to this plant. The average day flow to the plant has been about 1,700 m^3/day (0.45 MGD) over the past three years.

1.2.2.1 Preliminary Treatment

The influent is first screened with a spiral screen and degritted. The screenings at this plant are unlike the Regional STP in that they are not high in organics. These screenings are not suitable for digestion.

1.2.2.2 Biological Treatment

After preliminary treatment, the sewage is mixed with return activated sludge (RAS) which contain the critical microorganisms for the treatment process. The mixed influent passes through the selector zone and enters the two parallel extended aeration basins. The aeration basins are aerated using submerged aerators supplied with air by blowers in the Control building. Biologically-treated sewage leaving the aeration basins then flows to the two parallel secondary clarifiers where solids are removed. These clarifiers sometimes freeze over in the wintertime

1.2.2.3 Disinfection

Following biological treatment, the effluent is disinfected using UV disinfection and then discharged to the receiving water.

1.2.2.4 Sludge Handling

Waste sludge from the biological process is digested in the aerobic digester, located underneath the sludge thickening room. In an aerobic digester, the wastewater solids are broken down by bacteria which thrive in the presence of oxygen. This digester is aerated to provide it with air. The digested sludge is then conditioned with polymer and pumped through the belt filter press.

1.2.2.5 Performance and Outlook

The Greenwood STP has very strict effluent requirements of 5 mg/L CBOD and 5 mg/L TSS, which it generally meets year-round with no problems. Unusual features of its performance are that it has considerable seasonal swings in sludge production, the clarifiers can freeze over in winter, and the plant sometimes requires re-seeding with sludge from another plant to build up the bacterial population in spring. Nonetheless, this does not appear to significantly affect the effluent performance, and it is critical to maintain the satisfactory effluent performance.

1.3 Types of Available Waste

Three types of waste available from Municipality of Kings STPs were identified to be evaluated for energy production potential through anaerobic digestion.

- Regional STP sludge
- Regional STP screenings
- Greenwood STP sludge

Each of these is described in more detail below.

1.3.1 Regional STP Sludge

Lagoons settle out solids which then digest in place over a period of years. At this point, there is a considerable accumulation of sludge in the lagoon cells. Cell 1 contains an estimated 33,000 m^3 of sludge, and Cell 2 an estimated 30,000 m^3 of sludge, each at about 6% solids concentration.

The Municipality is currently developing a desludging plan for the lagoon cells because sludge is significantly reducing the treatment capacity of the lagoons at this point. This displacement of treatment capacity risks future poor compliance of effluent with provincial and federal requirements. Since lagoons are usually desludged in a short period of time rather than gradually as the sludge is produced, the sludge volumes tend to be very large compared to a typical digester capacity.

Lagoon sludge is often not well suited to energy production using anaerobic digesters, because it is already partially digested and stabilized, reducing the energy potential. To determine if this is the case with this material, the sludge was sampled and evaluated for anaerobic digestibility.

1.3.2 Regional STP Screenings

As described above, the Regional STP receives food processing wastewater, although in some cases it is pre-treated at source. The plant has four rotary drum screens for removal of a high proportion of solids from the influent, in order to lower the organic loading entering the lagoons. This reduces the risk of the influent strength exceeding the capacity of the lagoons.

The screenings are conveyed into a large 15 cu.yd. bin which is stored indoors. They are fairly consistent in volume all year round, with about 11 cu.yd. (8.5 m^3) produced per week at a solids concentration of about 15%. The screenings are transported to a licensed facility by a private contractor once a week for disposal. Alternative approaches will be developed as part of this study.

This material appears to be well suited for anaerobic digestion in terms of type of material and steadiness of supply. It was sampled and evaluated for anaerobic digestibility.

1.3.3 Greenwood STP Sludge

Greenwood STP sludge is aerobically digested and then dewatered to a solids concentration of about 11%. The dewatered sludge is conveyed into a large bin stored outdoors. The volumes produced vary significantly with season. Loads of about 11 cu.yd. (8.5 m^3) are produced up to daily in the middle of summer, but only every month or two in the middle of winter. The reason for this strong seasonal variation has not been identified, but affect other parts of the plant as well. The dewatered sludge is transported to a licensed facility by a private contractor as needed for disposal. Alternative approaches will be developed as part of this study.

This material appears to be only moderately well suited for anaerobic digestion in terms of type of material and steadiness of supply. It is already partially digested, and anaerobic digesters work better with a steady incoming load, rather than one that fluctuates. It was sampled and evaluated for anaerobic digestibility.

1.3.4 Municipal Partner STP Sludge

Other sources of sludge or other organic feedstock were sought among municipalities and businesses in the area. One possible municipal partner with feedstock was identified. This municipality has a wastewater treatment plant that produces secondary sludge which is briefly digested aerobically, but not enough to fully stabilize it. This is sludge is then dewatered to a solids concentration of about 22% and conveyed to a bin. It is transported to a licensed facility twice a week.

This material appears to be well suited for anaerobic digestion in terms of type of material and steadiness of supply. It was not sampled or evaluated for digestibility but is assumed to be similar to other municipal sludge for which we have data.

The types of sludge available and the characteristics of it are summarized in the table below:

Table 1.2: Summary of Wastewater Solids Available

Sample	Dry Solids (% D.S)	Volumes	Evaluated for Anaerobic Digestibility
Regional STP Screenings	15%	~8.5 m^3/week	Yes
Regional STP Lagoon Sludge	6%	>63,000 m^3	Yes
Greenwood STP Sludge	12%	Varies seasonally, averages 9.3 m^3/week	Yes
Municipal Partner STP Sludge	22%	~4.2 m^3/week	No, assumed typical

Chapter 2 Anaerobic Digestibility Evaluation

An anaerobic digestibility of the Municipality feedstocks was carried out to determine whether the different feedstocks were well suited to anaerobic digestion. Samples of each feedstock were collected for testing. The Verschuren Centre in Sydney, NS, used their small-scale digester to evaluate the digestibility of the various types of feedstock. The sampling program and benchtop digestions assessment is described below.

2.1 Sampling Program

On January 17, 2020, CBCL staff members collected lagoon sludge and screenings samples from the Regional STP site. Lagoon sludge was sampled from the bank of Cell #1, while screenings were sampled from the screenings bin. The samples were each collected in 2 USgal (8 L) buckets and frozen for overnight transport in coolers to the Verschuren Centre laboratory at the Cape Breton University campus.

On March 5, 2020, a CBCL staff member collected a sludge sample from the belt filter press at Greenwood STP and collected a second screenings sample from Regional STP. These were collected and frozen like the samples above and sent for analysis at the Verschuren Centre.

2.2 Benchtop Digestion Assessment

At the Verschuren Centre, both sets of samples were run through the benchtop anaerobic digester apparatus, as described in more detail in the analytical report provided in Appendix A. The samples were identified and digested as shown in Table 2.1.

Table 2.1: Samples Digested

Sample	ID	Collected	Digestion
1. Regional STP Screenings	Screenings A	January 17 2020	Digestion #1 and #2
2. Regional STP Lagoon Sludge	Lagoon Sludge	January 17 2020	Digestion #1
3. Regional STP Screenings	Screenings B	March 5 2020	Digestion #2
4. Greenwood STP Sludge	Sludge Press	March 5 2020	Digestion #2

The first set of samples ran to completion (12 days), but the second set of samples ran only 8 days before analysis. Verschuren Centre staff had to remove them earlier than intended because the laboratory was about to be closed due to the Covid-19 response. Nonetheless, the data provided by both digestion runs was informative in evaluating the digestibility of each of the Municipality's feedstocks. Data from this testing is summarized in Table 2.2. Dry solids refers to all solids in the material, both organic (e.g., food waste) and inorganic (e.g., silt). Volatile solids are organic solids, which can be broken down given appropriate conditions and sufficient time. Only volatile solids can be converted into biomethane. In this table, the gas volumes measured are specifically the methane component of the biogas methane-CO_2 mixture.

Table 2.2: Feedstock Analysis and Biomethane Potential

	Sample ID	Days	Dry Solids (DS%, w/w)	Volatile Solids (VS%, w/w)	Biomethane Potential (BMP, NmL/g VS)
Digestion #1	Inoculum Control	12	2.5	1.6	13.1
	Screenings A	12	13.2	12.7	33.9
	Lagoon Sludge	12	6.0	1.7	138.2
Digestion #2	Inoculum Control	8	4.1	2.6	4.9
	Screenings A	8	13.2	12.7	142.7
	Screenings B	8	17.5	17.0	137.6
	Sludge Press	8	10.6	8.9	77.5

2.2.1 Discussion of Benchtop Digestion Assessment

The initial digestion of Screenings A (Digestion #1) did not give representative results, probably due to the solids concentration used compared to the amount of inoculum. Therefore, another portion of this sample was digested in Digestion #2 to try to improve the testing method by diluting the material to a greater degree along with more inoculum. This second test in Digestion #2 gave significantly more biomethane and was very similar to the results for the second sample of Regional STP screenings collected in March.

The higher the biomethane potential (BMP), the higher the amount of biomethane that can be produced per gram of Volatile Solids (VS). When comparing the various feedstocks available, it is necessary to look at both the BMP and the VS values. The Lagoon sludge has a BMP that is comparable to the Regional Screenings samples, but the proportion of VS in the lagoon sludge samples is much lower. Regional Screenings are nearly all volatile, while the Lagoon Sludge is mostly non-volatile (i.e., stabilized, or inorganic). There is likely to be fresher sludge on top of the sludge layer in the lagoon with older, more stabilized sludge below, but it is not reasonably possible to separate these to digest only what is digestible.

Per gram of dry solids, the biomethane output for lagoon sludge is much lower than for screenings. This means that the volume of biogas produced per m^3 of lagoon sludge would be very low. The biomethane output of Greenwood aerobically digested sludge is somewhat better than lagoon sludge, but less than the output for Regional STP screenings, as shown in Table 2.3.

Compared to benchmarks, the Regional STP screenings are of moderate potential for anaerobic digestion. Ideally, the BMP values would be 350 NmL/g VS, or better.

Greenwood STP Sludge has relatively low potential for anaerobic digestion based on the testing above. However, this may be due to the sampling time in the winter. In summer the sludge would likely be more digestible because it would not have been digested as long before being dewatered. In addition, it was tested in the digestion trial that had to be cut short, so the actual results may have been somewhat higher could the trial have continued to completion, though still less favourable that the screenings.

Table 2.3: Biomethane Production Evaluation

Sludge Type	Sample ID	BMP (NmL/g VS)	Biomethane Output (NmL/g DS)
Regional STP Sludge	Lagoon Sludge	138.2	39.2
Regional STP Screenings (Ave)	Screenings A/B	140.15	135.5
Greenwood STP Sludge	Sludge Press	77.5	65.1

This data was used to classify the three materials that were tested during the options development phase of the project, as detailed in Chapter 3. It was subsequently used to calculate the rate of biomethane production for the materials selected for the anaerobic digestion option in Chapter 4.

Chapter 3 Options Development

Following the Anaerobic Digestibility Evaluation, a number of options were considered for each of the different feedstocks available. These are discussed below. The available quantities of each type are presented as well. There appear to be two broad categories:

- Thin sludge that is challenging to transport, and has low anaerobic digestibility; and
- Dewatered sludge that is transportable has reasonable anaerobic digestibility.

3.1 Regional STP Sludge

Regional STP sludge falls into the thin category which is challenging to transport. The Anaerobic Digestibility Evaluation indicated that the Regional STP sludge had poor anaerobic digestion potential. The sludge is available in significant quantities at a thickness about 6% in place, with about 33,000 m^3 in Cell 1 and 30,000 m^3 in Cell 2. In order to dredge and remove sludge, the thickness decreases because some water is pumped out along with the sludge. The removed sludge thickness is assumed to be about 4%, which would increase the quantity as shown in the table below. The Daily Removal Volume is the quantity of sludge which would need to be removed each day to empty the cell in two years. It is assumed that the Municipality would not want to undertake removal at a slower pace than this.

Table 3.1: Removal Volumes for Regional STP Sludge

Cell	Volume at 6%	Volume at 4%	Daily Removal Volume
Cell 1	33,000 m^3	49,500 m^3	68 m^3/day
Cell 2	30,000 m^3	45,000 m^3	62 m^3/day

This sludge would need to be transported to a different site for digestion, because the Regional STP site is not a good location for an anaerobic digester for a number of reasons. It has very little available space, it is very close to the Village of New Minas, and it has no spare organic loading capacity to treat digestion byproducts (digestate or centrate). The logistics of feeding lagoon sludge into an anaerobic digester located on another site are very challenging, as seen from the removal volumes in the table above. Furthermore, the digester volume needed to handle this sludge is poorly matched to the digester volume needed for the other sludge types below, and the potential for the sludge to produce attractive volumes of biogas is low. For these reasons, it was agreed that the anaerobic digestion of this sludge was not feasible.

Therefore, it was necessary to evaluate other ways of handling this sludge. The possibilities initially identified were:

- Sludge holding cell;
- Dredging and mechanical dewatering; and
- Dredging and dewatering using geotextile bags.

The sludge holding cell concept would involve moving all the sludge from Cell 2 into Cell 1 where it would continue to digest in place, and to move the influent pipe from Cell 1 to Cell 2. This would remove Cell 1 from the wastewater treatment train and use it only for sludge. The aeration in the remaining four cells would need to be upgraded significantly, including significant additional changes to the aeration equipment in Cell 3, which was just upgraded this year. It would delay but not eliminate the need to dredge and remove the sludge from site. Furthermore, it would decrease the total treatment capacity in the STP to less than it had been originally. For this reason, it was agreed that this option did not fulfill the requirements of the Municipality and would not be considered further.

Dredging and dewatering, either mechanically or with geotextile dewatering, are both feasible methods of efficiently removing the accumulated sludge from site. These are both methods that would allow the desludging to happen within a relatively short period of time, in order to gain significant addition treatment capacity at the Regional STP, and to allow the aeration system in Cells 1 and 2 to be renewed. These methods are discussed in more detail in Chapter 6

3.2 Transportable Feedstocks

The other three potential feedstocks are of a consistency and volume that can be readily transported to a suitable site for further treatment. Two treatment options were identified for the transportable feedstocks:

- Anaerobic digestion to produce a stabilized product and biogas; and
- Composting to produce a stabilized product for beneficial reuse or disposal.

Each of these feedstocks are discussed below and assessed against the treatment options.

3.2.1 Regional STP Screenings

The Anaerobic Digestibility Evaluation indicated that the Regional STP screenings had the best anaerobic digestion potential of the feedstocks tested. It is both thick enough, at about 15.4% solids, and of a reasonable quantity to be readily transported to another site for digestion and could be delivered once a week. It would also be suitable for composting.

The mass of wet screenings available each month is shown in Table 3.2.

Table 3.2: Regional STP Screenings at 15.4% Solids

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet Tonnes of Screenings per month	37	34	37	36	37	36	37	37	36	37	36	37

3.2.2 Greenwood STP Sludge

The Anaerobic Digestibility Evaluation indicated that the Greenwood STP sludge had moderate anaerobic digestion potential, and this may understate the true potential. It is both thick enough, at about 11% solids, and of a reasonable quantity to be readily transported to another site for digestion and could be delivered as needed. It would also be suitable for composting. This volume of sludge fluctuates significantly with seasonal patterns, which would make transport and treatment of this material more challenging.

The mass of wet sludge available each month is shown in Table 3.3.

Table 3.3: Greenwood STP Sludge at 11% Solids

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet Tonnes of Sludge per month	0	0	25	25	25	25	84	143	76	34	25	25

3.2.3 Municipal Partner STP Sludge

This sludge was not tested in the Anaerobic Digestibility Evaluation, but it is of a type that typically has good anaerobic digestion potential when similar sludge has been tested at other sites, and it will be assumed to be similar. It is both thick enough at about 22% solids and of a reasonable quantity to be readily transported to another site for digestion, and could be delivered once a week. It would also be suitable for composting.

The mass of wet sludge available each month is shown in Table 3.4.

Table 3.4: Partner STP Sludge at 22% solids

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet Tonnes of Sludge per month	24	10	23	14	21	22	20	20	15	20	19	16

3.2.4 Combined Feedstock Treatment Options

These three feedstocks that can be delivered to a treatment site have sufficiently similar characteristics that they will be combined in order to develop the two options of anaerobic digestion and composting for environmentally beneficial treatment and use:

- Anaerobic digestion; and
- Composting.

The characteristics of this combined feedstock material vary based on the option, so design loads will be developed for each of these options separately.

These options are discussed in more detail in Chapter 4 and Chapter 5, respectively.

Chapter 4 Anaerobic Digestion

4.1 Overview

Anaerobic digestion is a common method of wastewater solids treatment and stabilization and generally biodegrades about 50 percent of the volatile solids in wastewater sludge. This method is most commonly used at larger treatment facilities and is best suited to the feedstocks of primary sludge or mixed primary and secondary sludge where the stabilized product can be land applied.

Anaerobic digestion typically takes place in concrete digester tanks, often placed in series at larger plants. The tanks are well mixed and usually heated to 35°C to 38°C (95°F to 100°F). Complex organic matter in the feedstock is converted to organic acids, and in turn the organic acids are converted to methane gas (2/3 by volume) and carbon dioxide gas (1/3 by volume). Small amounts of hydrogen sulphide and other gases are generated. This biogas can be burned to provide heat to enhance the digestion process, or burned in a Combined Heat and Power (CHP) unit that can provide both electricity and heat.

4.2 Design Description and Discussion

Several locations were considered for this option, including Greenwood STP, the Partner STP, and a site with an existing anaerobic digester. Constructing an anaerobic digester on the Partner STP site was considered, but they do not have adequate space or spare digestate treatment capacity at their facility. Feeding into another municipality's STP with an existing anaerobic digester was also considered, but they do not have adequate capacity in their existing equipment, nor space to construct more equipment. Any site without an STP would need to have wastewater treatment capacity constructed as well, making this economically less attractive.

This option has been developed on the Greenwood STP site for a number of reasons:

- Adequate space for a digester;
- Remote site location from community, but accessible to all sources of feedstock;
- Possible digestate treatment capacity available on site;
- Existing beneficial use for heat and/or electricity at site;

- Opportunity to feed Greenwood STP sludge without prior aerobic digestion, thus improving the BMP of the sludge; and
- Opportunity to avoid transportation costs for Greenwood STP sludge.

A site layout of the proposed process is as shown in PSK01 in Appendix B. The screenings from Regional STP and the Partner STP sludge would be delivered weekly and offloaded into a mix tank complete with a mechanical mixer, where it would be combined with Greenwood unthickened Waste Activated Sludge (WAS) to dilute it to a digestible thickness. This mixture would be fed to the digester over the course of the week. The tank would have a cover to prevent it from becoming an odour nuisance. Digesters work best with consistent feed, and it would be important, though potentially challenging, to keep the feedstock as consistent as possible.

Figure 4.1: Small Anaerobic Digester in Atlantic Canada

The digester design was developed with the aim of processing the combined feedstock and producing the following outputs shown in Table 4.1, using the BMP values from the Verschuren Centre analysis for each type of sludge tested, and assuming that the dewatered digested sludge could be dewatered to a solids concentration of 20%.

Table 4.1: Combined Feedstock Inputs and Digestion Product Outputs

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Combined Feedstock (Wet Tonnes/d)	2.0	1.5	2.8	2.5	2.7	2.8	4.5	6.5	4.2	2.9	2.7	2.5	3.1
Dry Solids (kg/d)	354	260	440	380	420	436	622	835	569	447	419	384	464
Volatile Solids (kg/d)	307	235	379	334	364	377	534	713	493	387	364	337	402
Biomethane produced (m^3/d)	72	46	77	60	72	76	83	98	73	73	71	62	72
Energy value (kWh/d)	724	463	772	599	716	756	832	980	731	728	707	617	719
Digested sludge solids (kg DS/d)	276	165	332	280	318	348	501	696	463	332	343	273	361
Dewatered digested sludge (Wet Tonnes/d)	1.4	0.8	1.7	1.4	1.6	1.7	2.5	3.5	2.3	1.7	1.7	1.4	1.8

Anaerobic digestion at the Greenwood STP site offers the potential to decrease the overall volume and mass of solids which must be removed from site for beneficial use or disposal. When operated correctly, the end product is generally considered Class A and safe for land application by regulators.

This process also produces biomethane which can be used for a variety of purposes. Although electricity is produced at some sites, the scale of this digester is smaller than the smallest available CHP unit, which handles about 500 m^3 biomethane/day. While it is technically possible to use this unit on a smaller gas flow, the downtime would be so high that it would be cost-prohibitive once all the necessary equipment is provided, including a gas conditioning skid and the CHP unit.

Instead, the gas produced on this site would be used to provide heat for the digester using a small (30 kW) boiler, as well as to help protect the process equipment from freezing. This is an ongoing issue in winter. Warming the incoming effluent may also increase the biological activity in the winter time, and reduce occurrences of bacterial washout.

For this application, a single stage, low rate system is proposed. Digester tanks are of reinforced concrete construction. A single digester is proposed. The tank is 10 m in diameter with a side wall depth of about 8.3 m. The organic loading on the digester is about 0.6 kilogram of volatile solids per cubic meter of digester capacity per day, but varies seasonally. Likewise, the solids retention time (SRT) in the tank will be about one month, on average, but can be as low as 10 days in the middle of summer when the volume of Greenwood STP waste activated sludge increases. The digester is heated to 35°C by means of an external heat exchanger. One 30 kW boiler supplies heat to the system. The digester tank contents are mixed using mechanical mixers or a gas recirculation system. The digester is provided with a membrane gas holder cover capable of storing approximately 100 percent of the average daily gas production. Surplus gas, not required for the process, can be burned directly in a flare stack.

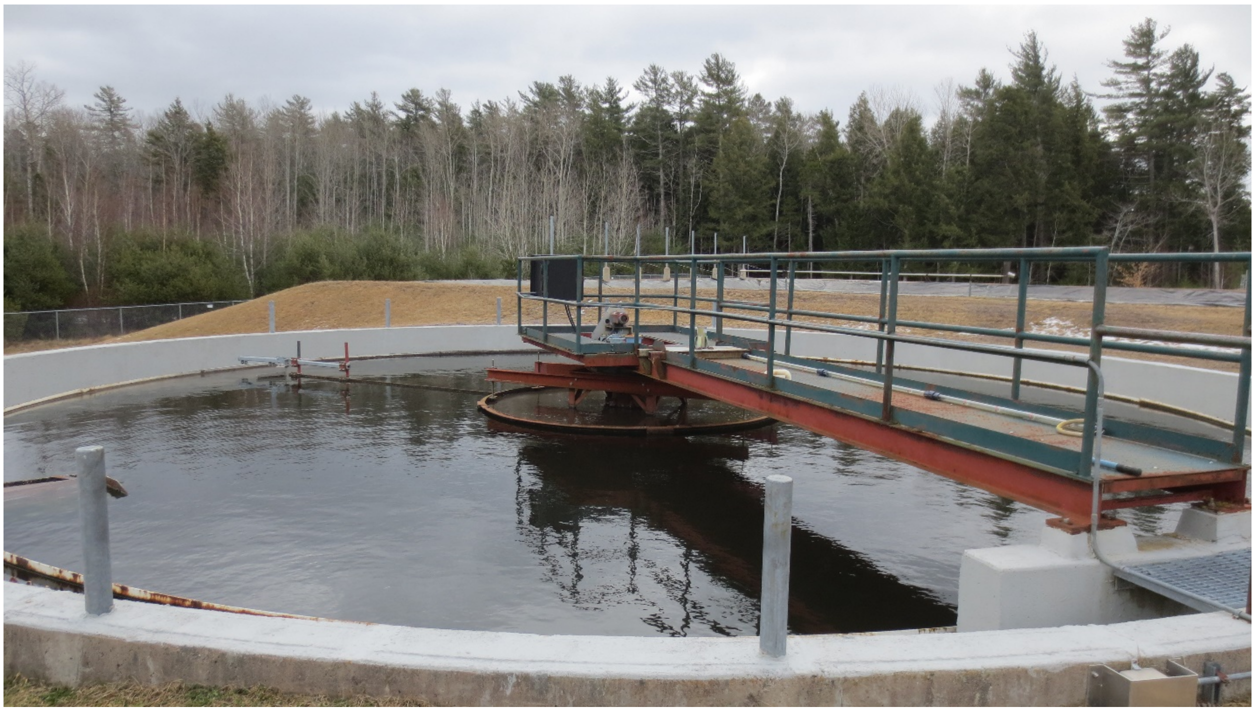

Figure 4.2: Existing Greenwood STP clarifier; surface freezes in winter.

Digester gas production is usually proportional to the feedstock volatile solids fed, so it would vary at this site due to fluctuations in material fed and would be higher in summer. Biomethane utilization rates can vary significantly depending upon end use. For example, where gas is used to heat physical plant or the process, there may be an excess in the summer and a shortage in the winter. Because the volume of gas storage provided is usually relatively small, it is difficult to recover all of the potential energy particularly where loads vary considerably. It appears that there would be enough biomethane produced to supply the needs of the digester itself in winter, with some to spare.

Following digestion, the solids will be conveyed to the sludge thickening building for dewatering using a small centrifuge. This would replace the existing belt filter press, which is not typically well suited for anaerobically digested sludge. The centrifuge would be operated for about 12 hours per week to thicken the digested solids to about 20%. The centrate would be directed back to the head of the plant.

Figure 4.3: Existing Greenwood STP Belt Filter Press

The Greenwood STP treatment capacity was evaluated to determine if the centrate load could be accommodated, and in the initial evaluation it appears that this is feasible during all times of the year. If this option proceeds to pre-design, additional evaluation is recommended to ensure that the additional loads can be treated without risk to the very low effluent requirements of this plant.

This option would be fully operated by Municipality staff and would require more time to be spent on Greenwood STP operations and maintenance than currently needed.

4.3 Probable Cost

Cost estimates for the anaerobic digestion system are presented in Table 4.2, including net present value and total annualized cost. These were developed based on a discount rate of 8%, as recommended by the Treasury Board of Canada, and a period of 30 years. In this case, there would be no revenue from energy production, and it is assumed that the Partner municipality would share the cost proportionally to their sludge dry solids contributions, which make up approximately 30% of the total.

Table 4.2: Opinion of Probable Cost – Anaerobic Digestion

Capital Cost	
Site Work	$446,000
Concrete	$252,000
Building	$201,000
Process Equipment	$1,450,000
Mechanical/Electrical	$336,000
Contingencies/Allowances	$1,074,000
Total Capital Cost	**$3,759,000**
Operation and Maintenance Costs	
Labour	$20,000
Energy	$10,000
Equipment/Supplies/Maintenance	$40,000
Polymer/Chemicals/Bulking agent	$5,000
Transportation/Disposal	$20,000
Total O & M Cost	**$95,000**
Annualized Costs	
Annualized Capital Cost (30 years, 8% discount rate)	$334,000
Total Annual Cost	$429,000
Solids Processed (dry tonnes/year)	170
Cost/tonne dry solids	$2,520

Chapter 5 Composting

5.1 Overview

Composting is the aerobic thermophilic decomposition of solid organic constituents resulting in the production of carbon dioxide, water, excess heat and a stabilized humus-like product. Like any aerobic biological process, composting requires several fundamental environmental conditions in order to proceed effectively. The correct balance of oxygen, temperature, moisture, pH and nutrients must be carefully considered in the design of a composting system.

The objective of wastewater solids composting are threefold:

- Stabilization of putrescible organics;
- Destruction of pathogens; and
- Evaporation of excess moisture.

When composting is carried out at appropriate temperatures the end product is generally considered Class A and safe for land application according to regulators.

Wastewater solids composting techniques are normally classified as unconfined or confined processes. Unconfined systems include windrows and uncovered aerated static piles. Windrows are dynamic systems in that aeration is accomplished by periodic mixing and turning of the composting material. In the aerated static pile system aeration is provided by means of fixed air headers and fans which draw air down through the static composting material.

Confined systems are those where the composting operation is carried out within an enclosed container or basin. This is commonly referred to as in-vessel composting. These systems are designed to minimize odours and process time by controlling environmental conditions such as air flow, temperature, moisture conditions, pH and nutritional requirements. In-vessel systems are generally more suitable for larger applications, more appropriate for composting of unstabilized wastewater solids and less affected by adverse weather conditions. Only in-vessel composting systems have been considered for application, to suit the intended inputs, and to make the siting of the composting system less sensitive.

5.2 Design Description and Discussion

Discussion with Valley Waste Resource Management (VWRM) indicated that there was a flat site near Highway 101 on land available to VWRM that could possibly be used for this purpose, and that VWRM is a potential partner for the Municipality for the purpose wastewater solids composting. This site is assumed as a general location, but we do not have a survey for it, so we have laid out the proposed composting process on a generic site.

A site layout of the proposed process can be found in PSK02 in Appendix B. It is proposed to process material through this system as shown in Table 5.1. The proposed process has a capacity of 3.1 wet tonnes of mixed sludge per day, or 22 wet tonnes per week.

Not all the wastewater solids produced can be processed in the proposed system. During the summer when Greenwood STP volumes increase significantly, they exceed the capacity of the composting system during July, August, and September (truncated values bolded in the table below). Furthermore, to make the labour requirements more reasonable, we have assumed that wastewater solids are delivered, mixed and loaded into bunkers only one day per week, and Greenwood STP requires more frequent sludge hauling in summer. While it would be theoretically possible to accommodate all deliveries, this would leave the system with significant excess capacity the rest of the year and decrease the overall cost-effectiveness of the system. During these months, therefore, an alternate sludge processing route would be required for a portion of the peak seasonal Greenwood STP solids (accounting for about 40% of the annual Greenwood STP sludge total).

Table 5.1: Sludge Volumes for Composting and Compost Outputs

	Partner STP Sludge	Regional STP Screenings	Greenwood STP Sludge	Total Inputs	Compost Outputs
Solids Content	22% D.S.	15% D.S.	11% D.S.	Varies	~45% D.S.
Jan (Wet Tonnes/d)	0.8	1.4	0.0	2.1	1.5
Feb (Wet Tonnes/d)	0.3	1.2	0.0	1.5	1.1
Mar (Wet Tonnes/d)	0.8	1.4	0.8	2.9	2.0
Apr (Wet Tonnes/d)	0.5	1.1	0.8	2.4	1.7
May (Wet Tonnes/d)	0.7	1.1	0.8	2.6	1.8
Jun (Wet Tonnes/d)	0.7	1.1	0.8	2.7	1.9
Jul (Wet Tonnes/d)	0.6	1.4	**1.1**	3.1	2.2
Aug (Wet Tonnes/d)	0.7	1.1	**1.4**	3.1	2.2
Sep (Wet Tonnes/d)	0.5	1.1	**1.5**	3.1	2.2
Oct (Wet Tonnes/d)	0.7	1.4	1.1	3.1	2.2
Nov (Wet Tonnes/d)	0.6	1.1	0.8	2.6	1.8
Dec (Wet Tonnes/d)	0.5	1.1	0.8	2.4	1.7
Ave. (Wet Tonnes/d)	0.6	1.2	0.8	2.6	1.9

Although composting is a continuous process, solids from the three sources would be fed to the system only 8 hours per day, 1 day per week, to minimize labour. Solids would be dewatered as they are currently and delivered to the site all on the same day. The solids would then be mixed with a bulking agent, such as wood chips or sawdust and recycled compost, in a mechanical tub mixer.

The tub mixer is sized to accommodate all the mixing on the same day for loading into the bunkers. A tub mixer ensures thorough mixing of the material and accelerates the composting process. Typical mix ratios for material with this moisture content are 1.5 tonnes of bulker per tonne of wastewater solids. If the moisture content of the Greenwood STP sludge can be reduced, then the amount of bulker could also be reduced. The bulking agent and recycled compost increases the porosity of the feed stock and prevents the material from being saturated with water to enhance the airflow and improve the composting process. The moisture content of the mixed feed stock prepared for processing is typically about 40 to 50 percent.

Figure 5.1: Gore Cover Lifter

The feed material is placed in a series of bunkers where the compost is stacked on an aeration floor and covered with a Goretex cover, which is permeable to water vapour but sheds liquid water. This helps greatly in retaining odours to prevent the process from becoming an odour nuisance. On test sites using this system, potentially odorous volatile organic compounds (VOCs) can be reduced by 90% by using these covers.

Blowers are included for providing air to the aeration floor system and a remotely accessible control panel is included for controlling the airflows and monitoring the system performance. A motorized cover winder would be provided to make cover-handling easier. The bunkers are required for year-round cover use, to prevent the covers from freezing to the ground. A leachate collection system is also provided to control leachate that is produced in the earlier stages of composting. This is then used to add some moisture to subsequent stages of composting.

The entire process has three phases and takes about eight weeks in total. The retention time in the first bunker is normally about 4 weeks. Excess heat is generated during auto-thermal oxidation in the reactor. Temperatures within the compost mass can exceed 55°C (130°F). The higher temperature greatly accelerates the stabilization process. The key mechanism of pathogen destruction during composting is through heat pasteurization. In addition, heat is required to vaporize moisture within the compost matrix, a fundamental step in the drying process. After removal from the first bunker the compost is then placed for approximately 2 weeks each in a second bunker and then a third bunker, during which time composting continues at a slower rate and usually at a lower temperature. Since volume decreases through this process, only 15 bunkers are needed in total.

After this period the compost should be stored on a pad for an additional maturation and cooling period without aeration, and then brought undercover for storage prior to trommeling to remove any oversized material, including bulker that may be reused. We have assumed that a trommel screen would be hired periodically to remove oversized material rather than purchasing one which would be idle much of the time.

The final compost product normally contains about 55 to 60 percent dry solids. The finished product has a lower level of available nitrogen than some other forms of treated solids due to the dilution of nutrients by bulking agents, and loss of ammonia nitrogen during the composting process. However, it is an excellent soil conditioner and its nutrients become available slowly over several years. The high temperature achieved during composting destroys virtually all pathogens. However, compost is a suitable medium for the regrowth of bacteria and care must be taken to prevent contamination. The product should be kept dry since wetting will encourage recontamination and subsequent odour production.

Two fabric buildings are proposed for storing bulker and storing the finished compost. This keeps both of them dry for optimal quality.

Odour control is one of the most critical elements in composting. In the past, several wastewater solids composting projects have been stopped because of public resistance to odours emitted from the composting site. The elimination of odour should therefore be a primary consideration in the design of any composting facility. The key to effective odour control is to rapidly achieve and continually maintain aerobic conditions throughout the composting mass. This requires effective control of aeration, temperatures, moisture level, porosity and mixing. The cover contributes significantly to odour control and data from other sites with the same process is available to demonstrate the odour control achieved.

This option could potentially be operated by VWRM staff as a VWRM facility, if they agreed there was a business case for doing so. It is modular and therefore has considerable expandability if for a larger sludge composting facility than that proposed here was attractive.

5.3 Probable Cost

Cost estimates for the anaerobic digestion system are presented in Table 5.2, including net present value and total annualized cost. These were developed based on a discount rate of 8% and a period of 30 years. We have assumed that the Partner municipality would share the cost proportionally to their sludge dry solids contributions, which is approximately 33% of the total.

Table 5.2: Opinion of Probable Cost – Composting

Capital Cost	
Site Work	$364,000
Concrete	$652,000
Building	$120,000
Process Equipment	$1,251,000
Mechanical/Electrical	$87,000
Contingencies/Allowances	$989,000
Total Capital Cost	**$3,463,000**
Operation and Maintenance Costs	
Labour	$30,000
Energy	$20,000
Equipment/Supplies/Maintenance	$30,000
Polymer/Chemicals/Bulking agent	$30,000
Transportation/Disposal	$20,000
Total O & M Cost	**$130,000**
Summary	
Annualized Capital Cost	$308,000
Total Annual Cost	$438,000
Solids Processed (dry tonnes/year)	150
Cost/tonne dry solids	$2,920

Chapter 6 Sludge Dredging and Dewatering

6.1 Overview

An aerated lagoon sewage treatment plant usually has the sludge periodically removed, approximately every 10 to 20 years. This allows the owners and operators to avoid continuous sludge handling tasks and costs which are performed by other types of STPs (for example, the sludge dewatering belt press at Greenwood STP). Over this time period, sludge settles to the bottom of the lagoon and remains there, digesting in place, until the volume becomes sufficiently large that the amount of treatment capacity taken up is unacceptable, or the sludge begins to interfere with the aeration process.

The most common method of removing sludge from a lagoon wastewater treatment plant is dredging the sludge and then dewatering the sludge for disposal. This typically involves hiring a contractor who brings a dredge for physically pumping the sludge out of the lagoon and equipment for dewatering the sludge, which can take several different forms. This service is generally contracted because periodic sludge removal does not make it cost effective for owners to purchase the specialized equipment needed, nor to hire trained staff to operate it at such infrequent intervals.

Two common methods of dewatering are mechanical dewatering with a centrifuge, and dewatering using geotextile bags. Both of these require conditioning of the sludge with polymer to produce better separation of solids from liquids in the sludge pumped from the dredge. These methods each have advantages and disadvantages, which will be discussed in the following sections.

The Regional STP has not been desludged for many years now, and the volume of sludge is taking up treatment capacity that is needed to meet the effluent requirements, as well as physically interfering with aeration. Sludge removal should be planned for and carried out in the near future to restore the treatment capacity of the aerated lagoon and also to allow for renewal and upgrade of the remaining old aeration equipment in the cells. The aeration system improvements will also add to the treatment capacity of the plant, providing adequate treatment capacity now and into the future, as well as allowing for some growth in the area.

Some site-specific challenges that may be encountered include the probable presence of concrete ballast blocks in Cell 1, as well as the possibility of other large debris in this cell. This may lead to some difficulty when dredging this cell but cannot be avoided with a different feasible method of sludge removal.

Figure 6.1: Regional STP Lagoon Cells

The areas, sludge volumes and average sludge depths are given in Table 6.1. Please note that there is considerable variation in the sludge depth within each cell, particularly in Cell 1, where in some places there is nearly 2.5 m of sludge. All these values are based on a limited number of measurements which may not capture the full range of depths and volumes. The volumes for the first two cells are based on a larger number of measurements than the volumes for the last three cells and are, therefore, considered to be more reliable. These sludge volumes indicate that the first two Cells are the ones that will benefit the most from desludging in the near future. The other three also appear to contain significant amount of sludge and should be assessed, then monitored, and desludged when necessary.

Table 6.1: Regional STP Cell Data

Cell	Area (approximate)	Sludge Volume	Sludge Depth (average)
1	32,000 m^2	33,000 m^3 (measured)	1 m
2	30,000 m^2	30,000 m^3 (measured)	1 m
3	30,000 m^2	20,000 m^3 (estimated)	0.7 m
4	30,000 m^2	15,000 m^3 (estimated)	0.5 m
5	30,000 m^2	10,000 m^3 (estimated)	0.3 m

If sludge removal is not carried out in Cells 1 and 2, we anticipate that the performance of the plant will continue not to reliably meet performance expectations, and it will not be possible to install the required aeration improvements.

6.2 Centrifuge Dewatering Description & Discussion

Centrifuge dewatering is an example of mechanical dewatering. For this option, a dredge and mobile centrifuge would be contracted to come to site. The equipment would be operated by contractor staff to remove the built up sludge from the cell, condition it with polymer, and dewater it using a mobile centrifuge. This typically produces a sludge cake between 22–25% dry solids, and the sludge cake is removed from site to a licenced facility where it is further processed and blended for beneficial reuse or final disposal. In order to remove and process the amount of sludge in Cells 1 and 2, it would take approximately 50 working days, working 6 days per week, and a laydown area of approximately 1,200 m² would be required. The work can only be carried out under non-freezing conditions.

6.3 Geotextile Bag Dewatering Description & Discussion

Geotextile Bag dewatering has been successfully used previously by the Municipality to dewater sludge from smaller sites. For this option, a dredge and mobile conditioning unit would be contracted to come to site. The equipment would be operated by contractor staff to remove the built up sludge from the cell, condition it with polymer, and dewater it by filling the geotextile bags. The geotextile bags are placed on a pad that must be prepared beforehand, and that would require an area of approximately 20,000 m², including berms. This could be located on the proposed Geotube Laydown area indicated on PSK03 in Appendix B. The filled geotextile bags are typically left on site through at least one freeze-thaw cycle to improve the dewatering and further reduce the volume of the solids to be removed from site, as well as improving the stability. This typically produces a sludge cake between 23–30% dry solids, and the sludge cake would in this case be removed from site to a licenced facility where it is further processed and blended for beneficial reuse or final disposal. In order to remove and process the amount of sludge in Cells 1 and 2, it would take approximately 230 working days, working 6 days per week, and a prepared laydown area of approximately 20,000 m² would be required. The work can only be carried out under non-freezing conditions.

6.4 Probable Cost

The estimated amount to be removed from Cells 1 and 2 is 3,800 dry tonnes (DT) of sludge. This is based on the volumes detailed in Table 6.1, at 6% solids as measured during this study. However, the consistency of the sludge could vary, and there could be more sludge present than anticipated. A contingency factor of 10% will be allowed on the dewatering and disposal costs which vary with amount of sludge.

The costs do not include securing the use of the proposed laydown area, which is not owned or leased by the Municipality at this time.

Table 6.2: Opinion of Probable Cost – Centrifuge Dewatering

	Item	Cost
1	Fixed Costs (Mobilization)	$90,000
2	Variable Costs based on 3800 BDT (Dredging, Dewatering and Processing at Licensed Facility)	$1,600,000
3	Contingency (10% of item 2 to allow for increase in mass of sludge)	$160,000
	Total for Cells 1 and 2	**$1,850,000**
	Mass removed	3800
	Cost per dry tonne	$490

Table 6.3: Opinion of Probable Cost – Geotextile Bags Dewatering

	Item	Value
1	Fixed Costs (Mobilization, Laydown Area and Geotextiles)	$700,000
2	Variable Costs based on 3800 BDT (Dredging, Dewatering and Processing at Licensed Facility)	$1,800,000
3	Contingency (10% of item 2 to allow for increase in mass of sludge)	$180,000
	Total for Cells 1 and 2	**$2,680,000**
	Mass removed	3800
	Cost per dry tonne	$710

The current solids disposal rate for Regional STP Screenings and Greenwood STP sludge is about $850 per dry tonne. This means that over a period of 20 years as the sludge built up, the Municipality avoided an annual cost that could have been about $160,000 a year (in 2020 dollars) in order to dispose of the sludge as it was produced.

Chapter 7 Comparison and Recommendations

7.1 Comparison of Options for Regional STP Sludge

The centrifuge dewatering option is best suited to processing large amounts of sludge, where the time for desludging is a factor, and where there is limited laydown room, as is the case at Regional STP.

The geotextile bag dewatering option is best suited to STPs where a moderate amount of sludge is to be removed, or where the geotextile bags can be left in place indefinitely or removed directly for beneficial reuse. It also works well on sites where there is an advantage to dewatering smaller quantities over multiple seasons. It can be possible to benefit from a freeze-thaw cycle in order to fill the bags a second time and achieve more dewatered sludge for the same bag cost and space.

There is a risk that the geotextile bags will produce objectionable odours after the initial dredging is complete and that these could be noticed by the public where the site is close to the walking trail. The odour risk of the centrifuge option is mainly during the time when desludging is actively occurring. The shorter desludging time for the centrifuge option is a significant advantage on a site this size, to limit the duration of the odour risks.

Economically, centrifuge dewatering appears to be the most cost effective, and this is reinforced, in our opinion, by significant advantages in terms of social benefits, such as reduced odour risk and reduced space needed. It also allows the excess sludge in Cells 1 and 2 to be removed sooner so that the much-needed aeration upgrades to these Cells can go forward and provide environmental benefits to the Municipality's residents.

7.2 Comparison of Options for Combined Solids

A cost comparison is shown in the table below, Although both anaerobic digestion and composting of the combined solids (including Regional STP screenings, Greenwood STP sludge, and the Partner Municipality sludge) are technically feasible, both of these options have significantly higher cost per dry tonne than the current processing and disposal routes used by the Municipality, and also by the Partner Municipality.

Handling Method	Cost per Dry Tonne (DT)
Anaerobic Digestion	$2,520
Composting	$2,920
Current MOK Disposal Route	$850

For anaerobic digestion, there are social, environmental, and operational benefits and risks. Social and environmental benefits include the beneficial use of the heat generated by the biogas; however, benefits at this scale are limited because there is not enough gas to generate green electricity that could be fed into the grid or used to offset other Municipal electrical use. Another combined social/environmental benefit is the production of a soil amendment, but this is limited due to the ban on land application of products derived from wastewater solids. An operational benefit is that applying the excess heat to the influent could improve the effluent quality at the plant in winter, and it may prevent the clarifiers from freezing.

Social risks of anaerobic digestion include the increased possibility of odours at the Greenwood STP, as well as additional traffic in the winter when road conditions are the worst. Although it appears that the digestate load could be handled by the existing Greenwood STP infrastructure, this plant has very tight effluent requirements and there is an environmental/operational risk that these limits could be exceeded, particularly in the case of a process upset.

For composting, there are also social and environmental benefits and risks. Social and environmental benefits include the production of a soil amendment, but again this is limited due to the ban on land application of products derived from wastewater solids.

Social risks include odours at the composting site despite measures to control this.   An operational risk is that a disposal route for the excess Greenwood STP summer sludge may be harder to secure than a year-round contract.

Overall, the benefits do not appear to outweigh the risks for either of these options, leaving the existing processing at a licensed facility as the preferred option for Regional Screenings and Greenwood STP sludge.

7.3 Recommendations

We recommend proceeding with dredging and centrifuge dewatering for the Regional STP sludge accumulation, as well as detailed design of aeration upgrades for Cells 1 and 2. This is the route with the most attractive social and environmental benefits, as well as the lowest cost to the Municipality per dry tonne of sludge.

We recommend continuing with the existing disposal path for the Regional STP screenings and the Greenwood STP sludge. This provides the lowest cost to the Municipality per dry tonne of sludge. Neither of the other options appear to be compelling, from a social or environmental perspective.

Prepared by:
Sarah Ensslin, M.Sc., P.Eng.
Process Engineer

Reviewed by:
Mike Abbott, M.Eng., P.Eng.
VP, Water Treatment

APPENDIX A

Verschuren Centre Report: Energy Generation Potential of Feedstocks

Verschuren Centre for Sustainability in Energy and the Environment
Sydney, Nova Scotia
info@verschurencentre.ca
902.563.1292

Client: CBCL Limited (Halifax, Nova Scotia)

INTRODUCTION

This report describes the evaluation of the feasibility of utilizing waste materials from local wastewater treatment facilities in Kings county for alternative bio-energy production. The materials tested in this report include screenings from headworks of the Regional Plant, lagoon sludge from the Regional Plant, as well as a sludge press from Greenwood site.

This report includes feedstock characteristics and biomethane production potential for the described feedstocks.

METHODS

Samples were collected on January 17 and March 5 2020 from Kings County, NS and frozen prior to analysis. Samples were kept frozen until shortly before analysis, taking approximately 2 days for the samples to thaw.

Table 1: Feedstocks received by Verschuren Centre for energy generation potential.

Sample	ID	Collected	Received	Processed
1. Regional STP Screenings	Screenings A	January 17 2020	January 21 2020	February 27 2020
2. Regional STP Lagoon Sludge	Lagoon Sludge	January 17 2020	January 21 2020	February 27 2020
3. Regional STP Screenings	Screenings B	March 5 2020	March 11 2020	March 12 2020
4. Greenwood STP Sludge Press	Sludge Press	March 5 2020	March 11 2020	March 12 2020

Anaerobic Digestion

The start-up inoculum used for the study was obtained from a locally sourced anaerobic digestion of agricultural waste streams. A initial inoculum to substrate ratio of 2:1 was chosen and the pH of both the samples and the mixed digestates was determined.

For samples collected January 17, batch assays were run as duplicates for a total of 12 days on an Automatic Methane Potential Test System (AMPTS II Light). 2 L glass bottles were used as reactors and the BMP assays were performed at a temperature of 37°C. Approximately 500 g of substrate was mixed with 1000 g of inoculum to produce a 2:1 ratio of inoculum to substrate (based on sample weight). The reactors were sealed and the contents were mixed intermittently by electric motors which ran for 60 seconds on and 60 seconds off. The biomethane output was measured in NmL (normalized milliliters) after absorption of CO_2 through 3M NaOH solution.

Because the inoculum to substrate ratio was based on sample weight, it was felt that excess substrate as screenings was added in the initial run, to the digestion resulting in an elevated ratio of substrate to inoculum. The results are presented in this report and a second digestion on the same substrate samples run alongside the sample collected on March 5th i.e. includes a second round of screenings (labelled B) collected in January with an increased ratio of 3:1 ratio based on the volatile solids results.

For the second digestion of samples collected on March 5, conditions were similar to those described above; however, the inoculum source was used with slightly lower volumes of substrate ratio; reactors had a volume of approximately 600 mL with between 28 and 52 g of substrate mixed with between 546 and 572 g of inoculum to produce a 3:1 ratio of inoculum to substrate based on volatile solid amounts. The second run was terminated early (day 8) due to a shut-down of the labs due to the pandemic.

Potential Feedstock Characteristics

Percent total solids (TS%) and percent total volatile solids (VS%) were determined in triplicates using methods described by the AMPTS II Operation and Maintenance Manual (2016).

Approximately 2 g of material was oven dried for 20 hours at 105°C to determine TS%, and the resulting material was calcined in a furnace at 550°C for 2 hours to determine VS%. The material remaining after calcination at 550°C was collected and ground into a powder for microwave assisted digestion.

Approximately 50 mg of material was digested in 8M nitric using a Mars 6 Microwave digester (CEM Corp). The resulting solution was centrifuged for 15 minutes at 3600 rpm prior to analysis on ICP-MS (Perkin Elmer Nexion 300D).

RESULTS

The pH results showed that when the inoculum and substrates were mixed, the resulting pH levels for the samples were between 7.07 and 7.74. This is at the high end of the typical 6.8-7.2 pH range for AD systems, depending on substrate.

Biomethane Potential

The following table summarizes the total solids, volatile solids, and biomethane potential of samples collected in January 2020. The inoculum control is included as reference and has not been subtracted from the sample totals. It should be noted that the starting inoculum had been collected from another digestor and there is often a lag period to adapt to new single source substrates, hence a stimulation using a 1g/L addition of glucose was used to preculture the inoculum. Anaero Technology (2018) suggests an acceptable starting inoculum should have a BMP of approximately 100 ml/g VS.

Table 2: Feedstock analysis and biomethane potential for Digestion #1 (samples collected January 17 2020) and Digestion #2 (samples collected March 5 2020).

	Sample ID	Days	DS % (w/w)	VS % (w/w)	VS in Sub. (g)	VS in Inoc. (g)	Inoc:Sub	Accumulation Biomethane (NmL)	BMP (NmL/g VS)
Digestion #1	Inoculum Control	12	2.5	1.6	0.0	16.4	1 to 0	214.8	13.1
	Screenings A	12	13.2	12.7	63.0	16.5	1 to 4	2347.3	33.9
	Lagoon Sludge	12	6.0	1.7	8.8	16.3	2 to 1	1438.9	138.2
Digestion #2	Inoculum Control	8	4.1	2.6	0.0	9.7	1 to 0	47.8	4.9
	Screenings A	8	13.2	12.7	4.8	14.6	3 to 1	503.6	142.7
	Screenings B	8	17.5	17.0	4.8	14.9	3 to 1	473.8	137.6
	Sludge Press	8	10.6	8.9	4.6	14.2	3 to 1	292.3	77.5

Typically, agricultural-based digestions (manures and fodder waste) will have BMPs around between 150 and 350 mL/g VS, and are thought to be of the lower value of substrate for AD systems. Kafle and Chen (2016) found that dairy manure, horse manure, and swine manure had BMPs of 204, 155, and 323 mL/g VS respectively. For waste-water treatment samples, Filer et al (2019) found that primary sludge had ~470 ml/g VS. There will be obvious differences between primary and secondary sludges due to the microbial activity in these systems.

Digestion #1 -- Samples collected January 17, 2020

Total accumulation of biomethane over the 12-day digestion are illustrated in Figure 1 below. The feedstock results presented in the graph present the biomethane produced from the samples (inoculum control has been subtracted from the total amount).

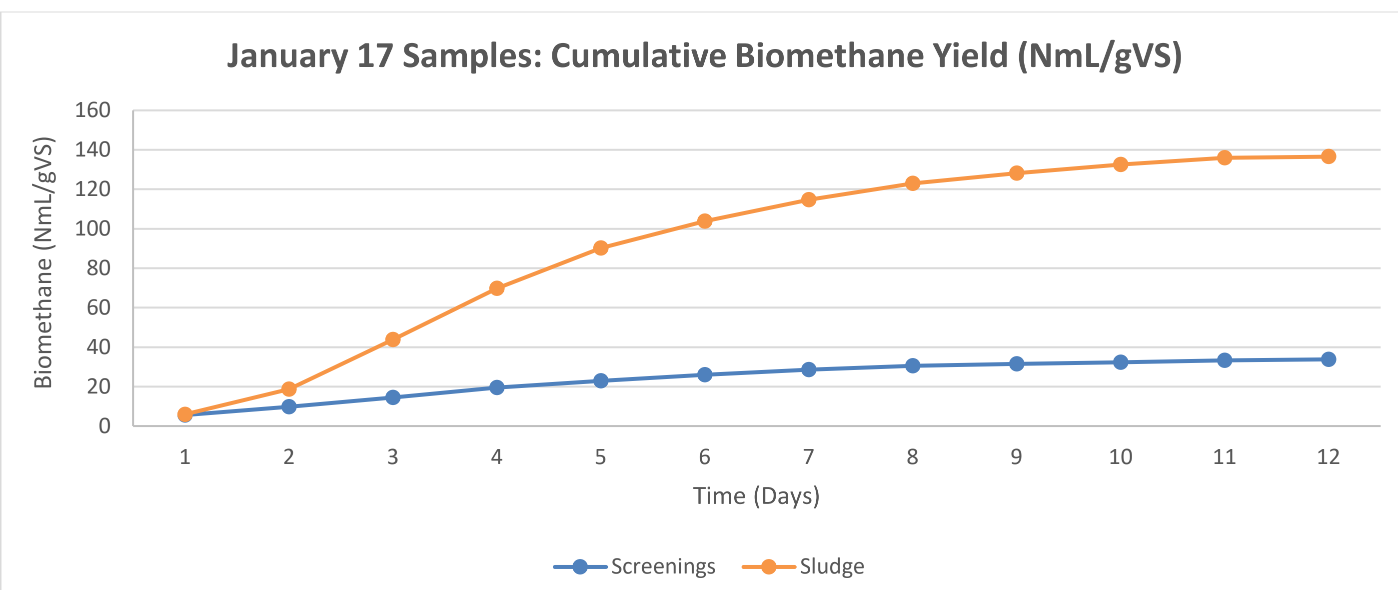

Figure 1: Accumulation of biomethane from samples collected January 17, 2020 (inoculum subtracted).

The first digestions with screenings had too thick a consistency for adequate mixing to optimize the contact with the inoculum, and were therefore run a second time with modified solids to inoculum ratio. Literature suggests that without mixing there is an approximate 50% decrease in biomethane production (Rojas et al., 2010 and Shanmugam et al., 2018). It was important to adjust the mix ratio for screening in a co-digestion with other lower solid substrates, as the screenings are on the high end of solids for a liquid based digestor, as indicated by the increased biomethane potential of Figure 2.

It is possible that the low volumes of biomethane produced from the screenings was due to an overloaded ratio of substrate solids to inoculum. For single substrate runs, often the inoculum requires a longer lag time to adapt. The system in Figure 1 may have been in the process of adaption to the excess single substrate to make use of the volatiles for biogas production combined with the challenges for the motors to stir the solution, it is therefore assumed the BMP of screenings may be slightly lower than maximum in this run. Sludge samples showed reasonably good BMP values, and it is possible that the lagoon sludge sample provided some inherent sources of bacterial colonies (assuming some secondary processing) capable of breaking down the substrate.

Figure 2 presented below illustrates the daily accumulation of biomethane from the two feedstocks in run #2. As with the previous figure, the inoculum control has been subtracted from the daily accumulation.

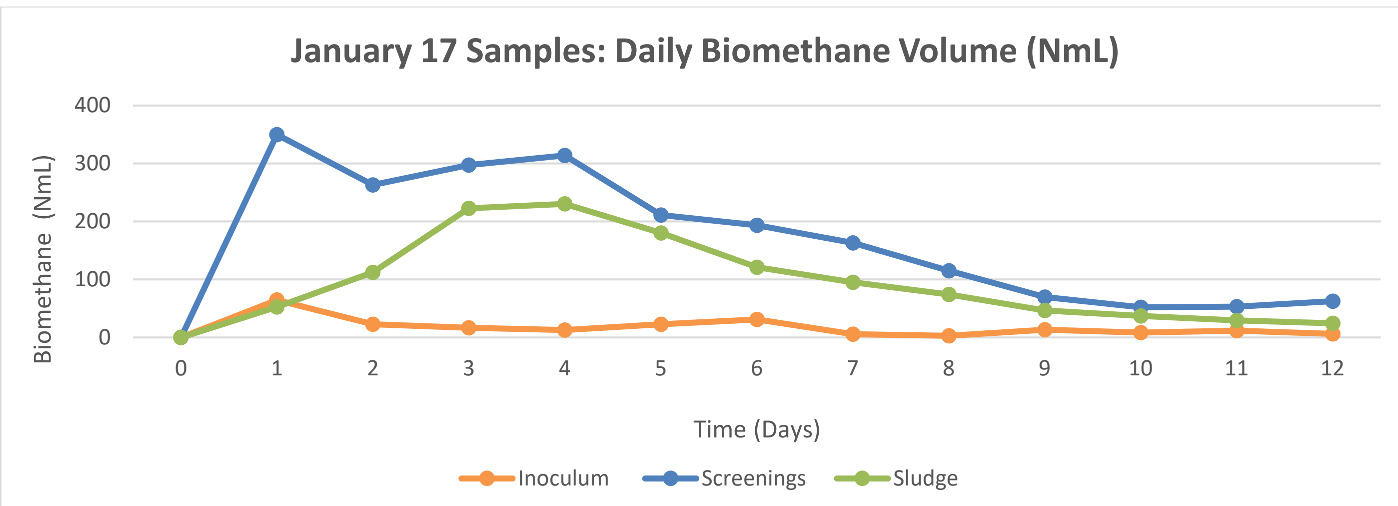

Figure 2: Daily volume of biogas produced from samples collected on January 17, 2020 (inoculum subtracted).

It would appear as though the digestion was reaching a point of completion by day 12; however, a typical digestion would usually run for at least 30 days.

Digestion #2 – Samples Collected March 5, 2020

Figure 3 shows the cumulative BMP for the second batch of samples over the first 8 days of the run, expressed per g of volatile solids. This run had to be terminated after day 8 due to the facility closure as a result of the pandemic, and so stopped before peak production. It can be seen that relative to typical manure based substrates these are relatively low.

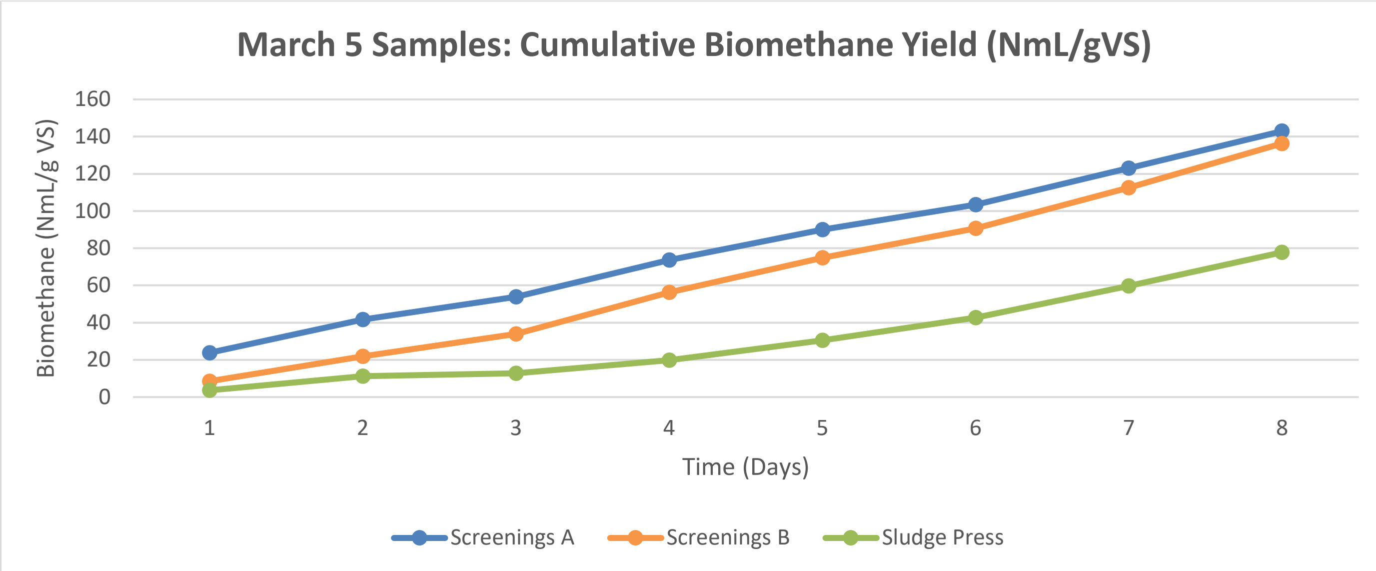

Figure 3: Accumulation of biomethane from samples collected March 5, 2020 (inoculum subtracted).

When comparing these results to results from the previous digestion, the BMP of the screenings (both A and B) are considerably higher at approximately 140 NmL/g VS versus only 34 NmL/g VS from the first digestion. It's assumed that this is in part due to a more reasonable inoculum to substrate ratio combined with better mechanical stirring of the lower solids mixture. This must be a consideration in any projections for BMP capacity in a true digester scenario.

The sludge press at 77 NmL/g VS did not perform as well as the Lagoon Sludge, which had a BMP of 139 NmL/g VS.

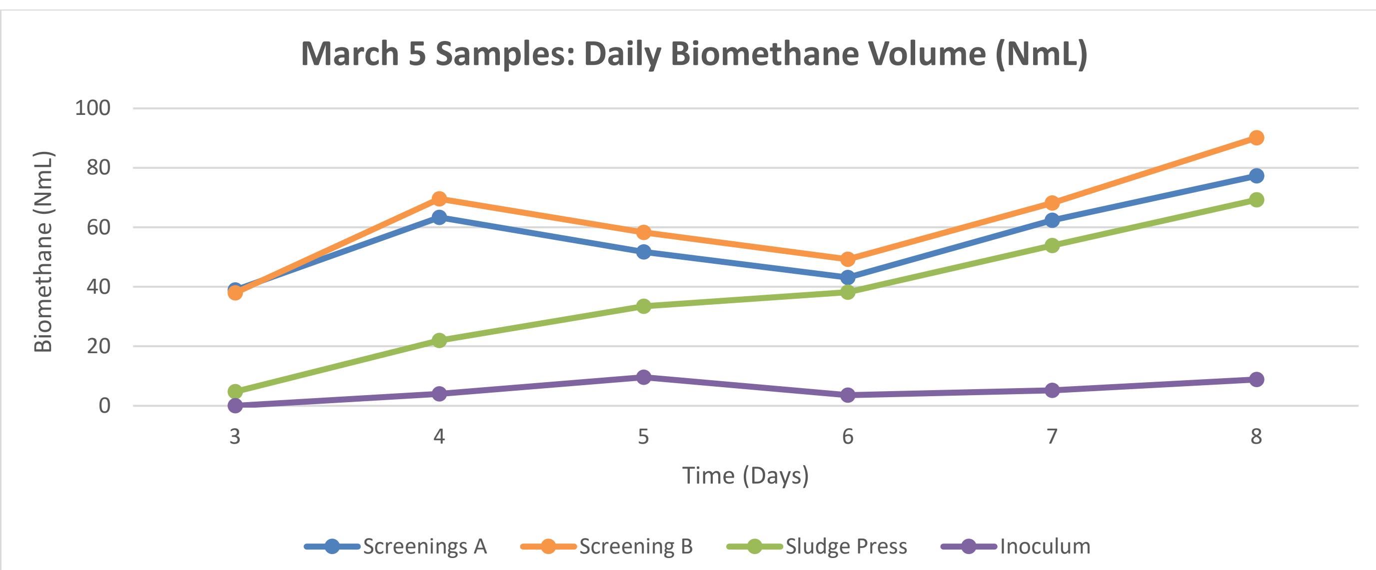

Figure 4: Daily volume of biogas produced from samples collected on March 5, 2020 (inoculum subtracted).

It is clear in Figure 4 that daily biomethane production was still increasing for all samples on day 8 of this digestion and may present greater potential with longer HRT (hydraulic retention time) in the digester, however, all substrates would likely perform better in a co-digestion scenario, particularly the screenings at such high solids content.

Extractable Metals

For total acid extracted metal amounts, the following tables highlight ICP-MS results from the microwave assisted digestion of the four feedstocks.

Table 3: Microwave digested ICP-MS analysis of total acid extracted metals.

Collection Date	Sample	Total Mass measured (mg)	Total acid extracted metals in sample (%)	Total potential acid extracted metals (mg)	Total acid extracted metals dry basis (%)	Total acid extracted metals dry basis (mg/kg)
January 17 2020	Screenings A	11.71	22.3	20.1	0.8	8.0
January 17 2020	Lagoon Sludge	7.14	14.8	159.0	10.9	108.6
March 5 2020	Screenings B	11.39	22.6	20.3	0.8	8.1
March 5 2020	Sludge Press	10.59	17.4	186.3	12.7	127.3

Table 4: Microwave digested ICP-MS analysis of potential feedstocks

	January 17 2020		March 5 2020	
Parameter	Screenings A	Lagoon Sludge	Screenings B	Sludge Press
Dry Matter (%)	13.2	6.0	17.5	10.6
Mg (%)	0.09	0.95	0.08	2.17
Al (%)	0.05	5.28	0.05	2.02
Si (%)	0.02	0.22	0.03	0.30
Ca (%)	0.53	0.73	0.54	3.31
Ti (%)	---	0.10	---	0.13
Fe (%)	0.08	3.47	0.09	4.02
Cr (%)	---	0.01	---	0.02
Mn (%)	---	0.05	---	0.32
Co (%)	---	---	---	---
Ni (%)	---	---	---	0.01
Cu (%)	---	0.02	---	0.20
Zn (%)	0.01	0.04	---	0.16
As (%)	---	---	---	---
Sr (%)	---	0.01	---	0.03
Mo (%)	---	---	---	---
Ag (%)	---	---	---	---
Cd (%)	---	---	---	---
Sn (%)	---	---	---	---
Pb (%)	---	---	---	---

To further illustrate the ICP-MS results, Table 4 shows the percent amount of various metals for both feedstocks. Results show that there is very little metallic residues in both the screenings and in the lagoon sludge. Because there is so little metal contained in the sample, the bulk of it is considered organic. However, there was non-acid soluble residue remaining after the digestion which is most likely quartz (SiO_2). These are relevant as it pertains to disposal of residual digestate post AD.

Overall, results showed that magnesium, aluminum, calcium, and iron were in the highest abundance in the samples.

These results suggest that both samples of Screenings had similarly low levels of extractable metals. They also suggest the Sludge Press has more concentrated levels of extractable metals when compared to both Lagoon Sludge and Screenings.

In Conclusion.

Overall the two sludge samples showed lower BMP per gram of VS, than the screenings, likely since some partial digestion occurs even through primary separation and some secondary sedimentation treatments, and as a result of a lower total volatile solids content. None of the samples are particularly high in VS, and as such show fairly low BMP potential relative to typical manure-based substrates. Often, synergies can be achieved through co-digestion of substrates, or addition of higher BMP capacity substrates such as FOG (fats oil and grease), which are often available in close proximity. Should the goal be to maximize biogas production, then co-digestion would be advised.

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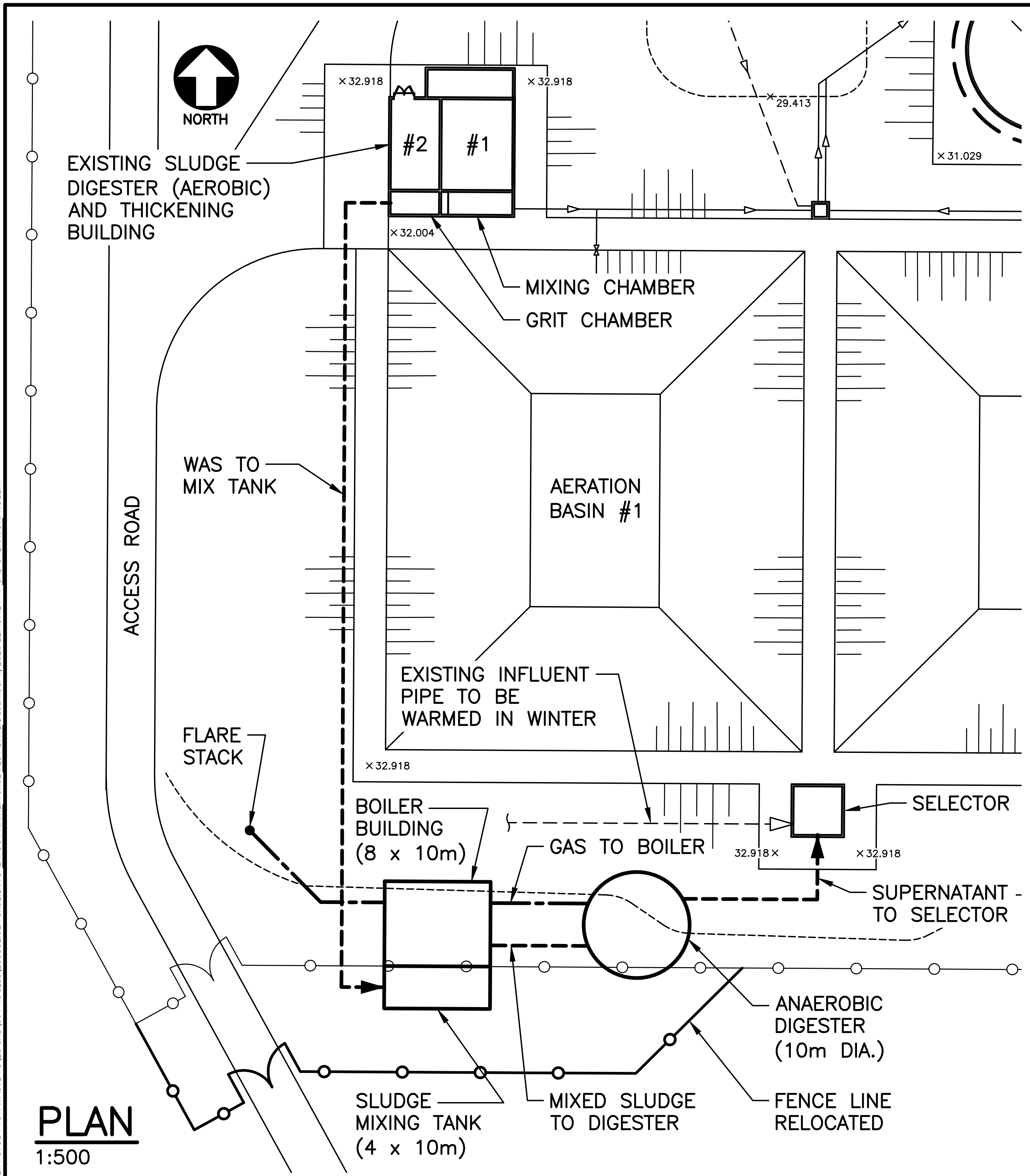
APPENDIX B

Sketches of Options



A	ISSUED FOR DRAFT REPORT - SEP 29/20	B	ISSUED FOR REPORT - DEC 07/20		
No.	Description	No.	Description	No.	Description

Date	Scale	Designed	Drawn	Checked	Approved	CBCL No.	Contract
DEC 07/20	1:500	SE	NHM	-	-	200801.01	-

CBCL

MUNICIPALITY OF THE COUNTY OF KINGS
WASTE TO ENERGY FEASIBILITY STUDY

OPTION 1
PROPOSED ANAEROBIC DIGESTER

Drawing
PSK01

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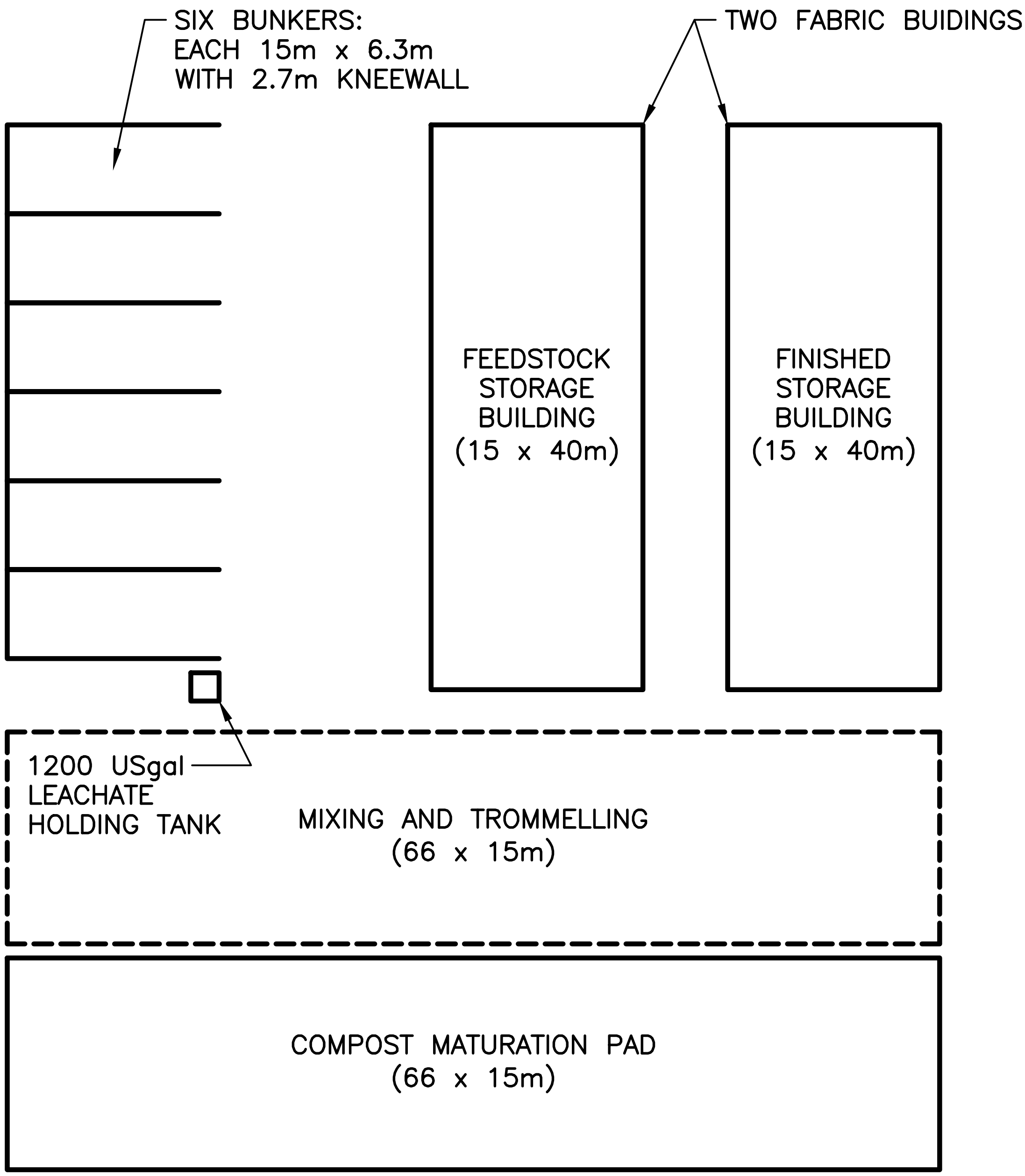

PLAN
1:500

No.	Description	No.	Description	No.	Description
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Date	Scale	Designed	Drawn	Checked	Approved	CBCL No.	Contract
DEC 07/20	1:500	SE	NHM	-	-	200801.01	-

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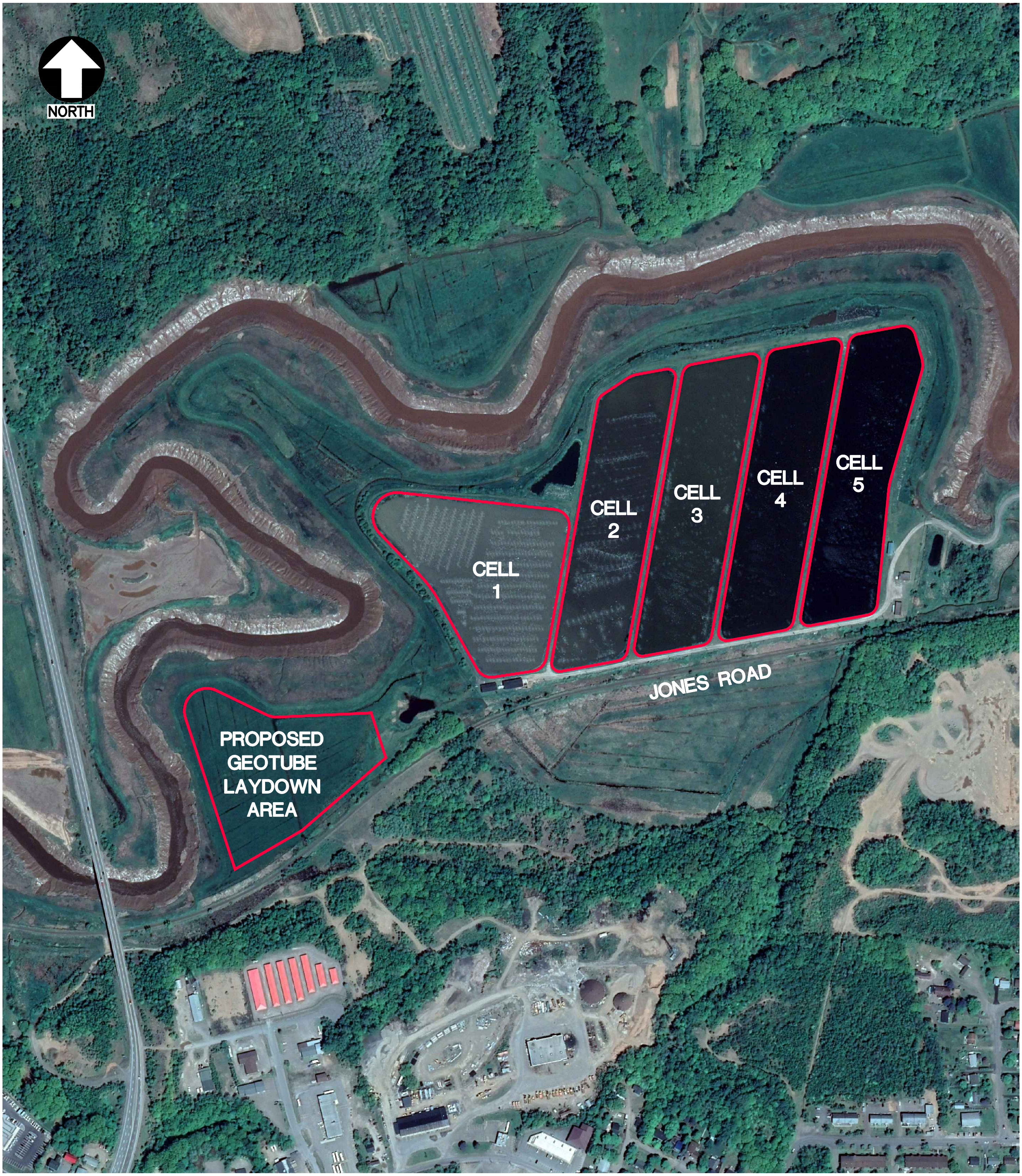
MUNICIPALITY OF THE COUNTY OF KINGS
WASTE TO ENERGY FEASIBILITY STUDY

OPTION 2
PROPOSED COMPOSTING FACILITY

Drawing
PSK02



No.	Description	No.	Description	No.	Description
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Date	Scale	Designed	Drawn	Checked	Approved	CBCL No.	Contract
DEC 07/20	N.T.S.	SE	NHM	-	-	200801.01	-

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MUNICIPALITY OF THE COUNTY OF KINGS
WASTE TO ENERGY FEASIBILITY STUDY

OPTION 3A & 3B
DREDGING AND DEWATERING

Drawing

PSK03

DRAWING NAME: K:\PROJECTS\200801.01 MOK - FEASIBILITY STUDY FOR WASTE TO\20 CAD\06 PROCESS\200801.01 PSK03.DWG LAYOUT NAME: PSK03 PLOT DATE:December 4, 2020 1:02:02 PM CAD OPERATOR: NOELM

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