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# Memorandum

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| To | Cameron Baughen, RDOS Solid Waste Management Coordinator<br>Mitch Moroziuk, City of Penticton General Manager of Infrastructure<br>Ian Chapman, City of Penticton City Engineer<br>Len Robson, City of Penticton, Manager of Public Works<br>Randy Craig, City of Penticton AWWTP Supervisor | Page | 1 |
| CC | | | |
| Subject | City of Penticton AWWTP – Co-Digestion Feasibility Assessment | | |
| From | Piero Galvagno, AECOM<br>Brandon Stearns, AECOM | | |
| Date | July 18, 2016 | Project Number | 60481460 |

The Regional District of Okanagan-Similkameen (RDOS) is developing a regional strategy that includes diverting food waste from the landfills and improved methods for handling of biosolids. An option of interest is the co-digestion of food waste and biosolids at the Penticton Advanced Wastewater Treatment Plant (AWWTP) which has the potential benefit of diverting food waste from the landfill as well as generating renewable energy in the form of biogas. This report documents the results of a co-digestion feasibility assessment scenario located at the Penticton AWWTP. The objective of the assessment is to provide an estimate of the mass of potential food waste and biosolids for co-digestion; volume of post-process solids streams for disposal or composting; capital/operating costs and revenues; and tipping fees for food waste disposal by private haulers. In addition, a conceptual design level layout of the major process components and on-site traffic flow is provided.

## 1. Wastewater Biosolids & Food Waste Substrate Projections

The primary objective of this task is to establish the volumes of potential biosolids and food waste sources that would be appropriate for digestion. This assessment serves as the basis for preliminary sizing of the digesters and associated supporting process components.

The current assessment is based on a 30 year life-cycle. This timeline is a realistic estimate of the operating life of the glass coated steel digester tanks and equipment which form principle process components of the co-digestion system. As a consequence, 30-year future food waste and biosolids substrate loading projections have been developed for the assessment.

### *1.1 Food waste*

RDOS' Regional Waste Management Strategy (RWMS) indicates that food waste makes up approximately 18% of the total generated solid waste and originates from both residential and commercial sources (CH2M, 2010). Based on Tetra Tech's most recent assessment (2014), the available food waste (assuming 65% diversion) within the Campbell Mountain Landfill catchment is estimated to be 6,104 ton/year (Tetra Tech, 2014). This estimate includes organics-soiled paper and other un-digestible single-use products and is derived from the RWMS. The RWMS solid waste characterization was extrapolated from audits conducted at other landfills in the Okanagan and does not allow for a detailed break-down of the various constituents. For the purposes of this feasibility study, it is assumed that 70% of the diverted organics can be recovered for digestion. Therefore, of the estimated 6,104 tons/year diverted organics, 4,272 tons/year or 11.7 $m^3$/day (assuming a density of 1,000 kg/$m^3$) is assumed to be recoverable substrate for the anaerobic digestion process. An audit of the Campbell Mountain Landfill municipal solid waste stream is required if co-digestion is selected for more detailed consideration.


Under a scenario where food waste is diverted to a centralized co-digestion facility, the organics are either collected at-source or through a system of neighbourhood collection points. The collection program adopted will ultimately determine the proportion of food waste that is actually diverted. The diversion rate will depend on how convenient it is for the consumer to dispose of their source-separated organics. For drop-off depots where the consumer must drive to a centralized site, the diversion rate may not exceed 25% whereas a curbside collection programme supported by education programmes can achieve participation rates of 90% (CH2M, 2010). The diversion rate of 65% on which the Tetra Tech (2014) food waste estimates are based assumes a good level of success and over time there is opportunity to achieve higher rates.

The RDOS' 2010 Regional Organic Waste Management Strategy projects an average annual growth of 0.53% in the volume of food waste substrate to 2020. For this analysis, a growth rate of 1.0% will be used. The higher growth rate in available food waste assumes that in time education and acceptance of food waste separation will increase and provide for a higher diversion from the assumed 65% target.

### *1.2 Biosolids*

The Penticton AWWTP currently dewaters fermented primary sludge (FPS) and thickened waste activated sludge (TWAS) using a centrifuge to produce a cake at an average totals solids (TS) content of 18%. The dewatered cake is transported to the Campbell Mountain landfill where it is composted. An estimate of the daily sludge feed was based on 2014 summary data provided by the City for the number of bins shipped to the Campbell Mountain landfill and an average FPS and TWAS mixed sludge solids content of 4.5%. Since the City has only recently commissioned its new primary sludge fermenter, there is limited data on mixed sludge solids characteristics. The 4.5% TS value is based on data taken from the City of Kelowna's mixed sludge feed characteristics. In year 2014, the average mass of cake shipped to composting was 24,500 kg/d (8,940 $m^3$/d ÷ 365.25 d * 1,000 kg/$m^3$). Based on this value, the year 2014 estimated mixed sludge (FPS and TWAS) flow is 98.2 $m^3$/d (24,500 kg/d * 18% cake solids ÷ 4.5% mixed sludge).

The wastewater generation growth rate for the City of Penticton was projected to be 2.5% per year based on the current Liquid Waste Management Plan (LWMP). However the actual growth rate in wastewater flow over the last 5-10 years has been relatively stagnant. The projected growth in wastewater flow was assumed to occur as both organic population growth within the existing sewered area and expansion of the sewer system to include un-sewered areas. Additional capacity was also allocated to allow for sewer extensions to include Penticton Indian Band (PIB) lands. Servicing of PIB lands has not occurred as expected but this is likely a result of a delay rather than a fundamental change in the development plans. The recently completed Okanagan River bridge at Green Avenue to access PIB lands and new residential construction west of the airport are indications that the potential for growth persists. For the purposes of this feasibility assessment, digestion capacity will be based on an assumed 2.5% annual growth rate in wastewater flow to the AWWTP and therefore biosolids production.

### *1.3 Substrate Characteristics*

In the absence of specific digestibility characteristics of food waste and biosolids, a review of available literature and lab data was undertaken. Recent digestion studies undertaken at the University of British Columbia using mixed sludge and dewatered cake from the City of Kelowna was also used as a basis for design. Table 1 provides a summary of the assumed sludge and food waste characterization. If the co-digestion project advances to subsequent design stages additional lab analyses is required to confirm these assumptions.

Table 1 – Wastewater biosolids and food waste characteristics

| Substrate | pH | Total Solids (TS) | Volatile Solids (VS) | Chemical Oxygen Demand (COD) | Reference |
|---|---|---|---|---|---|
| | | % | VS/TS % | g/kg | |
| Food Waste | 5.0 | 22% | 91% | 220 | Koch, K. et al, 2016; Tampio, E. et al, 2014 |
| Mixed Sludge | 5.5 | 4.5% | 83% | 42 | UBC Lab using City of Kelowna sludge |
| Cake | 6.0 | 18% | 84% | 200 | UBC Lab using City of Kelowna sludge |

## 2. Anaerobic Digestion Process Configuration Options

The anaerobic degradation of a complex wastewater or sewage sludge is a multi-step process comprising four major reactions as illustrated in Figure 1. Complex organic polymers in the waste are first hydrolysed by extracellular enzymes of facultative or obligate anaerobic bacteria. The hydrolysis step provides monomeric/oligomeric constituents small enough to allow transport across the cell membrane. These simple soluble compounds are then fermented, or anaerobically oxidised, to short chain fatty acid intermediates, alcohols, carbon dioxide, hydrogen and ammonia (acidogenesis). The short chain fatty acids (other than acetate) are converted to acetate, hydrogen and carbon dioxide (acetogenesis). Finally, methanogenesis occurs from carbon dioxide reduction by hydrogen, and form acetate resulting in the methane and carbon dioxide mixture that constitutes biogas.

Anaerobic digestion is a multi-step biodegradation process with the hydrolysis being the slowest and therefore the overall rate limiting step. The various anaerobic digestion processes have configurations which all achieve the digestion objective but have subtle differences which relate to the material to be digested, the level of volatile solids reduction, biogas generation potential and final biosolids quality.

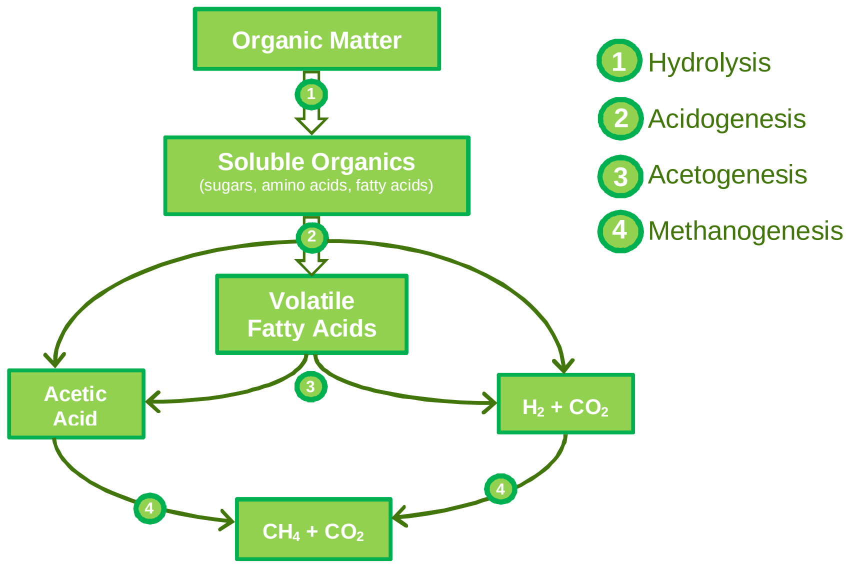


Figure 1 - Stages of Anaerobic Digestion

Selection of the appropriate digestion process for the Penticton AWWTP will need to address the following priorities, operating realities and desirable features:

1. Odour emissions – the close proximity of businesses and homes (<200m) makes minimizing nuisance odour discharges a high priority;
2. Robust and stable – digestion process must be able to accommodate food waste which consists of complex organics and will enter the site intermittently;
3. Flexible – the process should allow for growth in the City and surrounding area;
4. Environmentally sustainable – where possible, selection of processes which allow for beneficial reuse of recovered resources (ie, biogas, nutrients) is desirable; and
5. Cost effective – to benefit the community, the process must be affordable.

Descriptions of potential digestion technologies suitable for the City of Penticton AWWTP co-digestion facility, along with considerations related to the above objectives are discussed below.

## *2.1 Psychrophilic Anaerobic Digestion*

Psychrophilic anaerobic digestion consists of processing sludge in large, covered lagoons. Generally, the waste stream enters one end of the lagoon and is removed at the other. The digestion process operates at psychrophilic (<20°C) temperatures which are seasonally dependent.

The low biomass concentration and temperatures in a lagoon results in low solids conversion to biogas. Periodically the lagoons must be cleaned out due to solids accumulation. This activity results in a considerable amount of lost energy potential along with a much higher risk of odour discharges.

The lagoon covers have a large area and are generally fragile. If not completely air-tight, ingress of oxygen can result in the development of an explosive atmosphere or more likely generation of odours.

While the existing lagoons could be retrofitted to serve as psychrophilic digesters, their close proximity to businesses and homes combined with the potential risks of odour make this option a poor fit for the Penticton AWWTP.

### *2.2 Single Stage Mesophilic Anaerobic Digestion*

Mesophilic anaerobic digestion (MAD) is a simple, proven process for digestion of waste sludge at municipal wastewater treatment plants. Under the MAD process, waste sludge (<10% dry solids but normally 5 – 6%) is maintained at approximately 35 - 37°C for 16-20 days under anaerobic conditions in large (generally) cylindrical vessels. MAD is a common digestion process and was the basis for the digestion process originally used at the Penticton AWWTP for digestion of primary fermented sludge.

Under MAD condition, typical loading rates of 2.5 - 2.7 kg of volatile solids (VS) per cubic metre of reactor per day will result in a volatile solids destruction of 50-60%.

In order to maintain mesophilic temperatures, a heat exchanger or supplemental heat source is required.

### *2.3 Single Stage Thermophilic Anaerobic Digestion*

In contrast to MAD which is operated at 35°C, thermophilic anaerobic digestion (TAD) systems, are maintained at a higher temperature (50 – 57°C) for between 12 and 16 days. Similar to MAD, sludge (normally 5 – 6%) is fed to a digester that is comprised of cylindrical vessels.

The higher temperatures operated in the TAD system has several benefits including increased solubility of organic compounds, enhanced biological and chemical reaction rates, and an increased death rate of pathogens. The increased reaction rate results in a reduced HRT requirement and therefore a smaller footprint when compared to MAD. The use of thermophilic temperatures however has a higher energy requirement, a lower quality supernatant with larger quantities of dissolved solids and ammonia, a higher odour potential, and poorer process stability requiring greater operator care and attention.

As with mesophilic digestion, a heat exchanger or supplemental heat source is required.

### *2.4 Temperature Phased Anaerobic Digestion (Mesophilic or Thermophilic)*

Advanced two-tank digestion processes operating in series have been developed to combine the benefits of MAD and TAD processes. By partially separating these phases, the bacteria involved in each phase can operate under conditions that are closer to ideal and therefore the overall process is improved in terms of biogas production and volatile solids destruction.

For the Penticton AWWTP co-digestion application, a thermophilic stage followed by a mesophilic stage has the potential to reduce sludge odour which is common for a single-stage thermophilic process. The initial thermophilic stage of the process also has the capability of achieving high pathogen destruction.

The expectation is that the co-digested sludge will be dewatered and then composted. This exposes the sludge to pasteurization temperature and results in the pathogen destruction necessary to achieve Class A Compost status under the British Columbia Organic Matter Recycling Regulation (OMRR). However, in theory a TAD process could achieve a Class A Biosolids objective if direct application of the sludge was a desirable option in the future. Therefore, given the benefits of reduced odour potential and higher loading rates, the staged thermophilic-mesophilic process would be a good future upgrade option if direct land application were ever a consideration.

## *2.5 Acid Phased Digestion*

The acid phase anaerobic digestion (APAD) process involves separation of the hydrolysis and acidogenesis stages of anaerobic digestion into a pre-treatment stage that is installed in front of conventional mesophilic or thermophilic anaerobic digestion process. Its function is to provide optimum conditions for the groups of bacteria which break down constituents of sludge into volatile fatty acids which are then converted to biogas in the subsequent anaerobic digestion plant.

As APAD takes advantage of the fact that the acid forming bacteria have a much higher growth rate than the methanogens, the initial reactor can be much smaller than the subsequent methane producing digester. As a result, APAD offers greater efficiency in the size of the anaerobic digesters. Additionally, multi-stage systems provide some protection against a variable organic loading rate as the more sensitive methanogens are buffered by the first stage.

Typically, the first acid phase tank is operated at an SRT of 1-3 days to achieve hydrolysis and volatile fatty acid production without methanogenic biogas production. As a consequence, the acid stage does not include biogas capture but does have a high foul air generation potential, much like the existing primary sludge fermentation process used at the Penticton AWWTP.

## *2.6 High Rate Granular Sludge or Fixed Film Anaerobic Digestion*

High rate anaerobic digestion processes typically involve techniques to increase the sludge retention time of the anaerobic biomass to allow a greater hydraulic or substrate loading. Since the anaerobic biomass does not form a well-settling conventional floc, the most successful approaches involve introducing media to provide for fixed-film growth. Up-flow processes that promote granule sludge also have excellent potential. These high rate processes are well suited to wastewaters with a high proportion of dissolved COD. Substrate feed with high solids content, like waste activated sludge or primary sludge, would tend to plug the media or impede the formation of granules. Consequently, these high rate contact processes are not suitable for a sludge substrate.

## *2.7 Short-listed Option Used as a Basis for the Cost Estimate*

Given the above considerations identified above, a MAD process would likely be the most appropriate technology to implement for the Penticton AWWTP co-digestion facility. The mesophilic process provides the best approach for minimizing odour, simple operation and stability. To provide for redundancy and sludge attenuation, a two tank process would be preferred. The first tank could operate under a variable liquid level and allow for a nearly constant, balanced feed to the second tank operating under a full liquid level. Under this scenario, any sludge pumped from the first digester tank would overflow digested sludge in the second digester tank to the dewatering centrifuges.

# 3. Scope of the Selected Co-Digestion Option

This section identifies the scope of the proposed option based on the major components and key considerations for co-digestion of food waste and biosolids using a MAD process at the Penticton AWWTP. For the purposes of this feasibility assessment, the calculated reactor volume will be assumed to be split between two tanks and operated in series. By operating the tanks in series, short-circuiting is minimized and volatile solids destruction is optimized. Furthermore, if additional digestion capacity or pathogen destruction were required, the first stage could be converted to a thermophilic process.

## *3.1 General Description and Sizing*

Design loading rates for the two stage mesophilic co-digestion system is provided in Table 2, based on existing substrate loading estimates and assumed future growth. The calculated reactor volumes assumes the introduction of dilution water as part of the food waste pre-treatment to provide for an overall solids loading concentration of 6%. Mixing efficiency decreases and becomes more challenging for total solids loading greater than 6% resulting in process instabilities and loss of performance.

Table 2 – Total Substrate Loading and AD Reactor Sizing

| Substrate | Year 1 | | | Year 30 | | | Reactor Design | |
|---|---|---|---|---|---|---|---|---|
| | Substrate Loading | Dilution Water | Total | Substrate Loading | Dilution Water | Total | Stage 1 Volume | Stage 2 Volume |
| | $m^3/d$ | $m^3/d$ | $m^3/d$ | $m^3/d$ | $m^3/d$ | $m^3/d$ | $m^3$ | $m^3$ |
| Food Waste | 11.70 | 7.2 | 18.9 | 15.8 | 9.7 | 25.5 | | |
| Mixed Sludge | 107.2 | 0.0 | 107.2 | 188 | 0.0 | 188 | | |
| Total | 119 | 7.2 | 126 | 203 | 9.7 | 213 | 2,130 | 2,130.0 |

The sludge retention time (SRT) was selected to be 20 days which is at the high end of the design range for mesophilic digesters. The longer SRT will ensure the complex organics associated with the food waste will be have sufficient time to degrade.

A preliminary layout of the co-digestion process components is provided as Figure 2. In addition, Figure 3 is a process flow diagram showing how the various substrate feeds would be incorporated into the digestion scheme, as well as the residual waste streams produced by the process.

## *3.2 Food Waste Off-loading & Pre-treatment*

The food waste off-loading facility forms part of the building expansion. Under this co-digestion scenario, trucks carrying food waste would enter the facility and follow the same route as the septage trucks. A scale is provided to allow taring of the truck weights. From here the trucks would back into the building and once the over-head doors have closed would off-load food waste into a pit. A conveyor would carry food waste to a specialized pulper (Figure 4) that separates and removes the inorganics, including plastics, fibres, grit, etc. Pre-treated food waste would be pumped to a sludge blend tank and mixed with TWAS and FPS prior to being fed to the digester. The blend tank minimizes variable hydraulic and organic loading.

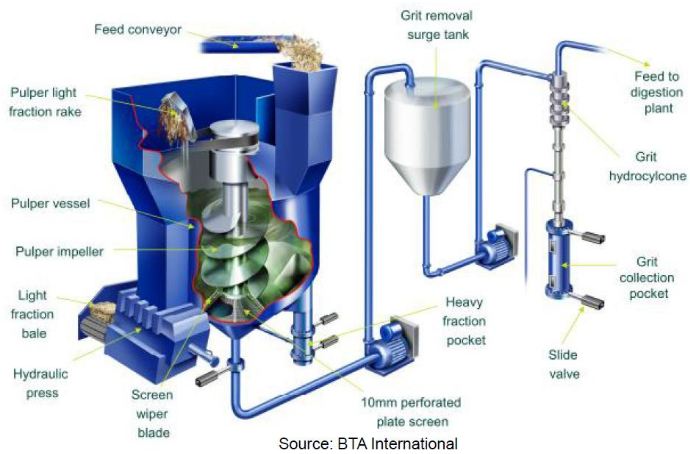


Figure 4 – Food waste pre-treatment

The success of the co-digestion scheme will be heavily influenced by the effectiveness of the food waste pre-treatment. Food waste can contain a variety of inorganic material that could affect the digester performance or reduce the quality of the final composted biosolids. In addition, a high performance pre-treatment stage can allow for acceptance of a more diverse waste stream, thereby increasing the diversion rate. The pulper depicted in Figure 4 is designed to remove plastics and allow for bagged food waste and diapers. At the Toronto food waste digestion facility, the flexibility in source separation that arises as a consequence of using an effective pulper has led to a diversion rate greater than 70%.

### *3.3 Integration with Existing Site*

In order to minimize the future impacts on the existing AWWTP, the food waste pre-treatment and digestion reactors are located adjacent to the existing biosolids processing area. This feature minimizes the conveyance distance of feed and waste sludge and allows a more centralized approach of foul air treatment. The additional tanks and building do not impinge on the future ability of the City to upgrade its mainstream wastewater treatment process.

The existing dewatered cake is pumped by means of progressive cavity pumps from the Sludge Dewatering Building to a bin room in the Sludge Treatment Building. With digestion, it is expected that the dewatered cake TS concentration will increase from the current 18% to at least 25%. The existing cake pumping system will not be able to accommodate the higher solids concentration. To provide for the higher cake solids concentration, a new bin room is proposed for the new Food Waste Building which would be located adjacent to the existing centrifuge room. The close proximity will eliminate the need for the cake pump system and will involve a much simpler screw conveyor and drop chute to load the bins.

With the provision of a new bin loading area, the existing bin room could be utilized for locating supporting processes and pumping.

### 3.4 Odour Control

The main sources of foul air discharge will occur as part of the unloading and pre-treatment of food waste and loading of dewatered sludge. The anaerobic digester is assumed to have a fixed roof and therefore, would be sealed with biogas conveyed to a scrubber to remove sulphides, as well as carbon dioxide, siloxanes and water vapour.

To minimize the potential for emissions of odours, the following approach is recommended:

1. Design the Food Waste Building to operate under negative pressure;
2. The air supply for each of the process areas should draw from an adjacent room (ie, air supply for a room with high odour potential draws from a room with low odour potential);
3. Provide point source extraction from equipment with high odour potential (ie, food unloading area, pulper, blend tank);
4. Provide redundant ventilation air fans to minimize the bypass of foul air if one of the fans fails; and
5. Provide fast opening and closing overhead doors for the Food Waste Building to minimize emissions.

The proposed Food Waste Building air is assumed to be exhausted to a wet trickling filter scrubber for humidification and attenuation of the hydrogen sulphide load prior to treatment in a biofilter. The proposed system is similar to the existing AWWTP odour treatment system.

Given the proximity of the proposed facility in relation to residential development, odour control is a high priority for the City. To establish confidence in odour mitigation strategies and better understand the impacts of odour, City staff would like to view first hand similar installations in similar proximity to people.

### 3.5 Centrate Treatment

The post co-digestion dewatering is expected to have significantly higher dissolved nutrients than the current centrate. The mainstream process would potentially become overwhelmed if the digested sludge centrate is returned untreated to the mainstream process, causing final effluent nutrient concentrations to exceed permitted levels. Research at UBC Okanagan has shown that an anaerobic ammonia oxidizing (anammox) process combined with a struvite precipitation stage and followed by polishing with poly aluminum chloride (PACL) will reduce the dissolved nitrogen and phosphorus concentration to pre-digestion levels. Consequently, this centrate treatment process train is included as part of the assumed co-digestion facility. The costing assumes that the two decommissioned fermenters could be re-purposed for the anammox process with the struvite recovery process incorporated into the Sludge Treatment Building.

Waste activated sludge (WAS) stripping was assumed to be included as part of the current assessment. WAS stripping involves exposing the waste sludge to fermented sludge or fermented sludge supernatant to stimulate phosphate release prior to thickening by the dissolved air flotation (DAF). Under this design condition, the DAF underflow would be routed to the struvite precipitator to remove phosphate, thereby reducing phosphate release in the digester and the potential for uncontrolled struvite precipitation in the anaerobic digesters. As a further benefit, WAS stripping allows for a mechanism for returning additional VFAs bound up in the fermented primary sludge, if required.

VFA's in the fermented sludge used to initiate WAS phosphate release would be elutriated in the DAF and returned to the mainstream process with the DAF underflow.

### *3.6 Struvite Recovery*

A struvite recovery process is able to remove up to 90% of the phosphate in the digested sludge centrate while allowing for recovery and beneficial reuse of nutrients. The capital and operating cost of a struvite precipitation process has been included as part of the co-digestion option. Struvite is an equimolar precipitate of ammonium, phosphate and magnesium ($NH_4MgPO_4 \cdot 6H_2O$). The struvite process is designed to remove 80-90% of the centrate phosphate but has a secondary benefit of producing a slow-release fertilizer suitable for agricultural and domestic reuse. The struvite reactor is specifically designed to optimize the formation of struvite and produce particles that can be dried and used as a conventional, slow-release fertilizer. If supplemented with potash the fertilizer is able to supply all the macro-nutrients necessary for growing most crops, including turf grass. The two most common struvite process configurations currently used in North America are sold by Ostara and Multiform Harvest. The Multiform process is a single pass, flow-through system that produces a struvite product that has the consistency of medium to fine sand (0.5 mm). A heater is used to dry and sterilize the struvite. Ostara also sells a similar struvite process that is designed to produce relatively large struvite granules (0.9 – 3 mm). However, compared to the Multiform reactor the Ostara process requires a longer retention time, a recycle pump and larger reactor size. The costing used in this assessment is based on the Multiform Harvest process which is sized for WAS stripping

The costing assumes that the struvite produced as part of the co-digestion process would be sold in bulk quantities back to Harvest Multiform for processing into value-added products (ie, fertilizer spikes, broadcast pellets, etc.). In addition, it is assumed that part of the upgraded struvite production would be purchased back by the City as a turf fertilizer for its parks. A similar fertilizer product is sold wholesale by a local supplier for $1,200/tonne. For this assessment, an average value of $750/tonne is used.  The projected centrate volume and nutrient concentration is expected to produce 89 tonnes of struvite in the first year which represents revenue of $67,000. The revenue from the struvite reactor will balance the additional costs associated with operating the struvite reactor.

Compared with the alternative approach of using a chemical coagulant for control of the centrate phosphate, struvite precipitation provides good long-term value. Based on the estimated centrate flow, the annual chemical supply cost of dosing with an aluminum-based coagulant is estimated to be $60,000 in the first year and would increase with sludge loading. In addition to added operational cost, the aluminum sludge could negatively impact the quality of final composted biosolids in the long-term. Dosing with an alternative coagulant like calcium hydroxide (lime) would avoid the biosolids quality impacts but requires a higher chemical dose, larger chemical storage facilities and potentially post-coagulation pH adjustment to mitigate impacts on the mainstream treatment process. The coagulant dosing option could be revisited in more detail in subsequent design stages but for this feasibility assessment, struvite recovery is used as the basis for the cost estimate.

### *3.7 Biogas Utilization*

The co-digestion option assumes that the biogas generated by the anaerobic digestion process will be upgraded to biomethane. Biogas consists of approximately 66% methane and has significant energy potential. The remaining 34% consists of primarily of carbon dioxide ($CO_2$) with a smaller proportion of impurities such as hydrogen sulphide ($H_2S$), siloxanes and water vapour. A variety of potential options is available for utilizing the biogas. However, each option necessitates providing different biogas pre-treatment. Currently, the pre-treatment option that derives the most potential for reuse and revenue potential is to upgrade the biogas to utility grade biomethane. Achieving utility grade biomethane involves the removal of $CO_2$ and other impurities to greater than 95% methane content. The refined biomethane can then be sold to Fortis for distribution or compressed and used as a vehicle fuel.

Implementing a biogas upgrade option to produce utility-grade biomethane has the highest capital cost but also the highest potential for revenue. For example, Fortis currently will pay $11 - $13/GJ for upgraded biomethane based on a 25 year contract. Fortis re-sells the biomethane to utility customers as a sustainably produced, carbon neutral heat energy source (Fortis, 2016). Based on the year 1 biogas generation estimate of 3,830 $m^3$/d, energy density of 0.024 GJ/m3 and a recoverable methane content of 85% through the upgrader, the digestion system can be expected to produce an average of 78.2 GJ/d of utility-grade biomethane (ie, 3,830 $m^3$ biogas/d * 0.024 GJ/$m^3$ biogas * 85% recovery). At a rate of $12/GJ, the revenue potential is $343,000 for the first year of operation (ie, 78.2 GJ/d * $12/GJ * 365.25 d/y). For comparison, biogas could also be used to generate heat and electricity (co-gen) using a reciprocating engine for a similar capital cost investment but higher operational and maintenance costs. The revenue potential from electricity sales from a co-gen scenario would be $228,000/year, based on an average 3,830 $m^3$/d biogas production, a typical electricity conversion rate of 35% and electricity value of $0.07/kWh, (ie, 3,830 $m^3$ biogas/d * 0.024 GJ/$m^3$ * 277.7 kWh/GJ * 35% conversion * $0.07/kWh * 365.25 d/y).

To capitalize on the potential revenue associated with selling biomethane to Fortis, the cost of incorporating a biogas upgrader will be used as the base option for this assessment.

The tipping fee estimate would be influenced by the revenue potential which could change as the supply of biomethane increases in the coming years. To address this issue, a low market price for upgraded biomethane is used to allow a high and low range to be calculated for the tipping fee – this is discussed in more detail in Section 4.

### *3.8 City-RDOS Operational Considerations*

Lab-scale research and experience from full-scale facilities shows that anaerobically digested sludge is able to be composted and achieve thermophilic temperatures to meet Class A standards for pathogenic reduction (Callahan, 2015; Epstein, 1976). The benefits of composting digested sludge over raw sludge include:

1. **Reduced composting time and increased compost facility capacity** - pile temperatures for digested sludge increase faster than raw sludge resulting in more through-put. The Mechanicsburg, PA (USA) facility achieves full compost stabilization (active aeration plus curing) of digested sludge on average in 35 days (Callahan, 2015). Composting raw sludge in the Okanagan usually occurs over a 56 day cycle (Kelowna, 2016).

2. **Lower carbon (wood chip) amendment requirements** – digestion partially stabilizes the biosolids through TS and VS reduction, resulting in a solids volume reduction of 40-50% and similar nitrogen profile. Assuming the same carbon amendment to sludge volume is targeted, the wood chip volume requirement would be reduced by a similar amount as the total solids reduction.

3. **Less odour emissions potential** – digestion destroys a large fraction of the volatile solids compounds in raw sludge that have historically resulted in a high foul air emissions potential at the Campbell Mountain compost facility.

The average day Year 1 combined food waste and mixed sludge solids loading to the digester is estimated to be 7,400 kg/d (dry). This value is calculated based on the characteristics defined in Table 1 and Table 2 ([11.7 $m^3$/d * 22% TS food waste + 107 $m^3$/d * 4.5% TS mixed sludge] * 10 kg/$m^3$/%). Based on a typical total solids reduction value of 45% for mesophilic digestion (Metcalf & Eddy, 2014), the Year 1 digested total solids would be 3,340 kg/d or 1,220 tonnes/y. Assuming that centrifuged digested sludge is able to achieve an average cake solids concentration of 28% (ibid.), the annual production of biosolids for composting would be 4,360 tonnes/y. For comparison, 8,940 tonnes/y of dewatered biosolids was transported to the Campbell Mountain compost facility in year 2014. As a consequence, the volume of dewatered biosolids for composting would be reduced by more than 50%.

As part of the food waste pre-treatment process, secondary waste streams will be produced. The light waste residue is typically composed of inorganic material, predominately plastic bags. The heavy waste residue consists of grit, metal and glass, bone fragments, etc. The pulper equipment is designed to wash and compact the waste residual material. Based on operating data for the Toronto food waste digestion facility, approximately 20% of raw collected source separated organics by weight is waste residue. Therefore, in order to provide for the food loading estimates in Table 2, the Year 1 light and heavy waste residue would be approximately 2,900 kg/d or 1,060 tonnes/y.

# 4. Probable Costs of the Proposed Option

## *4.1 Capital Cost Estimate*

Class D conceptual capital cost estimates for two options are provided in Attachment 1 and were developed based on the proposed option and the associated process selections identified in Section 3.

Option 1 capital cost scenario includes provision for an upgrader to allow for sale of biomethane to Fortis. Biogas would be collected and conveyed to the biomethane upgrader. Under this option, a heat pump using final effluent as a heat source is assumed to provide the primary source of supplemental maintenance heating for the digesters. The cost of a sludge heat exchanger and effluent heat pump is included in the Option 1 upgrade capital cost estimate.

For the Option 2 capital cost scenario, the biomethane upgrader is dropped in favour of a biogas fired boiler. The heat generated from the boiler would be used to keep the mesophilic digesters at the 35-37˚C temperature range. Any surplus biogas would be burned in the flare stack. This option reduces the up-front capital costs associated with the biomethane upgrader and effluent heat pump but eliminates the potential biomethane revenue stream

Provision for a flare stack is included in both options to allow for safe disposal of biogas in the event of an equipment failure and is consistent with the digester gas code (ANSI/CSA B149.6-15).

Including a construction and engineering contingency of 35%, the total capital cost is estimated to be $23,092,000 for the biomethane upgrader option (Option 1) and $19,697,000 for the biogas boiler option (Option 2).

The cost estimates are considered to be accurate within minus 15% to plus 50% in accordance with the guidelines published in ASTM E-2516 “Standard Classification for Cost Estimate Classification System” for a project that is defined 1% to 15% of complete definition (Estimate Class 4). Additional effort specific to risk mitigation will be required to better refine the cost estimate should the project progresses through subsequent design development stages.

### *4.2 Unaccounted Capital Cost Savings*

The capital cost estimates do not reflect the property value that would otherwise need to be purchased to provide for a co-digestion system. In addition, the estimates do not include provision for the savings associated with re-purposing existing equipment, building space and tanks. In particular,

- the two decommissioned fermenters identified as process tanks for the centrate treatment process;
- building space currently utilized for sludge loading is designated for pumps and struvite recovery in the co-digestion scheme; and
- use of the existing centrifuge decanter equipment to dewater digested food waste.

Accounting for the value of these items should be assessed in more detail, along with any composting process savings associated with the digestion process.

### *4.3 Annualized Costs and Tipping Fee Estimate*

Calculated annualized capital and operational costs are used to assess the tipping fee charged to dispose of food waste and biosolids at the co-digestion facility in the first year of operation. The annualized capital cost was calculated using a discount rate of 2.2% and return period of 30 years.

Operational costs include cost of increased labour to manage the new co-digestion facilities; cost of chemicals, including dewatering polymer and magnesium chloride for struvite precipitation; heat and power; and provision for an annual equipment replacement fund. In addition, the calculation also includes the revenue stream associated with struvite and biomethane.

The annualized costs do not account for the capital and operational savings that would be associated with the smaller volume of sludge needed to be transported and composted, shortened required compost time, lower odour control requirements and increase life-span of the Campbell Mountain Landfill.

Table 3 provides a summary of annualized capital and operational costs for three scenarios.

Table 3 – Annualized Costs and Estimated Tipping Fee

| Annualized Costs (Year 1) | Option 1a | Option 1b | Option 2 |
|---|---|---|---|
| | Sell upgraded biomethane at high value rate | Sell upgraded biomethane at low value rate | Use biogas for digester heating only |
| 1. Annualized Capital Cost | ($1,059,626) | ($1,059,626) | ($903,839) |
| 2. Operation & Maintenance (2 x FTE) | ($180,000) | ($180,000) | ($180,000) |
| 3. Consumables (Power & Chemicals) | ($213,137) | ($213,137) | ($120,137) |
| 4. Equipment Repair (7.5% of Annualized Capital Cost) | ($79,000) | ($79,000) | ($68,000) |
| 5. Administration & Overhead (18% of Costs) | ($275,700) | ($275,700) | ($229,000) |
| *Sub-Total* | *($1,807,463)* | *($1,807,463)* | *($1,500,976)* |
| **Annualized Estimated Revenue (Year 1)** | **Option 1a** | **Option 1b** | **Option 2** |
| 1. Biogas sale | $342,608 | $109,742 | $0 |
| 2. Struvite sale | $67,050 | $67,050 | $67,050 |
| *Sub-Total* | *$409,658* | *$176,792* | *$67,050* |
| Total (Annualized Costs/Savings) | ($1,397,804) | ($1,630,671) | ($1,433,926) |
| **Calculated Proportion of Total Solids Loading** | | **All Options** | |
| Food waste | | 35% | |
| Bisolids | | 65% | |
| **Estimated Food Waste Tipping Fee for Year 1 ($/tonne)** | **Option 1a** | **Option 1b** | **Option 2** |
| All Costs Recouped by Food Waste Tipping Fees Only (No Grant Funding) | $327 | $382 | $336 |
| Grant Funding Received to Cover Sewer Utility Portion of Capital Costs (ie, 65% of Capital Costs) | $137 | $191 | $173 |

Option 1 is divided into two subsets, Option 1a and Option 1b. Option 1a assumes that the renewable, carbon neutral methane is sold to Fortis at the current price of $12/GJ. Based on a production rate of 78.2 GJ/d of upgraded biomethane the revenue is $343,000.

Option 1b assumes that due to increased supply, the unit value of renewable methane decreases to $2.3/GJ (ie, the current market price of conventionally produced natural gas). The revenue under this scenario assuming production of 78.2 GJ/d of upgraded biomethane is $65,700 (ie, 78.2 GJ/d * $2.3/GJ *365.25 d/y). It is further assumed that biomethane production can be used by the City and result in a savings of the BC Carbon Tax which currently amounts to $0.057/m$^3$ methane. Based on a biogas production of 3,830 m3/d, methane content of 65% and recoverable methane of 85%, the BC Carbon Tax would be $44,100 (ie, 3,830 m$^3$ biogas/d * 65% $CH_4$ * 85% recoverable $CH_4$ *$0.057/m$^3$ $CH_4$ * 365.25 d/y). The total value of the biomethane assuming revenue based on the market rate of conventional natural gas plus the Carbon Tax savings amounts to $109,700 (ie, $65,700 + $44,000). The reduced biogas revenue potential in Option 1b increases the tipping fee estimate for food waste co-digestion.

Capital and operating costs for Option 2 are based on a co-digestion system where the raw biogas is burned in a boiler to heat the digester or in the flare stack, thereby obviating the need for a biomethane upgrader and effluent heat pump. Under this option, heating costs for the digester were eliminated since biogas would be used for this purpose and the revenue stream associate with sale of biomethane would be zero.

The annualized costs also include provision for an 18% administration fee to cover the City of Penticton's overhead expenses associated with operating the co-digestion facility.

Based on the foregoing considerations and associated analyses, the tipping fee estimate for food waste is estimated to be between $327 and $336 per tonne of food waste in the first year. This tipping fee calculation assumes that either Option 1a or Option 2 would be pursued, depending on the market price of upgraded biomethane. While the capital cost of Option 1a is greater than Option 2, the higher revenue potential associated with the sale of biomethane results in a lower overall total annual cost for Option 1a. In addition, the estimate assumes that all costs would be recouped through food waste tipping fees. This meets the criteria established by the City to have zero financial impact on sewer user fees. The City of Penticton would not be interested in pursuing a co-digestion system unless the sewer utility's portion of the capital was paid for by food waste tipping fees or Provincial/Federal grants.

For comparison, if grants were received to cover the sewer utility portion of the capital costs (ie, 65% of the total), the food waste tipping fees would be reduced to between $137 and $173/tonne.

To serve as a comparison, the current landfill tipping fee is $95/tonne.

It is expected that the availability of grant funding and changing market rate for biomethane will change the co-digestion strategy that would be pursued. In the absence of grant funding and decreasing biomethane pricing, Option 2 is probably the most likely option. Grant funding geared towards carbon reduction would favour Option 1a.

# 5. Conclusions

The current feasibility study provides a high-level overview for a potential co-digestion scenario at the City of Penticton AWWTP to allow food waste to be diverted from the Campbell Mountain Landfill. Food waste collected as part of a curb-side food waste program would be trucked to the Penticton AWWTP, pre-treated to remove any inorganics or heavy waste fractions, mixed with wastewater sludge and fed to a set of mesophilic digesters. The tipping fee will depend on the revenue potential for the biogas methane and recovered struvite product and may change as market rates change. Based on an assessment of capital and operating costs, the tipping fee for food waste would be $327 - $336/tonne based on a wet solids fraction. This estimate assumes that all capital and operating costs would be recovered through food waste tipping fees, thereby resulting in no increase to the City's sewer user fees. If grants were received to cover the sewer utility portion of the capital costs (ie, 65% of the total), the food waste tipping fees would be reduced to between $137 and $173/tonne.

The cost estimates considered as part of this assessment do not include off-site works. In particular, the following are not included in the cost estimate:

1. program costs for developing the curb-side source separated organics program;
2. capital and operational cost savings on the Campbell Mountain Landfill associated with food waste diversion;
3. savings and costs associated with trucking and composting the dewatered, co-digested sludge;
4. disposal costs for inorganic waste (ie, washed and dewatered light and heavy fractions) generated as part of the food waste pre-treatment process; and

5. capital cost savings associated with not needing to purchase land and re-purposing existing WWTP process equipment and building space.

# 6. References

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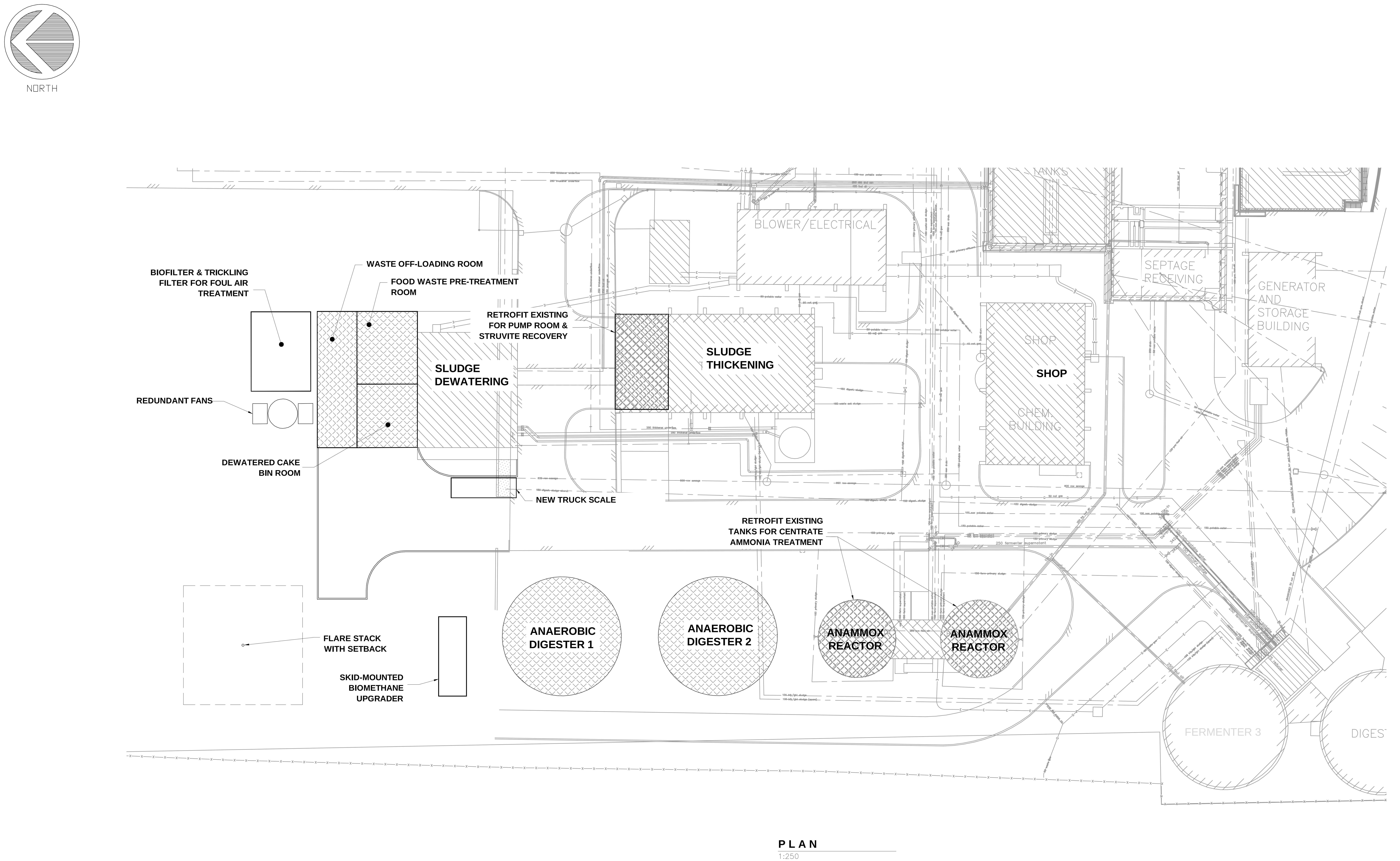



**PLAN**
1:250

NEW BUILDING STRUCTURE

| REV | DESCRIPTION | DRN | CHK | DATE (Y/M/D) |
| --- | --- | --- | --- | --- |
| A | WORK IN PROGRESS | KJW | PG | 2016/01/XX |

DRN BY: KJW
DES BY: PG
CHK BY: PG
APP BY: RDB

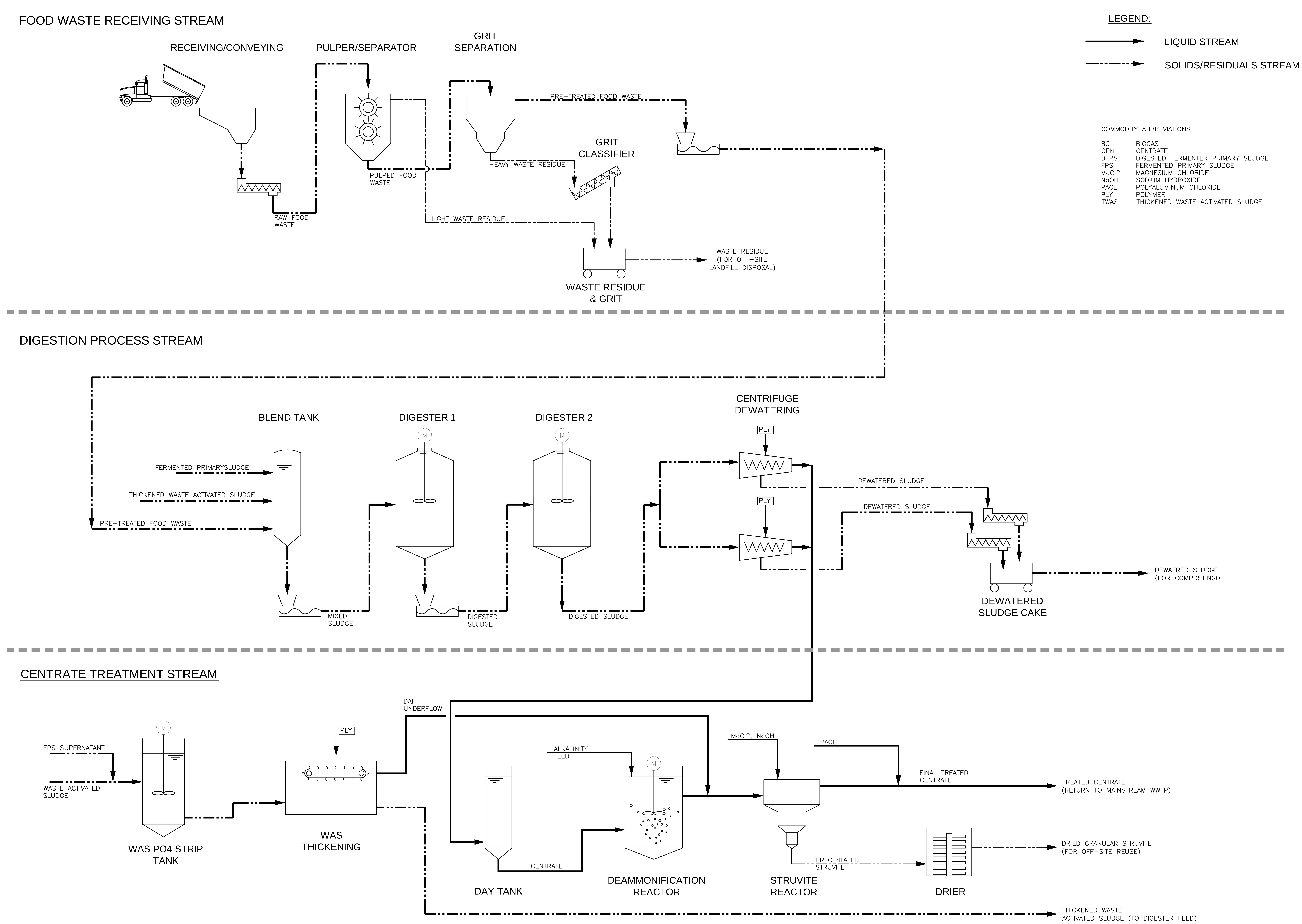
PREPARED FOR: THE CITY OF Penticton

PREPARED BY: AECOM

CITY OF PENTICTON
AWWTP UPGRADE
PENTICTON, B.C.

FIGURE 2
PROPOSED CO-DIGESTION FACILITY LAYOUT

PROJECT START DATE (M/Y) JANUARY 2016
PROJECT NO. XX
FILENAME CODIG FIG 2.dwg
SHEET NO.
DRAWING NO. FIG 2




| REV | DESCRIPTION | DRN | CHK | DATE (Y/M/D) |
|---|---|---|---|---|
| A | WORK IN PROGRESS | KJW | PG | 2016/01/XX |

DRN BY: KJW
DES BY: PG
CHK BY: PG
APP BY: RB

PREPARED FOR: THE CITY OF Penticton

PREPARED BY: AECOM

# CITY OF PENTICTON AWWTP UPGRADE PENTICTON, B.C.

## FIGURE 3 PROPOSED CO-DIGESTION FLOW SCHEMATIC

PROJECT START DATE (M / Y) JANUARY 2016

PROJECT NO. XX

FILENAME CODIG FIG 3.dwg

SHEET NO.

DRAWING NO. FIG 3

Plotted By: GalvagnoP Plot File Date Created: Feb/22/2016 3:19 PM
Layout-Sheet Name: G1-001
Filename: P:\60481460\900-WORK\910-CAD\20-SHEETS\1-GENERAL\CODIG FIG 3.DWG

# ATTACHMENT 1

# Capital Cost Estimates

**Regional District of Okanagan Similkameen** March 1, 2016
**Pentiction Co-Digestion Assessment**

## Option 1 Capital Cost Estimate - Upgrade Biogas and Sell Biomethane at Premium Price

| ITEM | | DESCRIPTION | UNITS | COST/UNIT | QUANTITY | | ESTIMATE |
|---|---|---|---|---|---|---|---|
| **1.0** | **DIVISION 1 - GENERAL REQUIREMENTS** | | | | | | |
| | | | | **SUB-TOTAL DIVISION 1** | | **$** | **350,000** |
| **2.0** | **DIVISION 2 - SITE WORKS** | | | | | | |
| | .1 | Demolition and Removal | LS | $20,000 | 1 | $ | 20,000 |
| | .2 | Excavation | LS | $100,000 | 1 | $ | 100,000 |
| | .3 | Dewatering | LS | $5,000 | 1 | $ | 5,000 |
| | .4 | Yard Piping (incl. Site Utilities) | LS | $50,000 | 1 | $ | 50,000 |
| | .5 | Asphalt Paving (Driveway) | $m^2$ | $20 | 1000 | $ | 20,000 |
| | .6 | Landscaping | LS | $2,000 | 1 | $ | 2,000 |
| | | | | **SUB-TOTAL DIVISION 2** | | **$** | **197,000** |
| **3.0** | **DIVISION 3 - CONCRETE** | | | | | | |
| | .1 | Foundation slab for new food waste process building | LS | $120,000 | 1 | $ | 120,000 |
| | .2 | Foundation slab for digester tank | LS | $120,000 | 2 | $ | 240,000 |
| | .3 | Foundation slab for acid phase tank | LS | $90,000 | 1 | $ | 90,000 |
| | .4 | Retrofit existing fermenters as process tanks | LS | $150,000 | 1 | $ | 150,000 |
| | .5 | Other Structures | LS | $50,000 | 1 | $ | 50,000 |
| | | | | **SUB-TOTAL DIVISION 4** | | **$** | **650,000** |
| **4.0** | **DIVISION 4 - MASONRY** | | | | | | |
| | .1 | Masonry block construction | $m^2$ | $600 | 400 | $ | 240,000 |
| | | | | **SUB-TOTAL DIVISION 4** | | **$** | **240,000** |
| **5.0** | **DIVISION 5 - METALS** | | | | | | |
| | .1 | Glass-coated steel tank, incl. cover and insulation (Meso-phase) | LS | $700,000 | 2 | $ | 1,400,000 |
| | .2 | Day tank | LS | $50,000 | 1 | $ | 50,000 |
| | .3 | Building roof structure (metal/wood truss system) | LS | $150,000 | 1 | $ | 150,000 |
| | .4 | Miscellaneous metals | LS | $75,000 | 1 | $ | 75,000 |
| | | | | **SUB-TOTAL DIVISION 5** | | **$** | **1,600,000** |
| **6.0** | **DIVISION 6 - WOODS AND PLASTICS** | | | | | | |
| | .1 | Miscellaneous walls & framing | LS | $100,000 | 1 | $ | 100,000 |
| | | | | **SUB-TOTAL DIVISION 6** | | **$** | **100,000** |
| **7.0** | **DIVISION 7 - THERMAL AND MOISTURE PROTECTION** | | | | | | |
| | .1 | Insulated standing seam metal roof | $m^2$ | $200 | 325 | $ | 65,000 |
| | | | | **SUB-TOTAL DIVISION 7** | | **$** | **65,000** |
| **8.0** | **DIVISION 8 - DOORS AND WINDOWS** | | | | | | |
| | .1 | Windows, doors and hardware | LS | $100,000 | 1 | $ | 100,000 |
| | | | | **SUB-TOTAL DIVISION 8** | | **$** | **100,000** |
| **9.0** | **DIVISION 9 - FINISHES** | | | | | | |
| | .1 | Paints and finishes | LS | $80,000 | 1 | $ | 80,000 |
| | | | | **SUB-TOTAL DIVISION 9** | | **$** | **80,000** |
| **10.0** | **DIVISION 10 - SPECIALTIES** | | | | | | |
| | | | | **SUB-TOTAL DIVISION 10** | | **$** | **-** |
| **11.0** | **DIVISION 11 - PROCESS** | | | | | | |
| | .1 | Organics pulper (c/w grit separator, compactor & critical redundancy) | LS | $1,700,000 | 1 | $ | 1,700,000 |
| | .2 | Air blower, diffusers and mixer for anammox SBR | LS | $350,000 | 1 | $ | 350,000 |
| | .3 | AD tank mixers (LMM) | LS | $200,000 | 2 | $ | 400,000 |
| | .4 | Heat pump and exchanger | LS | $650,000 | 1 | $ | 650,000 |
| | .5 | Process pumps | LS | $200,000 | 1 | $ | 200,000 |
| | | | | **SUB-TOTAL DIVISION 11** | | **$** | **3,300,000** |
| **12.0** | **DIVISION 13 - SPECIALTY EQUIPMENT** | | | | | | |
| | .1 | Foul air treatment system (c/w tanks & covers) | LS | $1,100,000 | 1 | $ | 1,100,000 |
| | .2 | Truck pad & scale | LS | $100,000 | 1 | $ | 100,000 |
| | .3 | Flare stack | LS | $300,000 | 1 | $ | 300,000 |
| | .4 | Skid-mounted biomethane upgrader | LS | $1,215,000 | 1 | $ | 1,215,000 |
| | .5 | Struvite precipitator & drier | LS | $2,100,000 | 1 | $ | 2,100,000 |
| | | | | **SUB-TOTAL DIVISION 13** | | **$** | **4,815,000** |
| **13.0** | **DIVISION 14 - CONVEYING SYSTEMS** | | | | | | |
| | .1 | Food waste feed to pulper | LS | $50,000 | 1 | $ | 50,000 |
| | .2 | Dewatered cake loading | LS | $75,000 | 1 | $ | 75,000 |
| | | | | **SUB-TOTAL DIVISION 14** | | **$** | **125,000** |
| **14.0** | **DIVISION 15 - MECHANICAL** | | | | | | |
| | | | | **SUB-TOTAL DIVISION 15** | | **$** | **2,740,000** |
| **15.0** | **DIVISION 16 - ELECTRICAL** | | | | | | |
| | | | | **SUB-TOTAL DIVISION 16** | | **$** | **1,870,000** |
| **16.0** | **DIVISION 17 - INSTRUMENTATION** | | | | | | |
| | | | | **SUB-TOTAL DIVISION 17** | | **$** | **870,000** |
| | | | | **SUB-TOTAL - DIVISION 1 to 17** | | **$** | **17,102,000** |
| | | | | Engineering (15%) | | $ | 2,570,000 |
| | | | | Construction Contingency Allowance (20%) | | $ | 3,420,000 |
| | | | | **TOTAL COST ESTIMATE (EXCLUDING TAXES)** | | **$** | **23,092,000** |

**Regional District of Okanagan Similkameen** March 1, 2016
**Penticton Co-Digestion Assessment**

## Option 2 Capital Cost Esimate - Use Biogas for Digester Heat Only

| ITEM | | DESCRIPTION | UNITS | COST/UNIT | QUANTITY | | ESTIMATE |
|---|---|---|---|---|---|---|---|
| **1.0** | **DIVISION 1 - GENERAL REQUIREMENTS** | | | | | | |
| | | | | | **SUB-TOTAL DIVISION 1** | **$** | **290,000** |
| **2.0** | **DIVISION 2 - SITE WORKS** | | | | | | |
| | .1 | Demolition and Removal | LS | $20,000 | 1 | $ | 20,000 |
| | .2 | Excavation | LS | $100,000 | 1 | $ | 100,000 |
| | .3 | Dewatering | LS | $5,000 | 1 | $ | 5,000 |
| | .4 | Yard Piping (incl. Site Utilities) | LS | $50,000 | 1 | $ | 50,000 |
| | .5 | Asphalt Paving (Driveway) | $m^2$ | $20 | 1000 | $ | 20,000 |
| | .6 | Landscaping | LS | $2,000 | 1 | $ | 2,000 |
| | | | | | **SUB-TOTAL DIVISION 2** | **$** | **197,000** |
| **3.0** | **DIVISION 3 - CONCRETE** | | | | | | |
| | .1 | Foundation slab for new food waste process building | LS | $120,000 | 1 | $ | 120,000 |
| | .2 | Foundation slab for digester tank | LS | $120,000 | 2 | $ | 240,000 |
| | .3 | Foundation slab for acid phase tank | LS | $90,000 | 1 | $ | 90,000 |
| | .4 | Retrofit existing fermenters as process tanks | LS | $150,000 | 1 | $ | 150,000 |
| | .5 | Other Structures | LS | $50,000 | 1 | $ | 50,000 |
| | | | | | **SUB-TOTAL DIVISION 4** | **$** | **650,000** |
| **4.0** | **DIVISION 4 - MASONRY** | | | | | | |
| | .1 | Masonry block construction | $m^2$ | $600 | 400 | $ | 240,000 |
| | | | | | **SUB-TOTAL DIVISION 4** | **$** | **240,000** |
| **5.0** | **DIVISION 5 - METALS** | | | | | | |
| | .1 | Glass-coated steel tank, incl. cover and insulation | LS | $700,000 | 2 | $ | 1,400,000 |
| | .2 | Day tank | LS | $50,000 | 1 | $ | 50,000 |
| | .3 | Building roof structure (metal/wood truss system) | LS | $150,000 | 1 | $ | 150,000 |
| | .4 | Miscellaneous metals | LS | $75,000 | 1 | $ | 75,000 |
| | | | | | **SUB-TOTAL DIVISION 5** | **$** | **1,600,000** |
| **6.0** | **DIVISION 6 - WOODS AND PLASTICS** | | | | | | |
| | .1 | Miscellaneous walls & framing | LS | $100,000 | 1 | $ | 100,000 |
| | | | | | **SUB-TOTAL DIVISION 6** | **$** | **100,000** |
| **7.0** | **DIVISION 7 - THERMAL AND MOISTURE PROTECTION** | | | | | | |
| | .1 | Insulated standing seam metal roof | $m^2$ | $200 | 325 | $ | 65,000 |
| | | | | | **SUB-TOTAL DIVISION 7** | **$** | **65,000** |
| **8.0** | **DIVISION 8 - DOORS AND WINDOWS** | | | | | | |
| | .1 | Windows, doors and hardware | LS | $100,000 | 1 | $ | 100,000 |
| | | | | | **SUB-TOTAL DIVISION 8** | **$** | **100,000** |
| **9.0** | **DIVISION 9 - FINISHES** | | | | | | |
| | .1 | Paints and finishes | LS | $80,000 | 1 | $ | 80,000 |
| | | | | | **SUB-TOTAL DIVISION 9** | **$** | **80,000** |
| **10.0** | **DIVISION 10 - SPECIALTIES** | | | | | | |
| | | | | | **SUB-TOTAL DIVISION 10** | **$** | **-** |
| **11.0** | **DIVISION 11 - PROCESS** | | | | | | |
| | .1 | Influent pulper, grit separator & washer/compactor | LS | $1,700,000 | 1 | $ | 1,700,000 |
| | .2 | Air blower, diffusers and mixer for anammox SBR | LS | $350,000 | 1 | $ | 350,000 |
| | .3 | AD tank mixers (LMM) | LS | $200,000 | 2 | $ | 400,000 |
| | .4 | Tank mixer (pitched blade) | LS | $80,000 | | $ | - |
| | .5 | Effluent heat pump and exchanger | LS | $650,000 | | $ | - |
| | .6 | Biogas fired boiler & heat exchanger | LS | $220,000 | 1 | $ | 220,000 |
| | .7 | Process pumps | LS | $200,000 | 1 | $ | 200,000 |
| | | | | | **SUB-TOTAL DIVISION 11** | **$** | **2,870,000** |
| **12.0** | **DIVISION 13 - SPECIALTY EQUIPMENT** | | | | | | |
| | .1 | Foul air treatment system (c/w tanks & covers) | LS | $1,100,000 | 1 | $ | 1,100,000 |
| | .2 | Truck pad & scale | LS | $100,000 | 1 | $ | 100,000 |
| | .3 | Flare stack | LS | $300,000 | 1 | $ | 300,000 |
| | .4 | Struvite precipitator & drier | LS | $2,100,000 | 1 | $ | 2,100,000 |
| | | | | | **SUB-TOTAL DIVISION 13** | **$** | **3,600,000** |
| **13.0** | **DIVISION 14 - CONVEYING SYSTEMS** | | | | | | |
| | .1 | Food waste feed to pulper | LS | $50,000 | 1 | $ | 50,000 |
| | .2 | Dewatered cake loading | LS | $75,000 | 1 | $ | 75,000 |
| | | | | | **SUB-TOTAL DIVISION 14** | **$** | **125,000** |
| **14.0** | **DIVISION 15 - MECHANICAL** | | | | | | |
| | | | | | **SUB-TOTAL DIVISION 15** | **$** | **2,340,000** |
| **15.0** | **DIVISION 16 - ELECTRICAL** | | | | | | |
| | | | | | **SUB-TOTAL DIVISION 16** | **$** | **1,610,000** |
| **16.0** | **DIVISION 17 - INSTRUMENTATION** | | | | | | |
| | | | | | **SUB-TOTAL DIVISION 17** | **$** | **720,000** |
| | | | | | **SUB-TOTAL - DIVISION 1 to 17** | **$** | **14,587,000** |
| | | | | | Engineering (15%) | $ | 2,190,000 |
| | | | | | Construction Contingency Allowance (20%) | $ | 2,920,000 |
| | | | | | **TOTAL COST ESTIMATE (EXCLUDING TAXES)** | **$** | **19,697,000** |