APPENDIX A7:
TM 7 – Long List Technology Screening and Alternative Evaluation

Technical Memorandum 7

Long List of Biosolids Treatment Alternatives and Detailed Evaluation of Strategies

2021 Biosolids Management Master Plan Update

November 2023

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Term or Acronym	Definition
AA	Average Annual
ATAD	Auto Thermophilic Aerobic Digestion
CO	Carbon Monoxide
CFIA	Canadian Food Inspection Agency
DT/d	Dry Tonnes per Day
FBI	Fluidized Bed Incinerator
FzA	Fertilizers Act
HSW	High Strength Waste
KG H_2O/H	Kilograms water evaporated per hour
LB H_2O/H	Pounds water evaporated per hour
MACT	Maximum Achievable Control Technology
MHI	Multiple Hearth Incinerator
mm	Millimeters
MM	Maximum Month
NASM	Non-Agricultural Source Material
NMA	Nutrient Management Act
O&M	Operating and maintenance
PPH	Pounds of Water Evaporated per Hour
RTO	Regenerative Thermal Oxidizer
SRT	Solids Retention Time
SSI	Sewage Sludge Incineration
THP	Thermal Hydrolysis Process
TPAD	Temperature-Phased Anaerobic Digestion
US EPA	United States Environmental Protection Agency
VSR	Volatile Solids Reduction
WAS	Waste Activated Sludge
WRC	Water Resource Center
WRF	Water Reclamation Facility

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Technical Memorandum 7 – Long List of Biosolids Management Alternatives and Detailed Evaluation of Strategies

QA/QC - SIGN OFF SHEET

This report has been reviewed and approved by the undersigned.

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1.0 Introduction

1.1 Background

The Region of Niagara is undertaking a biosolids and water treatment residuals management evaluation to determine the concept for meeting future solids management needs within the Region to the year 2051. The Region is serviced by ten (10) conventional wastewater treatment plants (WWTPs), one (1) future plant to serve South Niagara Falls, the lagoon plant serving Stevensville / Douglastown and six (6) water treatment plants (WTPs). The Region currently beneficially uses all the solids generated by these facilities and has not had to dispose of any biosolids by landfill.

The WWTPs include:

- Crystal Beach WWTP (Town of Fort Erie)
- Seaway WWTP (Town of Port Colborne)
- Welland WWTP (City of Welland)
- Port Weller WWTP (City of St. Catharines)
- Port Dalhousie WWTP (City of St. Catharines)
- Baker Road WWTP (Town of Grimsby)
- Anger Avenue WWTP (Town of Fort Erie)
- Niagara Falls WWTP (City of Niagara Falls)
- Niagara-on-the-Lake WWTP (Town of Niagara-on-the-Lake)
- South Niagara Falls WWTP (*Future Facility)* (City of Niagara Falls)
- Queenston WWTP (Town of Niagara-on-the-Lake)
- Stevensville /Douglastown lagoons (Town of Fort Erie)

Furthermore, six (6) water treatment plants (WTPs) service the Region's urban areas as listed below:

- DeCew WTP (City of St. Catherines)
- Grimsby WTP (Town of Grimsby)
- Niagara Falls WTP (City of Niagara Falls)
- Port Colborne (Town of Port Colborne)
- Rosehill WTP (Town of Fort Erie)
- Welland WTP (City of Welland)

The Region operates the Garner Road Biosolids Facility which serves several of the Regions WWTPs and WTPs and accepts both wastewater biosolids and water treatment plant residuals. From the Garner Road Facility, biosolids are either applied as a liquid on agricultural land or dewatered and transported by a third-party biosolids management firm, Walker Environmental, where the biosolids are further stabilized using an advanced alkaline stabilization process, N-Viro, at the Walker Environmental facility in Thorold. The N-Viro product is sold commercially as a fertilizer.

Currently all the WWTPs, except for Niagara Falls WWTP which has its own dewatering on-site, transport their solids to the Garner Road Facility as a liquid in tanker trucks. The wastewater solids are placed into the lagoons for storage and thickening. From there they are land applied as a liquid or dewatered and transported to Walker Environmental for further stabilization. The Average Annual and the Maximum Month solids generation by the 9 WWTPs that currently deliver liquid solids to the Garner Road Facility are 39 Dry tonnes per day (dt/d) and 56 dt/d, respectively. The Niagara Falls WWTP, which dewater their solids and transport directly to Walker Environmental, (Walker), generates 7 dt/d and 11 dt/d Annual Average and Maximum Month solids, respectively.

Three of the WTPs, DeCew, Grimsby and Niagara Falls, transport their water treatment residuals to the Garner Road Facility for management. The other three facilities, Port Colborne, Rosehill and Welland discharge their waste residuals into the wastewater collection system for disposal at the Seaway, Anger Avenue and Welland WWTPs, respectively. Biosolids from Seaway, Anger Avenue and Welland WWTPs are therefore a combination of digested wastewater biosolids and WTP residuals.

1.2 Purpose

The purpose of this Technical Memorandum No. 7 (TM 7) is to identify and screen technologies available to process and treat wastewater solids at the Garner Road Facility and to identify alternative strategies for managing the biosolids based on the shortlist of technologies and the market review findings (TM 9). TM 7 also describes the detailed evaluation of these strategies, and the recommended strategies to develop further. The overall goal is to provide the Region with a biosolids management strategy that will provide a dependable and cost-effective means to manage the solids generated at each facility.

2.0 Long List of Biosolids Technologies

There are many biosolids management practices and technologies, along with combinations of practices and technologies, available to municipalities for consideration. The biosolids market scan carried out in TM 9 identified the long-term biosolids management approach of continuing beneficial use of biosolids products via land application. This TM focuses on technologies to be considered at the Garner Road Facility.

The long list of technologies is grouped based on process type as follows:

1. Biological Digestion Technologies
    a) Anaerobic Digestion
        i. Thermal Hydrolysis Process (THP) Anaerobic Digestion

    Currently, the existing WWTPs are equipped with anaerobic digestion and the stabilized biosolids are trucked into the Garner Road Facility for storage and beneficial use. Biosolids at the Garner Road facility meet the NASM requirements for land application, to be documented in TM 5. For TM 7, it is anticipated that anaerobic digestion will continue to be practiced at the WWTPs and digested and stabilized biosolids will be trucked to the Garner Road Facility. As such, most digestion technologies will not be considered as a suitable technology for use at the Garner Road facility. The only digestion technology that is considered is THP, which can be implemented downstream of conventional anaerobic digestion.

2. Thermal Drying Technologies
    a) Direct Contact (Convection)
        i. Rotary Drum
        ii. Belt Dryer
        iii. Fluidized Bed

    b) Indirect Contact (Conduction)
        i. Paddle / Disc
        ii. Solar Dryer

3. Chemical Stabilization Technologies
    a) Alkaline Stabilization
        i. Alkaline Stabilization
        ii. Alkaline Stabilization with Supplemental Heat or Acid
        iii. Alkaline Stabilization with Heat and High-Speed Mixing

4. Composting

5. Thermal Conversion Technologies
    a) Incineration
    b) Gasification
    c) Pyrolysis
    d) Wet Oxidation
    e) Hydrothermal Liquification

2.1 Biological Digestion Technologies

2.1.1 Thermal Hydrolysis Process (THP)

The thermal hydrolysis process (THP) is often used to condition solids prior to anaerobic digestion. The process consists of a high-temperature, high-pressure steam, solids pre-treatment process that is installed upstream of mesophilic anaerobic digestion. The process hydrolyzes the feed solids, making them easier to digest. Hydrolyzing the solids and the resulting changes in the material's viscosity allows the anaerobic digesters downstream of THP processes to be fed at loading rates that are significantly higher than conventional high-rate digesters. The process requires pre-screening and pre-hydrolysis dewatering upstream of THP for minimizing the debris fed to the pressure vessels and to feed the system at ideal solids concentrations for optimum performance.

Cambi is the manufacturer with the greatest number of THP systems in North America. Cambi is credited with developing the original hydrolysis process prior to anaerobic digestion. Veolia has the second largest portfolio of hydrolysis systems. Other manufacturers also offer the THP technology including Haarslev, Eliquo Stulz and DMT Environmental.

The benefits of THP conditioning compared to conventional digestion include a higher loading rate to the anaerobic digestion system following hydrolysis, greater product stability, measured as Volatile Solids Reduction (VSR) through the process, improved dewaterability, which results in the reduction of the mass and volume of cake requiring transportation and a CP-1 product with no demonstrated regrowth of fecal coliform. The stabilization process associated with THP includes:

- Solids are heated in a batch mode in the THP reactors to 165°C (329°F) and held for more than 20 minutes. This provides enhanced pathogen reduction
- Digestion with THP typically achieves VSR of 55% or higher.

As an alternative to being installed upstream of digestion, THP can also be used in an intermediate configuration (between two phases of digestion) or downstream of digestion with COD rich dewatering filtrate returned to the digesters for treatment. Intermediate THP, however, requires significant digester capacity and is not considered viable for the Region of Niagara.

Figure 2-1 shows the THP system installed at the Davyhulme treatment facility in Manchester, UK.

Figure 2-1 THP system at Davyhulme, UK

A schematic showing a typical configuration for a THP, and anaerobic digestion system is provided in Figure 2-2. A key requirement of the system is steam supply for the THP unit. Steam can be generated directly by burning biogas (or natural gas), or by utilizing waste heat from an engine generator. A THP system downstream of anaerobic digestion may be considered at the Garner Road biosolids facility, rather than upstream as shown in Figure 2-2.

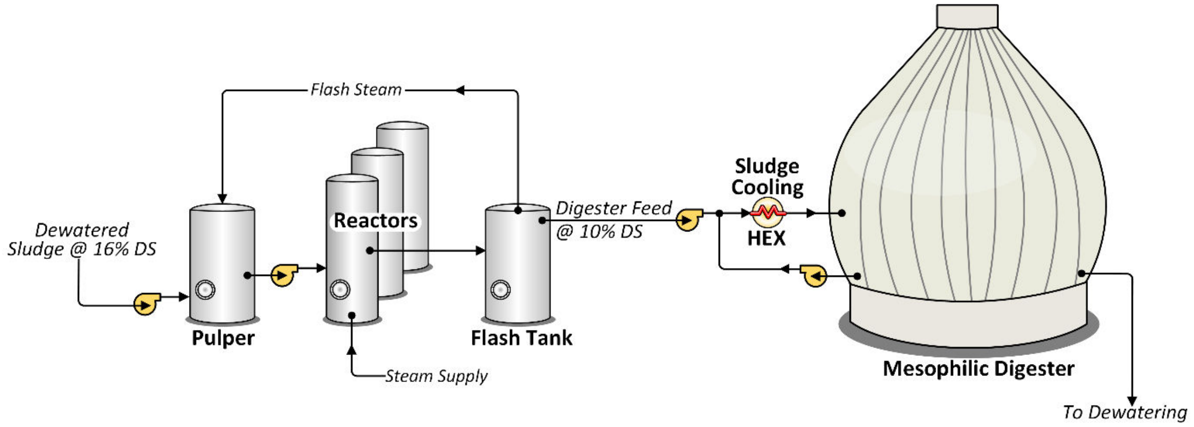

Figure 2-2 Typical Configuration with THP Upstream of Anaerobic Digestion

The advantages and challenges associated with Thermal Hydrolysis are summarized in Table 2-1.

Table 2-1 Advantages and Challenges of the Thermal Hydrolysis Process

ADVANTAGES	CHALLENGES
• Meet CP1 pathogen criteria • Proven technology • Allows higher loading of downstream anaerobic digesters • Increase Volatile Solids Reduction (VSR) (55-60%) • Improved dewaterability (~28-32%) depending on operating SRT in the digesters • Reduced wet mass for hauling (circa 30% saving vs. conventional digestion) • Minimal regrowth potential	• Additional mechanical equipment (screening, pre-dewatering, cake bin, THP) • Steam boiler operation (vs water boiler) • Increased side stream N & P loading including recalcitrant components (even more so with cake imports from other WWTPs) • Reactors operate at high temperature / pressure requiring annual inspection and suitable O&M procedures to ensure safe operation

2.2 THERMAL DRYING TECHNOLOGIES

Thermal (heat) drying involves the use of heat to evaporate moisture from wastewater solids, improving the handling characteristics of the solids and reducing their volume for final use. Drying systems can be operated to remove a portion of the moisture remaining in the dewatered cake or to further dry the cake, resulting in a product that can be marketed a fertilizer under the Canadian Food Inspection Agency's (CFIA) requirements under the Fertilizers Act (FzA).

Dried biosolids products that meet CFIA, FzA requirements are suitable for beneficial use as fertilizer, soil conditioner, or fuel. The energy required for heat drying is typically furnished by combusting natural gas, fuel oil, or biogas generated during anaerobic digestion.

Drying technologies used in North America can be grouped in two categories: direct and indirect systems.

- **Direct Drying Systems**. With direct systems, also called convection dryers, the solids are heated by direct contact with the drying medium, which can be heated air from gas fired burners or hot flue gases from other processes. The exhaust gas volume from direct dryers tends to be higher than with indirect systems.
- **Indirect Drying Systems**. With indirect dryers, also called conduction dryers, there is no physical contact between the heat carrier and the solids. Indirect systems use steam or hot oil to heat metal plates, disks, or paddles that transfer the heat by conduction to the biosolids. These systems have typically lower volumes of exhaust gases for treatment.

Table 2-2 provides an overview of drying technologies currently available in the municipal market. Both categories offer advantages and disadvantages. Typically, indirect systems operate at lower temperatures when compared to larger rotary drum direct dryers. Indirect dryers operating temperatures generally range from 200°C-232°C (390°F-450°F). The dryers generate significantly less exhaust air to treat and require a smaller footprint than direct systems with similar capacity. The disadvantages associated with indirect dryers include the potential to produce an irregularly shaped product with a relatively high concentration of fine material, dust. This is the case with several paddle dryers.

Direct dryer systems operate at a wide range of temperatures, between 150°C- 535°C (300°F-1,000°F). Direct dryers that include back mixing can produce uniform granules with lower dust concentrations when compared to indirect dryers.

Table 2-2 Overview of Drying Technologies

TYPE	COMMENTS
DIRECT CONTACT (CONVECTION)	
Rotary Drum	Most widely used technology in the municipal wastewater market with more than 25 installations in North America. Well suited for larger facilities (typically greater than 20 dry tonnes per day (dtpd)). Produces a pelletized product using back mixing with recycled product. Screening is typically used to improve pellet quality.
Belt Dryer	Relatively new technology with growing interest. Currently there are approximately 10 belt dryers operating with several more under construction. The belt dryer is an established technology in Europe with approximately 10 to 15 years-experience in full-scale applications. Product characteristics vary depending on the supplier due to different solids feed systems and handling. The technology is best suited for small to mid-sized facilities, typically less than 20 dtpd.
Fluidized Bed	Currently limited experience in North America, with only one installation. Produces a pelletized product using back mixing with recycled product. The technology is established in Europe with multiple installations.
INDIRECT CONTACT (CONDUCTION)	
Paddle/Disc	This technology has been widely used in North America. The systems work well for small to medium-sized facilities, below 20 dtpd. Some systems do not recycle or screen product, while others have incorporated recycling to improve product quality. The product is irregular shaped. The concentration of fines is dependent on screening and recycling.

2.2.1 Dryer Safety

While heat drying biosolids provides substantial benefits, there are safety considerations associated with this processing technology that must be considered. Dried biosolids are a combustible material, and in the presence of oxygen and an ignition source, the dried product will burn. As a result, common fire safety hazards associated with combustible materials are present with dried biosolids. In addition to the typical hazards associated with combustible materials, heat drying of biosolids can create some unique hazards, including production of explosive combustible dust as well as fires resulting from reheating of the dried material.

Combustible dust is produced as part of the material handling process of the dried product. Dust accumulation can occur if the solids that are too dry or if there is inadequate removal of dust from equipment as part of maintenance operations. Combustible dust can be an explosion hazard if it is suspended in the air in sufficient concentration when an ignition source is present.

Dried biosolids contain chemical and biological constituents that can undergo reheating if rewetted from condensation in storage bins and silos or if too much moisture remains in the product after the drying process. The moisture can restart exothermic chemical and biological degradation. The reheating process generates heat, which, if not dissipated, can result in smoldering combustion that can lead to a fire. In addition to the hazards associated with the fire itself, the fire can provide an ignition source for explosion of nearby combustible dust. Smoldering material can produce carbon monoxide, which is a combustible gas--although opinions are divided as to whether explosive levels would ever be reached in a drying system.

2.2.2 Rotary Drum Dryers

Rotary drum dryers are widely used throughout North America and Europe, with over 100 installations worldwide. The first system was installed in the United States, and possibly North America was installed Milwaukee in the 1920s. Currently, rotary drum dryers operate at more than 25 large and midsized wastewater treatment facilities in the North America, including those serving Toronto, ON, Milwaukee, WI, New York, NY, Baltimore, MD, Boston, MA, Louisville KY, Nashville, TN, Jacksonville, FL and Carlsbad, CA. The Irvine Ranch Water District in California is currently constructing a new rotary drum drying facility. The primary manufacturers of systems operating in the U.S., include Andritz-Ruthner (Andritz) and Baker Rullman, which is typically used by New England Fertilizer Company (NEFCO). Other dryer manufacturers with units in North America include Sernagiotto and Vomm.

Rotary drum dryers have the highest throughput among drying systems and are rated in terms of pounds of water evaporated per hour (pph), with an evaporation rate in the 4,400-24,000 pph range. This corresponds to a solids throughput of approximately 10-55 dry tonnes per day (dtpd) per unit, based on 20 percent cake solids and a 5 day per week operating schedule. These systems produce a high-quality pelletized product that is suitable for diverse outlets.

A process flow diagram for a typical rotary drum drying system supplied by Andritz is shown in Figure 2-3.

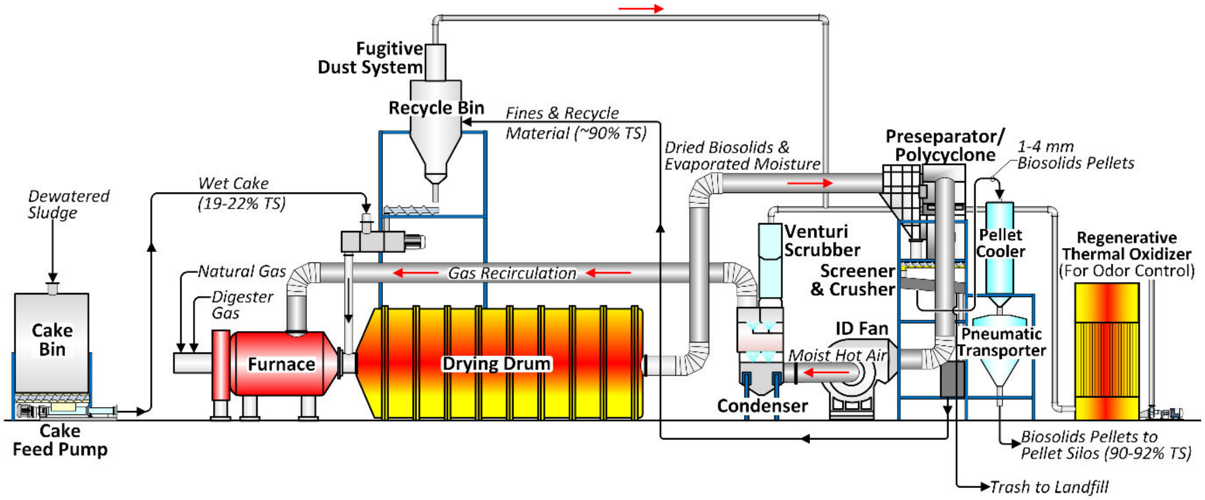

Figure 2-3 Rotary Drum Dryer Process Flow Diagram

The dried recycled product is coated with dewatered cake in a mixer before entering the rotary drum dryer. Heated process gas flows through the drum, heating the pellets and absorbing evaporated moisture while the rotation of the drum keeps the material in motion. At the exit of the drum, the dried product becomes entrained in the process gas flow and is carried to a pre-separator and cyclone, where the pellets are separated and conveyed to a screen. In the screen, oversized material and undersized material are separated from the desired size pellets. The oversized material is crushed and returned to the mixer, along with fines and a portion of the pellets may be crushed and returned as needed. The recycled material is recoated with dewatered cake and sent back through the dryer. A portion of the separated pellets downstream of the screen are cooled in a product cooler and conveyed to storage as finished product.

Downstream of the cyclone, the process gas flows through a wet scrubber condenser for removal of particulates and moisture. A large percentage of the gas is then returned to the furnace to repeat the cycle. A portion of the process gas stream is removed and directed to a high efficiency wet Venturi scrubber to remove fine particulates. This blow-down gas is then treated through a regenerative thermal oxidizer (RTO) for odour control.

Rotary drum dryers are equipped with extensive temperature and carbon monoxide (CO) monitoring systems, and oxygen levels throughout the dryer system are maintained at a concentration below six percent to prevent fires and explosions. The product is typically stored in silos, which are also typically monitored for temperature and CO, prior to discharge into trucks. Nitrogen inserting capability is recommended for silo storage systems in the event a smoldering fire is detected. An oil conditioning system can be used at loadout to agglomerate fines and reduce dust.

The advantages and challenges associated with rotary drum dyers are summarized in Table 2-3.

Table 2-3 Advantages and Challenges of Rotary Drum Dryers

ADVANTAGES	CHALLENGES
• Meets CP1 Pathogen criteria • High quality and uniformity of the end-product. • The finished granules resemble manufactured chemical fertilizers. • The product size can be varied to meet demand, but typically falls in the 2-4 millimeters (mm) in diameter size. • High throughput capacity. • Limited dust formation during product handling due to the hardness of the granules and use of a screening process. Oils can also be used to control dusting during product loadout.	• Complex system with high maintenance requirements. • System needs to operate continuously for extended periods. Continuous presence of operations staff is required to monitor the system. • Variability in the feed solids concentration can affect operations. • Safety must be a focus to minimize the potential for fire and explosions. • Requires natural gas or biogas.

2.2.3 Belt Dryer

Belt drying technology in municipal applications was first introduced in Europe in the mid-1990's with relatively widespread acceptance. The use of this technology in North America has been increasing. When compared to rotary drum dryers, belt dryers are mechanically simpler. Manufactures of belt dryers with operating facilities in North America include Veolia/Kruger, Andritz, Suez, Huber, Siemens, and Gryphon.

A belt dryer is a direct (convective) drying system that uses heated gas 127-165°C (260-330°F) in direct contact with the dewatered solids to evaporate water. The specific configuration differs based on the manufacturer. The dryer consists of one or two porous belts with a gas circulation system. Belts may be steel mesh or synthetic material like that used with belt filter presses. Dewatered cake is introduced onto the belt with a pumped extrusion system or is mixed with recycled dried material (back-mixing) and deposited on the belt as pre-formed granules. The feed material then is slowly conveyed by the belt while heated gas is brought in contact with the solids. The product is dry by the time it reaches the end of the belt(s).

For recirculating gas systems, hot gas is drawn or blown through the product on the belt with a fan and is then passed through a heat exchanger to recover energy. A belt dryer can use a gas-fired furnace (biogas or natural gas) for the energy source, or alternative energy sources. For example, hot water from cogeneration engines can be used in water-to-air heat exchangers to transfer the heat to the drying gas. A large percentage of the drying gas is recycled to improve thermal efficiency, but enough must be exhausted to remove the evaporated water collected in the gas during the drying process. The exhaust is typically treated through a condenser system, with the resulting condensate being returned to the liquid treatment process. The non-condensable exhaust is conveyed to an odour control system.

The odour control technology varies depending on the system supplier, although biofilters and wet scrubbers are predominantly used. RTOs are generally not considered with these systems due to the large volume of gas would make the system very expensive to operate.

The product from the belt dryers is irregular in shape and size, containing fines and particles up to 6 mm in diameter. The size and density of the product varies, depending on the methods of pre-processing and feeding the cake to the dryer used by the various manufacturers. Product screening is typically not used with these systems to reduce the materials handling complexity and cost. An oil conditioning system can be used at loadout to agglomerate fines and reduce dust. At least one manufacturer has added downstream processing to create a more uniform and denser pellet.

For safety, the operating temperatures are maintained below ignition levels, and monitoring systems are provided to identify safety problems and reduce the risk of fires and explosions. Some of the monitoring systems may include temperature and CO detection. Product storage should also be monitored for temperature and CO levels. Nitrogen purging capability is recommended for silo storage systems in the event a smoldering fire is detected. Due to the sizes of the drying systems' components belt dryers are best suited for small to medium sized drying applications.

A schematic showing the basic configuration of an Andritz belt dryer system is provided in Figure 2-4.

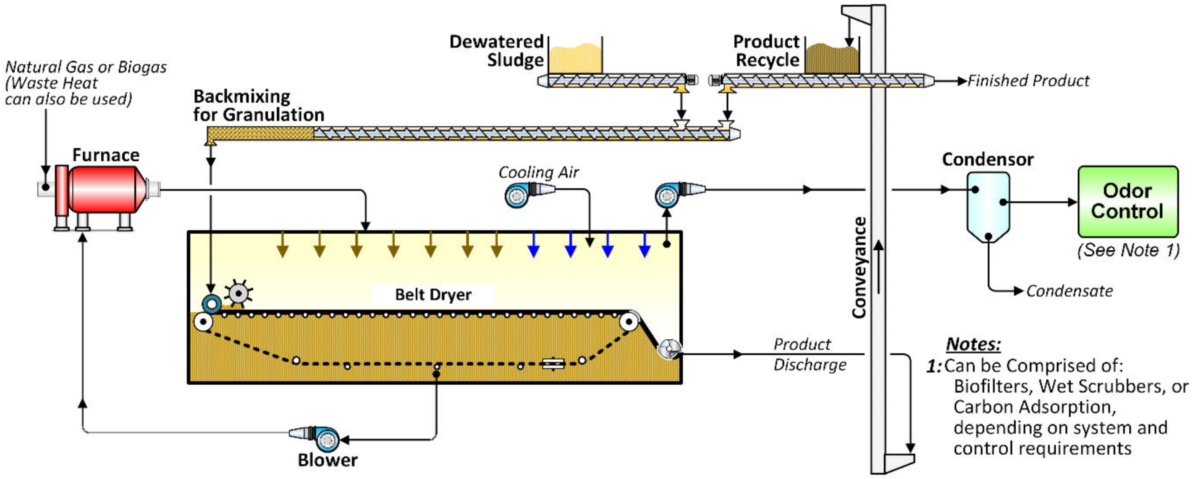

Figure 2-4 Belt Dryer Schematic

The advantages and challenges associated with belt dyers are summarized in Table 2-4.

Table 2-4 Advantages and Challenges of Belt Dryers

ADVANTAGES	DISADVANTAGES
• Maximizes volume reduction. • Relatively low mechanical complexity. Belt dryers generally involve less materials handling equipment, especially in comparison to rotary drum dryers. • Ability to use alternative energy sources (such as waste heat) to power belt dryers, which operate at low drying temperatures (below the ignition point of the dried solids).	• Because the drying gas is at a low. temperature, a large quantity of gas is needed to achieve the required evaporation, which in turn requires large equipment with a significant footprint. • Depending on the manufacturer, the volume of exhaust gas for odour control can be significant. Some manufacturers recycle the exhaust gases, resulting in a relatively low

ADVANTAGES	DISADVANTAGES
• Intrinsic safety associated to low drying temperatures. • Potential to operate the dryer unattended during night shifts. Shutdowns can be automated if problems arise that cannot be corrected remotely. • Less potential for dust due to low velocity of the belt moving along the length of the dryer.	volume of exhaust gas requiring odour control. • The product is irregularly shaped, and the concentration of fines varies depending on the manufacturer and feed characteristics. • For some manufacturers, the product has a low bulk density. • For systems using extrusion nozzles, these can get clogged, requiring periodic cleaning. • Dust builds up that does occur may require operators of some systems to access the dryer and manually remove deposits.

2.2.4 Fluidized Bed Dryer

Fluidized bed dryers have seen limited use in North America with biosolids. The Emerald Coast Utilities Authority (ECUA) in Pensacola, Florida developed a system in the 1990’s to replace an existing incinerator. When hurricane damage resulted in a relocation of the Water Reclamation Facility in 2004, the City implemented a paddle drying system. In 2014 ECUA stopped all drying and shifted to production of compost. In the early-2000’s, the North Shore Sanitation District developed a “Minergy Glass Pack” system that used a combination of a fluidized bed dryer and a high temperature furnace to “melt” the dewatered solids and create a glass aggregate that could be used as construction fill material. The furnace proved difficult to maintain, but the fluidized bed dryer remains in operation and is operating as a regional dryer. Worldwide, there are approximately 40 fluidized bed dryer installations processing biosolids.

In North America fluidized bed dryers are available through Andritz and Schwing/Bioset. Capacities are like those for a rotary drum dryer, but the largest units installed are approximately 75 percent of the capacity of the largest rotary drum dryer systems installed. A schematic of a fluidized bed dryer is shown in Figure 2-5.

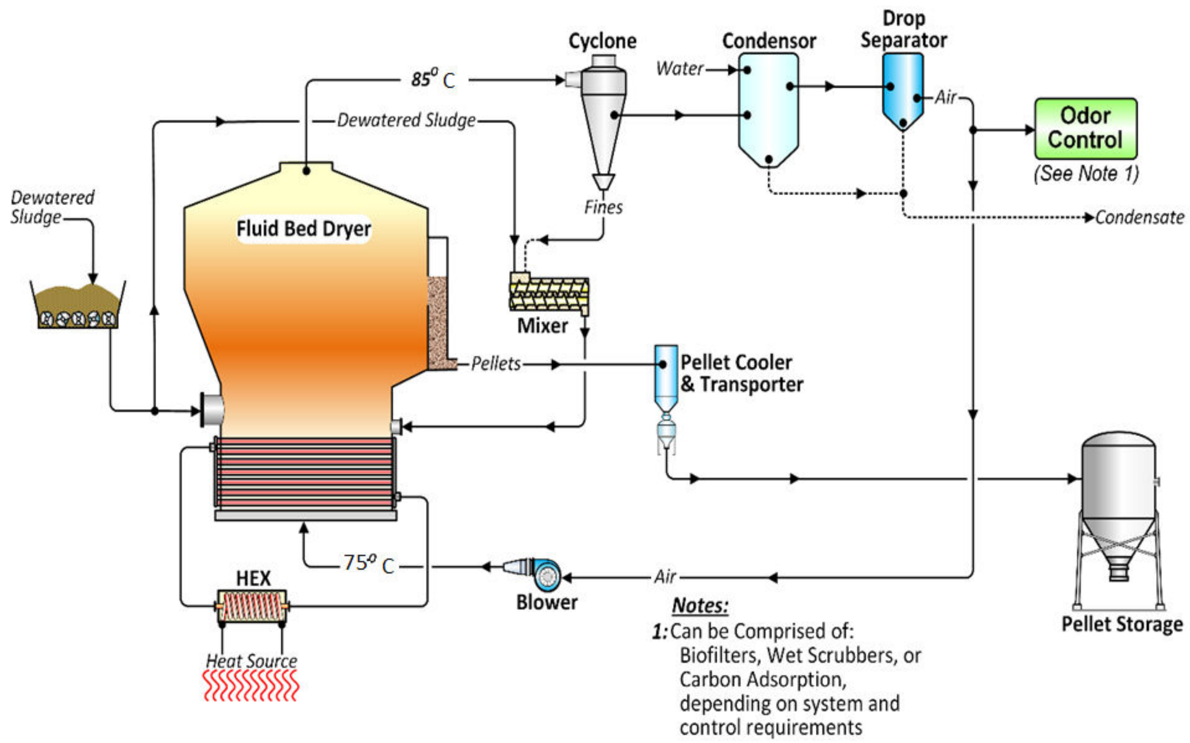

Figure 2-5 Fluidized Bed Dryer Schematic

The fluidized bed dryer is a combination of a direct and indirect system. Dewatered cake is injected into the dryer shell, where spinning cutters create small pieces of solids that drop into the fluidized mass of solids. Heat is transferred to the fluidized mass of solids from an internal heat exchanger. Fluidizing air (process gas) is recirculated through the dryer to fluidize the particles, help with heat transfer to the particles, and to remove the evaporated moisture. Steam or hot oil is used to provide heat through the heat exchange system.

The fluidized bed operates much like a fluidized bed incinerator, except the dried biosolids act as the fluidized sand in the system. The fluidizing motion in the bed produces a granular product that is relatively dust-free, but less uniform in size than the material from a rotary drum. Product size typically ranges from 1-5 mm. As the material dries, its density is reduced such that it rises to the overflow weir in the dryer and exits the dryer. The process gas is treated using a cyclone to capture fine particulates in the gas. These fine particles are recycled to drying by mixing with a side stream of dewatered cake.

Downstream of the cyclone, the process gas flows through a wet scrubber condenser for removal of particulates and moisture. A large percentage of the gas is then returned through the heat exchange system and through the dryer. A small portion of the process gas stream is removed and directed to a demister and is then sent to odour control. The exhaust can be treated with a biofilter or an RTO.

Fluidized bed dryers are equipped with temperature and oxygen monitoring systems. The oxygen concentration levels throughout the dryer system are maintained below six percent to prevent fires and explosions. The product is typically stored in silos, which are monitored for temperature and Carbon Monoxide. Nitrogen inerting capability is recommended for silo storage systems in the event a smoldering fire is detected. An oil conditioning system can be used at loadout to agglomerate fines and reduce dust.

The advantages and challenges associated with Fluidized Bed Dryers are summarized in Table 2-5.

Table 2-5 Advantages and Challenges of Fluidized Bed Dryers

ADVANTAGES	CHALLENGES
• Maximizes volume reduction. • Relatively uniform quality pellet. • Lower temperature drying. • Vertical system resulting in a slightly smaller footprint than rotary drum. • System can adjust to varying cake concentrations.	• Complex system with high maintenance requirements. • System needs to operate continuously for extended periods. Note, some European systems operate continuously with only yearly shutdowns (like incineration) and operate with minimal staffing or unattended overnight. • Safety must be a focus to minimize the potential for fire and explosions. • Requires natural gas or biogas.

2.2.5 Paddle Dryer

Paddle dryers and disc dyers use an indirect (conductive) system, with biosolids encountering a heated surface. Paddle dryers consists of two counter rotating agitator shafts with paddles or flights and a jacketed housing. Oil or steam is circulated through the paddles/flights and the housing to heat the dewatered cake and drive off moisture. Dewatered cake is introduced to one end of the dryer. The rotation of the agitators conveys the material through the dryer to the discharge end. Evaporated moisture and non-condensable gases are pulled from the top of the unit and conveyed to a condenser. Non-condensable gas is then discharged to an odour control system.

Komline-Sanderson (Komline) and Andritz supply similar paddle dryers in North America. Both designs are based on the NARA drying technology, which originated in Japan and has been licensed to both manufacturers. Until recently, all the paddle dryers operating in the U.S. were supplied by Komline. Andritz acquired the license through the acquisition of Royal GMF-Gouda and is actively marketing the NARA paddle dryer in North America. There are manufacturers of disc dryers, which are like the paddle systems. Some of the systems available have questionable track records and are best suited for small facilities. A schematic of a paddle dryer is shown in Figure 2-6.

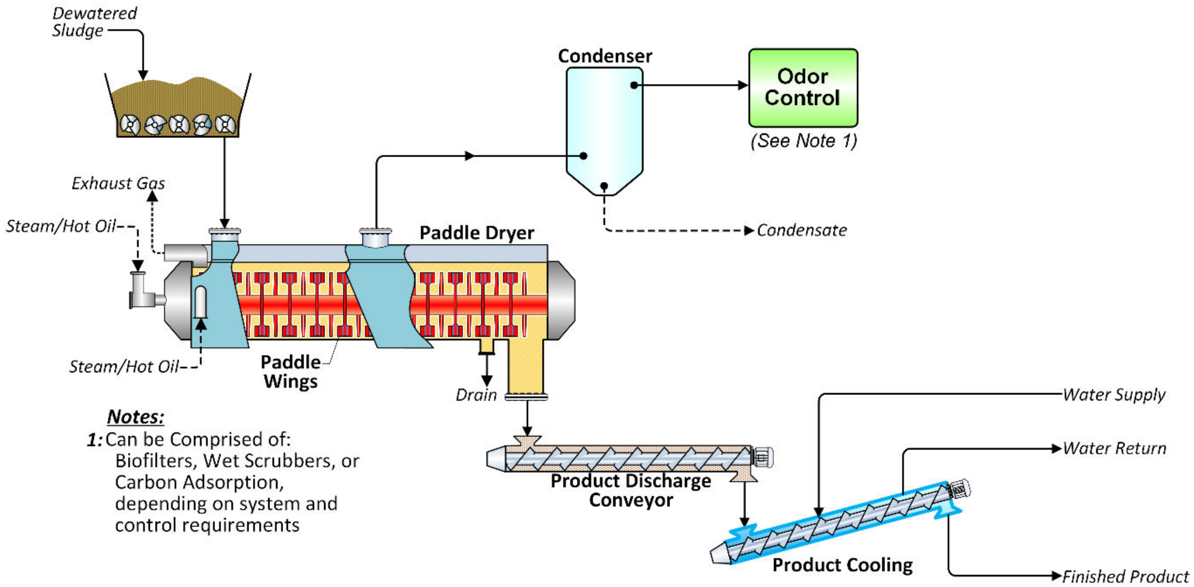

Figure 2-6 Paddle Dryer Schematic

The advantages and challenges associated with Paddle Dryers are summarized in Table 2-6.

Table 2-6 Advantages and Challenges of Paddle Dryers

ADVANTAGES	CHALLENGES
• Maximizes volume reduction. • Relatively small footprint. • Low volume of exhaust gas, limiting emissions and odour control requirements.	• Relatively long start-up and shut down period in comparison to belt dryers. • Potential wear of the surface of the paddles, which come in direct contact with the sludge. • The dried product is irregularly shaped, and the concentration of fines varies depending on the manufacturer. • Safety must be a focus to minimize the potential for fire and explosions.

2.2.6 Solar Drying

The use of the sun to dry biosolids is process that has been used for many decades. Over time the process has evolved, and recently solar drying system have included greenhouse enclosures, along with automated feed, material turning and discharge systems. The material turning systems till the biosolids that have placed in a relatively thin layer, less than 6 cm in depth. The mixing equipment mix the solids being dried and bring the moist material to the surface to accelerate the drying process.

Some solar drying systems use sensors to monitor drying conditions, and control air louvers and ventilation fans. The ventilation systems provide circulating air movement and remove the moisture-laden air. Several facilities with mechanical ventilation contain the air leaving the greenhouses and treat any odour using biofilters or wet scrubbers.

The dried biosolids product from a solar drying facility have a Total Solids (TS) concentration of approximately 70 percent or greater. In the United States, the US EPA does not consider solar drying to be "Process to Further Reduce Pathogens" (PFRPs) under US EPA 40 CFR Part 503 regulations due to the "weather-dependence" of the process. However, site-specific permitting is available for facilities that demonstrate production Class A pathogen reduction by testing for fecal coliform and by product TS concentration to meet Vector Attraction Reduction requirements, > 70 percent TS if the solids have been stabilized and > 90 percent TS if the solids have not been stabilized prior to drying. To comply with the CP1 pathogen criteria for NASM the dried product will need to test for E. coli.

Drying costs and energy consumption are lower for solar drying than thermal drying processes. However, the land area requirement is larger for solar drying than for other thermal drying technologies.

A solar dryer installation is shown in Figure 2-7.

Figure 2-7 A Solar Drying Facility

The advantages and challenges associated with solar drying are summarized in Table 2-7.

Table 2-7 Advantages and Challenges of Solar Drying Processes

ADVANTAGES	CHALLENGES
• Maximizes volume reduction. • Marketable product with high degree of diversity in use. • Can be combined with other processes like digestion. • Simple process. • Low risk for explosions. • No natural gas or biogas required for drying.	• Large area required. • Remote facility would be required along with associated transportation of dewatered cake. • Additional storage required or supplemental heat required in colder climates due to reduced winter drying performance. • Increased risk of odour. Off-gas requires treatment.

2.3 Alkaline Stabilization

2.3.1 Alkaline Stabilization

Alkaline stabilization uses alkaline materials, such as quicklime, to treat biosolids. The chemical reaction of the dewatered biosolids with the alkaline agent generates heat and elevates the pH. This allows the resulting product to meet both pathogen reduction requirements and VAR criteria. The product typically has a lower nutrient content than digested biosolids due to the dilution effect of adding the alkaline material and the resulting loss of ammonia from volatilization.

Biosolids require approximately one pound of lime per pound of dry solids to produce a material that can meet the CP1 pathogen criteria. The lime requirements are reduced to 0.2 to 0.3 pounds of lime per dry pound of wastewater solids to comply with the CP2 pathogen criteria.

Lime is typically added to dewatered cake rather than thickened solids. This reduces the loading to the dewatering equipment and reduces damage to the equipment that can take place when dewatering a mixture with an elevated pH.

A lime stabilization process can be implemented for a comparatively low capital cost. The operating costs, however, can be significant due to the volume of alkaline material that is required to increase the pH. The process results in an increase in the mass of solids produced due to the alkaline material added to increase the pH. There have also been odour issues associated with product. The odours have been experienced at the processing site as well as at the land application sites. A photograph of an alkaline stabilization facility is presented in Figure 2-8.

The product resulting from alkaline stabilization typically has a higher pH than digested biosolids and is usually managed as a liming agent. Consequently, land application requirements will differ from those used for anaerobically digested Class A biosolids.

Figure 2-8 Lime Stabilization System

2.3.2 Alkaline Stabilization with Supplemental Heat or Acid

While many alkaline stabilization systems are based solely on lime addition, there are proprietary alkaline stabilization processes available to meet CP1 pathogen criteria by combining alkaline material, with supplemental heat or an acid to reduce the quantity of lime required and to improve the dewatered cake characteristics. These include EnVessel pasteurization by RDP and Bioset Process by Schwing. A schematic diagram of a Bioset Alkaline Stabilization process is presented in Figure 2-9.

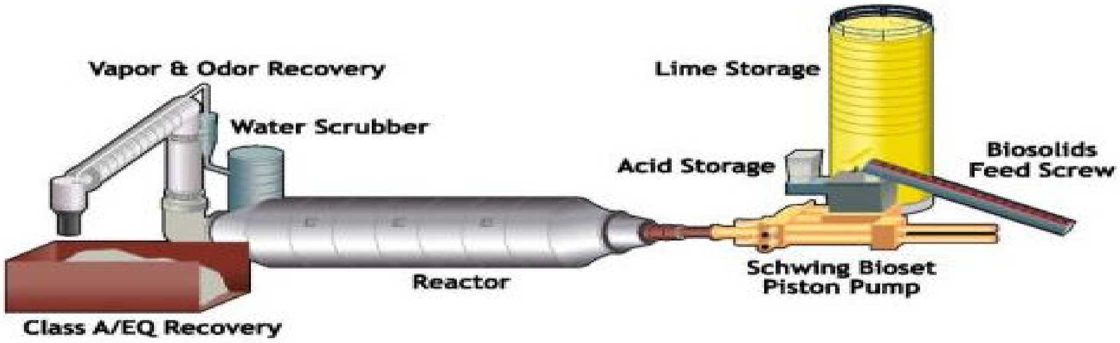

Figure 2-9 Bioset Process Schematic (Courtesy of Schwing)

2.3.3 Alkaline Stabilization with Heat and High-Speed Mixing

The Lystek® process is applied to dewatered cake and uses a combination of heat, the addition of alkaline material, and high shear mixing to generate conditions for pathogen reduction. The process can be designed to meet CP1 pathogen criteria. The process heats dewatered solids to 75°C (167°F) with steam, applies high speed mixing (max. 1,000 rpm) and increases the pH of the material to 9.5-10.0 using alkali to facilitate hydrolysis. The solids are treated through a batch or semi-batch process. The end-product is a pumpable liquid, with a high-solids concentration. The product can be anaerobically digested, or land applied as a liquid product. Lystek® reports to be able to operate at concentrations as high as 35 percent total solids. A schematic of the Lystek® process is shown in Figure 2-10.

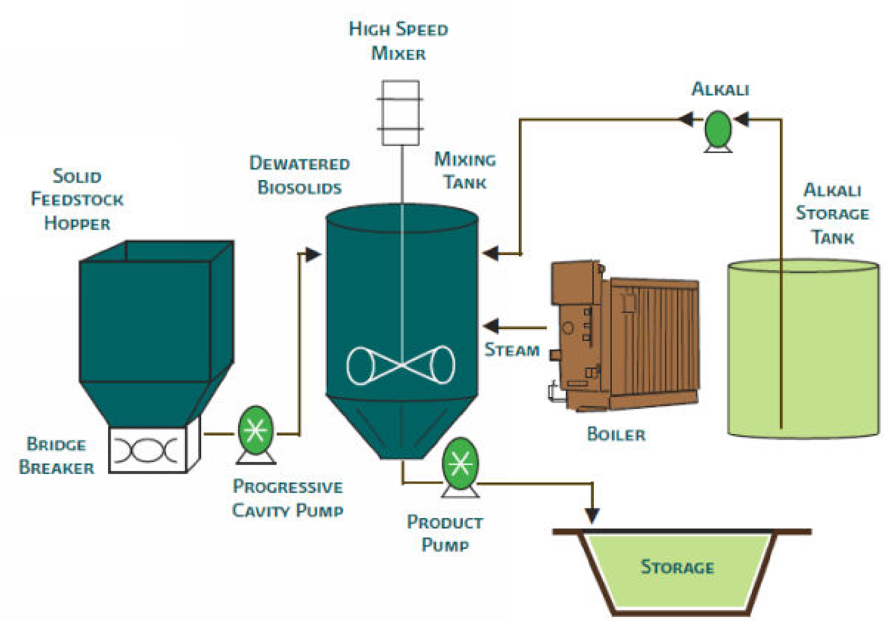

Figure 2-10 Lystek® Process Schematic (Courtesy of Lystek®)

There are currently eleven Lystek® facilities operating in the North America. Eight of the facilities, are in Canada. As mentioned above while the Lystek® process can be used to treat undigested wastewater solids, it can also be installed downstream of anaerobic digestion, which reduces the required capacity of the Lystek® system and has the benefit of generating biogas for energy recovery.

The advantages and challenges associated with alkaline stabilization processes are summarized in Table 2-8.

Table 2-8 Advantages and Challenges of Alkaline Stabilization Processes

ADVANTAGES	CHALLENGES
• Relatively low capital cost. • Addition of heat, chemicals and mixing can produce a material that meets the CP1 pathogen criteria. • Relatively simple process and operation. • Capable of handling a wide range of sludges. • The product can be used as fertilizer and is potentially marketable if farmers need to supplement soil alkalinity.	• Different processes require various amount of lime of other alkaline material. • Addition of alkaline material increases the volume of stabilized biosolids product to be managed. • The high pH precipitates various metals in the stabilized solids and reduces their solubility. • The high pH also results in the release of ammonia from the biosolids which can create odour and a corrosive environment. • The process and product can generate dust that is also corrosive and can create a poor work environment. • The decrease in pH over time that is associated with alkaline stabilization can result in bacterial regrowth

ADVANTAGES	CHALLENGES
	which can result in product odour generation and issues with beneficial use.

2.4 Composting

Composting is a natural process in which aerobic organisms break down organic matter and generate heat (exothermic). The temperatures reached during composting are high enough to kill pathogenic organisms; consequently, the compost product can meet CP1 pathogen criteria. The elevated temperature along with aeration and or mixing help to drive off moisture and increase the Total Solids of the compost product.

The composting process involves blending of dewatered biosolids with a carbonaceous amendment, typically ground wood wastes, to provide the appropriate amount of carbon to achieve a proper carbon to nitrogen ratio for biological degradation. Composting can be employed in several different configurations to produce a stabilized biosolids soil amendment and low-grade fertilizer. With proper operation composting processes can meet the requirements for Class A biosolids.

The first large scale composting program in North America began in the early 1970's at the City of Los Angeles. The City implemented a conventional, non-aerated windrow composting system that was open to the atmosphere. Other methods of composting, such as the aerated static pile process, soon followed. Most of the early systems were open air systems.

In the mid-1980's, several proprietary "in-vessel" systems were marketed to municipalities. These systems were enclosed, offering better control of odour and the process, but were more capital intensive and mechanically complex.

Compost system development peaked in the late 1980's. By this time, there was enough experience with the systems that utilities were able to fully evaluate the suitability of the process for their application.

The compost product can be easily stored in the open and is an excellent organic amendment for soil. The product has been used for landscaping, turf farming, soil blending, golf course construction, and nursery applications.

Composting is a relatively simple process and does not require specialized skills for the operators. It also provides an opportunity for using other waste products, such as yard waste, as an amendment to the process. The primary disadvantage of the composting process is the quantity of amendment that is required by the process. To reach an initial mixture total solids concentration of 40 percent Total Solids and a Carbon to Nitrogen Ration of 30:1 requires a significant volume of amendment which results in a large volume of compost product. Typically, amendment is a woody material such as, wood chips, sawdust or as mentioned above processed yard waste. The volume of these amendments can be as much as three times the volume of the biosolids entering the process. These materials need to be transported to the composting site. This increases the truck traffic into the site. The volume of the biosolids product that must be removed from the site impacts the vehicle traffic into and out of the composting site.

Photographs of an aerated static pile composting process and a horizontal agitated bin In-vessel composting process are presented in Figure 2-11 and Figure 2-12.

Figure 2-11 Denton, Aerated Static Pile, Composting Facility at Columbus, OH

Figure 2-12 In-Vessel, Horizontal Agitated Bin, Composting Facility

The advantages and challenges associated with composting technologies are summarized in Table 2-9.

Table 2-9 Advantages and Challenges of Composting

ADVANTAGES	CHALLENEGES
• High-quality, saleable product suitable for agricultural use. • Produces a product that meets CP1 pathogen criteria. • Relatively simple process that can also be used with a variety of amendments including yard waste and other carbonaceous wastes. • Compatible with anaerobic digestion; digestion helps to reduce overall odour potential from the process.	• Requires an amendment, which increases materials handling and truck traffic. • Requires significant land area. • Requires either forced air and / or turning. • Relatively high operational cost; labour intensive.

The Region of Halton has selected composting as part of their long term biosolids management plan. They have recently initiated a Class B EA to identify a site, conceptual design and confirm end use markets.

2.5 Thermal Conversion

Thermal conversion technologies for biosolids include Incineration, gasification, and pyrolysis. The processes differ in the amount of air, oxygen, used in the process and if the systems are currently used on a commercial scale or pilot scale. Incineration uses excess air in the process, gasification uses partial air and pyrolysis does not use air.

Incineration is a well-established, commercially available thermal conversion technology for biosolids. Most incineration facilities are serving water reclamation facilities that produce of 50 dry tonnes of solids daily.

Gasification and pyrolysis are becoming more viable as technologies for energy recovery. These technologies are currently considered as emerging with respect to their application with biosolids and are not currently sufficiently advanced to provide a realistic full-scale option for biosolids processing.

2.5.1 Incineration

Incineration achieves complete combustion of the volatile component of wastewater solids in the presence of excess air. The process results in the destruction of pathogens, the evaporation of moisture and production of a non-odorous ash consisting of inert solids that can be landfilled or further processed for a beneficial use

Two types of incinerators have been widely employed worldwide: multiple hearth incinerators (MHIs) and fluidized bed incinerators (FBIs). MHIs are less efficient than FBIs, leading to their gradual phase out. The MHI furnace consists of a cylindrical steel shell surrounding several solid refractory hearths, and a central rotating shaft to which rabble arms are attached. In FBI units, the reactor is a closed cylindrical vessel with refractory walls. Fluidizing and combustion air enter the unit and keeps silica sand particles in suspension for optimum contact of the cake with the combustion air. The sand bed retains the organic particles until they are reduced to ash.

A schematic showing a typical arrangement for a fluidized bed incinerator is provided in Figure 2-13.

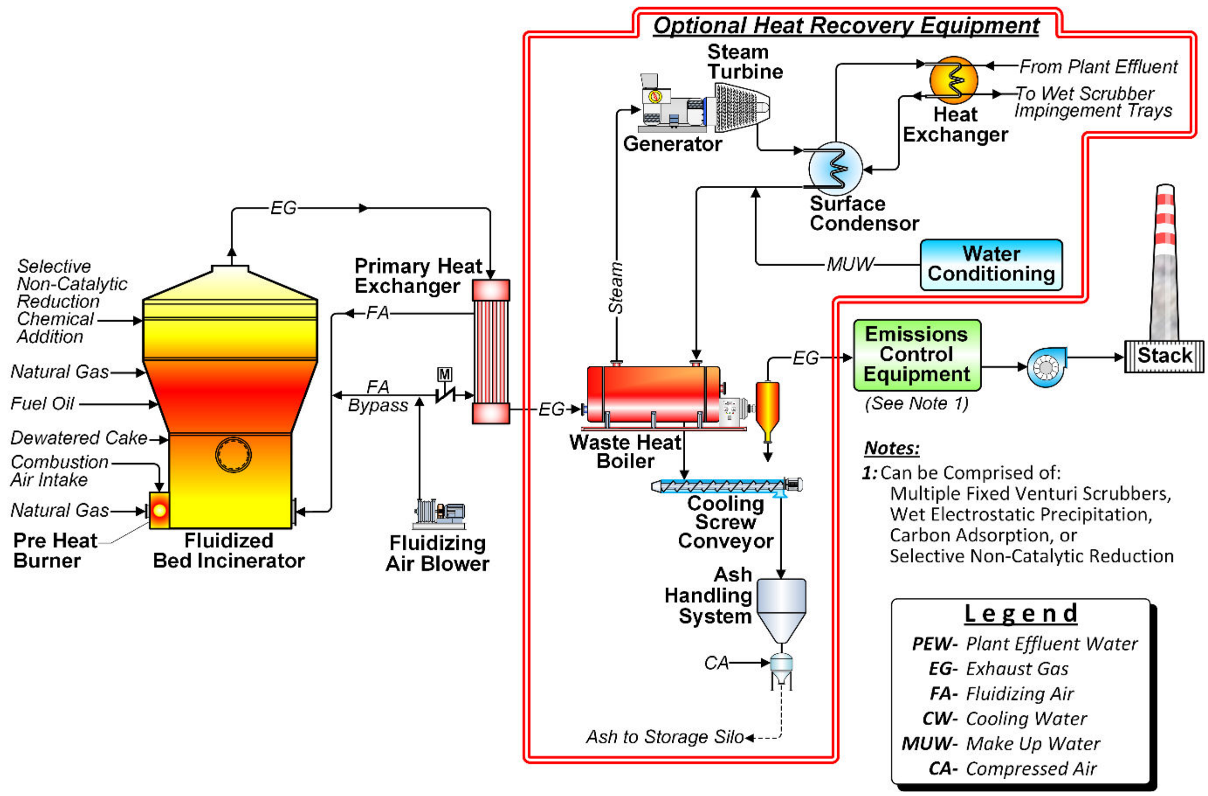

Figure 2-13 Fluidized Bed Incinerator Schematic

The advantages and challenges associated with incineration technologies are summarized in Table 2-10.

Table 2-10 Advantages and Challenges of Incineration

ADVANTAGES	CHALLENGES
• Proven Technology • Achieves the maximum reduction in the mass of final product for disposal (produces an inert ash). • Complete pathogen destruction. • Potential for energy recovery. • Produces inert Ash	• Relatively complex process from a mechanical and control perspective. • An auxiliary source of fuel is required for start-up, and possibly for normal operation depending on the characteristics of the solids entering the process. • Public perception can be a problem for incineration facilities. • Permitting of new or expanded facilities is challenging. • Exhaust gas treatment is often required to meet discharge requirements. • The process has a long start-up time to reach operating temperature and needs to be operated continuously for extended time periods. • The process requires a relatively uniform dewatered solids feed.

2.5.2 Gasification

Gasification involves the thermal conversion of biosolids with a limited oxygen supply. The process involves a chemical reaction of carbon in the solids with oxygen, steam, and carbon dioxide at temperatures between 260 and 760°C (500 and 1,400°F). The amount of air, oxygen, added to the process is limited to that required to support the chemical reactions. The process produces heat which can be used and synthetic natural gas (syngas). Depending on the operating temperatures, the feed characteristics and pressure of the process the energy within the syngas can range from 10 to over 90 percent of that in natural gas. The biosolids entering the gasification process are often thermally dried to achieve an optimum feed solids concentration.

2.5.3 Pyrolysis

Pyrolysis uses high temperature and pressure in the absence of oxygen to convert the organic material in wastewater solids into bio-oil, syngas, and biochar. The biochar is a combustible material. There are slow pyrolysis and fast pyrolysis processes. The slow process does not produce the bio-oil, while the fast pyrolysis does. The operating temperature of pyrolysis is lower than gasification, ranging between 450 and 750°C (900 and 1,100°F). Markets for the biochar produced are being explored and include soil amendment, including carbon sequestration credit, livestock feed, carbon electrodes, fuel cells and building materials. Currently there are no large-scale pyrolysis systems operating in North America.

2.5.4 Wet Oxidation

Wet air oxidation is high temperature, high pressure reaction of oxidizable material in water with oxygen. The oxidation is a chain type radical reaction which typically takes place in a vertical bubble column reactor. The oxidation reactions occur at a temperature between 150 and 320°C and a pressure of 10 bar to 220 bar. The history of wet air oxidation technology includes the Zimpro process which had systems in operation for over 50 years. All but one or two of those processes have been retired.

2.5.5 Hydrothermal Liquification

Hydrothermal liquification is a process to produce a biocrude oil which can be upgraded at an existing petroleum refinery to reduce the use of traditional crude oil. In the process wastewater solids and the water are pumped and heated to reactor conditions of approximately 3,000 psia and 339°C (622°F). The product leaving the reactor is a biocrude, a separate aqueous phase, solids, and gases. The solids are removed by filtration. The solids can be sold as a fertilizer with confirmation of meeting regulatory requirements or disposed of in a landfill. The gas generated in the hydrothermal liquification process is removed as part of the cooling process. The biocrude is transported to a petroleum refinery for processing to upgrade the product, the aqueous phase is treated using hydrothermal gasification. The resulting off gas can be used for process heat. Additional heat is required to support the hydrothermal liquification process and the catalytic hydrothermal gasification process.

The advantages and challenges associated with Gasification, Pyrolysis, Wet Oxidation and Hydrothermal Liquification are summarized in Table 2-11.

Table 2-11 Advantages and Challenges of High Temperature High Pressure Processes; Gasification, Pyrolysis, Wet Oxidation and Hydrothermal Liquification

ADVANTAGES	CHALLENGES
• The processes produce useable products including synthetic natural gas, biocrude, carbon products and biochar. • High temperature processes are reported to destroy PFAS Compounds. • Potential for energy recovery from the processes.	• Relatively complex process from a mechanical and control perspective. • These processes have not yet been implemented at full scale. • Several processes require upstream thermal drying to achieve optimum process feed characteristics.

3.0 Biosolids Technology Screening

Four screening criteria are established to screen the long list of technologies, as summarized in Table 3-1**Error! Reference source not found.**

Table 3-1 Screening Criteria

SCREENING CRITERIA	DESCRIPTION
Maturity of Technology	The technology must have been in use for long enough that most of its initial operational issues and inherent problems have been removed or reduced by further development. It must be robust, reliable and have a successful track record.
Compatibility with existing and future site development and biosolids end use markets.	The technology must be compatible with existing infrastructure investments and be constructible given existing site conditions at the Garner Road Facility. It must also compliment the end use alternatives and markets that have been identified for the Region of Niagara.
Proven application at similar scale facilities	The technology must be able to manage biosolids at the quantities that are and will be trucked to the Garner Road Facility; furthermore, the technology must have a successful operating history at facilities of similar capacity.
Implementable	The technology must be able to address implementation challenges at the Garner Road Facility or other centralized facilities. The challenges include space constraints, impacts of side stream waste generated, regulatory changes, public concerns including traffic, air quality and odour impacts.

The results of the technology screening are presented in Table 3-2.

Table 3-2 Technology Screening

Criteria	**Biological Digestion Technologies**	**Thermal Drying Technologies**				**Chemical Stabilization Technologies**			**Composting Technologies**	**Thermal Conversion Technologies**				
	Thermal Hydrolysis Post treatment (THP)	Direct Thermal Dryer (Drum Dryer, Belt Dryer)	Fluidized Bed Dryer	Indirect Thermal Dryer (Paddle Dryer, Disc Dryer)	Solar Dryer	Alkaline Stabilization	Alkaline Stabilization with Supplemental Heat or Acid	Alkaline Stabilization with Supplemental Heat and High Speed Mixing	Composting (Open Technologies Aerated Static Pile and Windrow Composting)	Incineration	Gasification	Pyrolysis	Wet Oxidation	Hydrothermal Liquification
Maturity of Technology	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗
Compatibility with Existing and Future site development and biosolids end use markets	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Proven Applicability at similar scale facilities	✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✗
Implement-able	✓	✓	✗	✓	✗	✗	✓	✓	✓	✓	✗	✗	✗	✗
Consider for Evaluation	✓	✓	✗	✓	✗	✗	✓	✓	✓	✓	✗	✗	✗	✗

4.0 Shortlisted Biosolids Management Alternative Strategies

Five technologies for biosolids treatment met all four of the screening criteria and were recommended to be developed into alternatives and evaluated. The technologies recommended for evaluation include:

1. Biological Digestion Technologies (at Garner Road facility)
    - Thermal Hydrolysis Process (THP) Post-Treatment following Anerobic Digestion
2. Thermal drying (at Garner Road facility)
    - Direct Thermal Drying
    - Indirect Thermal Drying
3. Advanced Alkaline Stabilization (by third party contractor)
    - Alkaline Stabilization with Supplemental Heat or Acid
    - Alkaline Stabilization with Supplemental Heat and High-Speed Mixing.
4. Composting (at Garner Road facility)
5. Incineration (at Garner Road facility)

Following review and discussion with the Region, seven biosolids management alternative strategies were selected for development and evaluation, based on the screened technologies, as listed below and summarized in Table 4-1:

1. Conventional mesophilic anaerobic digestion and land application of liquid biosolids
2. Conventional mesophilic anaerobic digestion, dewatering and land application of biosolids cake
3. Anaerobic digestion with Advanced THP post-treatment, dewatering and land application of fertilizer grade biosolids cake
4. Conventional mesophilic anaerobic digestion, dewatering, advanced alkaline stabilization and product distribution
5. Conventional mesophilic anerobic digestion, dewatering, aerated static pile composting and product distribution
6. Conventional mesophilic anaerobic digestion, dewatering, rotary drum direct thermal drying and product distribution
7. Conventional mesophilic anaerobic digestion, dewatering, fluidized Bed Incineration with Ash Management.

Table 4-1 Short List of Biosolids Management Alternative Strategies for Detailed Evaluation

Management Alternative	Process	Product	Final User
Beneficial Use on Land	AD	Stabilized Liquid biosolids	Land application with liquid biosolids
	AD + Dewatering	Stabilized Biosolids Cake	Land application with biosolids cake
	Advanced Digestion + Dewatering	Fertilizer quality Cake	Land application of cake / un-restricted use
	AD + Dewatering + Advanced Alkaline Stabilization	Fertilizer / soil amendment	Un-restricted use on land
	AD + Dewatering + Composting	Compost	Un-restricted use on land
	AD + Dewatering + Drying	Dried Product	Un-restricted use on land or fuel source
Thermal Process	AD + Dewatering + Incineration	Ash	Manufacturing or landfill

5.0 Alternative Strategy Development

As shown previously in Table 4-1, seven biosolids management strategies were developed for detailed evaluation. Section 5 describes the scope of each strategy. To limit variables and reasonably compare strategies, the following assumptions have been made:

1. All strategies are based on an on-site centralized biosolids management facility at Garner Road. Each strategy that utilizes dewatering assumes that centralized dewatering will be implemented at Garner Road, apart from Strategy 4 for advanced alkaline stabilization that would be completed offsite by a third-party contractor, similar to existing practices.
2. Biosolids produced at each WWTP prior to being trucked will be anaerobically digested.
3. Concepts are based on biosolids quantities predicted to 2051, as described in TM 4 – Treatment Facility Operations, Functions and Future Needs. Historical biosolids qualities from 2017 to 2021 at Garner Road have been used to determine existing conditions, and future biosolids volumes are projected based on a mass balance, incorporating future demand as determined through the 2021 Water/Wastewater Servicing Master Plan.
4. Digested liquid biosolids produced at Niagara Fall WWTP will continue to be dewatered and sent directly to the N-Viro facility for all strategies to continue existing contract with Walker Environmental. Any changes to dewatering at Niagara Falls WWTP will be reviewed as part of the implementation plan, discussed in TM 5.

5.1 Strategy 1: AD + Liquid Biosolids Land Application

Strategy 1 is similar to the Region's current biosolids strategy and involves transporting anaerobically digested liquid biosolids from each of the Region's WWTPs, with the exception of the Niagara Falls (NF) WWTP, to the Garner Road Facility.

The liquid biosolids received at the Garner Road Facility would be stored for the winter months when the biosolids cannot be land applied. The storage required for biosolids land application programs in Ontario is a minimum of 240 days. To meet this storage requirement based on the anticipated solids generation in 2051 and 2.4% total solids concentration, the Region will require a total liquid storage capacity of 400,000 m^3 (equivalent to 240 days of storage) at the Garner Road Facility. The current facility has nine lagoons for biosolids storage, each with a capacity of 6,800 m^3 with a total volume of 61,200 m^3. A tenth lagoon is used for centrate and supernatant storage with a capacity of 6,800 m^3. In addition, there are three biosolids storage tanks, each with a capacity of 8000 m^3 for a total tank storage capacity of 24,000 m^3. Overall, the current liquid biosolids storage at the Garner Road Facility is 85,200 m^3. This volume is insufficient for future needs, anticipating an average total solids concentration of 2.4%, and additional liquid storage would be required.

Due to lack of space on the Garner Road site for additional lagoons, additional tank storage would be required to increase liquid storage capacity. At a total solids concentration of 2 percent, the additional storage volume would be over 300,000 m^3, equivalent to over thirty-seven 8000 m^3 capacity tanks, which is impractical.

A representative from Thomas Nutrient Solutions noted that the total solids concentration drawn from the lagoons, as a result of settling and decanting, is between 3 and 6 percent. The difference in storage required between 2.4 and 6 percent is significant.

Storage for 240 days for 39 dry tonnes per day at 2.4% total solids would be over 400,000 m^3. If the total solids concentration were 4 percent, the 240-day liquid storage volume would decrease by half to 200,000 m^3. This would require 15 additional storage tanks, anticipating that the new storage tanks were equal in volume, 8,000 m^3, to those currently in use at the facility. An additional eight storage tanks, each with a volume of 14,400 m^3, could also provide that required additional storage. The tank size and number of tanks would be optimized during detailed design if this strategy is selected, although eight tanks each sized for 14,400 m^3 was used as a basis of comparison, as it is a more reasonable number of tanks, and allows the required storage volume to be divided evenly. As part of this strategy, the existing dewatering facility would be decommissioned, as all biosolids from the facility would be land applied as liquid.

Niagara Region staff report that Thomas Nutrient Solutions is currently able to decant throughout the winter except in the case of very extreme cold conditions due to ice formation. For this strategy, it is assumed that decanting can occur throughout the year, including winter months.

The process is illustrated in Figure 5-1 below:

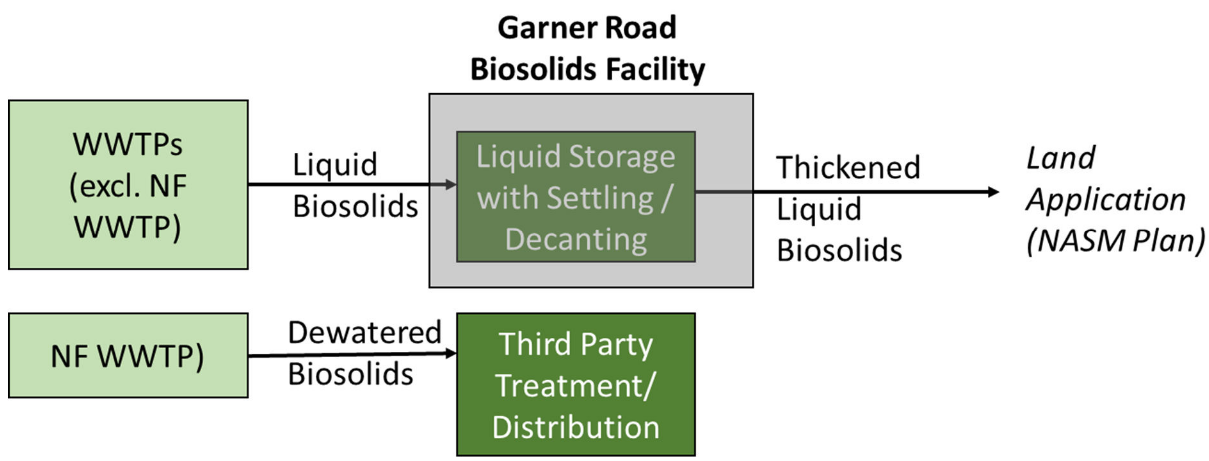

Figure 5-1: Schematic of Strategy 1

Figure 5-2 below illustrates the conceptual site plan for Garner Road under Strategy 1 showing the additional storage tanks required for thickened biosolids. The existing liquid storage lagoons would remain in place.

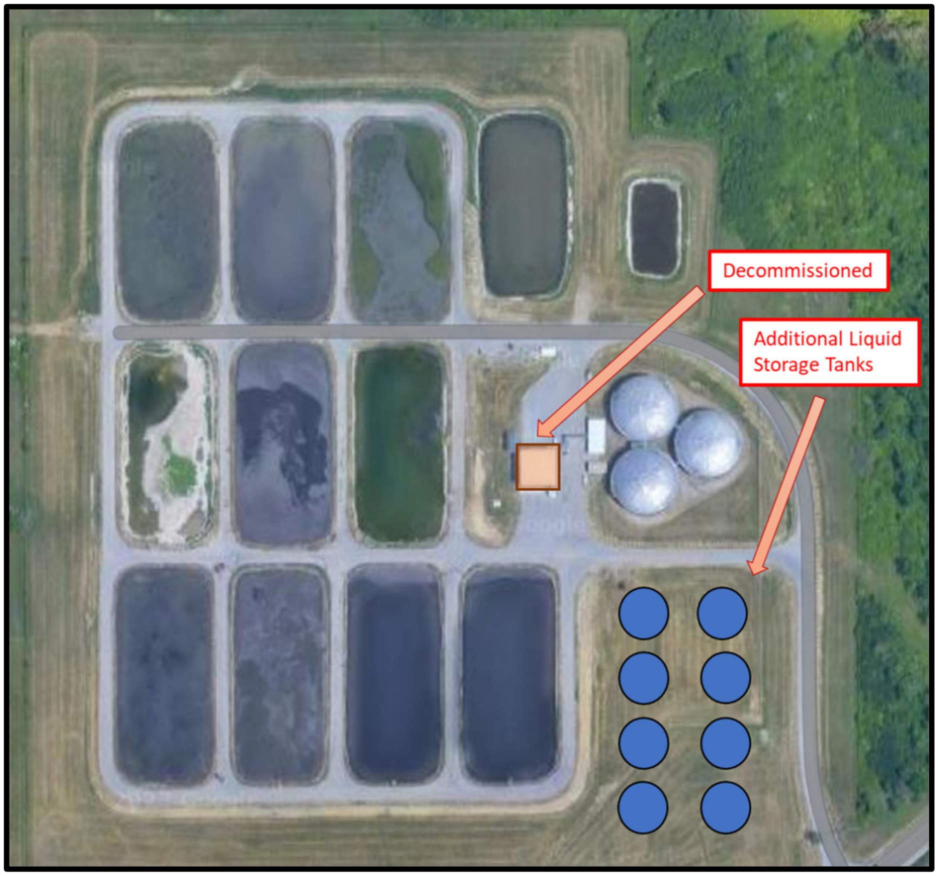

Figure 5-2: Strategy 1 – Garner Road Facility – Conceptual Site Plan

5.2 Strategy 2: AD + Dewatering + Cake Land Application

Strategy 2 also involves transporting anaerobically digested liquid biosolids from each of the Region's WWTPs, with the exception of NF WWTP, to the Garner Road Facility.

Liquid biosolids would be dewatered and stored at the Garner Road Facility during the winter months (240 days of required storage) and land applied as cake during the growing season. Under this strategy, the existing storage tanks and lagoons would be maintained for liquid storage prior to dewatering at a new larger dewatering facility, and the existing dewatering facility would be decommissioned. A cake storage area would provide storage during winter months.

The process is illustrated in Figure 5-3 below:

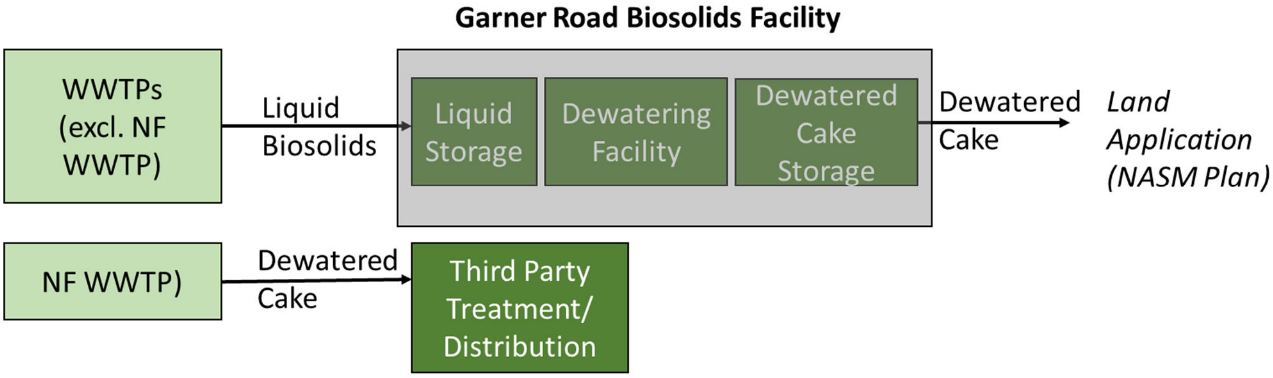

Figure 5-3: Schematic of Strategy 2

Figure 5-4 below illustrates the conceptual site plan for Garner Road under Strategy 2 showing the dewatering facility and cake storage area. The existing liquid storage lagoons would remain in place. The required storage capacity of 240 days during winter will be provided by the combination of existing lagoons, three storage tanks, and the new cake storage facility.

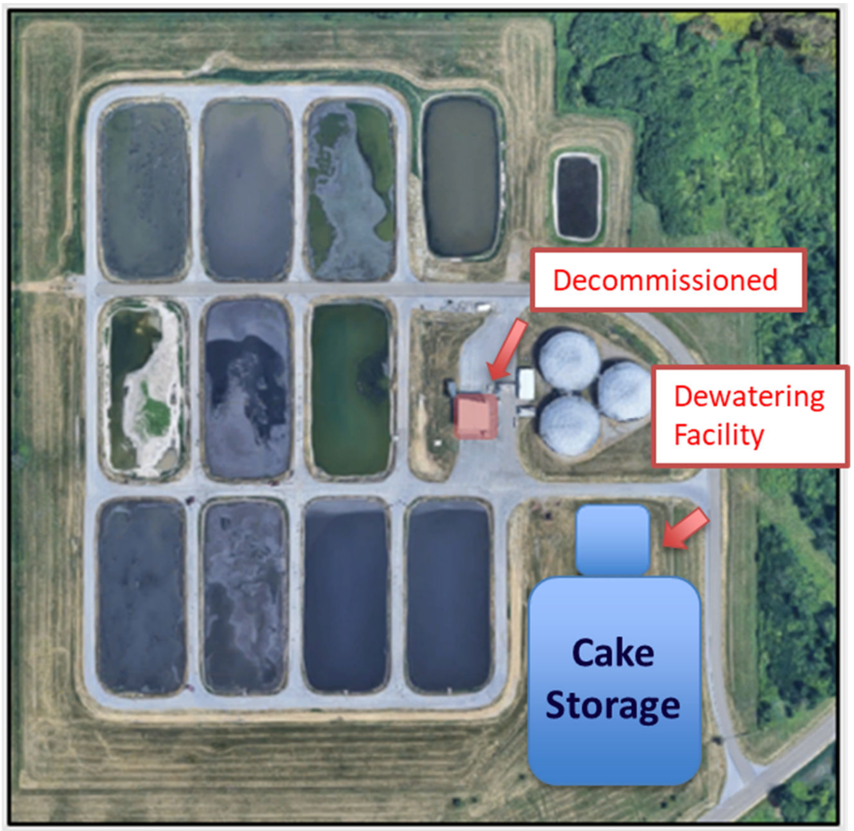

Figure 5-4: Strategy 2 – Garner Road Facility – Conceptual Site Plan

5.3 Strategy 3: AD + Advanced Stabilization + Fertilizer Quality Product

Strategy 3 also involves transporting anaerobically digested liquid biosolids from each of the Region's WWTPs, with the exception of NF WWTP, to the Garner Road Facility.

All liquid biosolids would receive advanced stabilization treatment, followed by dewatering and storage of the CFIA fertilizer product at the Garner Road Facility. Under this strategy, the existing lagoons would be maintained for liquid storage prior to advanced treatment and dewatering in a new facility, and the existing dewatering facility would be decommissioned. The final fertilizer product would be stored in a designated area onsite to accommodate fluctuations in market demand for product.

For the purpose of comparison, it is assumed that the Cambi Thermal Hydrolysis process will be used as the advanced stabilization process, as shown in Figure 5-5 below:

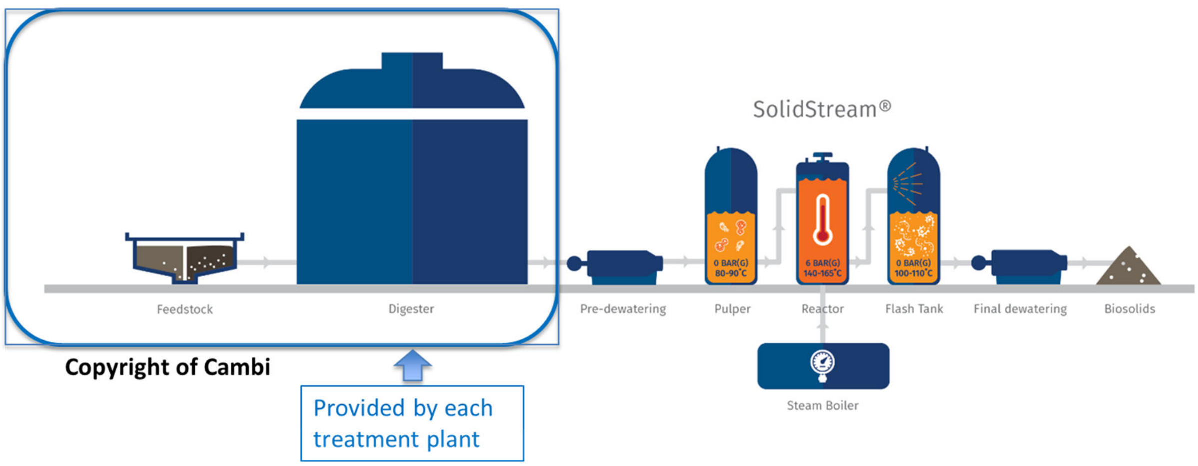

Figure 5-5: Schematic of Cambi Thermal Hydrolysis Process

If this strategy is selected, other forms of two-stage digestion may be considered. The overall process for Strategy 3 is illustrated in Figure 5-6 below:

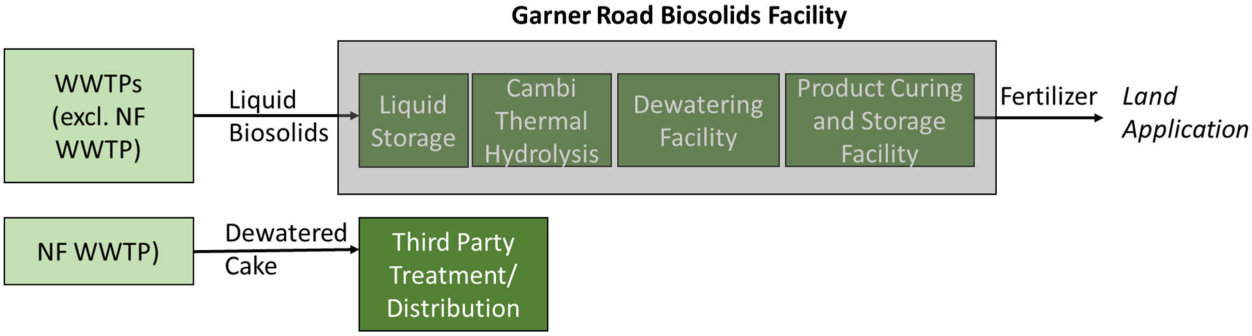

Figure 5-6: Schematic of Strategy 3

Figure 5-7 below illustrates the conceptual site plan for Garner Road under Strategy 3 showing the thermal hydrolysis and dewatering facility and fertilizer cake storage area. The existing liquid storage tanks and lagoons would remain in place.

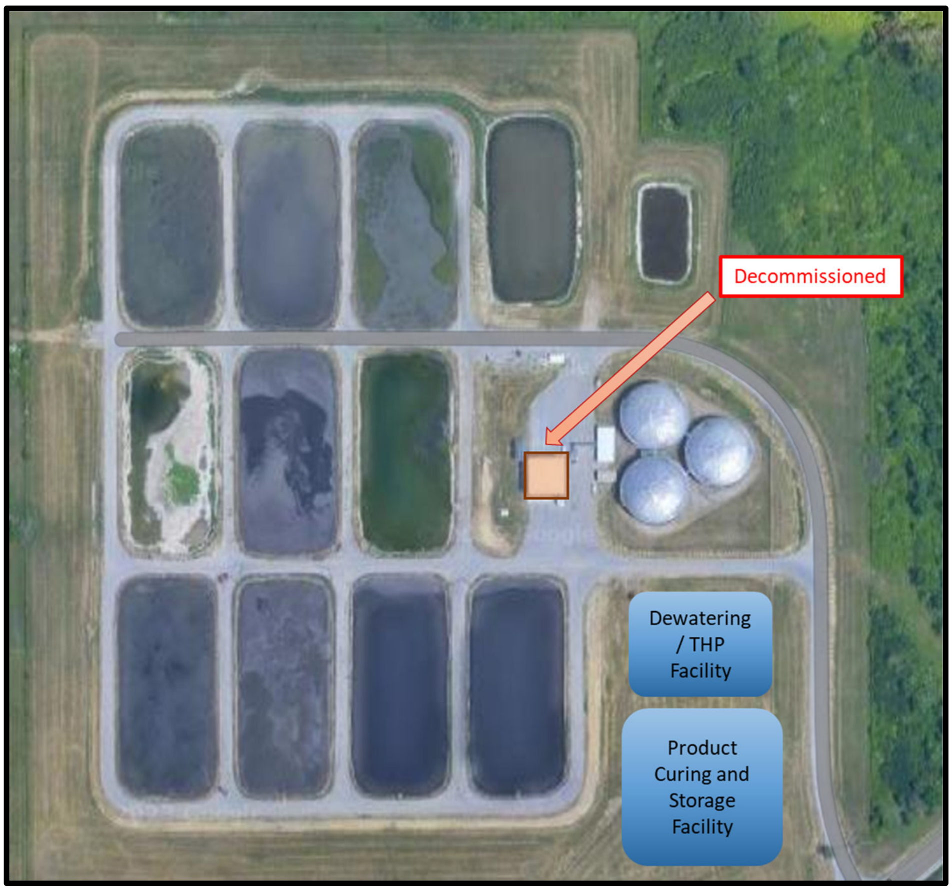

Figure 5-7: Strategy 3 – Garner Road Facility – Conceptual Site Plan

5.4 Strategy 4: AD + Dewatering + Advanced Alkaline Treatment

Strategy 4 also involves transporting anaerobically digested liquid biosolids from each of the Region's WWTPs, with the exception of NF WWTP, to the Garner Road Facility.

All liquid biosolids would be dewatered and stored at the Garner Road Facility prior to being transported by a third-party contractor to be processed offsite using advanced alkaline stabilization to generate a fertilizer grade product. The Region would work with a third-party contractor that operates advanced alkaline stabilization processes, such as N-Viro or Lystek, to meet the requirements for certification as a fertilizer. The third-party would also manage marketing and distribution of the final fertilizer product.

Under this strategy, the existing storage tanks and lagoons would be maintained for storage prior to dewatering in a new dewatering facility, and the existing dewatering facility would be decommissioned. As a conservative approach, cake would be stored in a designated area onsite until it is picked up by the third-party vendor. If this strategy is selected, omission of the cake storage could be considered if third party hauling is available year-round. Also, the new dewatering facility could be equipped with large hoppers and a truck loading bay to allow for on-going truck loading.

The conceptual process schematic for Strategy 4 is illustrated in Figure 5-8 below.

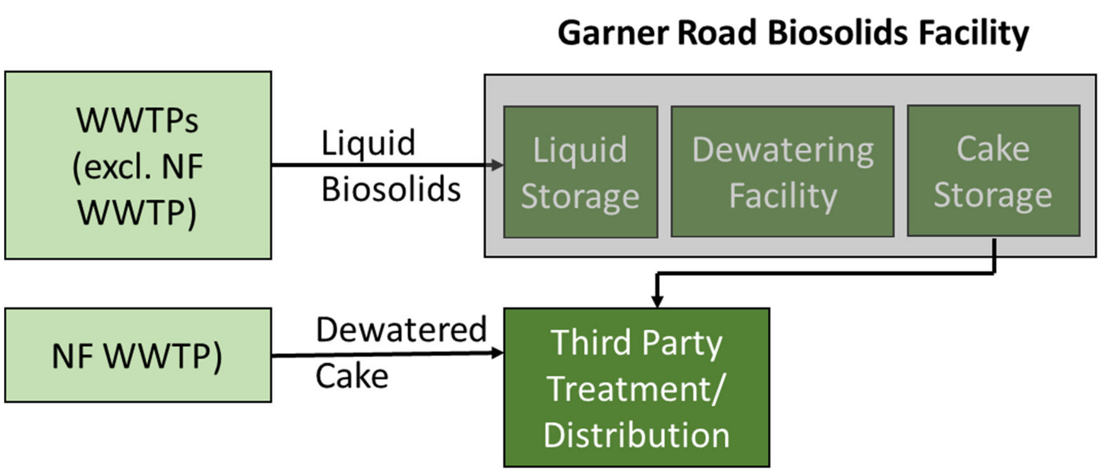

Figure 5-8: Schematic of Strategy 4

Figure 5-9 below illustrates the conceptual site plan for Garner Road under Strategy 4 showing the dewatering facility and cake storage area. The existing liquid storage lagoons would remain in place.

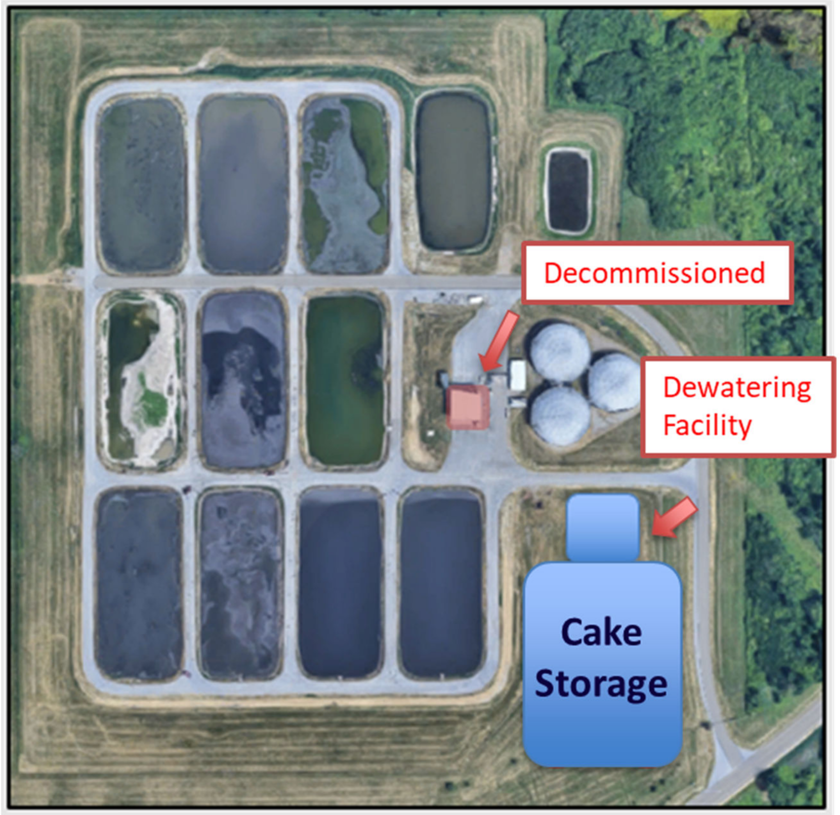

Figure 5-9: Strategy 4 – Garner Road Facility – Conceptual Site Plan

5.5 Strategy 5: AD + Dewatering + Composting + Product Distribution

Strategy 5 also involves transporting anaerobically digested liquid biosolids from each of the Region's WWTPs, with the exception of NF WWTP, to the Garner Road Facility.

All liquid biosolids would be dewatered, blended with organic material amendments and composted at the Garner Road Facility. It is anticipated that the aerated static pile (ASP) composting process would be used for this strategy. The aerated static pile process is relatively compact and more economical compared to other processes including windrow and horizontal agitated bin composting. The aeration provided in the ASP process provides better control and product quality than conventional, non-aerated, windrow composting. The ASP composting process is less costly than the horizontal agitated bin composting system, which includes a large structure to enclose the process along with significant ventilation and odour control systems.

In the aerated static pile process, active composting will last 21 days, followed by 30 days of curing and 90 days of finished compost onsite storage. Organic amendments may consist of wood chips or processed yard waste. Some composting facilities are sized to also process source separated organics (SSO), which may be considered at the Garner Road Facility if this strategy is selected.

The final composted product will have a total solids concentration of approximately 60% total solids concentration and would meet fertilizer standards before distribution. The Region could work with a third-party or be responsible for marketing and distributing the product to end users which could include landscape contractors, nurseries, golf courses, departments of public works and homeowners.

The conceptual process schematic for Strategy 4 is illustrated in Figure 5-10 below.

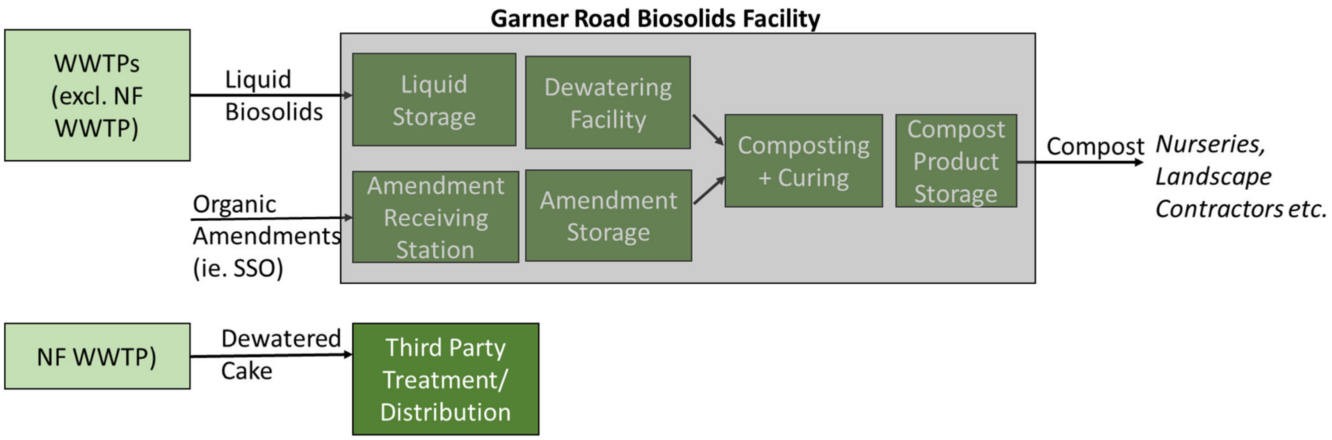

Figure 5-10: Schematic of Strategy 5

Figure 5-11 below illustrates the conceptual site plan for Garner Road under Strategy 5 showing the dewatering and composting areas. The amendment receiving station and storage would be incorporated into the 'Composting Facility' area shown. The composting facility may be located outside the area of the existing lagoons if the Region elects to maintain the lagoon storage. In this scenario, there may be other sites off the Garner Road property to locate the composting process; however, it may be difficult to locate a site in the area with reasonable buffer area. The site plan provided in Figure 5-11 allows individuals to understand the relative scale of the process. For evaluation of scenarios, it is assumed that the composting facility would be located on the existing property in the location of the existing lagoons.

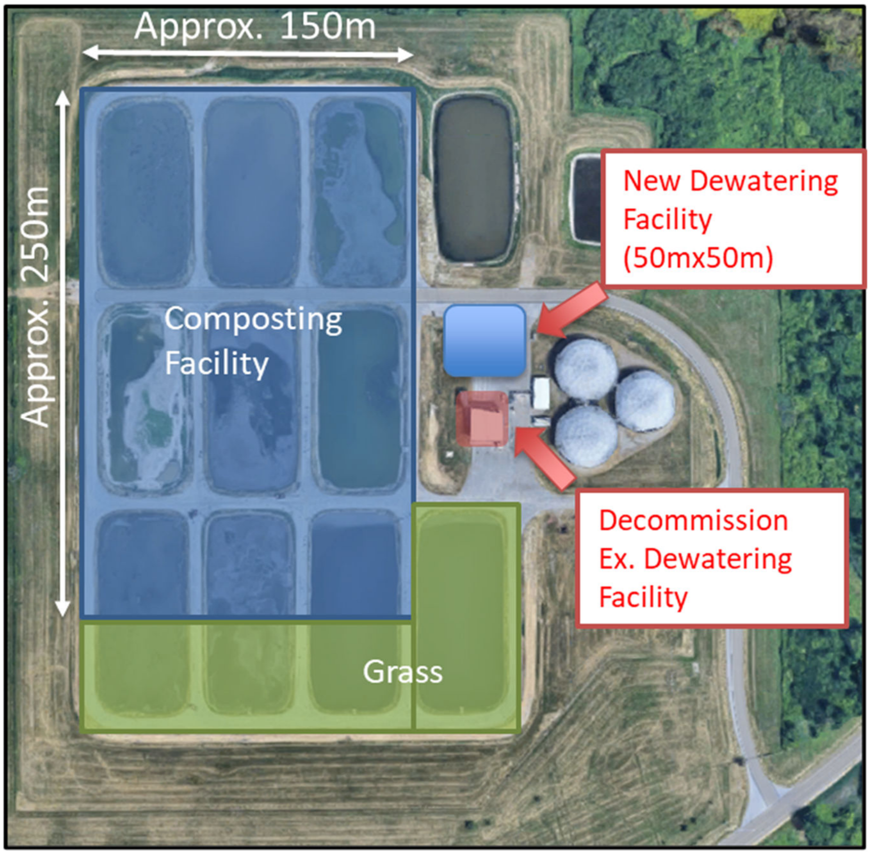

Figure 5-11: Strategy 5 – Garner Road Facility – Conceptual Site Plan

5.6 Strategy 6: AD + Dewatering + Thermal Drying + Product Distribution

Strategy 6 also involves transporting anaerobically digested liquid biosolids from each of the Region's WWTPs, with the exception of NF WWTP, to the Garner Road Facility.

This strategy anticipates that the liquid biosolids would be dewatered and thermally dried. At least one lagoon will be maintained to receive incoming liquid biosolids that would then be pumped to the existing storage tanks, the remaining lagoons could be decommissioned if desired by the region or maintained as a contingency to allow for liquid land application.

Rotary drum direct thermal drying will be used for comparison purposes. The rotary drum process is recommended for evaluation based on the scale required to process the solids to be generated by the Region and the characteristics of the final product. Rotary drum drying can produce a hard round pellet of a consistent size that is very marketable. If this strategy is selected as the preferred alternative, other drying technologies may also be considered. The final dried product will be of fertilizer quality and have a total solids concentration of 92%. Storage will be provided in a silo for approximately 50 tonnes of final product; additional offsite storage would also be provided by the Region or by a third-party distributor that would market the product to end users.

Supplemental heat is required to operate the dryer facility. It is assumed that biogas will not be available at the Garner Road Facility, as there is no anaerobic digestion at this location. Therefore, supplemental heat would be supplied by natural gas. Regenerative Thermal Oxidation will be used to treat the dryer off gas. The facility will be approximately 2 ½ stories tall with a floor area of approximately 1,500 m^2.

The conceptual process schematic for Strategy 6 is illustrated in Figure 5-12 below.

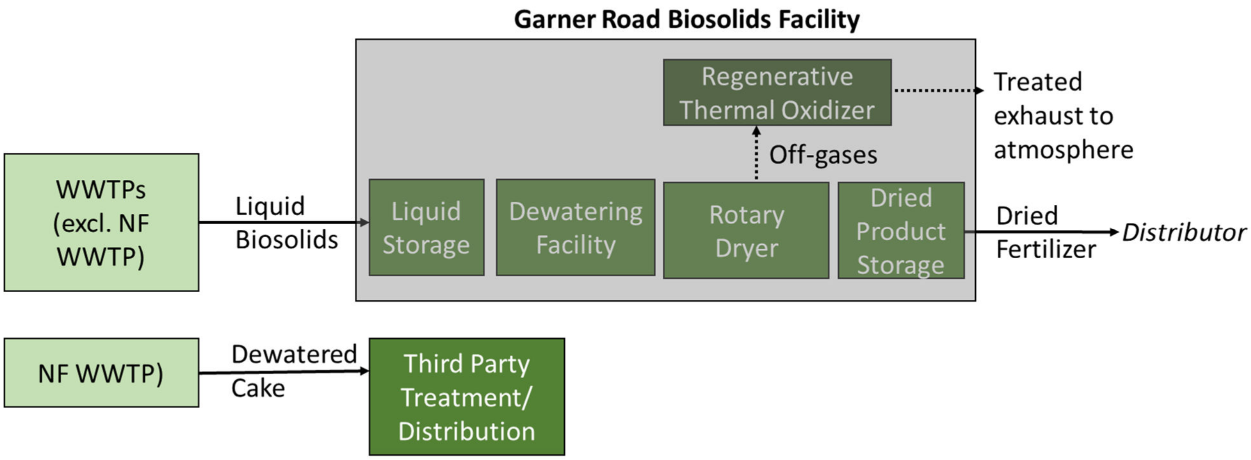

Figure 5-12: Schematic of Strategy 6

Figure 5-13 below illustrates the conceptual site plan for Garner Road under Strategy 6 showing the dewatering and drying facilities. The area where the existing lagoons are situated may be repurposed, as needed.

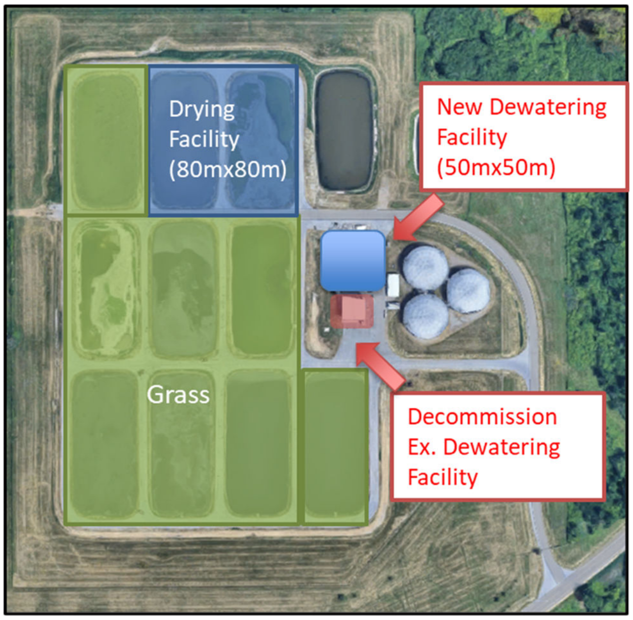

Figure 5-13: Strategy 6 – Garner Road Facility – Conceptual Site Plan

5.7 Strategy 7: AD + Dewatering + Thermal Processing

Strategy 7 also involves transporting anaerobically digested liquid biosolids from each of the Region's WWTPs, with the exception of NF WWTP, to the Garner Road Facility.

The Region expressed an interest in thermal processing to minimize the amount of material to be managed following processing. All liquid biosolids would be dewatered and thermally processed. It is anticipated fluidized bed incineration would be used as the method of thermal processing based on the current level of development and acceptance of this technology. This process is typically used when existing incineration facilities are upgraded. Other thermal treatments may be considered if this strategy is selected as the preferred alternative. The final ash product would be land-filled or could potentially be used in the production of concrete or bricks.

Under this strategy, the existing storage tanks would be used to receive liquid biosolids. The lagoons could be decommissioned or repurposed to serve as ash holding.

The new incineration facility would be approximately 3 stories tall with a floor area of approximately 2000 m^2. Emissions are produced from the incineration process, and emission treatment is included in the proposed strategy to ensure compliance with environmental regulations.

The conceptual process schematic for Strategy 7 is illustrated in Figure 5-14 below.

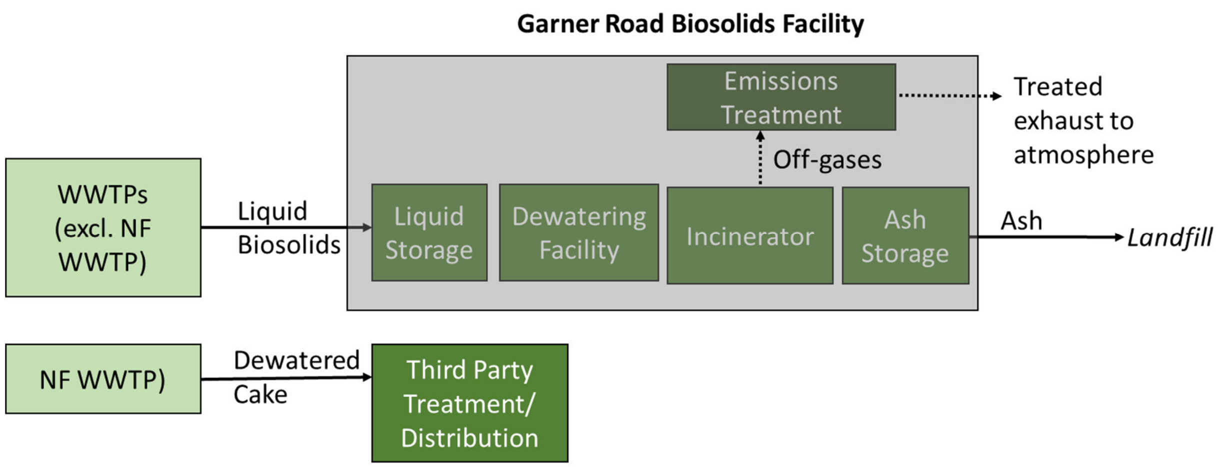

Figure 5-14: Schematic of Strategy 7

Figure 5-15 below illustrates the conceptual site plan for Garner Road under Strategy 7 showing the dewatering and incineration facilities. The area where the existing lagoons are situated may be repurposed, as needed.

Figure 5-15: Strategy 7 – Garner Road Facility – Conceptual Site Plan

6.0 Methodology for Detailed Evaluation of Strategies

6.1 Step 1: Detailed Evaluation

Each of the short-listed biosolids strategies developed in Section 5 were carried forward for detailed evaluation. The biosolids management strategies were evaluated against four key factors: natural environment impacts, socio/cultural impacts, technical feasibility, and financial viability (costs). Each factor is comprised of specific criteria, as described in TM 6 - Evaluation Methodology and Criteria. The rating scale of 1 to 10, as shown in Table 6-1, was used to evaluate the impact of each strategy based on those criteria and develop a score and ranking.

Table 6-1: Evaluation Rating Scale

Impact Description	Impact Rating
Positive or no impact	9-10
Minor impact	7-8
Moderate impact	5-6
High impact	3-4
Severe impact	1-2

6.2 Step 2: Differential Criteria Most Important to the Region

Based on the evaluation presented in the next section, there is minimal difference in the total scoring among the top 5 biosolids management strategies. Each strategy is effective at managing biosolids within the Region while also protecting human health and the environment and would meet the Region's objectives as defined in the Problem and Opportunity Statement. Consequently, to select the preferred design concept, a second level of assessment was undertaken that considered the key priorities of the Region as reflected by criteria that were notably different between the strategies. These criteria are referred to as 'differentiating criteria'.

Of the 30 total criteria, 10 criteria were selected that showed more variation between alternative strategies, and were also considered important to the Region. These criteria, known as 'differentiating criteria' are listed below, and are each given equal weighting in this level of evaluation.

1. Greenhouse Gas Emissions
2. Nutrient Recovery and Potential for Beneficial Reuse by Agricultural users
3. Proven Performance
4. Odour at Garner Road Facility
5. Truck Traffic
6. Long Term Sustainability

7. Ease of Operation
8. Resiliency
9. Ease of Implementation
10. Life Cycle Cost

The evaluation was performed again using only the "differentiating criteria". The strategies that had the most positive impacts or lowest negative impacts based on the above 10 criteria were selected as preferred and carried forward for further detailed development.

6.3 Step 3 – Optimization of the Strategy or Strategies

Following the selection of the preferred strategy or strategies, the different approaches for implementing the strategies will be identified and evaluated, including consideration of additional solids stream treatment at the WWTPs and WTPs and associated treatment requirements at Garner Road, as well as haulage requirements. An optimized biosolids management approach will be determined based on the evaluation with the objectives of reducing hauling, costs, greenhouse gas emissions and community impacts. Technical Memorandum (TM) 5 documents this evaluation and describes the optimized biosolids approach.

7.0 Evaluation of Alternative Strategies

The Alternative Evaluation Matrix used to compare the alternatives is included as Appendix A**.** The matrix provides scoring for each alternative relative to Environmental, Social–Cultural, Technical, and Economic Criteria as described in Section 5. Details on the assessment are described in the following sub-sections.

7.1 Natural Environment

7.1.1 Terrestrial and Aquatic Systems

All alternative strategies will use the Garner Road property as a centralized facility for biosolids management. As this property has been previously disturbed, it has little potential for terrestrial or aquatic habitats or species at risk. Minimal impacts are expected due to facility construction and can be mitigated.

All alternative strategies will meet applicable land application and fertilizer regulations. However, liquid biosolids managed under NASM will have slightly higher risks to aquatic systems, followed by direct land application of dewatered biosolids. Land application of fertilizer quality product has the lowest potential for aquatic system impacts, so Strategies 3, 4, 5, and 6 score higher. Incineration products have negligible aquatic impacts, as the ash will not be land applied.

7.1.2 Surface Water Quality and Groundwater Systems

Additional biosolids management facilities at Garner Road are not expected to have major impacts on surface water quality for all alternatives. However, open pile composting (Strategy 5) and incinerator ash storage lagoons (Strategy 7) may result in higher risk of runoff requiring more mitigation to control impacts (e.g., lining, directing runoff to the sanitary sewer system). Biosolids being land applied have potential to impact surface water systems through runoff into watercourses, with liquid biosolids managed under NASM having highest impacts, followed by direct land application of dewatered biosolids, and fertilizer quality land application. None of the alternatives are expected to significantly impact groundwater quality if land applied in accordance with NASM plan outside of Source Water Protection Areas. Composting leachate and ash lagoons would require containment to prevent infiltration for Strategies 5 and 7, accordingly.

Overall, the scores for surface and groundwater quality impacts are comparable for all strategies.

7.1.3 Soil Quality

Biosolids being land applied have potential to positively impact soil quality, with fertilizer products having the most benefits for soil quality (Strategies 3, 4, 5 and 6). Incineration will not affect soil quality. NASM products have a lower value than fertilizer quality products and are ranked lower.

7.1.4 Air Quality and Greenhouse Gas (GHG) Emissions

All alternatives would be designed to include emission controls such that all air quality standards are met, and impacts are mitigated. Trucking is a source of air quality impacts. As such, alternatives with the most volume of product will require the most trucks (e.g., Strategy 1 – digested liquid product and Strategy 5 - composted product) and potentially have more impacts on air quality.

GHG emissions were calculated using the Biosolids Emissions Assessment Model (BEAM) as developed by the Canadian Council of Ministers of the Environment (CCME), and consider three components:

1. Scope 1 – Direct Emissions, which could include emissions related to fugitive methane from anaerobic digestion, or natural gas heating, or other types of fuel combustion
2. Scope 2 – Indirect Emissions associated with electricity used at the facility, and
3. Scope 3 – All other indirect emissions, such as fuel burned for transportation of materials. Scope 3 also includes credits to offset fertilizer production when biosolids are land applied.

GHG emissions calculations for each strategy are summarized in the table below:

Table 7-1 – Greenhouse Gas Emissions Estimates

Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6	Strategy 7
AD + Liquid Biosolids Land Application	AD + Dewatering + Cake Land Application	AD + Advanced Stabilization (THP) + Fertilizer Quality Product	AD + Dewatering + Advanced Alkaline Treatment	AD + Dewatering + Composting + Product Distribution	AD + Dewatering + Thermal Drying + Product Distribution	AD + Dewatering + Thermal Processing
-759 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-3,724 mg CO2 eq/ mg dry solids	5,354 mg CO2 eq/ mg dry solids

The GHG calculation for each strategy does not incorporate the emissions related to transporting the liquid biosolids from the WWTPs and WTPs to Garner Road, as these would be the same for each strategy. The calculations also do not incorporate the emissions related to transporting the final products by truck to their end use markets. GHG emissions from trucking are considered in a qualitative manner under this criterion, while the social implications of truck traffic are considered under the "truck traffic" criterion under the "Social and Cultural Impacts" category described in the next section.

Incineration has the greatest potential to produce GHG emissions (Strategy 7) as it involved burning a product that directly releases CO_2. However, it will have less GHG emissions associated with trucking the final products. Liquid land application (Strategy 1) has the second highest impacts due to the highest trucking volumes and associated vehicle fuel combustion. Thermal drying (Strategy 6) has the next highest impact due to the heating requirements and associated natural gas consumption. All strategies except for Incineration (Strategy 7) include GHG credits for offsetting fertilizer production needs when biosolids are land applied. Overall, due to these credits, Strategies 1 through 6 are expected to have a net benefit (i.e., negative net GHG emissions value) based on the assumptions stated above.

7.2 Social and Cultural Impacts

7.2.1 Odour, Noise and Vibrations at Garner Road Facility During Operation

Composting (Strategy 5) has the greatest potential to generate odour at the Garner Road Facility, followed by long term cake storage of anaerobically digested cake at the facility (Strategy 2) and the thermal drying process (Strategy 6) if the process odour control is not operating properly. The thermal drying process uses regenerative thermal oxidation to treat the process air to reduce the chance of onsite odours. Overall, odour generated for each of the strategies can be reasonably contained and treated. The Garner Road Facility is also located away from sensitive receptors.

Noise and vibrations from operations will be minimal and controlled for all alternatives.

7.2.2 Truck Traffic

Strategies that transport larger volumes of biosolids will result in increased truck traffic and score lower. Liquid land application (Strategy 1) requires the largest volume of hauling and scores the lowest. Composting (Strategy 5) requires the addition of aggregate product (75% of total volume), which increases the hauling volumes to and from the Garner Road Facility.

7.2.3 Construction Disruptions

Minimal construction disturbances are expected for each strategy due to construction being isolated to the Garner Road Facility which is away from residential and commercial areas. The scoring is consistent for each strategy.

7.2.4 Property Acquisition and Easements, and Adjacent Land Use Compatibility

Given the assumptions in developing each alternative, the Garner Road site has sufficient space to accommodate each of the proposed strategies. However, composting requires large tracks of land and the area for composting may require additional land if liquid lagoon storage is to be maintained at the Garner Road Facility. As such, Strategy 5 scores lower.

Garner Road is zoned HI (heavy industrial) surrounded by HL (hazard land) that borders environmental protected areas. Prestige industrial (PI) zoned land is to the south. All alternatives are compatible with current zoning, and there is no difference in scoring.

7.2.5 Nutrient Recovery and Beneficial Use for Agricultural Land Users

Except for incineration, agricultural users will benefit from all of the biosolids products evaluated, those that are anaerobically digested and those that have been further processed to achieve fertilizer quality certification. They all provide essential plant nutrients and organics to improve soil quality. The products that achieve the fertilizer certification rank higher because they have a higher total nutrient concentration.

Advanced Stabilization (THP) (Strategy 3) and Thermal Drying (Strategy 6) reduce soil compaction associated with spreading. Advanced Alkaline Stabilization (Strategy 4) includes lime addition which is a benefit to many agricultural programs. Compost product, Strategy 5, could also be used in agriculture, but has a higher volume requirement to provide the same amount of nitrogen to the soil when compared with the other products. Incinerator ash is not applicable for use on agricultural lands and scores the lowest.

7.2.6 Archaeological and Cultural Heritage

None of the strategies are expected to impact cultural heritage or archaeological resources; Individual projects will have site specific archaeological and cultural heritage assessments, if required.

7.2.7 Other Social Impacts

None of the strategies will impact recreational uses, as Garner Road is not near any recreational facilities.

Regulations are present to protect human health and all strategies meet these requirements.

Composting and open lagoons have higher potential for visual impact than the other strategies. However, the impacts are expected to be minimal given that the Garner Road Facility is not easily viewed by the public. Thermal drying, dewatering and thickening operations would be enclosed in a building for minimal visual impacts.

7.3 Technical Considerations

7.3.1 Proven Performance

All strategies would be designed to effectively treat and manage biosolids. All processes are proven at a scale similar to Niagara Region except for THP, which does not currently have any installations post-digestion in North America.

7.3.2 Long Term Sustainability

While all biosolids products considered can be marketed, the products that meet fertilizer certification criteria can be marketed with no regulatory requirements outside of the processing facility. Thermally dried product has the highest marketability of the products considered. There is a strong demand in the agricultural and public markets. As such, Strategy 6 ranks the highest for sustainability.

Anaerobically digested biosolids, liquid and dewatered, can be marked to the agricultural community which has a significant demand in the Golden Horseshoe area. Advanced alkaline stabilized product also has a strong demand in the agricultural market which is boosted by the products ability to impact the soils pH. The product of advanced digestion, using THP, would be most suitable for the agricultural community, based primarily on its total solid concentration of approximately 40%. Compost can be marketed to the public, but the total demand is lower than that of agricultural and is strongest in the spring and fall horticultural seasons. Strategies 1, 2, 3, 4, and 5 are comparable in sustainability. The market for Incinerator ash is different: the market is with brick and block producers and not with the agricultural community or the general public. This market has lower predictability in the long term and Strategy 7 is ranked lowest for sustainability.

7.3.3 Ease of Operation

The Region can operate the processes considered in each of the alternative strategies. Technologies that the Region is currently operating, or are familiar with, were ranked the highest (Strategies 1, 2, and 4). The alternatives which include complex technologies, or require specific certifications, were ranked lower. In particular, Strategy 3 ranked the lowest, as it requires operators to have the Stationary Engineer certification to safely operate the facility. Staff with this qualification may be difficult to find, and additional training or hiring would be required.

7.3.4 Resiliency

Strategies that can generate products with a demand from multiple markets ranked higher, as they are more resilient to market fluctuations through diversification. The Region may consider a biosolids management program that has more than one outlet, such as land application and distribution to the public. As a result, strategies that have multiple market outlets or complement each other, for example those that include dewatering, ranked higher. Also, the ability to manage the material through all seasons was considered in the scoring. For example, the disposal of incineration ash for Strategy 7 can be done throughout the year, and is not seasonally dependent, such as liquid or cake which can only be land applied during the warmer months.

7.3.5 Ease of Implementation

The strategies that can be implemented without disturbing the current biosolids management program ranked higher. Alternatives that require additional storage at the Garner Road Facility or at a third-party managed location scored lower, partly due to the difficulty to move away from a specific third-party contractor without the equivalent storage identified at another location. Facilities with smaller footprints scored higher as did those that would not require significant changes to the infrastructure current serving the Garner Road Facility. Composting (Strategy 5) has the largest footprint and may require additional lands and scored the lowest. In addition, alternatives that do not have a proven market in Niagara for their products scored lower (i.e., incineration). Thermal drying also scored lower because it is a significant change to the facility layout and the biosolids management program would be significantly different.

7.3.6 Compatibility with Existing Infrastructure

The alternative treatment processes associated with each strategy, if implemented at the Garner Road Facility, are compatible with infrastructure in the area. However, thermal hydrolysis (Strategy 3), thermal drying (Strategy 6), and thermal processing (Strategy 7) require additional power and natural gas at the site.

7.3.7 Energy Use and Recovery

All strategies considered retaining the use of anaerobic digestion at the WWTPs. The biogas generated in the digestion process can be recovered and used. Since the Garner Road Facility is "remote" to the treatment facilities it will not be able take advantage of that gas. The alternatives that use the least amount of power at the Garner Road Facility were ranked higher.

7.3.8 Climate Change Adaptability

Climate change, and associated wet weather flows, severe weather events and the like will not impact the operation of the proposed strategies for a period long beyond the study period (2051). Severe wet weather events may limit the ability to apply biosolids on agricultural land. Also, open pile composting (Strategy 5) is more likely to be impacted by heavy rainfall as it is conducted outdoors.

7.3.9 Permits and Approvals

All strategies can be approved for construction and permitted for operation. Some will require additional site permitting based on the alternatives' level of pathogen reduction. Incineration (Strategy 7) would require a higher degree of review associated with air quality. Some may be required to perform a pilot operation to allow the Region and the Ministry to witness successful operation (i.e., Strategy 3 with thermal hydrolysis). Strategies that require additional actions to obtain required permits will score lower.

7.4 Economic Considerations

For each of the seven strategies, the capital, operating and maintenance (O&M) and 30-year life cycle cost were calculated for comparison purposes. The costing was based on the scope of work for each strategy described in Section 5. Table 7-2 summarizes the estimated costs for each alternative. Figures Figure 7-1 graphically compares the 30-year life cycle cost for each strategy.

Table 7-2: Cost Comparison of Biosolids Management Strategies

	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6	Strategy 7
	AD + Liquid Biosolids Land Application	AD + Dewatering + Cake Land Application	AD + Advanced Stabilization (THP) + Fertilizer Quality Product	AD + Dewatering + Advanced Alkaline Treatment	AD + Dewatering + Composting + Product Distribution	AD + Dewatering + Thermal Drying + Product Distribution	AD + Dewatering + Thermal Processing
Economic							
Capital Cost*	$ 122 M	$ 44 M	$ 112 M	$ 35 M	$ 55 M	$ 92 M	$ 274 M
Annual O&M Cost	$ 3.6 M	$ 5.9 M	$ 6.3 M	$ 8.1 M	$ 4.2 M	$ 7.4 M	$ 9.4 M
Life Cycle Cost	$ 189 M	$ 158 M	$ 236 M	$ 193 M	$ 137 M	$ 237 M	$ 453 M

*Capital cost excludes any land acquisition costs.

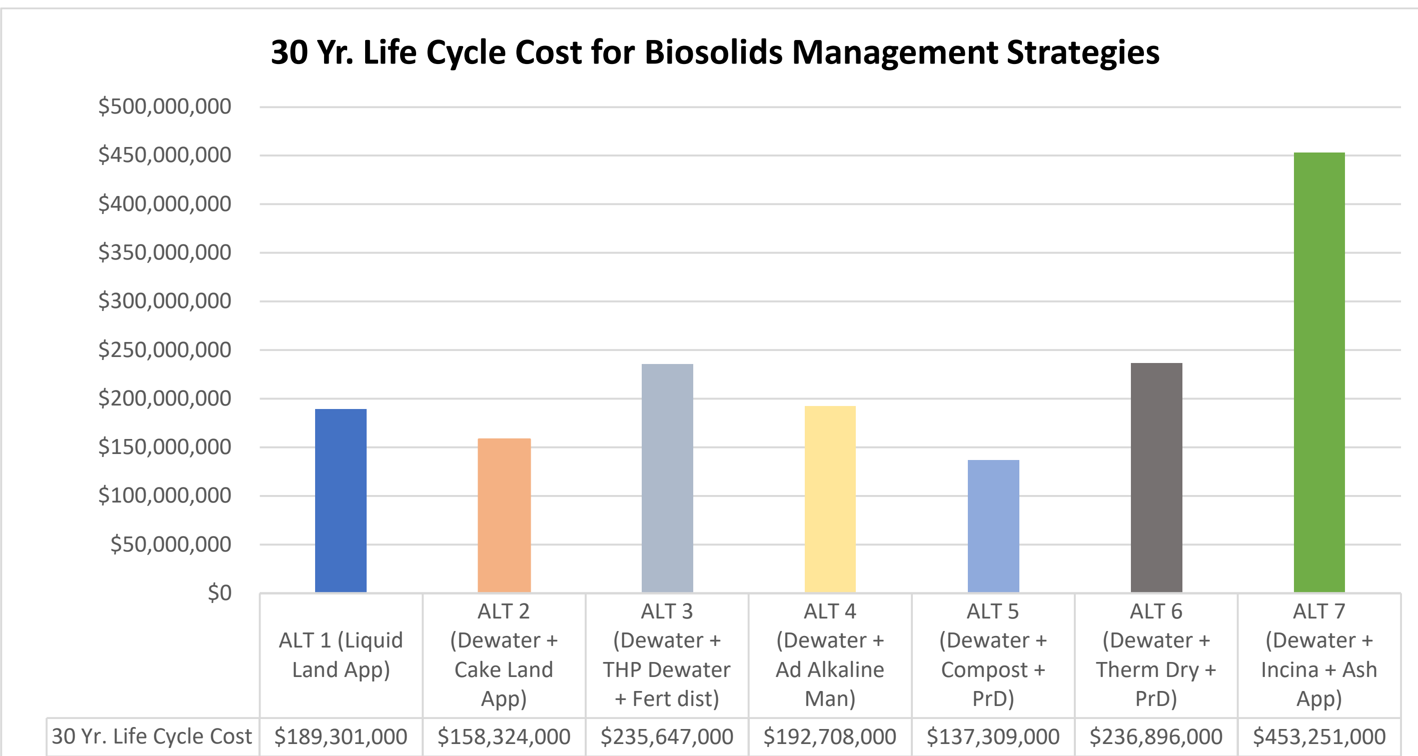

Figure 7-1 – Estimated 30 Year Life Cycle Cost for Biosolids Management Strategies

Overall, Composting (Strategy 5) has the lowest life cycle cost. Strategies 1, 2, 3, 4 and 6 have relatively similar life cycle costs. Incineration (Strategy 7) has the highest life cycle cost that is significantly higher than all other strategies. Refer to Appendix B for a detailed breakdown of costing for each strategy.

8.0 Selection of Recommended Biosolids Management Strategies

Based on the detailed evaluation described in Section 7 and as shown in the evaluation matrix in Appendix A, the strategy scores and rankings are summarized in Table 8-1.

Table 8-1: Summary of Detailed Evaluation Results Using All Criteria

	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6	Strategy 7
	AD + Liquid Biosolids Land Application	AD + Dewatering + Cake Land Application	AD + Advanced Stabilization (THP) + Fertilizer Quality Product	AD + Dewatering + Advanced Alkaline Treatment	AD + Dewatering + Composting + Product Distribution	AD + Dewatering + Thermal Drying + Product Distribution	AD + Dewatering + Thermal Processing
Environmental	16.8	18.2	20.4	20.4	18.9	19.6	17.5
Socio-Cultural	19.5	19.8	20.5	20.5	17.7	20.2	19.5
Technical	19.4	19.2	15.0	20.0	16.7	16.7	15.3
Economic	15.8	18.3	13.3	16.7	19.2	13.3	6.7
Total Score	71.6%	72.7%	69.1%	76.1%	72.7%	69.9%	59.0%
Ranking	3	2	5	1	2	4	6

Based on the detailed evaluation using all criteria and equal weighting for each of the four criterion types, the highest ranked strategy is Strategy 4 that uses anaerobic digestion with dewatering and advanced alkaline treatment prior to land application as a fertilizer quality product. Strategies 2 and 5 are tied for second, with Strategies 1, 3 and 6 ranked just slightly below Strategies 2 and 5.

As the strategy scores are relatively close for the top six strategies (strategies 1, 2, 3, 4, 5 and 6), a second level evaluation was undertaken that focused on differentiating criteria that were also deemed to be important to the Region as listed in Section 6.2.

The results of this second level of evaluation are summarized in the table below:

Table 8-2: Summary of Detailed Evaluation Results Using Only Differentiating Criteria

	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6	Strategy 7
	AD + Liquid Biosolids Land Application	AD + Dewatering + Cake Land Application	AD + Advanced Stabilization (THP) + Fertilizer Quality Product	AD + Dewatering + Advanced Alkaline Treatment + Fertilizer Quality Product	AD + Dewatering + Composting + Product Distribution	AD + Dewatering + Thermal Drying + Product Distribution	AD + Dewatering + Thermal Processing
Total Score	69%	72%	63%	75%	61%	66%	54%
Ranking	3	2	5	1	6	4	7

Based on the second level evaluation using only the differentiating criteria, Strategies 4 is still ranked the highest, with strategies 2 and 1 ranked second and third, respectively. There is a greater range of scores resulting from the second level of evaluation. The results also reinforce the top two ranked strategies, which are the same as the first level of evaluation considering all criteria. Each of the top three strategies include anaerobic digestion, with two of the three strategies also including dewatering. Strategy 4 includes advanced alkaline stabilization to create a fertilizer quality product, while Strategy 2 includes direct land application of the dewatered cake. Strategy 1 is similar to the Region's current approach with land application of liquid biosolids. As each of these strategies use anaerobic digestion, they are compatible with each other, and could be implemented together to increase diversification of biosolids management, which still utilizing some of the Region's existing infrastructure.

Strategy 6 using anaerobic digestion, dewatering, thermal drying and land application of a fertilizer quality product scored nearly as high as Strategy 1, and ranked forth. However, this alternative is more challenging to implement, as it would be a new technology for the Region with a significant learning curve for operation staff, and a new end-use market to develop.

Strategy 2, the second highest ranked strategy, includes dewatering followed by direct land application of cake. Although dewatering is currently done in by the Region, direct land application of the cake has not been done. As such, there is some uncertainty as to whether agricultural landowners that currently receive liquid biosolids would be open to receiving a cake product. To better understand the market and logistics of managing a cake land application program, the Region is planning a cake land application pilot program during the summer of 2024.

Overall, it is recommended that Strategies 2 and 4 be developed further, with consideration for continuing with liquid land application (Strategy 1) in combination with Strategy 4 if the cake land application pilot described above does not receive sufficient buy-in from farmers or encounters other operational issues. Liquid storage and provisions for liquid land application could also be maintained to ensure program diversification, considering liquid storage is already in place and the land being used for storage is not required to implement strategies 2 or 4.

9.0 Next Steps

Based on the results of the detailed evaluation, and the recommended strategies, the next step is to look at ways to optimize the diversified biosolids management program and develop an implementation plan. This will include reviewing options for dewatering at WWTPs to reduce trucking requirements, GHG emissions, and storage needs at the Garner Road Facility. Based on the optimized strategy, the final implementation plan will also consider diversification of markets, potential improvements to third-party contracts, contingency measures and phasing of the improvements.

Appendix A – Detailed Evaluation Matrices

Sub-Criteria	Strategy 1 - AD + Liquid Biosolids Land Application	Strategy 2 - AD + Dewatering + Cake Land Application	Strategy 3 - AD + Advanced Stabilization (THP) + Fertilizer Quality Product	Strategy 4 - AD + Dewatering + Advanced Alkaline Treatment	Strategy 5 - AD + Dewatering + Composting + Product Distribution	Strategy 6 - AD + Dewatering + Thermal Drying + Product Distribution	Strategy 7 - AD + Dewatering + Thermal Processing (Incineration)
Natural Environment							
Terrestrial Systems	All alternatives will use Garner Road property as centralized facility for biosolids management, which has been disturbed and has little potential for terrestrial habitats or species. Minimal impacts due to facility construction, with positive impacts associated with the benefical land use of the final products for strategies 1 - 6 and neutral land impacts for incineration.						
	8	8	8	8	8	8	8
Aquatic Systems	All alternatives will use Garner Road property as centralized facility for biosolids management, which has been disturbed and has little potential for aquatic habitats or species. Minimal impacts due to facility construction. Without proper application and set backs, biosolids being land applied have potential to impact aquatic systems through runoff into watercourses that could impact fisheries. All alternatives will meet applicable land application and fertilizer regulations. However, with liquid biosolids managed under NASM having slightly higher risks to aquatic systems, followed by direct land application of dewatered biosolids, and fertilizer quality land application.						
	7	7	8	8	8	8	8
Surface Water Quality	Additional biosolids management faciities at Garner Road are not expected to have major impacts on surface water quality for all alternatives. However, open pile composting (Alternative 5) and incinerator ash storage lagoons (Strategy 7) may result in higher risk of runoff requiring more mitigation to control impacts (e.g. lining, directing runoff to the sanitary sewer system). Biosolids being land applied have potential to impact surface water systems through runoff into watercourses, with liquid biosolids managed under NASM having highest impacts, followed by direct land application of dewatered biosolids, and fertilizer quality land application.						
	7	7	8	8	7	8	7
Groundwater Water Quality and Quantity, and Source Water Protection	None of the alternatives are expected to significantly impact groundwater quality if land applied in accordance with NASM plan outside of Source Water Protection Areas. Composting leachate and ash lagooon would require containment to prevent infiltration.						
	7	7	8	8	7	8	7
Soil Quality	Biosolids being land applied have potential to positively impact soil quality, with fertilizer products having the most benefits for soil quality. Incineration will not affect soil quality. NASM products have a lower value than fertilizer quality products and are ranked lower.						
	7	7	9	9	9	9	7
Air Quality	All alternatives would be designed to include emission controls such that all air quality standards are met and impacts mitigated. Trucking is source of air quality impacts; alternatives with the most volume of product will require the most trucks (e.g. Strategy 1 - digested liquid product and Strategy 5 - composted product) and potentially have more impacts on air quality.						
	6	7	8	8	6	8	8
Greenhouse Gas Emissions (GHG)	-759 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-3,724 mg CO2 eq/ mg dry solids	5,354 mg CO2 eq/ mg dry solids
	5	8	8	8	8	6	4
Total Score (Out of 70)	47	51	57	57	53	55	49
Weight	25	25	25	25	25	25	25
Normalized Score (Total 25)	**16.8**	**18.2**	**20.4**	**20.4**	**18.9**	**19.6**	**17.5**
Sub-Criteria	**Strategy 1 - AD + Liquid Biosolids Land Application**	**Strategy 2 - AD + Dewatering + Cake Land Application**	**Strategy 3 - AD + Advanced Stabilization (THP) + Fertilizer Quality Product**	**Strategy 4 - AD + Dewatering + Advanced Alkaline Treatment**	**Strategy 5 - AD + Dewatering + Composting + Product Distribution**	**Strategy 6 - AD + Dewatering + Thermal Drying + Product Distribution**	**Strategy 7 - AD + Dewatering + Thermal Processing**
Social - Cultural							
Odour at Garner Road Facility	Composting processes have the greatest potential to generate odour at the Garner Road Facility, followed by long term cake storage of anaerobically digested cake at the facility and the thermal drying process if the process odour control is not operating properly. The thermal drying process uses regenerative thermal oxidation to treat the process air to reduce the chance of onsite odours.						
	8	7	8	8	4	6	8
Noise/Vibrations during Operation	Noise and vibrations from operations will be minimal and controlled for all alternatives.						
	8	8	8	8	8	8	8
Visual/Aesthetics	Composting and open lagoons have higher potential for visual impact than the other alternatives, The impacts are expected to be minimal given that the Garner Road site is not easily viewed by the public. Thermal drying would be completely enclosed in a building						
	7	7	8	8	7	8	8
Truck Traffic / Transportation System	Alternatives that transport larger volumes of biosolids (ie. liquid land application) will result in increased truck traffic.						
	5	7	7	7	5	8	9
Disruption During Construction	Minimal construction disturbance is expected for each option.						
	7	7	7	7	7	7	7
Property Acquisition and Easements	The Garner Road site has sufficient space to accommodate all the alternatives, with the exception of composting. Composting requires large tracks of land and the area for composting may require potential land. Still need the same liquid volume capacity; lagoons.						
	9	9	9	9	7	9	9
Recreational Use and Users	None of the alternatives will impact recreational uses, as Garner Road is not near any recreational facilities						
	9	9	9	9	9	9	9
Nutrient Recovery Potential/Beneficial Reuse for Agricultural Land Users	Agricultural users will benefit from all of the biosolids products evaluated, those that are anaerobically digested and those that have been further processed to achieve fertilizer quality certification. They all provide essential plant nutrients and organics to improve soil. The products that achieve the fertilizer certification rate higher because they have a higher total solids concentration. Strategies 3 and 6 reduce soil compaction associated with spreading. Strategy 4 includes lime addition which is a benefit to many agricultural programs. Compost product, Strategy 5, could also be used in agriculture, but has a higher volume requirement to provide the same amount of Nitrogen to the soil when compared with the other products. Incinerator ash is not applicable for use on agricultural lands.						
	7	7	8	8	7	8	2
Human Health and Well-Being	Regulations are present to protect human health and all alternative meet these requirements						
	9	9	9	9	9	9	9
Existing and Future Adjacent Land Use Compatibility	Garner Road is zoned HI (heavy industrial) surrounded by HL (hazard land) that borders environmental protected areas. Prestige industrial (PI) zoned land is to the south. All alternatives are compatible with current zoning.						
	9	9	9	9	7	9	9
Archaeology, Cultural Heritage & Aboriginal Interest	None of the alternatives are expected to impact cultural heritage, archaeological or items of Aboriginal interest; Individual projects will have site specific archaeological assessments						
	8	8	8	8	8	8	8
Total Score (Out of 110)	86	87	90	90	78	89	86
Weight	25	25	25	25	25	25	25
Normalized Score (Total 25)	**19.5**	**19.8**	**20.5**	**20.5**	**17.7**	**20.2**	**19.5**
Sub-Criteria	**Strategy 1 - AD + Liquid Biosolids Land Application**	**Strategy 2 - AD + Dewatering + Cake Land Application**	**Strategy 3 - AD + Advanced Stabilization (THP) + Fertilizer Quality Product**	**Strategy 4 - AD + Dewatering + Advanced Alkaline Treatment**	**Strategy 5 - AD + Dewatering + Composting + Product Distribution**	**Strategy 6 - AD + Dewatering + Thermal Drying + Product Distribution**	**Strategy 7 - AD + Dewatering + Thermal Processing**
Technical							
Proven Performance	All alternatives would be designed to effectively treat and manage biosolids. All processes are proven at the Niagara scale with the exception of THP.						
	9	9	5	9	7	7	7
Long term Sustainability	While all biosolids products considered can be marketed, the products that meet fertilizer certification criteria can be marketed with no regulatory requirements outside of the processing facility. Thermally dried product has the highest marketability of the products considered. There is a strong demand in the agricultural and public markets. Anaerobically digested biosolids, liquid and dewatered, can be marked to the agricultural community which has a significant demand in the Golden Horseshoe area. Advanced alkaline stabilized product also has a strong demand in the agricultural market which is boosted by the products ability to impact the soils pH. The product of advanced digestion, using THP, would be most suitable for the agricultural community, based primarily on its total solid concentration of approximately 40%. Compost can be marketed to the public, but the total demand is lower than that of agricultural and is strongest in the spring and fall horticultural seasons. The market for Incinerator ash is different: the market is with brick and block producers and not with the agricultural community or the general public.						
	7	7	8	8	7	9	4
Ease of Operation	The Region can operate each of the processes considered in of the alternative strategies. Technologies that the Region is currently operating or familiar with were ranked the highest. The alternatives which include complex technologies, or require specific certifications, were ranked lower.						
	9	8	4	8	7	6	6
Resiliency /Risk (Seasonally)	Options that can generate products with a demand from multiple markets ranked higher. The Region may consider a biosolids management program that has more than one outlet, such as land application and distibution to the public. As a result, alterntives that complement each other, for example those with dewatering, ranked higher.						
	6	6	7	7	7	8	9
Ease of Implementation (including marketability)	The options that can be implemented without disturbing the current biosolids management program ranked higher. Alternatives that require additional storage on the Garner road site or at a third party managed location scored lower, partly due to the difficulty to move away from a specific third party contractor without the equivalent storage identified at another location. Facilities with smaller foot prints scored higher as did those that do not require significant changes to the infrastructure current serving the Garner road site. Composting has the largest footprint and may require additional lands. In addition alternatives that do not have a proven market in Niagara for their products scored lower.						
	7	8	3	8	3	3	3
Compatibility with Existing Infrastructure System	The alternative treatment processes, if implemented at Garner Road, are compatible with infrastructure in the area. Thermal hydrolysis, thermal processing, and Thermal drying however require additional power and natural gas at the site						
	8	8	6	8	8	6	6
Energy Use and Recovery	All the alternatives considered retain the use of anaerobic digestion at the various wastewater treatment facilities. The biogas generated in the digestion process can be recovered and used. Since the Garner Road facility is "remote" to the treatment facilities it will not be able take advantage of that gas. The alternatives that use the least amount of power at the Garner Road facility were ranked higher.						
	9	8	7	8	8	7	6
Climate Change Adaptability	Climate change will not impact the operation of these alternatives for a period long beyond the study period. Alternatives that can adapt to the impacts of climate change (ie. resistent to increased flooding, higher rainfall), score higher. Overall, Strategy 5 scores slightly lower, as it assumes open pile composting that would be more impacted by heavy rainfall. Also, severe wet weather events may limit the ability to apply biosolids on agricultural land while meeting NASM requirements.						
	7	7	8	8	7	8	8
Permits and Approvals	All alternatives can be approved for construction and permitted for operation. Some will require additional site permitting based on the alternatives' level of pathogen reduction. Some may require a higher degree of review associated with air quality. Some may be required to perform a pilot operation to allow the Region and the Ministry to witness successful operation.						
	8	8	6	8	6	6	6
Total Score (Out of 90)	70	69	54	72	60	60	55
Weight	25	25	25	25	25	25	25
Normalized Score (Total 25)	**19.4**	**19.2**	**15.0**	**20.0**	**16.7**	**16.7**	**15.3**
Sub-Criteria	**Strategy 1 - AD + Liquid Biosolids Land Application**	**Strategy 2 - AD + Dewatering + Cake Land Application**	**Strategy 3 - AD + Advanced Stabilization (THP) + Fertilizer Quality Product**	**Strategy 4 - AD + Dewatering + Advanced Alkaline Treatment**	**Strategy 5 - AD + Dewatering + Composting + Product Distribution**	**Strategy 6 - AD + Dewatering + Thermal Drying + Product Distribution**	**Strategy 7 - AD + Dewatering + Thermal Processing**
Economic							
Capital Cost (not including land acquistion costs)	$ 122 M	$ 44 M	$ 112 M	$ 35 M	$ 55 M	$ 92 M	$ 274 M
	5	9	5	9	8	6	2
Operation and Maintainence Cost	$ 3.6 M	$ 5.9 M	$ 6.3 M	$ 8.1 M	$ 4.2 M	$ 7.4 M	$ 9.4 M
	8	6	6	5	7	5	4
Life Cycle Cost	$ 189 M	$ 158 M	$ 236 M	$ 193 M	$ 137 M	$ 237 M	$ 453 M
	6	7	5	6	8	5	2
Total Score (Out of 30)	19	22	16	20	23	16	8
Weight	25	25	25	25	25	25	25
Normalized Score (Total 25)	**15.8**	**18.3**	**13.3**	**16.7**	**19.2**	**13.3**	**6.7**

SUMMARY	Strategy 1 - AD + Liquid Biosolids Land Application	Strategy 2 - AD + Dewatering + Cake Land Application	Strategy 3 - AD + Advanced Stabilization (THP) + Fertilizer Quality Product	Strategy 4 - AD + Dewatering + Advanced Alkaline Treatment	Strategy 5 - AD + Dewatering + Composting + Product Distribution	Strategy 6 - AD + Dewatering + Thermal Drying + Product Distribution	Strategy 7 - AD + Dewatering + Thermal Processing
Environmental	16.8	18.2	20.4	20.4	18.9	19.6	17.5
Socio-Cultural	19.5	19.8	20.5	20.5	17.7	20.2	19.5
Technical	19.4	19.2	15.0	20.0	16.7	16.7	15.3
Economic	15.8	18.3	13.3	16.7	19.2	13.3	6.7
Total Normalized Score	**71.6%**	**72.7%**	**69.1%**	**76.1%**	**72.7%**	**69.9%**	**59.0%**
Ranking	3	2	5	1	2	4	6

Impact Description	Impact Rating
Positive or no	9-10
Minor impact	7-8
Moderate impact	5-6
High impact	3-4
Severe impact	1-2

Sub-Criteria	Strategy 1 - AD + Liquid Biosolids Land Application	Strategy 2 - AD + Dewatering + Cake Land Application	Strategy 3 - AD + Advanced Stabilization (THP) + Fertilizer Quality Product	Strategy 4 - AD + Dewatering + Advanced Alkaline Treatment	Strategy 5 - AD + Dewatering + Composting + Product Distribution	Strategy 6 - AD + Dewatering + Thermal Drying + Product Distribution	Strategy 7 - AD + Dewatering + Thermal Processing (Incineration)
Natural Environment							
Greenhouse Gas Emissions (GHG)	-759 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-11,083 mg CO2 eq/ mg dry solids	-3,724 mg CO2 eq/ mg dry solids	5,354 mg CO2 eq/ mg dry solids
	5	6	8	6	6	6	4
Social - Cultural							
Odour at Garner Road Facility	Composting processes have the greatest potential to generate odour at the Garner Road Facility, followed by long term cake storage of anaerobically digested cake at the facility and the thermal drying process if the process odour control is not operating properly. The thermal drying process uses regenerative thermal oxidation to treat the process air to reduce the chance of onsite odours.						
	8	7	8	8	4	6	8
Truck Traffic / Transportation System	Alternatives that transport larger volumes of biosolids (ie. liquid land application) will result in increased truck traffic.						
	5	7	7	7	5	8	9
Nutrient Recovery Potential/Beneficial Reuse for Agricultural Land Users	Agricultural users will benefit from all of the biosolids products evaluated, those that are anaerobically digested and those that have been further processed to achieve fertilizer quality certification. They all provide essential plant nutrients and organics to improve soil. The products that achieve the fertilizer certification rate higher because they have a higher total solids concentration. Strategies 3 and 6 reduce soil compaction associated with spreading. Strategy 4 includes lime addition which is a benefit to many agricultural programs. Compost product, Strategy 5, could also be used in agriculture, but has a higher volume requirement to provide the same amount of Nitrogen to the soil when compared with the other products. Incinerator ash is not applicable for use on agricultural lands.						
	7	7	8	8	7	8	2
Technical							
Proven Performance	All alternatives would be designed to effectively treat and manage biosolids. All alternatives provide opportunities for beneficial use of biosolids products. All processes are proven at the Niagara scale with the exception of THP.						
	9	9	5	9	7	7	7
Long term Sustainability	While all biosolids products considered can be marketed, the products that meet fertilizer certification criteria can be marketed with no regulatory requirements outside of the processing facility. Thermally dried product has the highest marketability of the products considered. There is a strong demand in the agricultural and public markets. Anaerobically digested biosolids, liquid and dewatered, can be marked to the agricultural community which has a significant demand in the Golden Horseshoe area. Advanced alkaline stabilized product also has a strong demand in the agricultural market which is boosted by the products ability to impact the soils pH. The product of advanced digestion, using THP, would be most suitable for the agricultural community, based primarily on its total solid concentration of approximately 40%. Compost can be marketed to the public, but the total demand is lower than that of agricultural and is strongest in the spring and fall horticultural seasons. The market for Incinerator ash is different: the market is with brick and block producers and not with the agricultural community or the general public.						
	7	7	8	8	7	9	4
Ease of Operation	The Region can operate each of the processes considered in of the alternative strategies. Technologies that the Region is currently operating or familiar with were ranked the highest. The alternatives which include complex technologies, or require specific certifications, were ranked lower.						
	9	8	4	8	7	6	6
Resiliency /Risk (Seasonally)	Options that can generate products with a demand from multiple markets ranked higher. The Region may consider a biosolids management program that has more than one outlet, such as land application and distibution to the public. As a result, alterntives that complement each other, for example those with dewatering, ranked higher.						
	6	6	7	7	7	8	9
Ease of Implementation (including marketability)	The options that can be implemented without disturbing the current biosolids management program ranked higher. Alternatives that require additional storage on the Garner road site or at a third party managed location scored lower, partly due to the difficulty to move away from a specific third party contractor without the equivalent storage identified at another location. Facilities with smaller foot prints scored higher as did those that do not require significant changes to the infrastructure current serving the Garner road site. Composting has the largest footprint and may require additional lands. In addition alternatives that do not have a proven market in Niagara for their products scored lower.						
	7	8	3	8	3	3	3
Economic							
Life Cycle Cost	$ 189 M	$ 158 M	$ 236 M	$ 193 M	$ 137 M	$ 237 M	$ 453 M
	6	7	5	6	8	5	2

Total Score	69	72	63	75	61	66	54
Score based on 'most important' criteria	69%	72%	63%	75%	61%	66%	54%
Ranking	3	2	5	1	6	4	7

Appendix B – Biosolids Strategies Cost Breakdown

Region of Niagara

Alternative 1 Liquid biosolids storage at Garner Road and Land Application

11/27/2023

This preliminary opinion of cost, capital along with operation and maintenance, anticipates liquid biosolids storage for all of the biosolids generated in the Region except those generated at City of Niagara Falls WWTP which will continue to be dewatered at that WWTP. Storage facilities at the Garner Road Facility will be decanted to maintain a total solids concentration of 3.5 percent total solids, TS. Storage capacity of 240 day will be provided. A land application cost of $8.29/m3 for biosolids at 3.5 percent TS is anticipated.

Notes

Sizing Criteria, Equipment and Operating Parameters

Average Annual anaerobically digested biosolids	39.3	dry metric ton / day (dt/d)	Input Field
Maximum Month anaerobically digested biosolids	55.5	dt/d	
Storage at the Garner Road Facility			
Average Total Solids Concentration in storage	3.5	%	
Volume of Digested Biosolids in Storage			
Max Month	1,587	m3/d	
Average Annual	1,123	m3/d	
Required additional storage at Garner Road			
Volume in existing lagoons	61,200	m3	
Volume in existing three storage tanks	24,000	m3	
Total storage volume available	85,200	m3	
Total Volume required			
Days Storage Required	240	days	
Anticipated Biosolids Volume (Based on Average Annual Generation Rate)	1,123	m3/d	
Total required volume	269,486	m3	
Additional storage volume required.	184,286	m3	
Additional storage tanks required.			
Additional storage volume required.	184,286	m3	
Volume of each additional storage tanks	14,200	m3 / existing storage tank	
	13.0	additional storage tanks	
Total number of tanks	13		
Financial Information			
Interest Rate	3.00%		
Study Period	30	years	
Power Cost	$0.15	$/kw	
Natural gas cost	$10.00	MMBTU	
Fuel Cost	$4.00	$/liter	
Cost of transport and management of a liquid land application program	$8.29	$/m3	
Cost of liquid Biosolids Storage	$400.00	$/m3	
Operation Labor Cost	$60.00	$/hr	
Maintenance Labor Cost	$60.00	$/hr	

At 3.5% TS the weight of the biosolids is equal to the weight of water; 1000 kg/m3
1 wet ton = 1m3

39.3 dt AA	1wet ton (wt)	= 1,123wt
day	0.035 dt (3.5%)	

1,123m3 * 240days storage = 269,486 m3 subtract 85,200 m3 current storage =184,286m3; I feel that this is too much to implement

Preliminary Opinion of Capital Cost

Item Description	Qty	Unit	Unit cost	Cost (1)	Remaining Value of Buildings and Equipment: Projected Life (yrs.)	% Remaining	($)
Biosolids Storage							
Storage Site							
Site grading	14,600	m3	9.00	131,000			
Paved Area	13,500	m2	11.00	149,000			
Stormwater collection and retention							
Grading	600	m3	8.00	5,000			
Catch basins and collection	1	ls	20,000.00	20,000			
Liner and outfall	29,200	m2	5.00	146,000			
Subtotal Storage Site				**451,000**			
Thickened Biosolids Storage Tanks							
New 14,000m3 Glass Lined Bolted Steel Storage Tanks	184,600	m3	400	73,840,000	30	10	7,384,000
Allowance for mixing systems and piping	13	ea.	100,000	1,300,000			
Allowance water system, drains and piping	1	ls	500,000	500,000			
Electrical and instrumentation (%) of structures & equipment	0.25	%		185,000			
Subtotal Thickened Biosolids Storage Tanks				**75,825,000**			7,384,000
Indirect Costs							
Contingency and estimating allowance % of improvements & equipment	30	%		22,880,000			
Contractor overhead, profit, mobilization and bonds (%) of improvements	15	%		11,440,000			
Engineering, (%) of improvements	15	%		11,440,000			
Subtotal indirect costs				**45,760,000**			
TOTAL				**122,036,000**			7,384,000

INITIAL OPERATION & MAINTENANCE COSTS

Item Description	Staff/shift	Shifts/Op day	Annual Qty	Unit	Unit Cost ($/unit)	Cost (1) ($/yr)	
Labor							
Operation Labor Thickening	1	1	2,080	hr	60.00	125,000	
Maintenance Labor Thickening and Storage	1	0.3	520	hr	60.00	31,000	
Dewatering Operation							
Power			50,000	$/KWh	0.15	8,000	
Storage facility maintenance			1	ls	25,000	25,000	
Transportation and land application of liquid biosolids.							
3rd Party transportation and land application			409,843	m3/yr	8.29	3,398,000	Based on cost in Thomas Nutrient Solution Contract
Subtotal for O&M						**3,587,000**	

LIFE CYCLE COSTS

	P/F Factor	P/A Factor	Total Present Worth ($)
Initial Capital			$122,036,000
Present Value of Remaining Value	0.4120		($3,042,000)
Present Value of Annual O&M		19.6004	$70,307,000
TOTAL			**$189,301,000**

Unit Cost, $/dt	Unit Cost, $/dt (O&M Only)
$ 439.89	$ 250.06

(1) Rounded to nearest $10,000
(2) Based on average annual solids generation

Region of Niagara

Alternative 2 Dewatering, and Cake Land Application

11/27/2023

This preliminary opinion of cost, capital along with operation and maintenance, anticipates that all of the liquid biosolids generated in the Region with the exception of those generated at the Niagara Fall WWTP will be transported to the Garner Road Facility for storage, dewatering and land application. The biosolids generated at City of Niagara Falls WWTP will continue to be dewatered at that WWTP. Storage facilities at the Garner Road Facility will be decanted to maintain a total solids concentration of 3.5 percent total solids. The alternative anticipates new dewatering facilities for all of the biosolids transported there and additional cake storage that along with the liquid storage capacity will provide 240 days of storage. Land application cost of $85/m3 for biosolids is anticipated.

Sizing Criteria, Equipment and Operating Parameters

			Notes
		Input Field	
Average Annual anaerobically digested biosolids	39.3	dry metric ton / day (dt/d)	
Maximum Month anaerobically digested biosolids	55.5	dt/d	
Dewatering at the Garner Road Facility			
Digested Biosolids to Dewatering (dtpd)			
Max Month	55.5	dt/d	
Average Annual	39.3	dt/d	
Total Volume of Digested Biosolids Loading to Dewatering			
Number of days for dewatering	260		
Average Annual	55.2	dt/dewatering day	
	55,171	dkg/dewatering day	
Total Digested Biosolids Flow to Dewatering			
Total solids concentration	3.5	%	
Average Annual	11,034,231	l/wk.	
Number of centrifuges	6		
Number of duty centrifuges	5		
Number of standby centrifuges	1		
Anticipated days of centrifuge operation during max month (days/week)	5	days / week	
Operating shifts per day	1		
Anticipated shift hours of operation, allowing time for start up and shut down	7	hr/day	
Required throughput Average Annual	1,051	l/m	950 l/m to 1,100 l/m target feed
Anticipated dewatered biosolids total solids concentration	25	%TS	
Anticipated thickener solids capture	90	%	
Anticipated Polymer Consumption	11	kg/dt	
Anticipated digested biosolids cake production Average Annual	35.4	dt/d	
Anticipated dewatered biosolids Average Annual	141	wt/d	
Anticipated dewatered solids bulk density	1003	wet kg / m3 (wkg/m3)	
Anticipated dewatered biosolids volume Average Annual	141	m3/d	
Anticipated days of cake storage	240	days	75 days of storage of the required 240 days total could be provided in the existing lagoons and storage tanks at the Garner Road Facility. Cake storage of 240 days provides additional felxibilty
Required cake storage at Garner Road			
Cake storage required	33,854	m3	
Anticipated pile height	3	m	
Approximate cake storage area required	11,285	m2	
Financial Information			
Interest Rate	3.00%		
Study Period	30	years	
Power Cost	$0.15	$/kw	
Natural gas cost	$10.00	MMBTU	
Fuel Cost	$4.00	$/liter	
Cost of transport and management of a cake land application program	$85.00	$/m3	
Cost of polymer	$5.00	$/kg	
Operation Labor Cost	$60.00	$/hr	
Maintenance Labor Cost	$60.00	$/hr	

Preliminary Opinion of Capital Cost

Item Description	Qty	Unit	Unit cost	Cost (1)	Remaining Value of Buildings and Equipment: Projected Life (yrs.)	% Remaining	($)
Biosolids Dewatering							
Dewatering Facility Site Work							
Site grading	11,000	m3	9.00	99,000			
Paved Area	7,000	m2	11.00	77,000			
Stormwater collection and retention							
Grading	1,000	m3	8.00	8,000			
Catch basins and collection	1	ls	25,000.00	25,000			
Liner and outfall	1	ls	15,000.00	15,000			
Subtotal Dewatering Site				**224,000**			
Dewatering Facility							
Decommission existing dewatering facility	1	LS	750,000.00	750,000			
Pre-engineered structure							
Dewatering Structure	3,000	m2	2,500	7,500,000	30	10	750,000
Office Area	400	m2	1,000	400,000			
Centrifuge dewatering system	6	ea.	1,200,000	7,200,000			
Centrifuge system installation (%) of equipment	40	%		2,880,000			
Allowance water system, compressed air system, drains and piping	1	ls	1,000,000	1,000,000			
Electrical and instrumentation (%) of structures & equipment	10	%		1,510,000			
Subtotal Dewatering Facility				**21,240,000**			
Dewatered Biosolids Storage							
Storage Site							
Site grading	30,000	m3	9.00	270,000			
Paved Area	16,000	m2	11.00	176,000			
Pre-engineered cake storage structure	11,285	m2	500	5,642,000	30	10	564,200
Stormwater collection and retention							
Grading	600	m3	8.00	5,000			
Catch basins and collection	1	ls	20,000.00	20,000			
Liner and outfall	1	ls	7,000.00	7,000			
Subtotal Dewatering Site				**6,120,000**			
Indirect Costs							
Contingency and estimating allowance % of improvements & equipment	30	%		8,280,000			
Contractor overhead, profit, mobilization and bonds (%) of improvements	15	%		4,140,000			
Engineering, (%) of improvements	15	%		4,140,000			
Subtotal indirect costs				**16,560,000**			
TOTAL				**44,144,000**			1,314,200

INITIAL OPERATION & MAINTENANCE COSTS

Item Description	Staff/shift	Shifts/Op day	Annual Qty	Unit		Unit Cost ($/unit)	Cost (1) ($/yr)
Labor							
Operation Labor Dewatering	2.0	1	4,160	hr		60.00	250,000
Maintenance Labor Dewatering and Storage	1.0	0.5	1,040	hr		60.00	62,000
Dewatering Operation							
Power			900,000	$/KWh		0.15	135,000
Polymer			157,790	kg		5.00	789,000
Dewatering equipment maintenance (%) of process equipment			1		%	12,842,000	128,000
Storage Facility Maintenance (%) of storage volume			2	%		5,642,000	113,000
Transportation and land application of dewatered cake .							
3rd Party transportation and application of dewatered cake			51,486	m3/yr		85.00	4,376,000
Subtotal for O&M							**5,853,000**

LIFE CYCLE COSTS

Unit Cost, $/dt	Unit Cost, $/dt (O&M Only)
$ 367.91	$ 408.03

	P/F Factor	P/A Factor	Total Present Worth ($)
Initial Capital			$44,144,000
Present Value of Remaining Value	0.4120		($541,000)
Present Value of Annual O&M		19.6004	$114,721,000
TOTAL			**$158,324,000**

(1) Rounded to nearest $10,000
(2) Based on average annual solids generation

Region of Niagara

Alternative 3 Post Anaerobic Digestion, Thermal Hydrolysis Treatment, dewatering, and agricultural application of a CFIA dewatered Product

11/27/2023

This preliminary opinion of cost, capital along with operation and maintenance, anticipates that all of the liquid biosolids generated in the Region with the exception of those generated at the Niagara Fall WWTP will be transported to the Garner Road Facility for Thermal Hydrolysis Process (THP)treatment, post Anaerobic digestion, dewatering and land application. The biosolids generated at City of Niagara Falls WWTP will continue to be dewatered at that WWTP. Storage facilities at the Garner Road Facility will be decanted to maintain a total solids concentration of 3.5 percent total solids. The alternative anticipates new dewatering facilities for all of the biosolids transported there pre and post the THP and additional cake storage that along with the liquid storage capacity will provide 240 days of storage. Land application cost of $40/m3 for biosolids is anticipated.

Sizing Criteria, Equipment and Operating Parameters

			Input Field	Notes
Average Annual anaerobically digested biosolids	39.3	dry metric ton / day (dt/d)		
Maximum Month anaerobically digested biosolids	55.5	dt/d		
Dewatering at the Garner Road Facility				
Digested Biosolids to Pre THP Dewatering (dtpd)				
Average Annual	1,638	dkg/hr		
Max Month	2,314	dkg/hr		
Total Digested Biosolids Pre THP to Dewatering				
Total solids concentration	3.5	%		
Average Annual	7,860,000	l/wk.		
Max Month	11,108,000	l/wk.		
Number of centrifuges	5			
Number of duty centrifuges	4			
Number of standby centrifuges	1			
Anticipated days of centrifuge operation during max month (days/week)	5	days / week		
Operating shifts per day	1			
Anticipated shift hours of operation, allowing time for start up and shut down	7	hr/operating shift		
Required throughput Average Annual	936	l/m		950 l/m to 1,100 l/m target feed
Anticipated dewatered biosolids total solids concentration	16	%TS		
Anticipated thickener solids capture	90	%		
Anticipated dewatered biosolids Average Annual	221.1	wt/d		
Anticipated dewatered biosolids Average Annual	9,211	wkg/hr		
Anticipated dewatered solids bulk density	1003	wet kg / m3 (wkg/m3)		
Anticipated dewater biosolids volume Average Annual	220	m3/d		
Capacity of CAMBI B6 THP Skid	85	dry metric ton / day (dt/d)		
Units required for Average Annual Solids generation	0.46	Units		
Units used in Estimate of Capital Cost	1	Units		
Energy consumption	2	MMBTU /Hr of operation		
Total Digested Biosolids Post THP to Dewatering				
Total solids concentration	10.0	%		
Average Annual	31.8	dt/d		
Average Annual	318.3	wt/d		
Average Annual	2,228,310	l/wk.		
Number of centrifuges	3			
Number of duty centrifuges	2			
Number of standby centrifuges	1			
Anticipated days of centrifuge operation during max month (days/week)	5	days / week		
Operating shifts per day	1			
Anticipated shift hours of operation, allowing time for start up and shut down	7	hr/operating shift		
Required throughput Average Annual	531	l/m		
Anticipated dewatered biosolids total solids concentration	40	%TS		
Anticipated dewatering solids capture	90	%		
Anticipated dewatered biosolids Average Annual	28.6	dt/d		
Anticipated dewatered biosolids Average Annual	71.6	wt/d		
Anticipated dewatered solids bulk density	700	wet kg / m3 (wkg/m3)		
Anticipated dewater biosolids volume Average Annual	102	m3/d		
Anticipated days or cake storage	165	days		75 days of storage of the required 240 days total would be provided in the lagoons and tanks
Required cake storage at Garner Road				
Cake storage required	16,883	m3		
Anticipated pile height	3	m		
Approximate cake storage area required	5,628	m2		
Financial Information				
Interest Rate	3.00%			
Study Period	30	years		
Polymer consumption	2.5	kg/dt		
Polymer cost	$5.00	$/kg		
Power Cost	$0.15	$/kw		
Natural gas cost	$10.00	MMBTU		
Fuel Cost	$4.00	$/liter		
Cost of transport and management of a fertilizer cake application program	$40.00	$/m3		
Operation Labor Cost	$95.00	$/hr		
Maintenance Labor Cost	$60.00	$/hr		

Preliminary Opinion of Capital Cost

Item Description	Qty	Unit	Unit cost	Cost (1)	Remaining Value of Buildings and Equipment: Projected Life (yrs.)	% Remaining	($)
Biosolids Dewatering							
Dewatering Facility Site Work							
Site grading	12,000	m3	9.00	108,000			
Paved Area	8,000	m2	11.00	88,000			
Stormwater collection and retention							
Grading	2,000	m3	8.00	16,000			
Catch basins and collection	1	ls	25,000.00	25,000			
Liner and outfall	1	ls	15,000.00	15,000			
Subtotal Dewatering Site				**252,000**			
Dewatering Facility Pre and Post THP							
Decommission existing dewatering facility	1	LS	750,000.00	750,000			
Pre-engineered structure							
Dewatering Structure	5,000	m2	2,500	12,500,000	30	10	1,250,000
Office Area	400	m2	1,000	400,000			
Centrifuge thickening system	8	ea.	1,200,000	9,600,000			
Centrifuge system installation (%) of equipment	40	%		3,840,000			
Allowance water system, compressed air system, drains and piping	1	ls	1,000,000	1,000,000			
Electrical and instrumentation (%) of structures & equipment	10	%		2,250,000			
Subtotal Dewatering Facility				**30,340,000**			
Thermal Hydrolysis Process							
THP Facility Site Work							
Site grading	5,000	m3	9.00	45,000			
Paved Area	2,500	m2	11.00	28,000			
Stormwater collection and retention							
Grading	600	m3	8.00	5,000			
Catch basins and collection	1	ls	15,000.00	15,000			
Liner and outfall	1	ls	10,000.00	10,000			
Subtotal Dewatering Site				**103,000**			
Thermal Hydrolysis Process Equipment							
THP B6 Units	1	ls	15,000,000	15,000,000			
Steam Generators and HEX system	1	ls	8,000,000	8,000,000			
THP system installation (%) of equipment	40	%		9,200,000			
THP Structure	600	m2	3,000	1,800,000	30	10	180,000
Electrical and instrumentation (%) of equipment	10	%		2,300,000			
Subtotal Thermal Hydrolysis Process				**36,506,000**			
Dewatered Biosolids Storage							
Storage Site							
Site grading	8,600	m3	9.00	77,000			
Paved Area	4,300	m2	11.00	47,000			
Pre-engineered cake storage structure	5,628	m2	500	2,814,000	30	10	281,400
Stormwater collection and retention							
Grading	600	m3	8.00	5,000			
Catch basins and collection	1	ls	20,000.00	20,000			
Liner and outfall	1	ls	7,000.00	7,000			
Subtotal Dewatering Site				**2,970,000**			
Indirect Costs							
Contingency and estimating allowance % of improvements & equipment	30	%		21,050,000			
Contractor overhead, profit, mobilization and bonds (%) of improvements	15	%		10,530,000			
Engineering, (%) of improvements	15	%		10,530,000			
Subtotal indirect costs				**42,110,000**			
TOTAL				**112,281,000**			**1,711,400**

INITIAL OPERATION & MAINTENANCE COSTS

Item Description	Staff/shift	Shifts/Op day	Annual Qty	Unit		Unit Cost ($/unit)	Cost (1) ($/yr)	Notes
Labor								
Operation Labor Thickening	3	1	6,240	hr		60.00	374,000	
Maintenance Labor Thickening and Storage	1	1	1,040	hr		60.00	62,000	
Operation Labor THP	4	1	8,320	hr		95.00	790,000	
Maintenance Labor THP	2	1	2,080	hr		95.00	198,000	
Dewatering systems Operation								
Power			1,800,000	$/KWh		0.15	270,000	
Polymer			71,723	kg		5.00	359,000	
Dewatering equipment maintenance (%) of process equipment			2		%		192,000	
Solids Stream post anaerobic digestion THP								
Natural Gas (based on average annual solids production)			20,000	MMBTU		10.00	200,000	based on 2MMBTU / Hour of operation
Power (based on average annual solids production)			300,000	$/kwh		0.12	36,000	
THP equipment maintenance (%) of process equipment			2		%		460,000	
Structure maintenance			1	%			171,000	
Transportation and land of fertilizer product								
3rd Party Transportation and application of fertilizer product			80,446	m3/yr		40.00	3,218,000	Cost reduced due to fertilizer product potential
Subtotal for O&M							**6,330,000**	

LIFE CYCLE COSTS

Unit Cost, $/dt	Unit Cost, $/dt (O&M Only)
$ 547.59	$ 441.28

	P/F Factor	P/A Factor	Total Present Worth ($)
Initial Capital			$112,281,000
Present Value of Remaining Value	0.4120		($705,000)
Present Value of Annual O&M		19.6004	$124,071,000
TOTAL			**$235,647,000**

(1) Rounded to nearest $10,000
(2) Based on average annual solids generation

Region of Niagara

Alternative 4 Dewatering, and Advanced Alkaline Treatment and Product management by a Third Party Biosolids Management Firm

11/27/2023

This preliminary opinion of cost, capital along with operation and maintenance, anticipates that all of the liquid biosolids generated in the Region with the exception of those generated at the Niagara Fall WWTP will be transported to the Garner Road Facility for dewatering and advanced alkaline treatments and product marketing and distribution by a third party biosolids management firm. The biosolids generated at City of Niagara Falls WWTP will continue to be dewatered at that WWTP. Storage facilities at the Garner Road Facility will be decanted to maintain a total solids concentration of 3.5 percent total solids. The alternative anticipates new dewatering facilities for all of the biosolids transported there. Short term cake storage, 20 days will be provided in addition to the current liquid storage capacity. A transportation, processing and distribution cost of $128.5/m3 for biosolids is anticipated.

Sizing Criteria, Equipment and Operating Parameters

				Notes
Average Annual anaerobically digested biosolids	39.3	dry metric ton / day (dt/d)	Input Field	
Maximum Month anaerobically digested biosolids	55.5	dt/d		
Dewatering at the Garner Road Facility				
Digested Biosolids to Dewatering (dtpd)				
Max Month	55.5	dt/d		
Average Annual	39.3	dt/d		
Total Volume of Digested Biosolids Loading to Dewatering				
Number of days for dewatering	260			
Average Annual	55.2	dt/dewatering day		
	55,171	dkg/dewatering day		
Total Digested Sludge Flow to Dewatering				
Total solids concentration	3.5	%		
Average Annual	11,034,231	l/wk.		
Number of centrifuges	6			
Number of duty centrifuges	5			
Number of standby centrifuges	1			
Anticipated days of centrifuge operation during max month (days/week)	5	days / week		
Operating shifts per day	1			
Anticipated shift hours of operation, allowing time for start up and shut down	7	hr/day		
Required throughput Average Annual	1,051	l/m		950 l/m to 1,100 l/m target feed
Anticipated dewatered biosolids total solids concentration	25	%TS		
Anticipated thickener solids capture	90	%		
Anticipated Polymer Consumption	11	kg/dt		
Anticipated digested biosolids cake production Average Annual	35.370	dt/d		
Anticipated dewatered biosolids Average Annual	141.48	wt/d		
Anticipated dewatered solids bulk density	1003	wet kg / m3 (wkg/m3)	Here is the unit weight at 25% TS	
Anticipated dewater biosolids volume Average Annual	141.06	m3/d	35.370dt at 25% TS = 141.48 wt	
Anticipated days or cake storage	20	days	at 1003kg/m3	
			(141.48wt * 1000kg/wt)/ 1,003 kg/m3 =141.06m3/day	
Required cake storage at Garner Road			141.06 * 365 day =51,486m3 (row 128)	
Cake storage required	2,821	m3		
Anticipated pile height	3	m		
Approximate cake storage area required	940	m2		

Financial Information

Interest Rate	3.00%	
Study Period	30	years
Polymer cost	$5.00	$/kg
Power Cost	$0.15	$/kw
Natural gas cost	$10.00	MMBTU
Fuel Cost	$4.00	$/liter
Cost of transport and management of Advanced Alkaline stabilization program	$128.50	$/m3
Operation Labor Cost	$60.00	$/hr
Maintenance Labor Cost	$60.00	$/hr

Preliminary Opinion of Capital Cost

					Remaining Value of Buildings and Equipment		
Item Description	Qty	Unit	Unit cost	Cost (1)	Projected Life (yrs.)	% Remaining	($)
Biosolids Dewatering							
Dewatering Facility Site Work							
Site grading	11,000	m3	9.00	99,000			
Paved Area	7,000	m2	11.00	77,000			
Stormwater collection and retention							
Grading	1,000	m3	8.00	8,000			
Catch basins and collection	1	ls	25,000.00	25,000			
Liner and outfall	1	ls	15,000.00	15,000			
Subtotal Dewatering Site				**224,000**			
Dewatering Facility							
Decommission existing dewatering facility	1	LS	750,000.00	750,000			
Pre-engineered structure							
Dewatering Structure	3,000	m2	2,500	7,500,000	30	10	750,000
Office Area	400	m2	1,000	400,000			
Centrifuge dewatering system	6	ea.	1,200,000	7,200,000			
Centrifuge system installation (%) of equipment	40	%		2,880,000			
Allowance water system, compressed air system, drains and piping	1	ls	1,000,000	1,000,000			
Electrical and instrumentation (%) of structures & equipment	10	%		1,510,000			
Subtotal Thickening Facility				**21,240,000**			
Dewatered Biosolids Storage							
Storage Site							
Site grading	3,700	m3	9.00	33,000			
Paved Area	2,100	m2	11.00	23,000			
Pre-engineered cake storage structure	1,000	m2	500	500,000	30	10	50,000
Stormwater collection and retention							
Grading	500	m3	8.00	4,000			
Catch basins and collection	1	ls	15,000.00	15,000			
Liner and outfall	1	ls	5,000.00	5,000			
Subtotal Dewatering Site				**580,000**			
Indirect Costs							
Contingency and estimating allowance % of improvements & equipment	30	%		6,610,000			
Contractor overhead, profit, mobilization and bonds (%) of improvements	15	%		3,310,000			
Engineering, (%) of improvements	15	%		3,310,000			
Subtotal indirect costs				**13,230,000**			
TOTAL				**35,274,000**			

INITIAL OPERATION & MAINTENANCE COSTS

Item Description	Staff/shift	Shifts/Op day	Annual Qty	Unit	Unit Cost ($/unit)	Cost (1) ($/yr)
Labor						
Operation Labor Dewatering	2	1	4,160	hr	60.00	250,000
Maintenance Labor Dewatering and Storage	1	1	1,040	hr	60.00	62,000
Dewatering Operation						
Power			900,000	$/KWh	0.12	108,000
Polymer			157,790	kg	5.00	789,000
Dewatering equipment maintenance (%) of process equipment			2	%	7,200,000	144,000
Facility Maintenance (%) of Structure cost			1	%	8,000,000	80,000
Transportation processing and land application of alkaline material						
3rd Party transportation processing and application of alkaline material			51,486	m3/yr	128.50	6,616,000
Subtotal for O&M						**8,049,000**

LIFE CYCLE COSTS

Unit Cost, $/dt	Unit Cost, $/dt (O&M Only)
$ 447.81	$ 561.12

	P/F Factor	P/A Factor	Total Present Worth ($)
Initial Capital			$35,274,000
Present Value of Remaining Value	0.4120		($330,000)
Present Value of Annual O&M		19.6004	$157,764,000
TOTAL			**$192,708,000**

(1) Rounded to nearest $10,000
(2) Based on average annual solids generation

Region of Niagara

Alternative 5 Dewatering improvements, aerated static pile composting and product distribution

11/27/2023

This preliminary opinion of cost, capital along with operation and maintenance, anticipates that all of the liquid biosolids generated in the Region with the exception of those generated at the Niagara Fall WWTP will be transported to the Garner Road Facility for dewatering and aerated static pile composting. The compost product would be managed by a third party biosolids management firm. The biosolids generated at City of Niagara Falls WWTP will continue to be dewatered at that WWTP. Storage facilities at the Garner Road Facility will be decanted to maintain a total solids concentration of 3.5 percent total solids. The alternative anticipates new dewatering facilities for all of the biosolids transported there and a composting facility which includes curing and storage areas. A transportation and distribution cost of $40/m3 for the compost product is anticipated.

Notes

Sizing Criteria, Equipment and Operating Parameters

Average Annual anaerobically digested biosolids	39.3	dry metric ton / day (dt/d)	Input Field
Maximum Month anaerobically digested biosolids	55.5	dt/d	
Additional Dewatering at Garner Road Facility			
Digested Biosolids to Dewatering (dtpd)			
Max Month	55.5	dt/d	
Average Annual	39.3	dt/d	
Total Volume of Digested Biosolids Loading to Dewatering			
Number of days for dewatering	260		
Average Annual	55.2	dt/dewatering day	
	55,171	dkg/dewatering day	
Total solids concentration	3.5	%	
Average Annual	11,034,231	l/wk.	
Number of centrifuges	6		
Number of duty centrifuges	5		
Number of standby centrifuges	1		
Anticipated days of centrifuge operation during max month (days/week)	5	days / week	
Operating shifts per day	1		
Anticipated shift hours of operation, allowing time for start up and shut down	7	hr/day	
Required throughput Average Annual	1,051	l/m	
Anticipated cake total solids concentration (%TS)	25		
Anticipated Polymer Consumption	11	kg/dt	
Anticipated digested biosolids cake production Annual average	35.4	dt/d	
Anticipated biosolids cake production Average Annual	141	wet metric ton / day (wt/d)	
Anticipated Cake Bulk Density	1003	wet kg / m3 (wkg/m3)	
Anticipated biosolids cake production Max Month	141	m3/d	
Semi Trailer capacity	34	wt/load	
Financial Information			
Interest Rate	3.00%		
Study Period	30	years	
Polymer cost	$5.00	$/kg	
Power Cost	$0.15	$/kw	
Natural gas cost	$10.00	MMBTU	
Fuel Cost	$4.00	$/liter	
Cost of transport and management of a compost product	$40.00	$/m3	
Operation Labor Cost	$60.00	$/hr	
Maintenance Labor Cost	$60.00	$/hr	

Preliminary Opinion of Capital Cost

Item Description	Qty	Unit	Unit cost ($/unit)	Cost (1) ($)	Remaining Value of Buildings and Equipment: Projected Life (yrs.)	% Remaining	($)
Biosolids Dewatering							
Dewatering Site							
Site grading	11,000	m3	9.00	99,000			
Paved Area	7,000	m2	11.00	77,000			
Stormwater collection and retention							
Grading	1,000	m3	8.00	8,000			
Catch basins and collection	1	ls	25,000.00	25,000			
Liner and outfall	1	ls	15,000.00	15,000			
Subtotal Dewatering Site				**224,000**			
Dewatering Facility							
Decommission existing dewatering facility	1	LS	750,000.00	750,000			
Pre-engineered structure							
Dewatering Structure	3,000	m2	2,500	7,500,000	30	10	750,000
Office Area	400	m2	1,000	400,000			
Centrifuge dewatering system	6	ea.	1,200,000	7,200,000			
Centrifuge system installation (%) of equipment	40	%		2,880,000			
Allowance water system, compressed air system, drains and piping	1	ls	1,000,000	1,000,000			
Electrical and instrumentation (%) of structures & equipment	10	%		1,510,000			
Subtotal Dewatering Facility				**21,240,000**			
Biosolids Composting							
Active Composting Area							
Site grading	65,000	m3	9.00	585,000			
Paved Area	32,000	m2	11.00	352,000			
Stormwater collection and retention							
Grading	8,000	m3	9.00	72,000			
Catch basins and collection	1	ls	30,000.00	30,000			
Liner and outfall	1	ls	20,000.00	20,000			
Office Area	300	m2	1,000.00	300,000			
Engineered Compost systems							
Active Composting Pad 70m X 36m	2	ls	1,300,000.00	2,600,000			
Pre-engineered structure	5,000	m2	500.00	2,500,000	30	10	250,000
Misc. Piping and Fittings	2	%		52,000			
Biofilter concrete and materials (% of ECS System)	3	%		78,000			
Electrical (% of ESC System)	10	%		260,000			
Subtotal Active Composting				**6,849,000**			
Curing Area							
Pre-engineered structures (cover only, no side walls)							
Cured compost storage structure 45m x 45m	2,500	m2	500	1,250,000	30	10	125,000
Electrical (%) of Structure	10	%		125,000			
Product and fresh amendment storage							
Pre-engineered structures (cover only, no side walls)							
Product / amendment storage structure 60m x 60m	4,000	m2	500	2,000,000	30	10	200,000
Electrical (%) of Structure	10	%		200,000			
Subtotal curing and storage covers				**3,575,000**			
Equipment (Owner procured)							
Wheeled loader Cat 950M	3	ea.	350,000	1,050,000			
Roto mix 1220-20	1	ea.	450,000	450,000			
Trommel Screen Terex Phoenix 1600	1	ea.	350,000	350,000			
Transportation tractor	3	ea.	250,000	750,000			
Trailer	4	ea.	125,000	500,000			
				3,100,000			
Indirect Costs							
Contingency and estimating allowance % of improvements & equipment	30	%		10,500,000			
Contractor overhead, profit, mobilization and bonds (%) of improvements	15	%		4,780,000			
Engineering, (%) of improvements	15	%		4,780,000			
Subtotal indirect costs				**20,060,000**			
TOTAL				**55,048,000**			575,000

INITIAL OPERATION & MAINTENANCE COSTS

Item Description	Staff/shift	Shifts/Op day	Annual Qty	Unit	Unit Cost ($/unit)	Cost (1) ($/yr)	Notes
Labor							
Operation Labor Dewatering	3	1	8,736	hr	60.00	524,000	
Maintenance Labor Dewatering	1	1	2,912	hr	60.00	175,000	
Operation Labor for Composting	5	1	14,560	hr	60.00	874,000	
Maintenance Labor for composting	1	1	2,912	hr	60.00	175,000	
Item Description			Annual Qty	Unit	Unit Cost ($/unit)	Cost (1) ($/yr)	
Equipment Maintenance							
Dewatering equipment maintenance (%) of process equipment			2	%		144,000	
Composting maintenance (%) of process equipment			2	%		52,000	
Item Description			Annual Qty	Unit	Unit Cost ($/unit)	Cost (1) ($/yr)	
Energy and Conditioning							
Dewatering							
Power			900,000	$/KWh	0.15	135,000	
Polymer			157,790	kg	5.00	789,000	
Item Description			Annual Qty	Unit	Unit Cost ($/unit)	Cost (1) ($/yr)	
Amendment							
Amendment			2,300	m3	50.00	115,000	
Item Description			Annual Qty	Unit	Unit Cost ($/unit)	Cost (1) ($/yr)	
Composting Fuel and Power							
Fuel			50,000	l	4.00	200,000	
Power			1,100,000	$/kwh	0.15	165,000	
Transportation and application of compost.							
3rd Party transportation and application of compost			21,517	m3/yr	40.00	861,000	Cost reduced due to fertilizer product potential
Subtotal for O&M						**4,209,000**	

LIFE CYCLE COSTS

	P/F Factor	P/A Factor	Total Present Worth ($)
Initial Capital			$55,048,000
Present Value of Remaining Value	0.4120		($237,000)
Present Value of Annual O&M		19.6004	$82,498,000
TOTAL			**$137,309,000**

Unit Cost, $/dt	Unit Cost, $/dt (O&M Only)
$ 319.07	$ 293.42

(1) Rounded to nearest $10,000
(2) Based on average annual solids generation

Region of Niagara

Alternative 6 Dewatering improvements, thermal drying and product distribution

11/27/2023

This preliminary opinion of cost, capital along with operation and maintenance, anticipates that all of the liquid biosolids generated in the Region with the exception of those generated at the Niagara Fall WWTP will be transported to the Garner Road Facility for dewatering and direct thermal drying using a rotary drum dryer. Dried product would be managed by a third party biosolids management firm. The biosolids generated at City of Niagara Falls WWTP will continue to be dewatered at that WWTP. Storage facilities at the Garner Road Facility will be decanted to maintain a total solids concentration of 3.5 percent total solids. The alternative anticipates new dewatering facilities for all of the biosolids transported there and a drying facility which includes short term product silo storage. A transportation and distribution cost of $40/m3 for the dried product is anticipated.

Sizing Criteria, Equipment and Operating Parameters

Parameter	Value	Unit		Notes
Average Annual anaerobically digested biosolids	39.3	dry metric ton / day (dt/d)	Input Field	
Maximum Month anaerobically digested biosolids	55.5	dt/d		
Additional Dewatering at Garner Road Facility				
Digested Biosolids to Dewatering (dtpd)				
Max Month	55.5	dt/d		
Average Annual	39.3	dt/d		
Total Volume of Digested Biosolids Loading to Dewatering				
Number of days for dewatering	260			
Average Annual	55.2	dt/dewatering day		
	55,171	dkg/dewatering day		
Total Digested Sludge Flow to Dewatering				
Total solids concentration	3.5	%		
Average Annual	11,034,231	l/wk.		
Number of centrifuges	6			
Number of duty centrifuges	5			
Number of standby centrifuges	1			
Anticipated days of centrifuge operation during max month (days/week)	5	days / week		
Operating shifts per day	1			
Anticipated shift hours of operation, allowing time for start up and shut down	7	hr/day		
Required throughput Average Annual	1,051	l/m		950 l/m to 1,100 l/m target feed
Anticipated cake total solids concentration (%TS)	25			
Anticipated thickener solids capture	90	%		
Anticipated Polymer Consumption	11	kg/dt		
Anticipated digested biosolids cake production Average Annual	35.4	dt/d		
Anticipated biosolids cake production Average Annual	141	wt/d		
Anticipated Cake Bulk Density	0	wet kg / m3 (wkg/m3)		
Anticipated biosolids cake production Average Annual	#DIV/0!	m3/d		
Semi Trailer capacity	34	wt/load		
Financial Information				
Interest Rate	3.00%			
Study Period	30	years		
Polymer cost	$5.00	$/kg		
Power Cost	$0.15	$/kw		
Natural gas cost	$10.00	MMBTU		
Fuel Cost	$4.00	$/liter		
Cost of transport and management of a dried product	$40.00	$/m3		
Operation Labor Cost	$60.00	$/hr		
Maintenance Labor Cost	$60.00	$/hr		

Preliminary Opinion of Capital Cost

Item Description	Qty	Unit	Unit cost ($/unit)	Cost (1) ($)	Remaining Value of Buildings and Equipment: Projected Life (yrs.)	% Remaining	($)
Biosolids Dewatering							
Dewatering Site							
Site grading	11,000	m3	9.00	99,000			
Paved Area	7,000	m2	11.00	77,000			
Stormwater collection and retention							
Grading	1,000	m3	8.00	8,000			
Catch basins and collection	1	ls	25,000.00	25,000			
Liner and outfall	1	ls	15,000.00	15,000			
Subtotal Dewatering Site				**224,000**			
Dewatering Facility							
Decommission existing dewatering facility	1	LS	750,000.00	750,000			
Pre-engineered structure							
Dewatering Structure	3,000	m2	2,500	7,500,000	30	10	750,000
Office Area	400	m2	1,000	400,000			
Centrifuge dewatering system	6	ea.	1,200,000	7,200,000			
Centrifuge system installation (%) of equipment	40	%		2,880,000			
Allowance water system, compressed air system, drains and piping	1	ls	1,000,000	1,000,000			
Electrical and instrumentation (%) of structures & equipment	10	%		1,510,000			
Subtotal Dewatering Facility				**21,240,000**			
Biosolids Rotary Drum Drying							
Dryer Site							
Site grading	7,100	m3	8.00	57,000			
Paved Area	4,200	m2	11.00	46,000			
Stormwater collection and retention							
Grading	1,000	m3	8.00	8,000			
Catch basins and collection	1	ls	20,000.00	20,000			
Liner and outfall	1	ls	15,000.00	15,000			
Subtotal Dryer Site				**146,000**			
Drying Structure							
Pre-engineered structure							
Dryer Structure	3,500	m2	2,500	8,750,000	30	10	875,000
Office Area	400	m2	1,000	400,000			
Bridge Crane	2	ls	250,000	500,000			
Drying system DDS 60 (includes cake bins, cake pumps, conveyance, dryer train, product silos, 200 tons each and safety systems)	1	ea.	20,000,000	20,000,000			
Drying system installation (%) of equipment	10	%		2,000,000			
Allowance for digester / natural gas supply, water system, Nitrogen gas system, compressed air system, drains and piping	1	ls	1,500,000	1,500,000			
Electrical and instrumentation (%) of structures & dryer system	10	%		2,965,000			
Subtotal Drying Structure				**36,115,000**			
Indirect Costs							
Contingency and estimating allowance % of improvements & equipment	30	%		17,320,000			
Contractor overhead, profit, mobilization and bonds (%) of improvements	15	%		8,660,000			
Engineering, (%) of improvements	15	%		8,660,000			
Subtotal indirect costs				**34,640,000**			
TOTAL				**92,365,000**			1,625,000

INITIAL OPERATION & MAINTENANCE COSTS

Item Description	Staff/shift	Shifts/Op day	Annual Qty	Unit	Unit Cost ($/unit)	Cost (1) ($/yr)	Notes
Labor							
Operation Labor Dewatering	2.0	1.0	5,824	hr	60.00	349,000	
Maintenance Labor Dewatering	1.0	0.5	1,456	hr	60.00	87,000	
Operation Labor for drying	2.0	3.0	17,472	hr	60.00	1,048,000	
Maintenance Labor for drying	1.0	1.0	2,912	hr	60.00	175,000	

Item Description	Annual Qty	Unit		Unit Cost ($/unit)	Cost (1) ($/yr)	Notes
Energy, Conditioning and Transportation						
Dewatering						
Power	900,000	$/KWh		0.15	135,000	
Polymer	157,790	kg		5.00	789,000	
Dewatering equipment maintenance (%) of process equipment	2		%	7,200,000	144,000	
Rotary Drum Dryer						
Natural Gas (based on average annual solids production)	300,000	MMBTU		10.00	3,000,000	
Power (based on average annual solids production)	4,800,000	$/kW		0.15	720,000	
Dryer equipment maintenance (%) of process equipment	2		%	20,000,000	400,000	
Transportation and application of dried product						
3rd Party transportation and management of a dried product	14,033	m3/yr		40.00	561,000	Cost reduced due to fertilizer product potential
Subtotal for O&M					**7,408,000**	

LIFE CYCLE COSTS

	P/F Factor	P/A Factor	Total Present Worth ($)
Initial Capital			$92,365,000
Present Value of Remaining Value	0.4120		($669,000)
Present Value of Annual O&M		19.6004	$145,200,000
TOTAL			**$236,896,000**

Unit Cost, $/dt	Unit Cost, $/dt (O&M Only)
$ 550.49	$ 516.43

(1) Rounded to nearest $10,000
(2) Based on average annual solids generation

Region of Niagara

Alternative 7 Dewatering, Incineration and ash management

11/27/2023

This preliminary opinion of cost, capital along with operation and maintenance, anticipates that all of the liquid biosolids generated in the Region with the exception of those generated at the Niagara Fall WWTP will be transported to the Garner Road Facility for dewatering and incineration. The ash generated by the incineration process would be managed by a third party waste disposal firm. The biosolids generated at City of Niagara Falls WWTP will continue to be dewatered at that WWTP. Storage facilities at the Garner Road Facility will be decanted to maintain a total solids concentration of 3.5 percent total solids. The alternative anticipates new dewatering facilities for all of the biosolids transported there and a fluidized bed incineration facility. A transportation and disposal cost of $100/m3 for the incineration ash is anticipated

Sizing Criteria, Equipment and Operating Parameters

				Notes
Average Annual raw solids	39.3	dry metric ton / day (dt/d)	Input Field	
Max Month raw solids	55.5	dt/d		
Additional Dewatering at Garner Road Facility				
Digested Biosolids to Dewatering (dtpd)				
Max Month	55.5	dt/d		
Average Annual	39.3	dt/d		
Total Volume of Digested Biosolids Loading to Dewatering				
Number of days for dewatering	260			
Average Annual	55.2	dt/dewatering day		
	55,171	dkg/dewatering day		
Total Digested Biosolids Flow to Dewatering				
Total solids concentration	3.5	%		
Average Annual	11,034,231	liters/week (l/wk.)		
Number of centrifuges	6			
Number of duty centrifuges	5			
Number of standby centrifuges	1			
Anticipated days of centrifuge operation during max month (days/week)	5	days / week		
Operating shifts per day	1			
Anticipated shift hours of operation, allowing time for start up and shut down	7	hr/day		
Required throughput Average Annual	1,051	l/m		950 l/m to 1,100 l/m target feed
Anticipated cake total solids concentration (%TS)	25			
Anticipated thickener solids capture	90	%		
Anticipated Polymer Consumption	11	kg/dt		
Anticipated digested biosolids cake production Average Annual	35.4	dt/d		
Anticipated biosolids cake production Average Annual	141	wt/d		
Anticipated Cake Bulk Density	1003	wet kg / m3 (wkg/m3)		
Anticipated biosolids cake production Average Annual	141	m3/d		
Semi Trailer capacity	34	wt/load		
Financial Information				
Interest Rate	3.00%			
Study Period	30	years		
Power Cost	$0.15	$/kw		
Natural gas cost	$10.00	MMBTU		
Fuel Cost	$4.00	$/liter		
Cost of transport and management of ash	$100.00	$/m3		
Operation Labor Cost	$60.00	$/hr		
Maintenance Labor Cost	$60.00	$/hr		

Preliminary Opinion of Capital Cost

Item Description	Qty	Unit	Unit cost ($/unit)	Cost (1) ($)	Remaining Value of Buildings and Equipment: Projected Life (yrs.)	% Remaining	($)
Biosolids Dewatering							
Dewatering Site							
Site grading	11,000	m3	9.00	99,000			
Paved Area	7,000	m2	11.00	77,000			
Stormwater collection and retention							
Grading	1,000	m3	8.00	8,000			
Catch basins and collection	1	ls	25,000.00	25,000			
Liner and outfall	1	ls	15,000.00	15,000			
Subtotal Dewatering Site				**224,000**			
Dewatering Facility							
Decommission existing dewatering facility	1	LS	750,000.00	750,000			
Pre-engineered structure							
Dewatering Structure	3,000	m2	2,500	7,500,000			
Office Area	400	m2	1,000	400,000			
Centrifuge dewatering system	6	ea.	1,200,000	7,200,000			
Centrifuge system installation (%) of equipment	40	%		2,880,000			
Allowance water system, compressed air system, drains and piping	1	ls	1,000,000	1,000,000			
Electrical and instrumentation (%) of structures & equipment	10	%		1,510,000			
Subtotal Dewatering Facility				**21,240,000**			
Biosolids Incineration							
TOX Facility Site							
Site grading	7,500	m3	9.00	68,000			
Paved Area	5,000	m2	11.00	55,000			
Stormwater collection and retention							
Grading	1,000	m3	8.00	8,000			
Catch basins and collection	1	ls	20,000.00	20,000			
Liner and outfall	1	ls	15,000.00	15,000			
Subtotal TOX Facility Site				**166,000**			
TOX Facility							
Pre-engineered structure							
TOX Structure	2,500	m2	3,000	7,500,000	30	10	750,000
Office Area	400	m2	1,000	400,000	30	10	40,000
TOX Units, 1 duty, 2 Standby	3	ea.	40,000,000	120,000,000	30	10	12,000,000
TOX system installation (%) of equipment	10	%		12,000,000			
Allowance natural gas supply, water system, compressed air system, piping	1	ls	1,000,000	1,000,000			
Electrical and instrumentation (%) of structures & equipment	10	%		12,790,000			
Subtotal TOX Facility				**153,690,000**			
Indirect Costs							
Contingency and estimating allowance % of improvements & equipment	30	%		52,600,000			
Contractor overhead, profit, mobilization and bonds (%) of improvements	15	%		23,080,000			
Engineering, (%) of improvements	15	%		23,080,000			
Subtotal indirect costs				**98,760,000**			
TOTAL				**274,080,000**			12,790,000

INITIAL OPERATION & MAINTENANCE COSTS

Item Description	Staff/shift	Shifts/Op day	Annual Qty	Unit	Unit Cost ($/unit)	Cost (1) ($/yr)	
Labor							
Operation Labor Dewatering	2.0	1.0	4,160	hr	60.00	250,000	
Maintenance Labor Anaerobic Digestion and Dewatering	1.0	0.5	1,040	hr	60.00	62,000	
Operation Labor for TOX	2.0	3.0	17,472	hr	60.00	1,048,000	Anticipates operation of incineration System 365 days each year
Maintenance Labor for TOX	1.0	1.0	2,080	hr	60.00	125,000	

Item Description	Annual Qty	Unit		Unit Cost ($/unit)	Cost (1) ($/yr)	
Energy, Conditioning and Transportation						
Dewatering						
Power	1,800,000	$/KWh		0.12	216,000	
Polymer	286,890	kg		2.00	574,000	40.01533689
Dewatering equipment maintenance (%) of process equipment	2		%	7,200,000	144,000	
TOX Units						
Natural Gas (based on average annual solids production)	150,000	MMBTU		10.00	1,500,000	
Power (based on average annual solids production)	12,000,000	$/kW		0.15	1,800,000	
TOX equipment maintenance (%) of process equipment	2		%	120,000,000	2,400,000	
Transportation and management of ash						
3rd Party transportation and management of ash	12,910	dt/yr		100.00	1,291,000	
Subtotal for O&M					**9,410,000**	

LIFE CYCLE COSTS

	P/F Factor	P/A Factor	Total Present Worth ($)
Initial Capital			$274,080,000
Present Value of Remaining Value	0.4120		($5,269,000)
Present Value of Annual O&M		19.6004	$184,440,000
TOTAL			**$453,251,000**

Unit Cost, $/dt	Unit Cost, $/dt (O&M Only)
$ 1,579.88	$ 656.00

(1) Rounded to nearest $10,000
(2) Based on average annual solids generation

Alternative	Total Capital Cost	Total Annual O&M	30 Yr. Life Cycle Cost	Estimated Unit Cost ($/dt)
ALT 1 (Liquid Land App)	$122,036,000	$3,587,000	$189,301,000	$ 439.89
ALT 2 (Dewater + Cake Land App)	$44,144,000	$5,853,000	$158,324,000	$ 367.91
ALT 3 (Dewater + THP Dewater + Fert dist)	$112,281,000	$6,330,000	$235,647,000	$ 547.59
ALT 4 (Dewater + Ad Alkaline Man)	$35,274,000	$8,049,000	$192,708,000	$ 447.81
ALT 5 (Dewater + Compost + PrD)	$55,048,000	$4,209,000	$137,309,000	$ 319.07
ALT 6 (Dewater + Therm Dry + PrD)	$92,365,000	$7,408,000	$236,896,000	$ 550.49
ALT 7 (Dewater + Incina + Ash App)	$274,080,000	$9,410,000	$453,251,000	$ 1,579.88