TO: Frank Russo, P.E.

FROM: Kumil Ali

DATE: 05/07/2021

SUBJECT: Purpose and Lessons Learned

Our team has learned many lessons since the start of this project in the fall of 2020. After reaching the 35% completion mark in the first semester, our team committed to learning from our past shortcomings and to improve how our team operated for the completion of this report. Now arriving at the time for the report to be submitted, our team now recognizes where we succeeded and failed on our commitments.

Increasing collaboration between team members was one of the main goals of this past term. Team collaboration was still difficult to manage, however there were noticeable improvements. Members of the team were less shy to call one another in order to collaborate for a specific task. This in turn allowed for more constant communication between the members of our team, leading to less confusion. This also meant that there was less information being syphoned through the project manager allowing him to more properly manage and aid in the project’s direction.

One of the largest continuing issues was the presence of the pandemic. Despite now having adapted to the existence of the pandemic and having learned to better collaborate, new problems arose as a result of its presence. This problem came in the form of one of our team members contracting COVID-19 in March of this year. While we had hoped this would be a milder case of the virus, this team member was incapacitated for nearly a month only returning at full capacity by the start of April. Despite accounting for the possibility of this happening to one or more of our team members, it still put a strain on the progression of our report and other assignments. Despite the occurrence of this event, however, our team did its best to adapt to this change and continued with the project until he returned.

Task definition and completion was another one of the most glaring issues the team faced before reaching the 35% completion mark. Many tasks were undefined or unknown to team members. This was a result of both poor communication and poor task understanding. To combat this issue, our team first started to work with the Google Tasks program. This program allowed members to tag other members for tasks to be completed and due dates to be defined. This increased the accountability of the team to get tasks completed on time. If a task was incomplete by the assigned date, the one responsible was able to be held accountable for not completing that task. As a result, the rate of task completion for this report increased significantly. Secondly, our team was better able to define tasks by shrinking the size and scope of tasks. Generalized tasks were made more specific allowing the team to know exactly what tasks needed to be done and when those tasks needed to be completed.

Despite our improvements, our team still faced many issues. While intermember communication increased, meeting attendance slightly decreased. These team meetings were recorded for those missing to be updated on the project's progress but being absent meant less feedback for the rest of the group. There were also imbalances on who was assigned tasks. Certain members were given very few or very small tasks to complete while others were given much more difficult tasks to complete. While these differences exist in most group efforts, we believe certain members were given far too much or too little to complete, leading to unintended bouts of friction. This was not intentional, however, only a circumstance of who specialized in a part of the report or in a treatment option. Our team did, however, come together in the end and was able to complete the report without vex.

In summary, our team has learned to overcome challenges more efficiently throughout the progression of the report. Our teamwork evolved and arrived at a point far beyond what we initially expected to achieve. Our team holds pride in what we have accomplished and hope that those who read this will find value in the report we have completed. Our team hopes the lessons we have learned as a result of this report carry with us into the future and that this learning experience will do us well in our future careers. We thank you for your time and appreciate the experience you have afforded to us.

Kumil Ali

TOWN OF RIVERHEAD
CLASS A BIOSOLIDS STUDY

Project Team:

Kumil Ali
Robert Seaman
Stephen Okolowich
Aaron Mairzadeh
Syed Islam

Prepared for:

Superintendent Michael Reichel
Town of Riverhead
200 Howell Avenue
Riverhead, NY 11901-2596

Prepared by:

CIV 440 Engineering
Stony Brook University
Civil Engineering
AY 2020-2021

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CIV 440 Engineering

CIV 440 Engineering

Executive Summary

The subject of this engineering report is executing a feasibility study on how an existing wastewater treatment plant located in the Town of Riverhead, New York can produce Class A biosolids through the addition of a sludge treatment option. This report also determines which treatment options available are the most cost-effective in achieving the Class A biosolids designation. This facility aims to reuse the material by donating to local businesses and farms as a soil amendment or fertilizer to reduce disposal costs. Disposal costs are nearly $680,000 per year according to Superintendent Michael Reichel, our client for this report. These disposal costs mainly derive from transporting the sludge nearly 6 hours by truck to a landfill located in Pennsylvania. By redirecting this material to local farms and businesses, this facility can reduce these costs significantly.

This report completes a comprehensive and thorough analysis of Class A biosolids, analyzing both their benefits and the methods of achieving them. This report fully analyzes the project problem statement, recommended design alternatives, the costs associated with those alternatives, and current facility processing costs and conditions. Also included in this report are the federal and state regulations encompassing pollutant restrictions, land application and storage requirements, pathogen reduction requirements, and vector-attraction reduction requirements. Information on dewatering options, specifically the currently used belt filter presses as well as the option of a centrifuge can be found in this report. Information on odor and dust control systems, including biofilters, can be found in this report as well. The treatment options discussed in this report are analyzed for practicality and differentiated based on their respective advantages, disadvantages, and costs. The equipment required for each process is detailed in their respective analyses. A thorough cost analysis is included detailing the costs of each process stretched on a 30-year timescale. This report ends covering the regional demand for Class A biosolids and some reuse options after treatment.

Our recommended design alternatives include thermal drying and autothermal thermophilic aerobic digestion (ATAD). Both processes have advantages and disadvantages, yet both meet the requirements for Class A classification and are both viable options for the project site given the site limitations.

Significant results achieved by our group include, but are not limited to, a cost-effective analysis, an assessment of regional demand, analysis of proprietary and vastly effective treatment options and an assessment of manufacturer products and their benefits. In conclusion, our group finds that the proposed improvements listed in this report are indeed worth the extra expenditure, as they will lead to saving money on a long-term basis. These improvements, although challenging due to the unique nature of the site, are indeed possible. We reached this conclusion through completing the feasibility study listed below. It is our hope that after reading through our findings that the same conclusions can be found.

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1. BACKGROUND INFORMATION

1.1. Project Problem Statement

The Town of Riverhead owns and operates three wastewater treatment facilities: Riverhead Water Resource Recovery Facility (RWRRF) (1.65 MGD), Calverton Advanced Wastewater Treatment Facility (0.1 MGD), and the Scavenger Waste Treatment Facility (0.1 MGD). Each of these facilities produces a waste sludge from their biological treatment process that is disposed of off-site by a contracted sludge hauler. Sludge removal costs per year total approximately $680,000. The liquid sludge from the Calverton plant is directly hauled off to a regional sludge processing facility. The sludge from the Water Resource Recovery Facility / Scavenger Waste plants are blended and dewatered onsite before being hauled to another state for landfill disposal. The purpose of this study is to determine a cost-effective method to achieve the Class A biosolids designation to be able to reuse the material for local businesses as a soil amendment or other products to reduce disposal costs.

1.2. Background on Biosolids

The treated waste sludge that is the result of wastewater treatment is known as biosolids. There are multiple different classifications for biosolids, and they are categorized by the 40 CFR Rule put forward by the EPA (Environmental Protection Agency). The main factors for classification of biosolids (Class B, Class A, and Class A EQ) is the level of pathogens present as well as the material's properties in terms of Vector Attraction Reduction requirements as mentioned in the EPA Part 503 Rule. Class B biosolids are classified based on their level of detectable pathogens. In Class A biosolids, the detectable level of pathogens, through treatment, has been effectively reduced to zero. In Class A EQ biosolids, the treated sludge meets and exceeds all requirements for pathogens and vector attraction reduction, making them of exceptional quality. Each classification of biosolids has benefits in terms of cost, potential use, and health effects. Class A EQ is the most beneficial and least restricted for land use.

1.2.1. What are Class A Biosolids?

Class A biosolids are dewatered and heated sewage sludge that has the potential for land application uses because it meets EPA guidelines. There are three main factors that must be accounted for when considering converting a sludge into a biosolid. These include the pollutant concentration, the vector attraction, and the pathogen concentration. Despite these three factors being extremely important, it is the pathogen concentration that separates Class A and Class B biosolids. Pathogens present in Class A biosolids are inactivated during the process of converting the sludge to Class A biosolids since these pathogens have the potential to be dangerous to plant and animal life during land application. How the Class A biosolids are classified and used during this land application is completely dependent on how the pollutants and vector attraction in the biosolids are regulated. The federal regulations that distinguish Class A biosolids from other types of biosolids are outlined in the Code of Federal Regulations (CFR) Title 40 Part 503.

For treated sewage sludge to achieve Class A classification, multiple requirements must be met. Firstly, pathogens must be inactive and/or virtually undetectable through processes such as UV treatment. Aside from pathogens, Part 503 of the EPA 40 CFR Rule specifies other standards to be met, mainly vector attraction reduction, inorganic pollutant concentration and odor. These factors are what set Class A biosolids apart from Class B biosolids.

1.2.2. Use and Benefits of Class A Biosolids

Class A biosolids are a classification of biosolids that are well suited for land application. Class A biosolids are more viable for land application over other classifications of biosolids since the level of dangerous pathogens in the resulting Class A biosolid sludge is reduced to virtually zero. Class A biosolids have a variety of highly effective uses, such as fertilizer for agriculture as well as soil rehabilitation and re-oxygenation. These biosolids have the added benefit of reducing the landfill restrictions of the biosolids. For example, sludge with a Class A designation would no longer needs to be hauled out of state. These biosolids can instead be sold to buyers such as farms or deposited in forest biomes to improve the soil composition. Class A biosolids, however, are mainly used in agriculture as fertilizers since they are rich in nutrients such as nitrogen, phosphorus and potassium. These biosolids also improve the soil structure and reduce demand for synthetic fertilizers. Depending on the type of Class A biosolids produced, these biosolids can be used on larger farms or smaller personal gardens. Composting is also an option for these biosolids. When discussing these biosolids effects on forests, Class A biosolids have been found to promote rapid timber growth, thereby allowing quicker and more efficient timber harvesting or more effective forest rejuvenation. With the host of benefits that Class A biosolids provide, an increased effort needs to be made to improve the quality of the sludge being produced by the Town of Riverhead to reach the Class A threshold.

1.2.3. Biosolids Production, Use and Disposal in NY State

In 2015, there were 612 publicly owned treatment facilities in New York State treating approximately 2,400 mgd of wastewater. The total biosolids produced at these facilities reaches approximately 1,000 dry tons of solids (DTS) per day (NYS DEC. 2018). The processes used to treat the sludge produced at these treatment facilities producing biosolids include aerobic or anaerobic digestion, heat drying, composting, and alkaline stabilization. Disposal of biosolids in New York State is primarily done by shipping and disposing the biosolids in landfills both in and out-of-state as shown in Figure 1. In 2015, an estimated 68% of the biosolids produced in New York treatment facilities were disposed of in landfills. Another 16% of the biosolids produced were incinerated in order to reduce the volume of material that was being disposed of in landfills. Only 16% of the biosolids produced in New York State were used to benefit the community or surrounding environment (NYS DEC. 2018). Landfill disposal has seen an increase mainly because it is the cheapest and easiest option for disposal and has the least number of restrictions on the biosolids. The beneficial uses of the biosolids produced at treatment facilities in New York State include direct land application, composting to enhance soil, heat drying to form a commercial fertilizer, and chemical stabilization to form a lime substitute for agriculture.

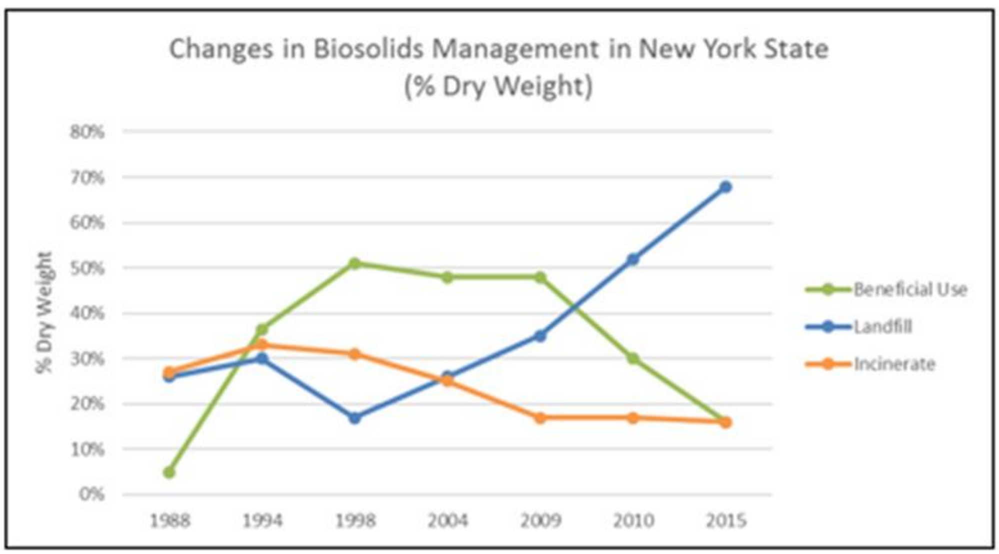

Figure 1: Graph of biosolids disposal in New York State. Source: NYS DEC, 2018

1.3. Riverhead Wastewater Treatment and Current Processes

The Town of Riverhead's Water Resource Recovery Facility (RWRRF) is where the town's wastewater is treated, and the sludge is produced. The facility is located just north of the Peconic River and lies between the Indian Island Golf Course and Peconic Estuary as shown in Figure 2.

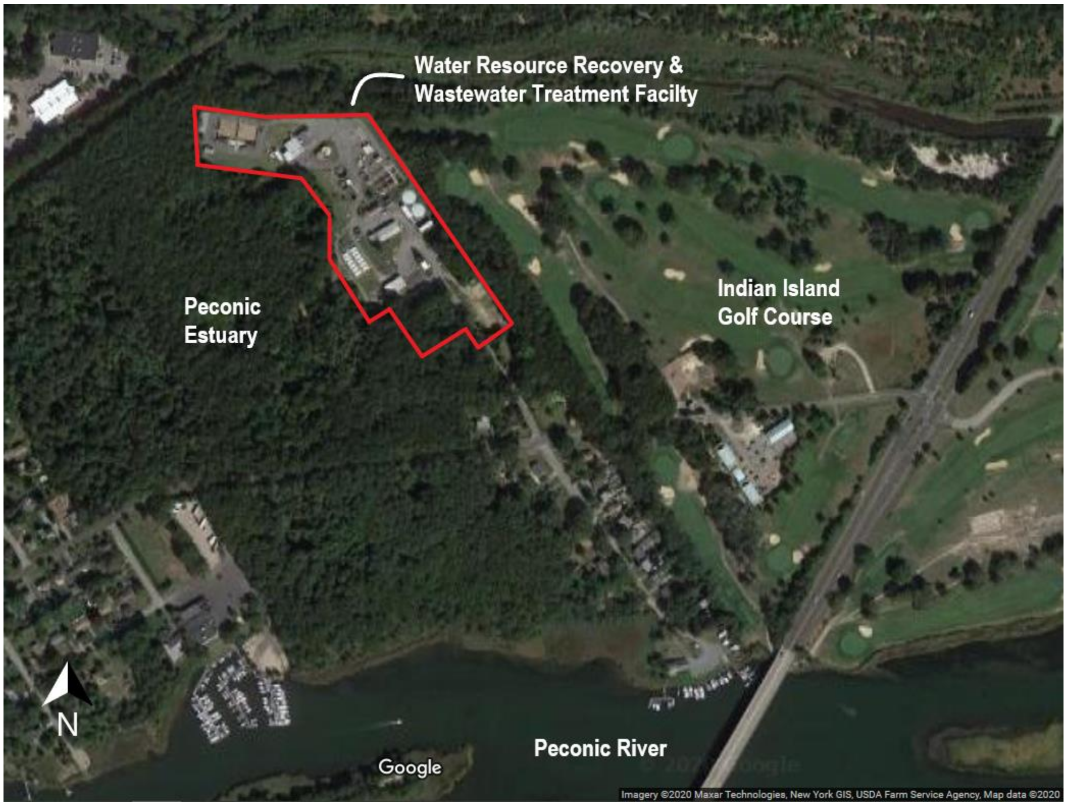

Figure 2: Aerial view of project site location.

This facility has a design flow of 1.5 mgd and is currently treating about 1 mgd of wastewater. The treatment facility primarily treats the wastewater from the Town of Riverhead's sewage system. Stormwater drainage is not connected to the Town's sewer system and is therefore not treated at the treatment facility. Septic sewage delivered by septic tank delivery trucks is treated separately from the sewer wastewater before being combined with the sewage system water and further treated. The design flow for the septic sewage treatment is 0.1 mgd and currently treats about 0.047 mgd of septic sewage. Power for the facility is provided by the power grid with back-up generators on-site using diesel generators. The fuel storage capacity for the on-site power generator is 7,900 gals. This storage capacity only lasts for 3 days.

1.3.1. Current Riverhead Wastewater Processing Facilities

The wastewater treatment process currently used at RWRRF is shown in Figure 3. The facility is designed for redundancy, so the facility does not stop running. This is to account for the sewage that never stops flowing into the facility. The main wastewater treatment facility has three stages. The first stage is the preliminary treatment of the influent from the Riverhead sewer system. This stage consists of fine screening, grit removal settling, and equalization. From the equalization tanks the wastewater is pumped to the second treatment stage, the Membrane Bioreactor (MBR) system. The MBR system first treats the wastewater in large aeration tanks where nitrification and denitrification take place. The nitrification and denitrification processes aid in removing the BOD and ammonia in the wastewater. The wastewater is then filtered through a series of 0.04 µm diameter hollow fiber membranes. The treated sludge from the MBR system is pumped to the sludge blending tanks where the sludge is combined with the sludge produced from the septic sewage treatment process and homogenized. At this point, the treated sludge contains only 0.5% solids. The blended sludge is then pumped to the third treatment stage consisting of a gravity belt thickening system and belt filter press. An emulsion polymer is added to the sludge to act as a coagulate to solidify and clump the solid sludge together. After the sludge has been thickened by the gravity belt thickener, it is pumped to the thickened sludge tank where it is temporarily stored. The thickened sludge contains approximately 2-3% solids. The thickened sludge is then pumped to the belt filter press where the sludge is thickened further and then pressed to remove water. Then the sludge is collected in an auger and loaded onto the truck to be hauled away. The final sludge product contains about 16% solids. Aerobic digestion to treat sludge was used at RWRRF in the past but certain disadvantages such as high capital cost for aeration equipment and high operating cost resulted in this process being terminated.

The water that is treated in the facility is then reused and reapplied to the Indian Island Golf Course. The facility maintains a water reuse system that takes the treated wastewater and applies it to the Golf Course. Due to the treated wastewater being reused, the facility desired a procedure similar for the left-over sludge which would directly correlate to achieving Class A Biosolids. The addition of a few extra facilities would enable the facility to make use of its resources to directly benefit the local community.

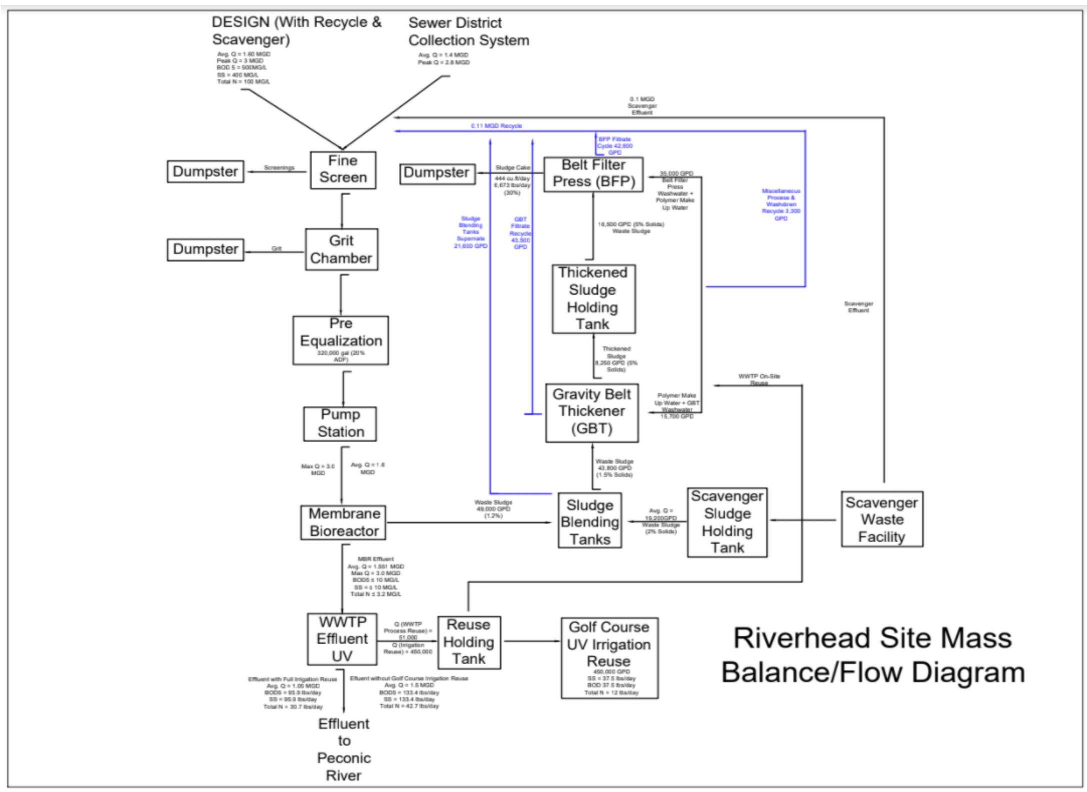

Figure 3: Flow chart/mass balance diagram of the treatment process at the RWRRF.

The scavenger waste treatment facility treats sewage from local septic collection trucks. These trucks have to register with the facility, so they know where the septic sewage comes from if any problems with the sewage occur. The sewage is first sent through bar screens to remove any debris in the sewage and then into the aeration grit chamber which removes grit from the sewage. The sewage is then pumped into equalization tanks where it is aerated and mixed. From there, the sewage flow is controlled and pumped to the flocculation tank where the solid particles are attracted together and clump together. The sewage is then pumped to the primary clarifier which separates the water from the sludge. Then the sludge is thickener. First, sodium bicarbonate is added to the sludge to increase the pH to 10. Next the sludge is sent through the rotating biological clarifier (RBC) system. The RBC system treats the sludge using a fixed film media for BOD and ammonia removal. Then the sludge is pumped to the final clarifier to remove more water from the sludge. The water that is separated from the sludge in both the primary and final clarifiers are pumped to the fine screening of the primary treatment facility where the water is further treated with the other sewage. The sludge is then pumped to the gravity belt thickening and pumped to the blending tanks to be combined and mixed with the other treated sludge from the MBR system. Information on the system was provided by RWRRF Superintendent Michael Reichel during a site visit.

1.3.2. Current Sludge Disposal and Associated Costs

The sludge that is treated at the RWRRF is currently being hauled away to a landfill located deep in Pennsylvania. This landfill is currently the closest location that accepts the quality of sludge that is currently being generated at the RWRRF. The sludge is hauled away multiple times a week by a semi-truck with a hauling capacity of 21 tons. There are three to four truckloads of sludge that are hauled away each week at the current flow of the facility. There could be as many as five to six truck loads per week at the facilities design capacity. The cost for each truck load to ship the sludge is over $3,000. Extrapolating that information, it means that approximately $680,000 is used just to haul away the sludge produced at the RWRRF annually. This high transportation cost is one of the driving factors behind aiming for a Class A biosolid classification for the sludge being produced by this facility.

1.4. Other Facilities with Class A Biosolid Processing and Disposal

Biosolids production has been implemented across the country for beneficial use. Some examples of facilities currently producing biosolids from sludge are the Immokalee Water and Sewer District in Florida, City of Centralia wastewater treatment plant in Washington, Syracuse Wastewater Treatment Plant in New York, and Rensselaer County Sewer District Wastewater Treatment Facility in New York.

The Immokalee Water and Sewer District in Florida originally produced Class B biosolids containing 1-1.5% solids. This facility has a design flow of 4.0 mgd. The annual costs associated with dewatering and hauling away to landfill the produced Class B biosolids was $500,0000/yr. After 2013, they upgraded the facility to produce Class A biosolids. The new system produces Class A biosolids by first dewatering the sludge in a screw press getting the material to 16% solids. Lime and sulfamic acid are then added to the dewatered sludge and heated in a reactor for 30 to 40 minutes at 122℉. These processes were chosen since there was limited available land to expand the facility. The final product is Class A biosolids that regional agricultural areas use as a fertilizer. The facility operating costs associated with producing Class A biosolids is $130,000/yr which is considerably less than originally dewatering and hauling Class B biosolids to landfills. There was the added benefit that local farms got to use the biosolid material as a fertilizer, saving up to $50,000/yr in fertilizer costs (Trojak, 2016).

In the City of Centralia in Washington, the wastewater treatment plant was designed to produce Class A biosolids. The design flow of the facility is 10.3 mgd and uses a belt filter press for dewatering the sludge which is then treated by lime stabilization and pasteurization. After only 5 years in operation the costs of lime went up considerably and the City investigated other cheaper alternatives. They decided to switch the facility to compositing to produce Class A biosolids. The dewatered biosolids are mixed with ground woody debris and composited to produce Class A biosolids. The product is either sold at $10/yd, donated, or used on city properties (City of Centralia, 2016).

The Syracuse Wastewater Treatment Plant in New York is an example of a metropolitan wastewater treatment plant that produces biosolids. This facility has a peak design flow of 126 mgd but operates at 84 mgd on average. This facility services the City of Syracuse and other areas outside of the city in Onondaga County. After primary, secondary, and tertiary treatment, a polymer is added to the sludge and is thickened by gravity belt thickeners. The thickened sludge is then blended and treated by anaerobic digestion. Then the sludge is heated, mixed, and dewatered in a centrifuge. The biosolids produced contain 30-35% solids. The biosolids are either recycled or disposed of in landfills (Onondaga County, 2020).

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Rensselaer County's Sewer District Wastewater Treatment Facility (RCSDWTF) in New York has a peak design flow of 63 mgd but operates on average at 24 mgd. Figure 4 shows the process used at this facility to produce biosolids for beneficial use. The sludge produced at this facility is treated by anaerobic digestion and is then dewatered. The resulting biosolids contain 23% solids. This dewatered biosolids is then further treated in a heat drying system. The heat drying system uses a mixture of air and biogas that is produced from the digestion process. This air/biogas mixture is then heated and used to heat and dry the biosolids. This system produces a 90+% dry product which is then hauled away or stored on site for up to 90 days. The biosolids produced at this facility are sold to help offset the cost of operation at the facility (Smith CDM, 2016).

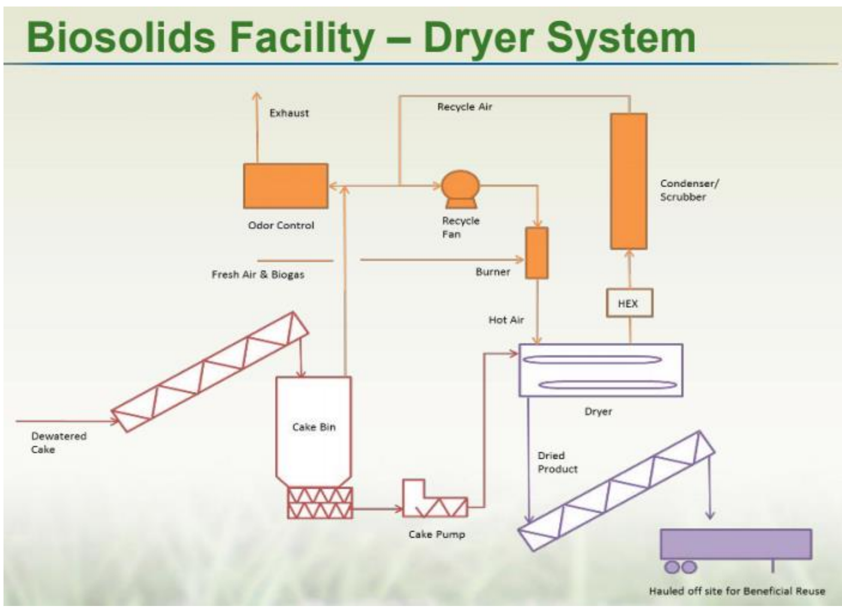

Figure 4: Schematic of RCSDWTF Dryer System.

The Marsh Creek Wastewater Treatment Plant located in Geneva, NY currently has its own ATAD process for producing biosolids material. This facility uses an ATAD system made by Thermal Process Systems (TPS), a manufacturer based in Indiana. The TPS system uses a two-stage process of digestion. The first stage is where thermophilic digestion takes place, causing cells to rupture and degrading a high percentage of biological material. The second stage of the digestion process uses a second reactor, better known as a Storage Nitrification Denitrification Reactor (SNDR). During this, mesophilic temperatures are maintained in order to provide a suitable environment for the reduction of remaining soluble chemical oxygen demand (COD), nitrogen compounds, and volatile fatty acids (VFAs) (TPS ThermAer Process).

The resulting biosolids sludge has a total solids (TS) reduction ranging from 45-55%, far exceeding minimum requirements by EPA 503 regulations. Other benefits of this system include stable operating conditions, pathogen destruction, control of foam generated in the process, minimal odor production, low nitrogen recycle to the plant head works, high cake solids after dewatering, and high-quality product. Minimal odor production is worthy of note in the case of RWRRF due to its proximity to densely populated and residential areas.

2. FEDERAL AND STATE REGULATIONS

2.1. Federal and State Regulation Codes

The federal biosolids regulations that must be followed were instated by the United States Environmental Protection Agency in 1993. It was established as a part of Title 40 of the Clean Water Act known as The Standards for the Use or Disposal of Sewage Sludge. The regulations specifically geared towards biosolids are outlined in Part 503 of this title. This rule details how biosolids are to be classified and the uses for those biosolids depending on their classification. This classification process depends on the concentration of pathogens and pollutants contained within. An in-depth guide to the rule published by the EPA offers suggestions on how certain concentrations of pathogens and pollutants can be achieved to reach certain biosolid classification thresholds. This rule also describes how biosolids would be used for land-application, one of the possible routes of removal for the biosolids if Class A is achieved (EPA, 1993).

The New York State regulations that must be followed are found in Title 6 CRR-NY, Chapter IV: Quality Services, Subchapter B: Solid Wastes. There are a few parts of this subchapter that are related to biosolids production, use, storage, facility operation, permits and more. Part 360 focuses on solid waste management facilities and general requirements. Part 361 focuses on the facility processes and requirements for Class A biosolids. Subpart 361-2 discusses the requirements for design and operation requirements for land application and storage. Subpart 361-3 discusses pathogen reduction, vector attraction reduction, and pollutant limit requirements to achieve Class A biosolids for use (NYS DEC, 2020).

2.1.1. Pollutant Restrictions

The pollutant restrictions described in Title 6 CRR-NY Subpart 361 section 3.9 and Title 40 CFR Part 503 Subpart C section 23 must be met. Subpart 361 section 3.9 describes the requirements that must be met if Class A biosolids are to be used for land application in New York specifically. Part 503 Subpart B section 13 details the requirements that must be met for land application to be considered anywhere in the United States. Table 1 shows the ceiling pollutant concentration limit requirements for both Federal and State regulations. As shown, the State requirements are more restrictive than the federal requirements. These state regulations will need to be met for Class A biosolids production if New York land application is to be considered.

Refer to Table 1 for a direct comparison of the state and federal regulations for biosolids pollutants. By showing a direct comparison of these ceiling requirements, it is easier to see how much stricter the restrictions are on a state level. This will be important to consider moving forward when deciding on a treatment process for disposal since it will be the state restrictions that will have to be followed (EPA, 1993).

Table 1 – Federal and State Pollutant Limit Requirements for Class A Biosolids

Parameter	Federal	State
	Maximum Concentration (mg/kg)	
Arsenic (As)	75	41
Cadmium (Cd)	85	10
Chromium (Cr-total)	3,000	1,000
Copper (Cu)	4,300	1,500
Lead (Pb)	840	300
Mercury (Hg)	57	10
Molybdenum (Mo)	75	40
Nickel (Ni)	420	200

Selenium (Se)	100	100
Zinc (Zn)	7,500	2,500

While these ceiling concentrations are important when first considering land application and reaching Class A biosolid classification, these concentrations do not consider the pollutant limits for specific land use situations. The pollutant concentrations for bulk land use are different than that for packaged and individual land use. Part 503 outlines the four main types of biosolids based on how they are used for land application. These types include Excellent Quality (EQ), Pollutant Concentration (PC), Cumulative Pollutant Loading Rate (CPLR), and Annual Pollutant Loading Rate (APLR) biosolids. These types are differentiated by their pollution level and how they are applied. Figure 5 below helps with visualizing how these types are separated based on use.

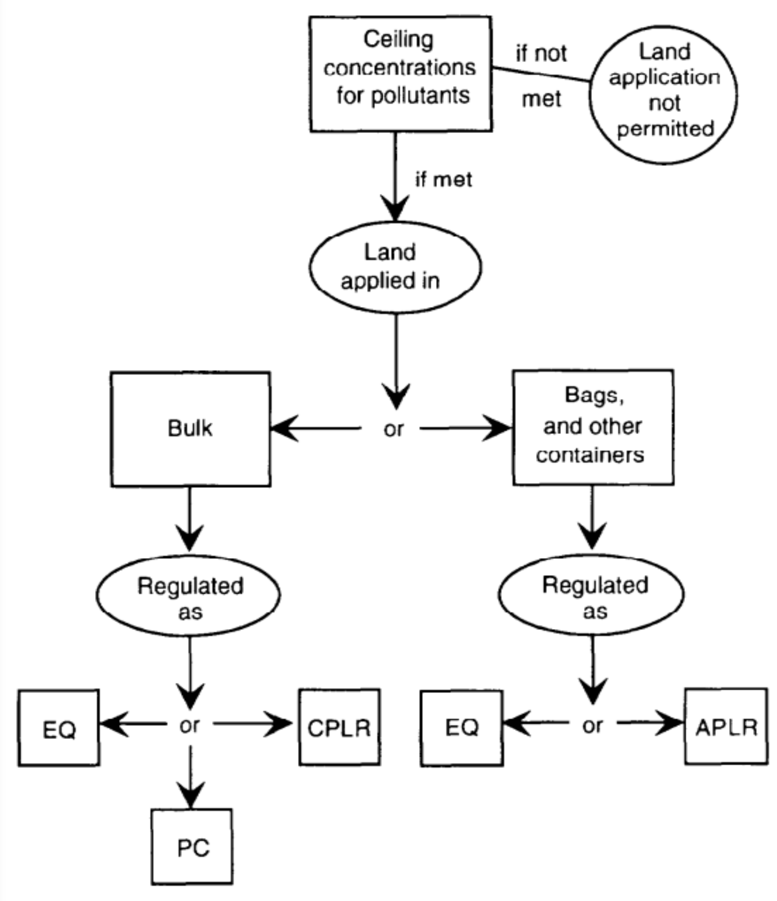

Figure 5: Types of Class A biosolids that are land applicable (Cook, 1994)

EQ biosolids are virtually unregulated for bulk land-application due to how strict the pollutant limits and vector attraction reduction requirements are to achieve the EQ standard. It is also possible for EQ to be bagged for commercial consumer use. These biosolids are typically the highest quality biosolid type people aim for. PC biosolids have the same pollutant limits as EQ biosolids only with less strict vector reduction requirements. PC biosolids have more restrictive management practices during the land application as well, making them slightly less desirable compared to EQ biosolids. They also are not viable for commercial bagging. The pollutant concentration limits for EQ and PC biosolids are very close to the New York pollutant limits for land application. This means that these types of Class A biosolids may be desirable when considering a land-application alternative for the biosolids. It should be noted however that the pollutant limits for Selenium in EQ and PC biosolids are a bit more restrictive than the standards set by New York state and the United States. The selenium limit set for EQ and PC biosolids is 36mg/kg while the limit set by both the state and federal government is only 100 mg/kg. Every other pollutant limit set by New York State either matches or exceeds the limits for EQ and PC biosolids (Cook, 1994).

CPLR biosolids are a bit less restrictive in their pollutant limits in comparison to the PC and EQ biosolid limits. The limit on Selenium for CPLR biosolids matches both the federal and state limit of 100mg/kg. While this option is much easier to achieve in comparison to the previous two options, there are more management practices that must be followed and pollutants that must be tracked. This puts more pressure on the biosolid applier, making it less desirable to farmers who would potentially use the biosolids for land application (Cook, 1994).

APLR biosolids are much more restrictive that any of the biosolid types previously discussed. The pollutant limits for this type of biosolid are much lower than that for the other types of biosolids. The vector attraction requirement is just as strict as the EQ requirement. The reason behind these strict pollutant limits and demanding vector attraction reduction requirements is that these biosolids are specifically catered for commercial bagging and individual use. They are not used for bulk application due to the cost of reaching such a standard of quality (Cook, 1994).

All four of these land application classifications can achieve the pathogen requirements for Class A biosolid distinction. As described, the main differences between them are the restrictions on pollutant concentrations.

Refer to Table 2 for the federal pollutant limits for these designations. Table 2 shows the pollutant ceiling concentration levels for all four types of Class A biosolids. By comparing these levels to those noted in Table 1, the ideal type of Class A biosolids for state land application can be found. From these tables, EQ and PC pollutant concentration levels seem to mostly match or exceed the state requirements for these pollutants (Cook, 1994).

Table 2 – Federal Land Application Classification Requirements

Parameter	EQ and PC (mg/kg)	CPLR (kg/he)	APLR (kg/he/year)
Arsenic (As)	41	41	2
Cadmium (Cd)	39	39	1.9
Chromium (Cr-total)	1,200	3,000	150
Copper (Cu)	1,500	1,500	75
Lead (Pb)	300	300	15
Mercury (Hg)	17	17	0.85
Molybdenum (Mo)	-	-	-
Nickel (Ni)	420	420	21
Selenium (Se)	36	100	5
Zinc (Zn)	2,800	2,800	140

It should be noted that most of the pollutant limits for PC and EQ biosolids are met with the state concentration limits aside from the limit for selenium. This will be useful when considering which Class A distinction goal should be recommended for the RWRRF.

2.1.2. Pathogen and Vector Attraction Reduction

The requirements for wastewater sludge to achieve Class A biosolids are outlined in regulation code Title 6 CRR-NY Subpart 361 section 3.7(a). Pathogens in the waste for Class A biosolids must either contain a fecal coliform density less than 1,000 most probable number per gram of total dry solids or the density of salmonella sp. bacteria in the biosolids is less than 3 most probable number per 4 grams of total dry solids. The reduction of pathogens in the biosolids must be met at the time the material is used or disposed of and must be treated by one of the alternatives described in subpart 361-3.7.

Vector attraction reduction criteria for Class A biosolids are also outlined in regulation code Title 6 CRR-NY Subpart 361 section 3.7(b). One of the methods described in that section must be achieved before the biosolids leave the facility. Vector attraction reduction must be met either after meeting the pathogen reduction requirements or at the same time the pathogen reduction requirements are met.

There are two main options when it comes to dealing with the pathogens that are present in untreated sewage. These options include high heat temperature treatment and high pH treatment. Part 503 Subpart D Section 32 outlines these processes and how these processes are to be executed based on the solids content of the influent sludge. The high temperature alternative uses high heat in order to kill any pathogens that are living within the sludge. The sludge must be heated for an extended period of time to ensure that all the sludge is properly heated and rid of any pathogens living within. For the high temperature alternative, there are calculations presented in this section that outline how high the temperature of the sludge should be raised and the amount of time that the sludge should be kept at that temperature. The equation to be used for this calculation can be found below where D is the time in days and t is the temperature above the minimum 50 degrees Celsius required for treatment. These variables, as shown in the equation below, have an indirect relationship (EPA, 1993).

$$D = \frac{131{,}7000{,}000}{10^{0.1400t}}$$

For the pH alternative, a high pH material is added to the sludge in order to kill pathogens that cannot survive in the high pH atmosphere. During this treatment method, the temperature also needs to be raised in order to improve the effectiveness of the treatment. While the duration and temperature of the heating is not nearly that of the first alternative, it does mean that a heating system would need to be implemented in both alternatives. The total time required for this process to be executed is 72 hours or 3 full days. An additional 12-hour heating period above 50 degrees Celsius is also required in this process. With this information, alternatives for treatment can be analyzed for their relative feasibility and effectiveness in meeting these requirements (EPA, 1993).

2.1.3. Land Application and Storage Requirements

Subpart 361-2.4-2.7 of the State regulations code Title 6 CRR-NY must be followed for land application and storage of biosolids. These subparts describe the requirements that must be met if Class A biosolids are to be used for land application or storage. The biosolids used for land application must meet all requirements stated above for pollutant limits, pathogen reduction, and vector reduction. Sections 361-2.4 and 361-2.5 must be followed for land application and include information for permit application requirements, land application criteria including nutrient loading, monitoring and recordkeeping requirements, access and crop restrictions.

If biosolids are being produced but there is no immediate use for them, the biosolids must be stored. The requirements specified in Subpart 361-2.6 and 361-2.7 must be met. These sections include information on permit application requirements, storage location in relation to site features, sampling and inspection, and construction options.

2.1.4. Requirements for Other Disposal Options

Landfill disposal is also an option to consider for the resulting biosolids since landfill disposal has far fewer pollutant removal and stabilization requirements. Subpart C section 23 of the Part 503 rule outlines the pollutant federal limits for surface disposal. Title 6 CRR-NY Subpart 363-7.1(j) outlines the New York state requirements for disposal of biosolids in landfills. The federal and state pollutant requirements for disposal can be found in Table 3 below. These limits do not include domestic sewage as a source of sludge.

Refer to Table 3 for the ceiling concentrations for disposing of biosolids through landfill disposal. Comparing this with the ceiling concentrations for land-application, this table helps in illustrating how different the requirements are between landfill dumping and land-application. This also shows how much the treatment processes will have to achieve on this metric, and it will be something to keep in mind when deciding on a treatment option.

Table 3 – Federal and State Pollutant Limit Requirements for Landfill Disposal

Parameter	Federal	State
	Maximum Concentration (mg/kg)	
Arsenic	73	41
Chromium	600	1,000
Nickel	420	200

New York State also requires that the biosolids are stabilized, dewatered to at least 20% solids, and exhibit no free liquid to be disposed of in landfills. Stabilization can be achieved either by digestion or lime stabilization. Other state requirements can be met if digestion or lime stabilization are not met at the treatment facility. These other state requirements are outlined in Title 6 CRR-NY Subpart 363-7.1(j).

2.2. Permits

Freshwater wetlands, also known as marshes, is a valuable resource that is needed for flood control, surface and groundwater protection, open space and water resources. Under Article 24, of the Environmental Conservation law implementing regulations 6NYCRR Part 662, Part 664, and Part 665, freshwater wetlands and its wildlife must be preserved and protected. The Peconic Estuary located within the vicinity of the RWRRF is classified as a Class 1 wetland. Class 1 wetlands are the most heavily protected wetlands thereby requiring the most stringent standards under the Department of Environmental Conservation (NYS DEC, 2020) regulations. The Peconic Estuary provides a rich layout of coastal and underwater habitats that support 140 globally and locally rare species (Nature, 2017). The placement of its unique freshwater supply as well as its unique spawning and nursery grounds all contribute to its Class 1 rating. According to the Freshwater Wetlands Permit Program, the DEC regulates activities in freshwater wetlands and seeks to minimize the impairment of wetland functions. According to the Freshwater Wetlands Act of 1975, any activity that may adversely impact the natural values of a wetlands area must be regulated and parties involved must apply for a permit to do so. The condition for requiring a permit is as follows: the construction of buildings, roadways, septic systems, the modification of existing structures, the placement of fill, excavation, and grading. Building new facilities will require this permit granted by the DEC. To be considered for a permit, however, the US Geological Survey must also recognize the location and scope of the proposed project. Project plans must then be drawn up indicating the location of the project and what construction is to be completed in that location. To obtain the final permit after these steps are completed, the permit fee of about $15,000 must be paid (NYS DEC, 2020).

An additional permit is required for the RWRRF. This permit falls under the requirements of the Part 360 Permits, Rules and Regulations in accordance with the New York State Management Program (NYS DEC, 2018). In order to manage solid waste and help preserve and protect our environment, all forms of solid waste are subject to point of discharge regulations under 33 USC 1342 (NYS DEC Chemical, 2020). Additionally, any solid waste material must satisfy the criteria set by the DEC under Part 360.12(c)(1)(ii) for disposal. The RWRRF must obtain the Part 360 permit provided by the NYS DEC in order to dispose or reuse the sludge generated from the treatment process. To obtain the final permit, a permit fee of approximately $15,000 must be paid to the NYS DEC.

3. DESIGN ALTERNATIVES

3.1. Parameters for Design Considerations

There are a few design elements that we must consider in addition to which process we recommend to produce Class A biosolids. These design considerations include site limitations, dewatering techniques, odor control, and dust control. Each design alternative will need to address these appropriately.

3.1.1. Cost

There were several parameters that governed our decision-making process. One of the main parameters was total cost including operating, maintenance, and capital over a span of 30 years. Furthermore, the Town of Riverhead superintendent Michael Reichel emphasized that expenditures were already too high for RWRRF, and so our design alternatives were affected heavily since cost was the greatest concern.

3.2. Space Limitations

The second parameter was available space. Our recommended design alternatives both call for on-site storage of the product before distribution, and so our team had to investigate how and where storage facilities/silos could be implemented. This proved challenging since the site itself is already small and has limited space and there are several site limitations that must be considered when choosing a process for producing Class A biosolids. On the West border of the facility site there are wetlands. Expansion of the facility near these wetlands will result in environmental concerns being accounted for. There also needs to be room for trucks to move throughout the site from River avenue on the south side of the site. Storage silos can be large, and this could possibly interfere with the movement of the trucks. In addition to the limited space, preexisting conditions also had an influence on our design choices. Also, there are many pipes below the site that must be navigated with caution. Additionally, there is an old sludge mixing tank currently not in use, which we had to consider for reuse/repurposing or demolition.

3.2.1. Solid Percentage

The third parameters involve the solid percentage of sludge. Given that water is heavy and takes up a large amount of space, the feasibility of determining the product solid percentage needs to come into consideration in order to properly assess hauling costs and the reduction in overall costs.

3.2.2. Odor Control

The fourth parameter is odor control. Due to the proximity of RWRRF to residential neighborhoods and the Indian island golf course, our choices were limited to designs that included odor control as part of the process. Odor control is needed however not just a concern for treatment plants in residential areas. Treated wastewater sludge needs to be assessed for odor when used for fertilizer, soil rejuvenation, compost, and etcetera. In order to control this odor, there are odor contributing factors that can be controlled, as well as several design choices for odor control options. Odor, or nuisance odors can affect property value, aesthetic value, and the quality of life of those in constant contact with it. All waste sludge has toxic airborne pollutants in its odors that can be extremely harmful if not controlled correctly. These odors originate from the very composition of waste sludge or biosolids, as well as their nature. It is important to remember that waste sludge originally started out as sewage or cesspool waste. Because of this, odor assessment was a required element to consider during design. The processes that did not have odor reduction mechanisms were eliminated from the selection process such as composting.

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3.3. Design Selection Process

During the design selection process, we had to select the most feasible and viable method to achieve Class A biosolids designation. Through our research, we found a total of six viable options that achieved Class A biosolids designation. The six methods we had to choose from were thermal drying, advanced alkaline stabilization (AAS), thermal hydrolysis with anaerobic digestion, thermal hydrolysis without anaerobic digestion, ATAD, and mesophilic anaerobic digestion (MAD). Out of these options, only thermal drying and ATAD were considered for the final design. The other options had glaring issues that made them much less feasible than the two selected as will be described in the four sections that follow.

3.3.1. Advanced Alkaline Stabilization

The advanced alkaline stabilization (AAS) process involves the addition of alkaline material to the dewatered sludge in order to raise the pH. This increase in pH reduces favorable conditions for pathogen survival, thereby meeting the condition to achieve Class A classification. The materials used for AAS include but are not limited to hydrated lime, quicklime (calcium oxide), lime and cement kiln dust, lime ash, and carbide lime. The most common materials used is quicklime as it has a greater heat of hydrolysis allowing for a greater reduction in the number of pathogens. The other materials listed are less effective substitutes. Our group ruled this option out due to the dangerous level of particulate matter and ammonia released during this process, the additional cost of ordering shipments of the quicklime material, as well as the nearly 50% increase in volume of the material as a result of the quicklime addition (Parsons Engineering Science, Inc., 1999).

3.3.2. Mesophilic Anaerobic Digestion

The Mesophilic Anaerobic Digestion (MAD) process requires the use of mesophilic anaerobic bacteria to kill harmful pathogens contained within sludge effluent. Mesophilic anaerobic bacteria thrive in room temperature settings deprived of oxygen. The relatively low odor and production of usable methane made MAD an option to consider. Our group ruled this out, however due to the long processing time of the sludge reaching nearly 35 days for one batch to be processed. Aside from this, the storage and reactor sizes needed to accommodate for the long processing time. This size requirement made making a project plan for this option unfeasible and so the MAD process was not considered further (Schnaars, 2012).

3.3.3. Thermal Hydrolysis with Anaerobic Digestion

Thermal hydrolysis with anaerobic digestion generates Class A biosolids with the use of thermophilic and mesophilic digestion. Thermal hydrolysis uses heat and pressure via injected steam in order to catalyze thermophilic digestion. This occurs when the thermophilic bacteria that survive in high heat deactivate harmful pathogens. This 30-minute process cuts the process time of a typical mesophilic digestion cycle from 35 days to only 12 days, roughly one third the original digestion time. Our group found this option not to be the most feasible however. The main reason our team deemed this unfeasible is due to the high space requirements for the digester, thermal hydrolysis system, as well as the other equipment associated with operating the thermal hydrolysis system totaling well over 10,000 sq. ft. This system also required required many co-generative energy systems to optimize the system, making spacing for an optimized system nearly impossible, thereby eliminating it as a feasible option (Water Environment Federation, 2019).

3.3.4. Thermal Hydrolysis without Anaerobic Digestion

Thermal hydrolysis without anaerobic digestion was to be achieved through a proprietary process made by the thermal hydrolysis manufacturer Lystek. The information gathered for this system is based on a conversation with Lystek Business Development Manager James Dunbar. Dunbar explained how the system produces Class A biosolids without the anaerobic digestion reactor requirement. This eliminated the space requirement issue that plagued the variant thermal hydrolysis process only requiring a total of 2,000 sq. ft. According to Dunbar, Class A classification was attainable because while the system does involve steam power to hydrolyze the biosolids, it also uses alkaline material that gets injected into the system. By reaching the required pH of 9.5, harmful pathogens are effectively deactivated. Due to the enclosed nature of the system, it did not require an odor control system. The issue that deemed this option unfeasible was the lack of ownership after processing. After processing, Lystek would have full ownership and responsibility of the material. This put restrictions on the freedom of the RWRRF to choose how and where the material is distributed, likely being shipped out of state. This, along with the host of backend charges associated with completing this project made it unfeasible as an option (Lystek, 2020).

3.3.5. Conclusion of Design Selection Process and Other Mitigating Factors

It was determined that only two out of the six processes were feasible for the site: thermal drying and ATAD. We narrowed down these choices by doing in depth comparisons of each design. We compared the six listed treatment alternatives by several factors including our design parameters, preliminary cost estimates for equipment, installation and O&M, product quality/solid percentage, setup requirements such as running a gas line for the thermal drying system, availability of equipment from manufacturers, and NYS regulations for each design. After applying these criteria to each treatment alternative, all but ATAD and thermal drying were eliminated. From there, we performed a more in-depth cost-effective analysis and looked further into the details of each design until we managed to make our final decision.

There were other factors that influenced our design selection process. The presence of wetlands on the west border of the facility lead to environmental concerns. The presence of unused digester and holding tank as well as the old UV treatment building also played a factor in determining how we would space out our improvements. Any underground utilities would need to be considered. Dewatering alternatives were another factor: side from belt filter press, our group investigated centrifuge, rotary drum vacuum filter, filter press, and belt filter press. We mainly considered biofilters and sludge basins, but also considered wet chemical scrubbers, regenerative thermal oxidizers, counteractants, neutralizing agents, and oxidizing agents.

3.4. Feasible Design Alternatives

There are a few design elements that we must consider in addition to which process we recommend producing Class A biosolids. These design considerations include site limitations, dewatering techniques, odor control, and dust control. Each design alternative will need to address these appropriately.

3.4.1. Thermal Drying

Thermal drying involves heating sludge to a high temperature for extended periods of time to dewater and kill any pathogens contained in the sludge. This process utilizes direct or indirect heat to drive water out of wastewater solids and produce a Class A biosolid with 90% or higher dry solids percentage. This process dewaters the sludge through evaporation and kills the bacteria through the high heat. Thermal drying meets state regulation requirements from Title 6 CRR-NY Part 361 Subpart 3.7 section a subsection 1-i-b for pathogen reduction. This also meets state regulation for vector attraction reduction according to Title 6 CRR-NY Part 361 subpart 3.7 section b subsection 1-viii since the resulting biosolids produced by thermal drying has a solids content higher than 90%.

3.4.2. Dewatering Alternatives and Natural Gas Line

The thermal drying process is most efficient for a wet sludge with an already high solids content. The higher the solids percentage of the wet sludge that goes into the drying unit, the less energy is required to remove water from the wet sludge as well as less time being required to complete the drying process.

The current dewatering device at the RWRRF is a belt filter press. The belt filter press dewaters the sludge to a solid's percentage of only 16%. If we implement a centrifuge to use for dewatering the sludge, we can get a solids percentage of 25% to 35%. Table 4 shows a comparison of the fuel consumption and associated cost for the drying process for various sludge cake solid percentages. These comparisons also account for the additional costs associated with installing a centrifuge and natural gas line where applicable.

The natural gas line has an estimated installation cost of $100/ft. The length of the gas line would be about 1,400 ft. from the closest gas main on Riverside Drive to the required location on the project site. This means the natural gas line installation cost is $140,000. The centrifuge has a capital cost of about $500,000 with an additional $200,000 for construction and installation.

Table 4 - Comparison of Fuel Consumption and Associated Cost

Dewatering Process	Belt Filter Press (Current)		Centrifuge (Proposed)			
Equipment + Installation Cost	$140,000 for Natural Gas Line		$700,000 + $140,000 for Natural Gas Line			
Produced Wet Cake % Solids	16% Solids		25% Solids		35% Solids	
Fuel Type	Natural Gas	Oil	Natural Gas	Oil	Natural Gas	Oil
Required BTU / DTS[1]	14.754×10^6		8.294×10^6		5.008×10^6	
Required Fuel Amount	14,324 c.f.	106.1 gal.	8,052 c.f.	59.64 gal.	4,862 c.f.	36.0 gal.
Cost / DTS[2]	$286.48	$318.30	$161.04	$178.92	$97.24	$108.00
Total Cost / Year[3]	$200,536	$222,810	$112,728	$125,244	$68,068	$75,600
30-Year Fuel Cost	$6,016,000	$6,684,300	$3,381,840	$3,757,320	$2,042,040	$2,268,000
Total 30-Year Cost[4]	$6,230,280	$6,684,300	$4,667,540	$4,828,720	$3,327,740	$3,339,400

1 - Values based on 1450 BTUs required to remove 1 lb. of water from wet sludge cake.
2 - Fuel cost based on assumed price of $3.00/gal. for oil and $0.02/c.f. for natural gas.
3 - Total cost based on 700 DTS per year of sludge produced by the treatment facility.
4 - 30-year total calculated based on a 30-year bond for capital costs at 3% interest rate.

Table 4 clearly shows the benefit from upgrading the dewatering device from the current belt filter press to a centrifuge. The cheapest option is to dewater the sludge to 35% solids using a centrifuge and using natural gas for the fuel source. Although there is only a small difference between the fuel cost for natural gas and oil when the sludge is 35% solids, if the centrifuge outputs a sludge cake less than 35%, that difference increases. The addition of the natural gas line will also be available for future projects or upgrades on the site. Also, burning natural gas has a lesser environmental impact than burning oil (EIA, 2020).

The centrifuge design we have chosen is the Centrisys CS18-4 2 phase centrifuges. This centrifuge has an installed 50 horsepower at a design capacity of 21,000 GPD and a feed capacity of 50-100gpm. It has the potential to yield a solid percentage of up to 40%, more than double the output of the belt filter press currently used at the Riverhead facility. It has a record high torque to weight ratio and top of the line process control with a nonproprietary touchscreen interface allowing for quick start/stop times.

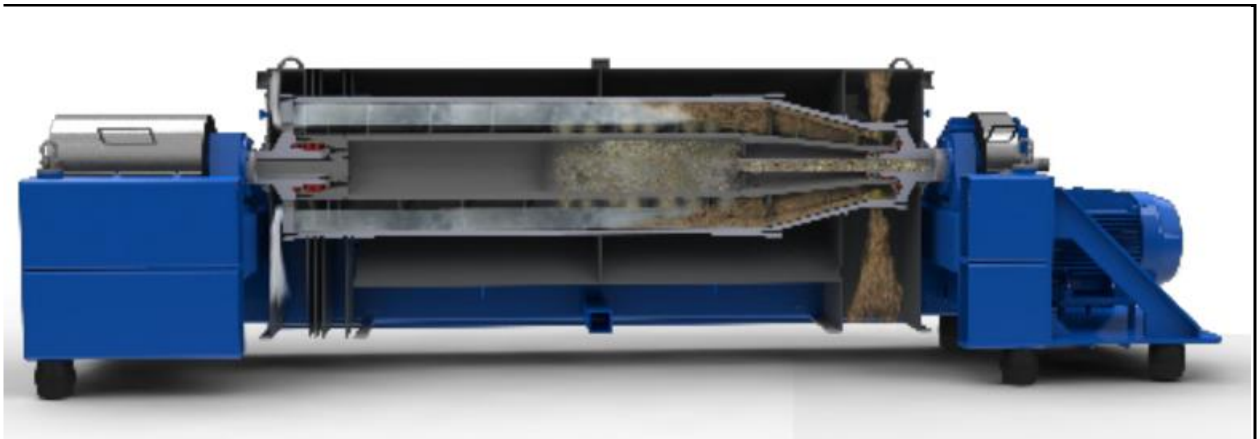

Figure 7: Cutaway image of a Centrisys centrifuge. (Centrisys, 2020)

As seen in Figure 7, the centrifuge works by taking both water and solids in through a feed tube. The rotating assembly driven by an electric motor through V-belts uses centrifugal force to separate solids from liquids. The bowl speed can be adjusted with a Variable Frequency Drive (VFD). The centrifuge's axial flow design promotes the settling of very fine solids, which increases recovery rate and decreases polymer consumption (Centrisys, 2020).

The conveyor that feeds the material into the centrifuge is powered by a separate drive. The separate drive is a fully automatic back drive independent of the bowl. The actual separation takes place in the chamber of the bowl. The solids then settle along the wall of the bowl and are slowly moved to the conical end. At the conical end the solids are dried even further before they are discharged. During this, the separated water travels in the opposite direction and is discharged over adjustable weirs into a separate compartment.

The Centrisys CS18-4 2 phase centrifuge measures 151 in. long by 44 in. wide and is 41 in. tall (Centrisys, 2020). This would replace the belt filter press and easily fit where the current belt filter press is housed in the facility. The current sludge input flow can be retrofitted to the centrifuge. The dewatering sludge would discharge onto a conveyor that transports the sludge cake to a wet cake feed hopper where the sludge cake will be stored until it is dried in the thermal drying process.

3.4.3. Process Design and Feasibility

Our design for the thermal drying process revolves around using a Komline-Sanderson 9w-840 paddle dryer system. This system has a variety of equipment shown in the schematic in Figure 8. This schematic shows the equipment required for the thermal drying process and the flow of materials throughout the process. This design uses the centrifuge previously discussed as the dewatering device and natural gas as the fuel source for the thermal fluid heating system.

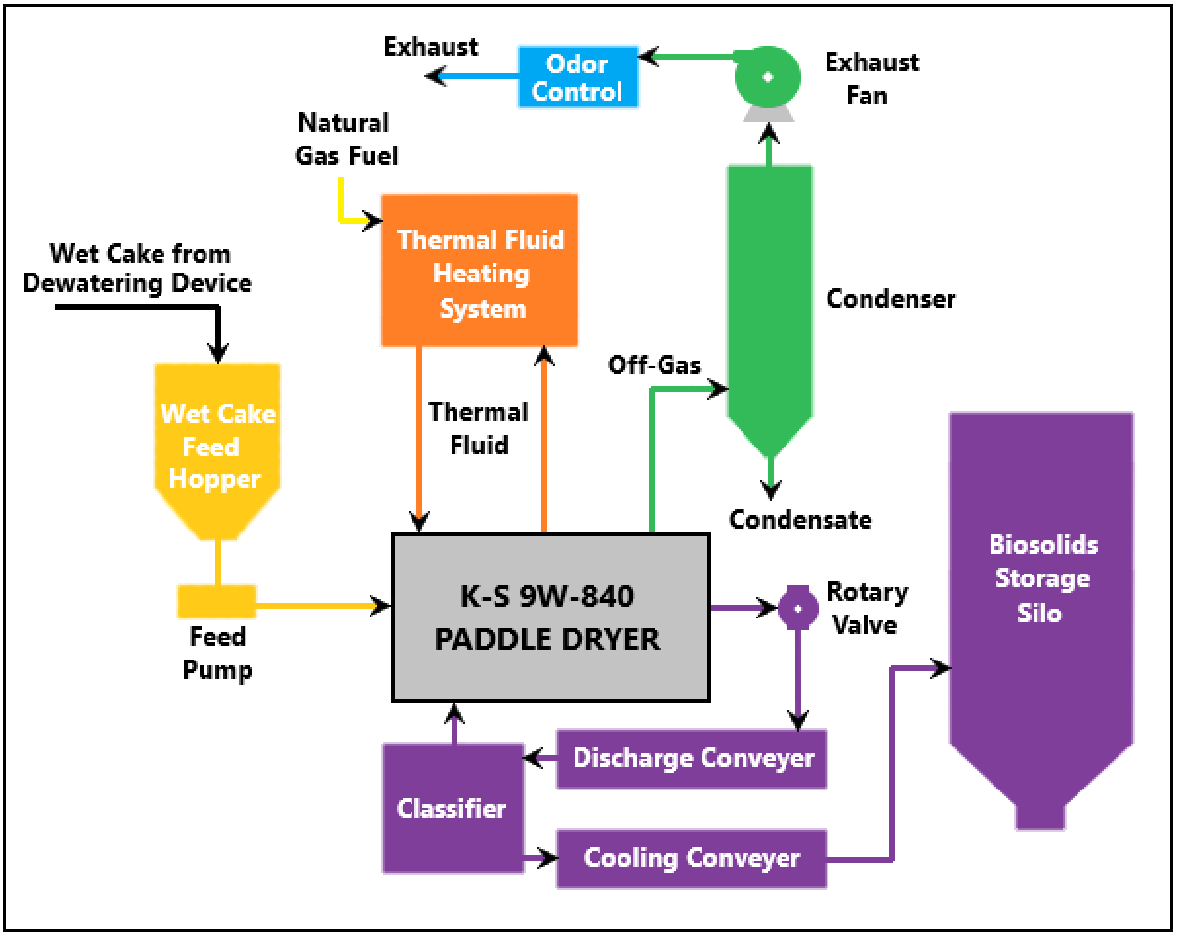

Figure 8: Schematic diagram for the thermal drying process design.

Equipment used in this process is listed and described below:

- **Wet Cake Feed Hopper** - Temporary storage of wet cake from the centrifuge that will feed the sludge cake to the thermal drying unit. Approximately 20 yd^3 of storage.
- **Feed Pumps** - Progressive cavity feed pump used to transport wet sludge cake from the feed hopper to the dryer unit. Located directly under the feed hopper and controlled by a VFD. Power of the feed pump is 15 hp.
- **Dryer Unit** - This is where the sludge is heated and dried to produce the Class A EQ biosolids. Komline-Sanderson 9W-840 paddle dryer uses indirect drying by transferring heat from thermal fluid to the hollow paddles of the dryer unit as seen in Figure 9. The design of the paddles pushes the sludge along the length of the dryer unit and the end product is 90%+ solids. Power of the motors used to drive the unit is 75 hp.
- **Rotary Valve** - Controls the flow of the dried biosolids from the dryer unit to the discharge conveyor.
- **Discharge Conveyor** - This transport the dried biosolids from the dryer unit to a classifier.

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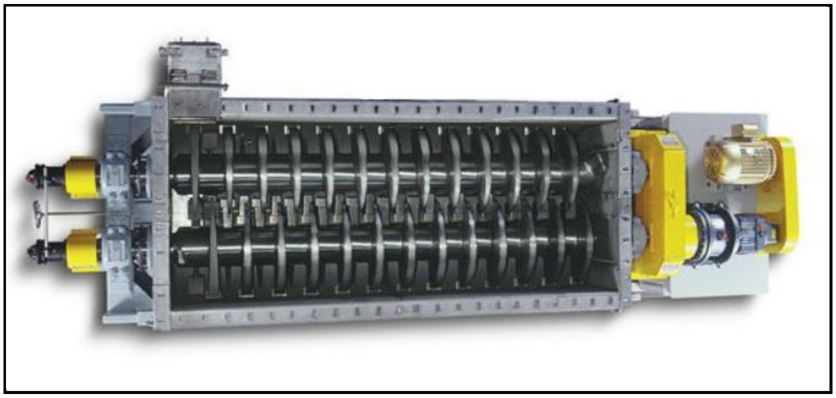

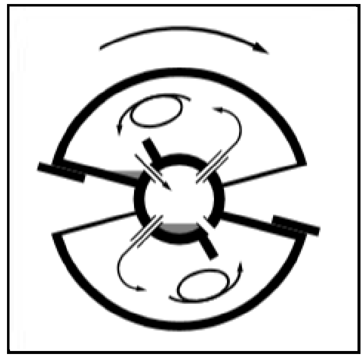

Figure 9: Image of a Komline-Sanderson paddle dryer unit and the hollow paddles. (Komline-Sanderson, 2008)

- **Classifier** - Screens the size of the dried biosolids. Any dried biosolids material that is not to specification is then screened and sent back into the dryer unit mixed with the wet cake from the feed pump. Material that passes through the classifier screen is sent to the cooling conveyor.

- **Product Cooling Conveyor** - This is used to take the product from the dryer unit to be cooled and transported to storage.

- **Dry Biosolids Storage Silo -** After the dry biosolids are cooled, it is stored in a storage silo. A closed container is needed due particulate matter and to protect the dried biosolids. Oxygen content in the silos is controlled to prevent any chance of a fire inside of the silo since the dried biosolids can be easily combustible. Also, a filtered vent is located on the silo to protect the silo exhaust vent from dust.

  Design for the storage silo would be an approximate 7500 c.f. silo with a diameter of 20 ft. and height of 25 ft. An additional height for vehicles to be loaded below the silo can be added to this height estimate. For 6 months of storage, multiple storage silos would be needed which is not included in the overall cost calculations. JMS Equipment manufactures storage silos among other equipment.

- **Condenser** - Exhaust from the dryer unit including the evaporated water from the drying process is cooled and the water is condensed and separated from the gas. Gases are removed by use of an off-gas fan and the water is drained off. The drained condensate will be added back into the pretreatment of the facility, so it is treated. The off-gas is filtered through a biofilter for odor control since the off-gas has high concentrations of odorous gas such as ammonia.

- **Thermal Fluid System -** This is where heat is transferred to the thermal fluid by a fuel source, typically natural gas or oil. The thermal fluid is heated up to 400℉ and has a thermal transfer efficiency of approximately 85% in the K-S dryer unit. Fulton Thermal Corporation manufactures thermal fluid systems that are compact and efficient in design. This system includes a natural gas burner, recirculating pump, and expansion tank for the thermal fluid. Total power of the system is approximately 50 hp.

- **Other Equipment Required -** includes gaskets, piping, wiring, and control panels for the equipment such as a motor control center (MCC), VFDs, and a free-standing Allen Bradley NEMA 4x panel mounted Programmable Controls PLC with operator interface terminal located near the dryer unit (provided by K-S). Control panels will be in a small separate room adjacent to the dryer process room for safety reasons.

This process requires a separate fire protection system for the dryer unit due to the high operating temperatures and the dry particulate matter generated by the process. The dry biosolids is a combustible material and precautions must be in place to prevent fire.

The components of this thermal drying system are compact and can easily fit within a 2,000 sq. ft. building which can be incorporated on the RWRRF site as shown in the design plan in Appendix B. The old digester, as shown on the plan, will have to be demolished to make room for the storage silo. This additional room makes it easy to expand for more storage silos as needed for long term (off-season) storage and for easy access to the storage silo(s). The fact that the equipment for this process can be incorporated onto the site, in addition to the produced product being Class A EQ, makes thermal drying a feasible design alternative for the RWRRF.

The thermal drying process advantages and disadvantages are as follows:

Advantages:

- Reduced weight and volume from increased percent solids and water reduction
- Reduced volume decreases storage needs
- Dried biosolids can be utilized easily
- Installed system is compact
- Low equipment maintenance cost

Disadvantages:

- High power and fuel consumption
- Particulate matter and odor produced from dried biosolids
- Equipment is complex and requires the addition of trained operators
- Better suited for larger facilities
- Safety issues pertaining to fire risk

3.5. Autothermal Thermophilic Aerobic Digestion

Autothermal Thermophilic Aerobic Digestion (ATAD) involves the use of a two-reactor digester system in order to make use of both thermophilic and mesophilic digestion to eliminate any active pathogens. This process uses indirect heating methods in order to heat the sludge, generating a liquid biosolid that meets Class A standards. This liquid biosolid then has the option to be dewatered after the ATAD process if a solid material is desired. The belt filter press would be able to produce a solid material of 16% solids.

3.5.1. Process Design and Feasibility

Our design for the ATAD process revolves around the use of the two reactors. The first reactor is the TPS ThermAer reactor which enables the thermophilic digestion process while the second reactor would be the Storage Nitrification/Denitrification Reactor, or SNDR. These two reactors work in coordination with each other as shown in the schematic in Figure 10. The way in which the sludge and off-gas moves through the system as well as the main equipment used is also displayed in Figure 10.

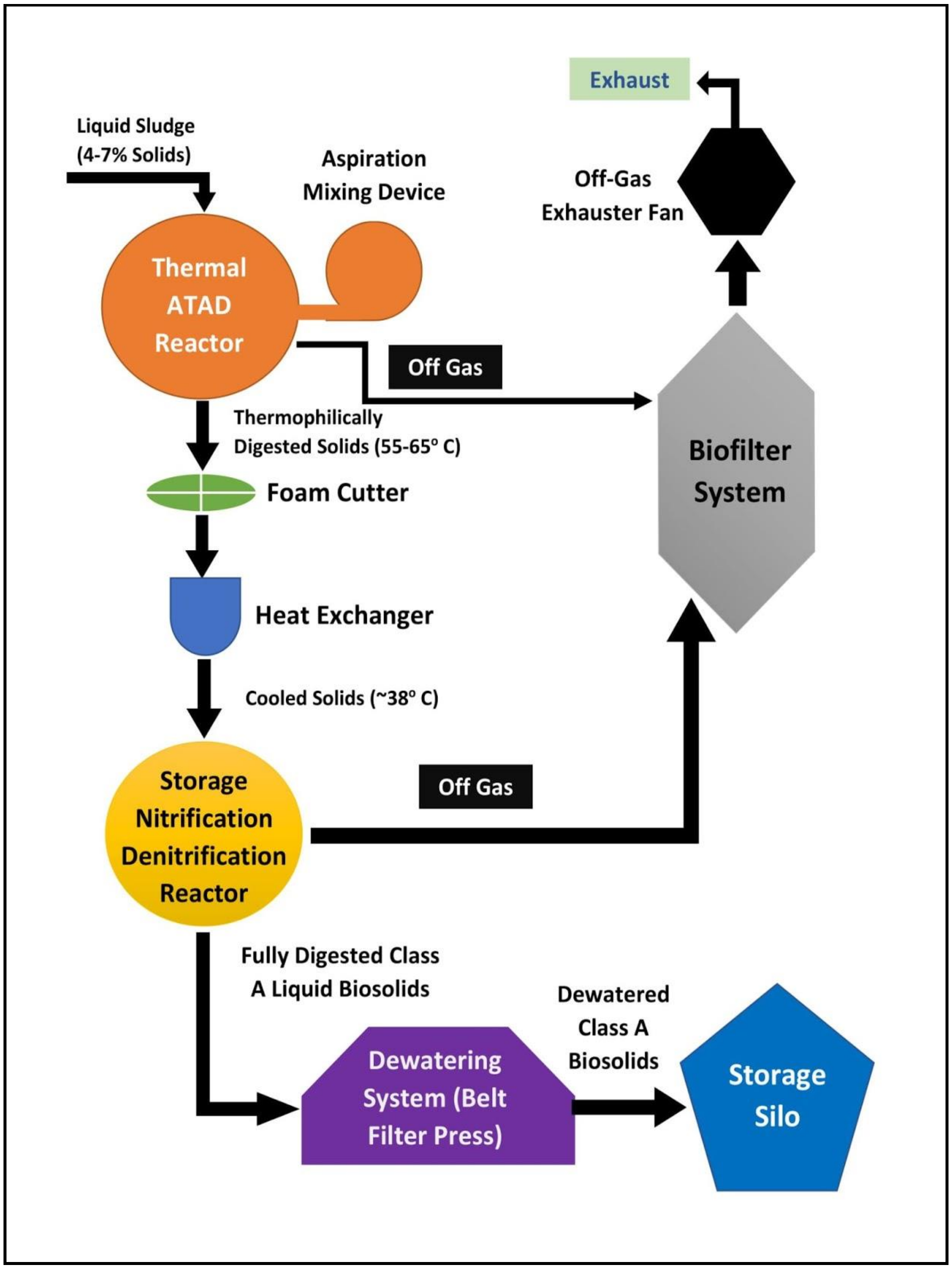

Figure 10: Schematic diagram for the ATAD process design.

The ATAD process occurs before the belt filter dewatering process in the case of the RWRRTF. Upon entering the ATAD system, it immediately enters the TPS reactor, initiating thermophilic digestion within the reactor. This digestion is done in batches, meaning the reactor will not need to be constantly running. The TPS reactor heats the sludge to between 55 and 65 degrees Celsius, providing an opportunity for thermophilic digestion to occur. The aspiration mixing device injects air into the reactor to mix the reactor and inject oxygen, aiding in the digestion process. Biomass and volatile solids levels are reduced during this step, as well as effectively deactivating present pathogens. During this process, off-gases generated by the digestion process are redirected to the biofilter to be scrubbed before being released, thereby reducing the vector attraction rates. After nearly an hour of heating and mixing, the sludge moves through a foam cutter and heat exchanger. The foam cutter removes excess foam while the heat exchanger extracts some of the heat from the sludge in preparation for mesophilic digestion. The heat exchanger cools the sludge to between 32 and 38 degrees Celsius, the temperature at which mesophilic digestion can occur. Upon entering the SNDR reactor, mesophilic digestion occurs for a total of 10 days. The volatile solids concentration and polymer required for dewatering are decreased during this digestion process. Off-gases will still be emitted by the sludge material at this stage, meaning these will also need to be redirected to the biofilter. After the 10-day digestion process, the liquid sludge achieves the desired Class A classification and can be sent through the belt filter press dewatering system. Upon dewatering, it can be sent to a storage silo temporarily for later retrieval (TPS ThermAer Process 2021).

Figure 11: ThermAer reactors for Speedway, Indiana ATAD process (TPS ThermAer Process, 2012)

Equipment used in this process is listed and described below:

- **Aspiration Mixing Device -** this device mixes and aerates influent sludge in order to promote a greater degree of oxygen transfer. Jet flow or air injection aerators use pressurized air to create implosions that aerate the sludge.

- **Foam Breaker/Foam Cutter -** this device removes excess foam created during the ATAD process when mesophilic bacteria still contained in the sludge undergoes lysis. This device is used in coordination with the mixing device to maximize the process performance.

- **ATAD Temperature Reactor** - this reactor heats the sludge to thermophilic temperatures (55-65 C°), allowing for thermophilic digestion to occur. This reactor requires a great deal of energy to power, greatly contributing to the yearly operating costs.

- **Storage Nitrification/Denitrification Reactor** - before dewatering the biosolids, this reactor reduces thermophilic biological activity and increases mesophilic digestion by holding the sludge at a lower temperature. This process decreases the volatile solids concentration, as well as the coagulant and polymer requirement for dewatering. An image of an installed reactor is shown in Figure 11.

- **Biofilter -** since this process generates odorous off-gas, any off-gas released from the system must be scrubbed to remove any harsh odors and gases contained in it. This would direct the gas to be scrubbed to a safe level. A photo alongside a schematic diagram can be found on the next page in Figure 12.

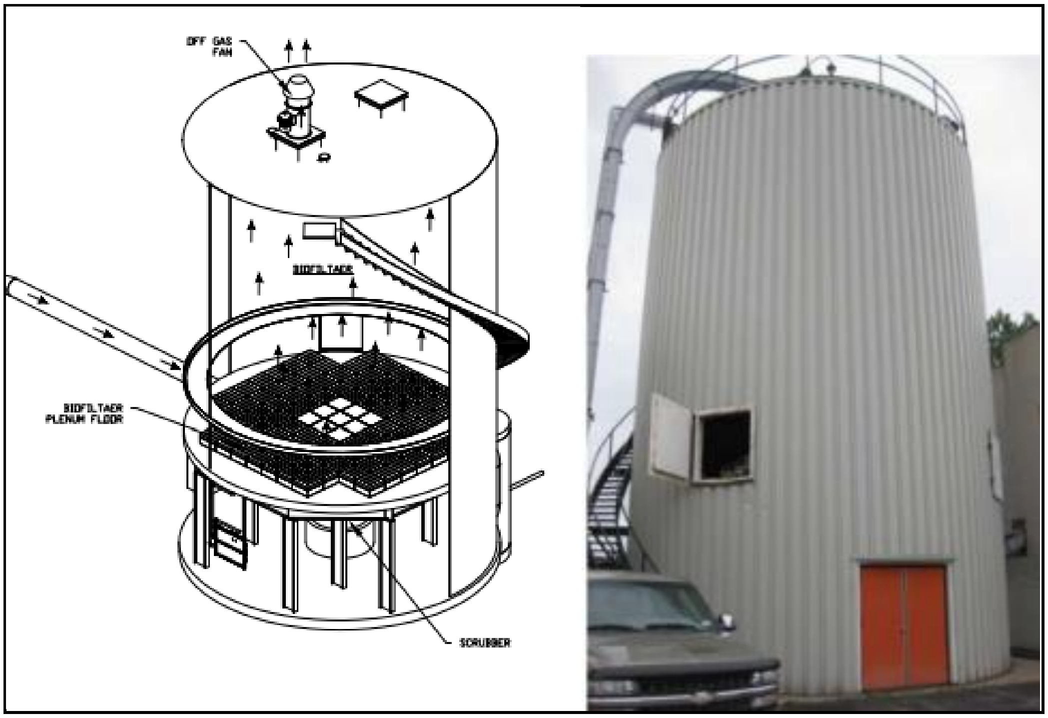

Figure 12: Image and Schematic of the BiofiltAer Biofilter System (TPS ThermAer Process, 2021)

- **Off-Gas Exhauster/Fan -** this pulls the air through the biofilter, allowing air to pass through quickly and effectively.
- **Temperature Level Monitors -** monitors are required in order to keep the sludge at the correct temperature for each step of the ATAD process. This ensures that the sludge is heated enough for the thermophilic stage, while being cool enough for the mesophilic stage.
- **Foam Level Monitors** - monitors the foam level to ensure that the foam does not interfere with the efficiency of the process.
- **Magnetic Flow Meters** - monitors the flow of the sludge through the system to ensure there are no interruptions and to alert when an interruption occurs.
- **Automatic Valves -** these, while not required in a smaller facility, could help with reducing operating costs, thereby reducing the attention this process would need during normal operation. These valves would control the flow of the sludge, thereby removing the need for a manual valve.

In terms of feasibility, this process indeed meets the requirements of what is deemed feasible for the RWRRF. First, this process achieves the Class A EQ biosolids that our recommended process aims to achieve. While this process is larger than the compact process of Thermal Drying, requiring approximately 5800 sq. ft., it does indeed fit within the spaces available despite being a bit difficult to fit correctly. The process does not release any hazardous odors that can be noticed by nearby residents due to the use of the biofilter. The processing time reaching nearly 10 days should not be an issue for the facility. Storage silos can be used to store biosolid material in the off seasons when land application is not possible or demanded. The cost of the system, while being greater than that of Thermal Drying, is made up for by its lower O&M costs, making it economically feasible as well and a cheaper option than not processing the material on a 30-year scale. This is investigated further in Section 4.2 of this report (TPS ThermAer Process, 2020).

The ATAD process advantages and disadvantages are as follows:

Advantages

- Automated design not requiring experienced operators
- Low operation and maintenance costs
- Use of unused tanks will reduce costs
- Additional dewatering not required
- Large reduction in volatile solids
- Less polymer required for dewatering
- Results in much less total material volume and mass (65% Reduction)

Disadvantages

- Off-gas odor control is required
- Higher capital costs
- Long treatment period (10 days)
- Larger construction space required (5,800 sq. ft.)

3.6. Disposal Options

New York regulations do not allow for the disposal of sludge below Class A designation meaning the only viable option currently available for disposal is to haul the sludge to be landfilled in Pennsylvania. With these proposed improvements, several new possibilities would become available, including but not limited to land application and incineration. In terms of land application, the sludge effluent with Class A biosolids designation has the potential to be used as fertilizer, due to its nutrient dense and soil enriching properties. This means that RWRRF would be able to distribute biosolids for reuse to local farms (more information on local farms can be found in section 4.3). Residential families interested in tending to their home gardens would also be able to use the biosolids, and even landscaping companies could use the biosolids as a fertilizing agent. Reuse through land application (as mentioned above) is one of the biggest benefits of achieving Class A designation, although there are others as well. Incineration is another viable disposal option with the achievement of Class A designation. Currently, EPA regulations only allow for the incineration of treated biosolids with Class A or higher designation. If the demand for Class A biosolids is below supply, incineration could be an appropriate alternative. With the use of a storage silo with the intention of applying the material to land, however, incineration would likely not be required.

4. COST ANALYSIS AND RECOMMENDED DESIGN

For the two selected feasible design alternatives, we conducted a cost-effective analysis. These cost analyses were based on a 30-year life cycle for the projects. We then compared the total 30-year project cost of each design alternative to the 30-year projected cost of the sludge disposal currently at the Riverhead facility. Our recommended design is based on the cheapest and most convenient implementation available for the RWRRF.

4.1. Thermal Drying Cost Analysis

The thermal drying process has several components that contribute to the cost of the project. The equipment provided by Komline-Sanderson includes the K-S 9W 840 paddle dryer, thermal fluid heater system, progressive cavity feed pump, wet cake storage/feed hopper, rotary valve, product cooling conveyor, off-gas system and miscellaneous items including instrumentation and controls, OEM manuals, flow diagrams, equipment layout drawings, 30-day startup service and operator training. The other required equipment includes a dry biosolids storage silo, classifier, discharge conveyor, biofilter odor control system, piping, wiring, MCC, VFDs, and concrete supports for equipment. A 2,000 sq. ft. building will be constructed to house all the new equipment except for the storage silo and the new Centrisys CS18-4 2 phase centrifuges.

The operation, maintenance, and consumables cost include the electric cost for the equipment, fuel cost for the thermal fluid heater system, two additional staff members required to operate the thermal drying process, and equipment maintenance cost. The yearly cost of equipment maintenance includes equipment replacement and part replacement throughout the 30-year period. The construction and installation costs for the project are estimated to be an additional 40% of the capital costs. The engineering startup and contingency costs are estimated to be an additional 20% of the total capital cost, construction costs, and installation costs.

Refer to Table 5 for a breakdown of the electric cost for the different components of the thermal drying process. The daily costs are based on the daily runtime for the equipment. Since electric rates vary throughout the year, we simplified this by calculating the electric cost for 6 months based on the average wintertime rate and 6 months based on the average summertime rate.

Table 5 - Power Consumption and Electric Cost for Thermal Drying Equipment

Equipment	Horsepower	Wattage	Daily Power[1]
Dryer Unit	75 hp	55.93 kW	671 kWh
Wet Cake Pump	15 hp	11.18 kW	134 kWh
Thermal Fluid System	50 hp	37.28 kW	447 kWh
Off-Gas Exhaust Fan	3 hp	2.24 kW	27 kWh
Conveyor Motors	10 hp	7.46 kW	90 kWh
Centrifuge	50 hp	37.28 kW	447 kWh
		Total Power Usage	**1,816 kWh**
Electric Cost			
	6-Month Winter Rate	$0.14/kWh	$46,000
	6-Month Summer Rate	$0.18/kWh	$60,000
		Total Electric Cost	**$106,000/year**

1 - Daily power based on a daily runtime of 12 hrs.

Table 6 shows a summary of all the costs associated with the thermal drying process. The total cost of the project includes capital costs for new equipment and a building to house the equipment, equipment installation and construction, operation and maintenance (O&M), engineering start-up and contingency, installation of a gas line, and required permits.

Table 6 - 30-Year Cost Analysis for Thermal Drying Process

Thermal Drying Project Cost Summary	
Capital Costs	
Komline-Sanderson Provided Equipment Cost	$2,500,000
Other Required Equipment Cost	$500,000
Building to House Equipment ($300/sq. ft.)	$600,000
Centrifuge	$500,000
Capital Cost Total	**$4,100,000**
Operation and Maintenance Costs including Consumables	
Total Power Consumption of Equipment	1816 kWh/day
Total Electric Cost[1]	$106,000/year
Fuel Cost[2]	$68,000/year
Additional Required Staff[3]	$200,000/year
Equipment Maintenance Cost[4]	$85,000/year
O&M Cost Total	**$459,000/year**
O&M 30-Year Cost Total[5]	**$18,625,000**
Construction & Installation	$1,640,000
Engineering Startup and Contingency	$1,148,000
Installation of Gas Line provided by PSEG ($100/ft)	$140,000
Required Permits Cost[6]	$30,000
30-Year Project Cost Total	**$29,425,000**

1 - Electric cost based on a 6-month winter rate of $0.14/kWh and 6-month summer rate of $0.18/kWh.
2 - Fuel costs based on using natural gas as the fuel type and a wet cake solids percentage of 35% from the centrifuge.
3 - Two additional staff members are required at an estimated cost of $100,000 per year per staff member which includes staff salary, insurance, benefits, etc.
4 - Equipment maintenance includes parts and replacement averaged over a 30-year period.
5 - O&M 30-year cost total based on a constant yearly inflation rate of 2%.
6 - Two permits are required at an estimated $15,000 for each permit.

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4.2. Autothermal Thermophilic Aerobic Digestion Cost Analysis

The ATAD process has many components to consider when discussing the cost analysis. In terms of equipment, this includes the thermal reactor, SNDR reactor, foam cutter, aspiration mixing device, biofilter system, off-gas exhauster and fan, temperature and foam level monitors, off-gas and sludge piping, storage silos, heat exchanger and a host of other monitors. Some other equipment involved include splash cones, jet aeration systems, vacuum priming pumps and valves, as well as a host of transducers and other instrumentation. This system, including the two reactors and biofilter system, should require approximately 5800 sq. ft. Operation and maintenance costs consist of mainly electrical costs, regular maintenance, and the use of consumables, such as biofilter scrubbers and polymer additives.

Table 7 - 30-Year Cost Analysis for ATAD Process

ATAD Project Cost Summary	
Capital Costs	
ThermAer Equipment Cost • includes the thermal reactor, SNDR reactor, polymer systems and biofilter systems, as well as all any monitors or valves required	$3,500,000
Building to House Equipment	$1,500,000
Engineering Cost	$900,000
General Conditions • Includes overhead and insurance costs	$1,000,000
Soft Cost/Contingency (20%)	$1,380,000
Capital Cost Total	**$8,280,000**
Capital Costs with 30-Year Bond at 3% Interest	**$12,660,000**
Operation and Maintenance Costs Including Consumables	
Total Power Consumption of Equipment	1839 kWh/day
Total Electric Cost[1]	$110,000/year
Additional Required Staff	N/A
Equipment Maintenance Cost[4]	$70,000/year
Annual O&M Cost	**$180,000/year**
30-Year O&M Cost Total	**$5,400,000**
30-Year O&M Cost Total with Inflation	**$7.302,000**
Required Permit Cost (2)	**$30,000**
Contingency	**$1,380,000**
30-Year Project Cost Total	**$19,992,000**

Table 7 shows a summary of all the costs associated with the ATAD process. The total cost of the project includes capital costs for new equipment and a building to house the equipment, equipment installation and construction, reactor and biofilter installation, operation and maintenance (O&M), engineering start-up and contingency, and required permits.

4.3. Recommended Design

Our feasibility study and cost-effective analysis concludes with a final selected design and disposal scheme. Our group has elected the ATAD process to be the most viable option for implementation into the treatment process at RWRRF. This was selected mainly for being the most cost effective, requiring the least amount of consumables, and having the lowest O&M costs. Referring to Figure 13, it is evident that ATAD is the least costly process over the 30-year period despite ATAD having the highest initial cost. Comparing the 30-year projected total costs of the 3 options, ATAD was deemed the least costly by nearly 30%. While this is definitely a reduced cost, there is still potential to lower this cost further. If there is more demand than supply available, selling the biosolids to offset some of the processing costs is an option the facility can take to further increase cost efficiency.

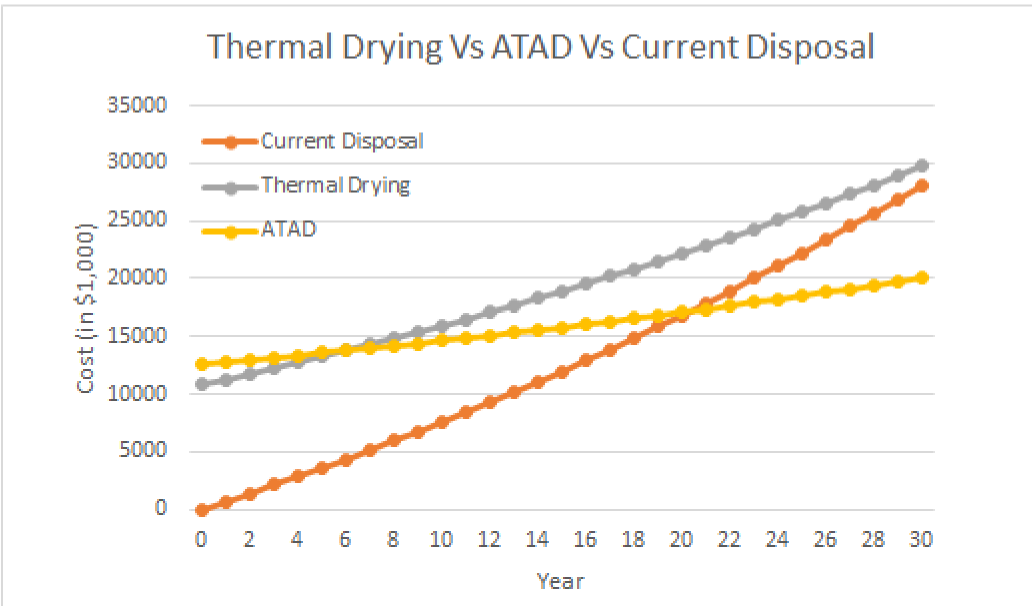

Figure 13: Cost Comparison of Selected Design Alternatives

Referring to the graph in Figure 13, we can see how the cost of the ATAD process breaks even with the cost of thermal drying at year 6 at an approximate total of $14,000,000. At year 21, the ATAD process breaks even with the current disposal cost at an approximate total of $17,500,000. However, since these costs will be distributed over time through bond payments and yearly O&M costs, the yearly cost of ATAD will always be significantly lower than the other options available as seen in Table 8. By year 30, the savings from the ATAD process versus the current sludge disposal will be almost $500,000 per year.

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Table 8 - Cost Comparison of Design Alternatives and Current Process

Cost Comparison[2]	Current Sludge Disposal[1]	Thermal Drying	ATAD
Total Projected 30-Year Cost	$27,586,000	$29,425,000	$19,992,000
Projected 1st Year Cost	$680,000	$819,000	$602,000
Projected 5th Year Cost	$736,000	$857,000	$617,000
Projected 10th Year Cost	$813,000	$909,000	$637,000
Projected 15th Year Cost	$897,000	$966,000	$660,000
Projected 20th Year Cost	$991,000	$1,029,000	$684,000
Projected 25th Year Cost	$1,094,000	$1,098,000	$712,000
Projected 30th Year Cost	$1,208,000	$1,175,000	$742,000

1 - 30-year cost for current disposal based on a constant yearly 2% inflation rate.
2 - Projected Nth year cost for each process includes bond payment plus O&M cost factoring in a 2% inflation rate.

Table 8 breaks down how the yearly cost changes with respect to time as a result of inflation. This shows that while all three options become progressively more expensive, ATAD still proves to be the least costly. This also shows that despite thermal drying appearing to be the costliest in Figure 13, is actually less costly than the current disposal option after inflation is incorporated in the cost.

While the reduced cost is a large reason to recommend the ATAD process, there are other factors that contribute to this recommendation. As mentioned previously, this process does not require any additional skilled labor due to the process's automation. This not only removes the difficult task of finding the skilled labor, but the added cost of hiring and training additional staff members throughout the 30-year period. ATAD also does not benefit from the installation of a new dewatering process since this process happens before dewatering occurs. This means that no new dewatering systems would be needed for this process to be optimized, as is not the case if a thermal drying system were installed. Additionally, this process leads to a huge reduction of material due to the volatile solid, ammonia and COD removal capabilities of the digestion process. A nearly 65% reduction in total solids is expected if this process was implemented. This will lead to needing less storage to hold the solids as well as needing to haul less material for the same volume of unprocessed sludge. These conditions make ATAD the recommended option for the RWRRF as the means of achieving the Class A biosolids classification.

4.3.1. Disposal

In terms of disposal, we believed the use of a storage silo with the intention of land application would be the most fitting solution. Our group discovered many farms and homes that could accept the biosolid material located within the area. Through our feasibility study, we reached out to several of these farms, of which many of them expressed interest in the product. Many of these farms are quite large, meaning that a shortage in demand is not to be expected. Figure 14 shows a map detailing how close in proximity the RWRRF is to local farms. Shortages of demand would still occur seasonally. The only shortages of demand we expect is during the winter months where sod and crops do not need the extra material. A storage silo would aid in solving this problem. Having multiple storage silos and/or a storage bunker would allow for the long-term storage of biosolids, minimizing the need for alternative disposal such as incineration. The use of a storage silo would allow processed sludge material to be stored in the winter months and used as a soil additive in the summer months when demand is high. Due to the high reduction in material as a result of the ATAD process, we believed storage will not be difficult, nor will a great deal of space be required.

With these factors in mind, our team has decided that ATAD is the preferred option of treatment. The reduced cost, automation capabilities, and high reduction in volatile solid material make this option the most feasible and most recommended option available for the RWRRF. It is our hope that through this detailed analysis the RWRRF adopts this method of sludge treatment and achieves the goal of generating a nutrient rich biosolid material while also reducing the sludge hauling and disposal costs for the RWRRF.

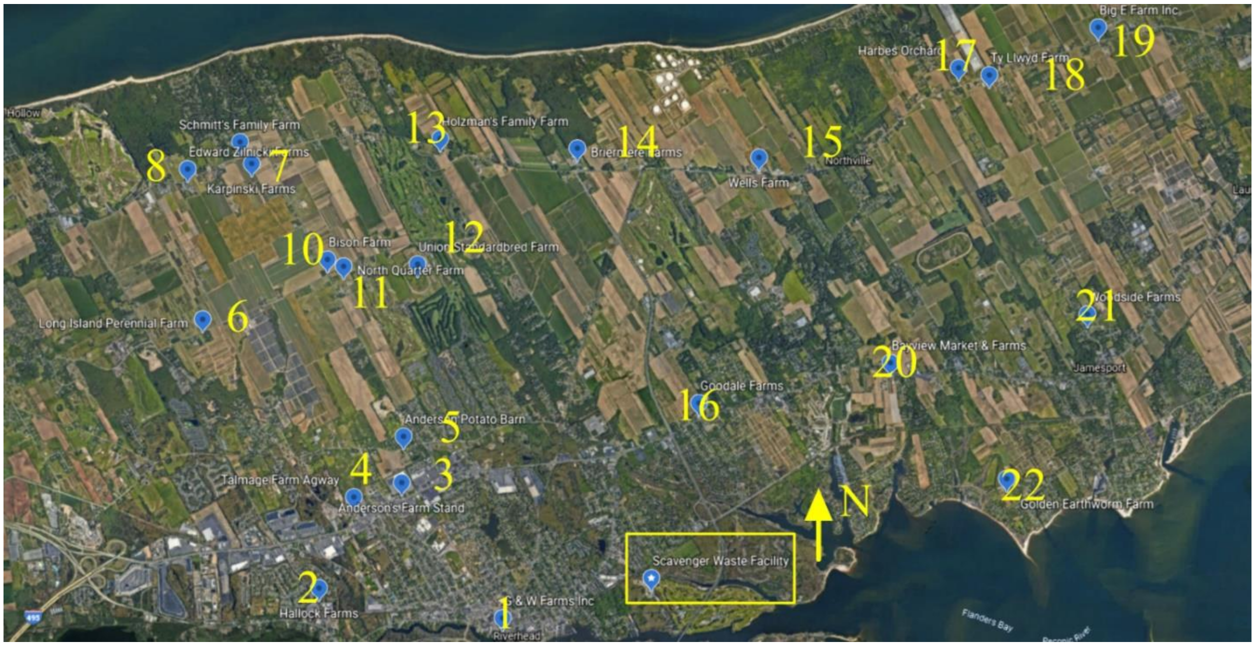

Figure 14: Map of Farms Surrounding RWRRF

Table 9 - *Proximity of RWRRF to Local Farms*

Number	Farm	Distance by Car (mi)	Number	Farm	Distance by Car (mi)
1	G & W Farms Inc	1.5	12	Union Standardbred Farm	5.8
2	Hallock Farms	3.2	13	Holzman's Family Farm	5.1
3	Anderson's Farm Stand	3.0	14	Briermere Farms	4.5
4	Talmage Farm Agway	3.4	15	Wells Farm	4.9
5	Anderson's Potato Barn	3.1	16	Goodale Farms	2.1
6	Long Island Perennial Farm	5.4	17	Harbes Orchard	5.9
7	Karpinski Farms	6.6	18	Ty Llwyd Farm	6.1
8	Edward Zilnicki Farms	7.0	19	Big E Farm Inc	7.0
9	Schmitt's Family Farm	7.0	20	Bayview Market & Farms	3.6
10	Bison Farm	4.4	21	Woodside Farms	5.6
11	North Quarter Farm	4.3	22	Golden Earthworm Farm	4.2

Source: Google Maps

Table 9 details the distance between the farms and the RWRRF in reference to Figure 14. Using this reference, one can understand how close in proximity these farms are to the RWRRF. This shows that transportation will not be a problem so long as these farms have a continued interest in the Class A biosolids.

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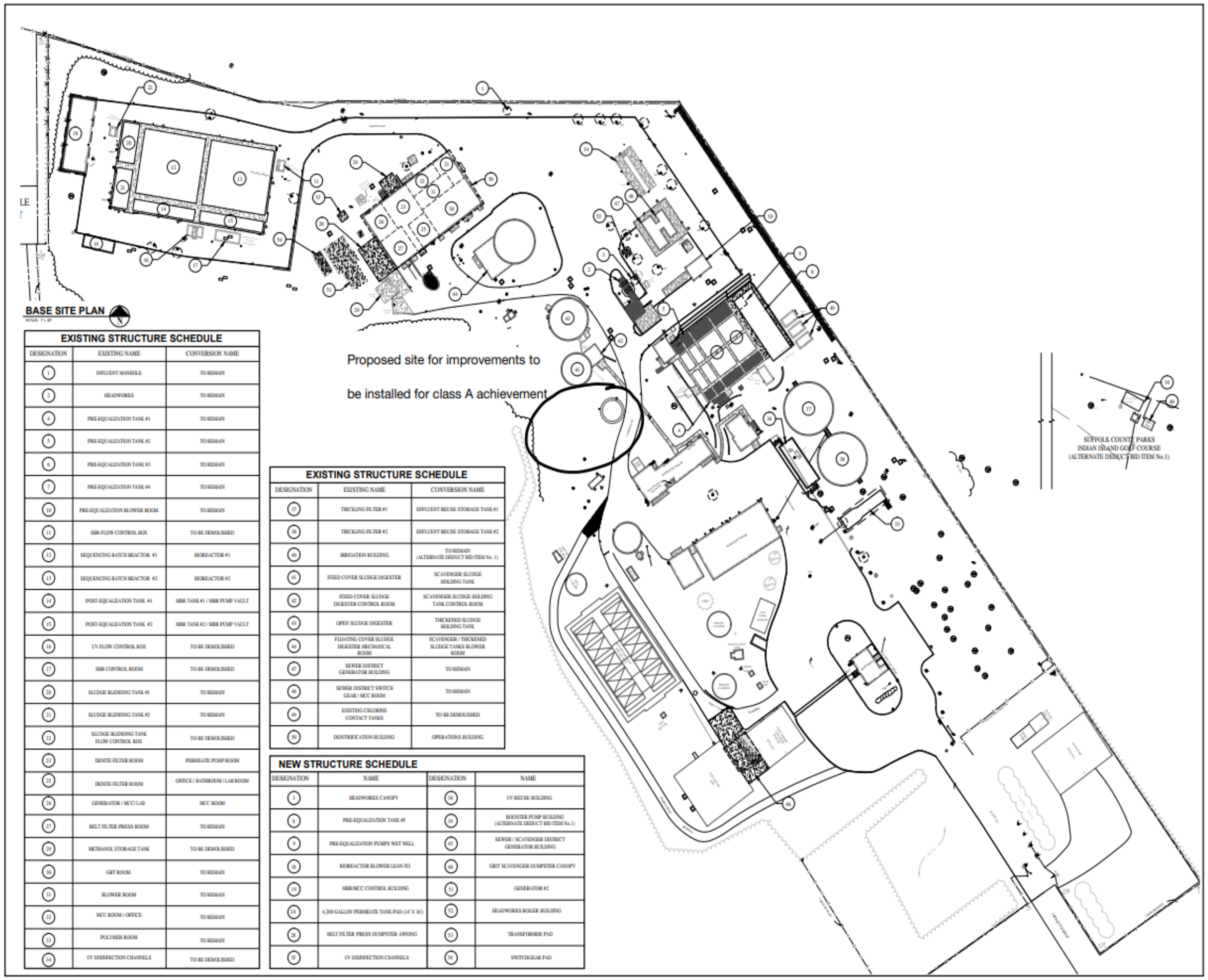
Appendix A - Riverhead WRRF Site Plans
provided by H2M Engineering.

Base Site Plan



EXISTING STRUCTURE SCHEDULE

DESIGNATION	EXISTING NAME	CONVERSION NAME
1	INFLUENT MANHOLE	TO REMAIN
2	HEADWORKS	TO REMAIN
4	PRE-EQUALIZATION TANK #1	TO REMAIN
5	PRE-EQUALIZATION TANK #2	TO REMAIN
6	PRE-EQUALIZATION TANK #3	TO REMAIN
7	PRE-EQUALIZATION TANK #4	TO REMAIN
10	PRE-EQUALIZATION BLOWER ROOM	TO REMAIN
11	SBR FLOW CONTROL BOX	TO BE DEMOLISHED
12	SEQUENCING BATCH REACTOR #1	BIOREACTOR #1
13	SEQUENCING BATCH REACTOR #2	BIOREACTOR #2
14	POST-EQUALIZATION TANK #1	MBR TANK #1 / MBR PUMP VAULT
15	POST-EQUALIZATION TANK #2	MBR TANK #2 / MBR PUMP VAULT
16	UV FLOW CONTROL BOX	TO BE DEMOLISHED
17	SBR CONTROL ROOM	TO BE DEMOLISHED
20	SLUDGE BLENDING TANK #1	TO REMAIN
21	SLUDGE BLENDING TANK #2	TO REMAIN
22	SLUDGE BLENDING TANK FLOW CONTROL BOX	TO BE DEMOLISHED
23	DENITE FILTER ROOM	PERMEATE PUMP ROOM
25	DENITE FILTER ROOM	OFFICE / BATHROOM / LAB ROOM
26	GENERATOR / MCC/ LAB	MCC ROOM
27	BELT FILTER PRESS ROOM	TO REMAIN
29	METHANOL STORAGE TANK	TO BE DEMOLISHED
30	GBT ROOM	TO REMAIN
31	BLOWER ROOM	TO REMAIN
32	MCC ROOM / OFFICE	TO REMAIN
33	POLYMER ROOM	TO REMAIN
34	UV DISINFECTION CHANNELS	TO BE DEMOLISHED

EXISTING STRUCTURE SCHEDULE

DESIGNATION	EXISTING NAME	CONVERSION NAME
37	TRICKLING FILTER #1	EFFLUENT REUSE STORAGE TANK #1
38	TRICKLING FILTER #2	EFFLUENT REUSE STORAGE TANK #2
40	IRRIGATION BUILDING	TO REMAIN (ALTERNATE DEDUCT BID ITEM No. 1)
41	FIXED COVER SLUDGE DIGESTER	SCAVENGER SLUDGE HOLDING TANK
42	FIXED COVER SLUDGE DIGESTER CONTROL ROOM	SCAVENGER SLUDGE HOLDING TANK CONTROL ROOM
43	OPEN SLUDGE DIGESTER	THICKENED SLUDGE HOLDING TANK
44	FLOATING COVER SLUDGE DIGESTER MECHANICAL ROOM	SCAVENGER / THICKENED SLUDGE TANKS BLOWER ROOM
47	SEWER DISTRICT GENERATOR BUILDING	TO REMAIN
48	SEWER DISTRICT SWITCH GEAR / MCC ROOM	TO REMAIN
49	EXISTING CHLORINE CONTACT TANKS	TO BE DEMOLISHED
50	DENITRIFICATION BUILDING	OPERATIONS BUILDING

NEW STRUCTURE SCHEDULE

DESIGNATION	NAME	DESIGNATION	NAME
3	HEADWORKS CANOPY	36	UV REUSE BUILDING
8	PRE-EQUALIZATION TANK #5	39	BOOSTER PUMP BUILDING (ALTERNATE DEDUCT BID ITEM No. 1)
9	PRE-EQUALIZATION PUMPS WET WELL	45	SEWER / SCAVENGER DISTRICT GENERATOR BUILDING
18	BIOREACTOR BLOWER LEAN-TO	46	GRIT SCAVENGER DUMPSTER CANOPY
19	MBR/MCC CONTROL BUILDING	51	GENERATOR #2
24	4,200 GALLON PERMEATE TANK PAD (14' X 16')	52	HEADWORKS BOILER BUILDING
28	BELT FILTER PRESS DUMPSTER AWNING	53	TRANSFORMER PAD
35	UV DISINFECTION CHANNELS	54	SWITCHGEAR PAD

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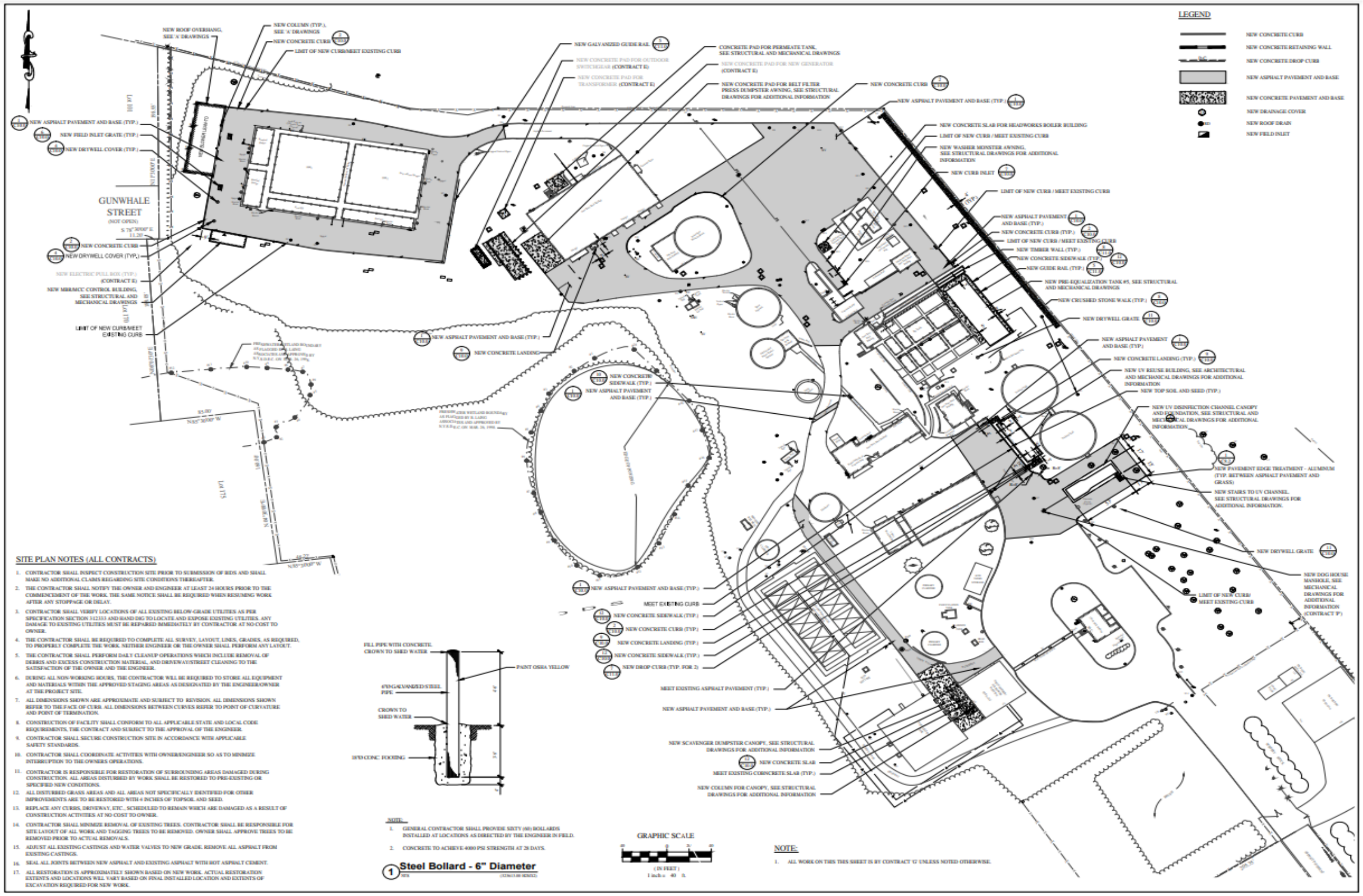
Dimensional Site Plan



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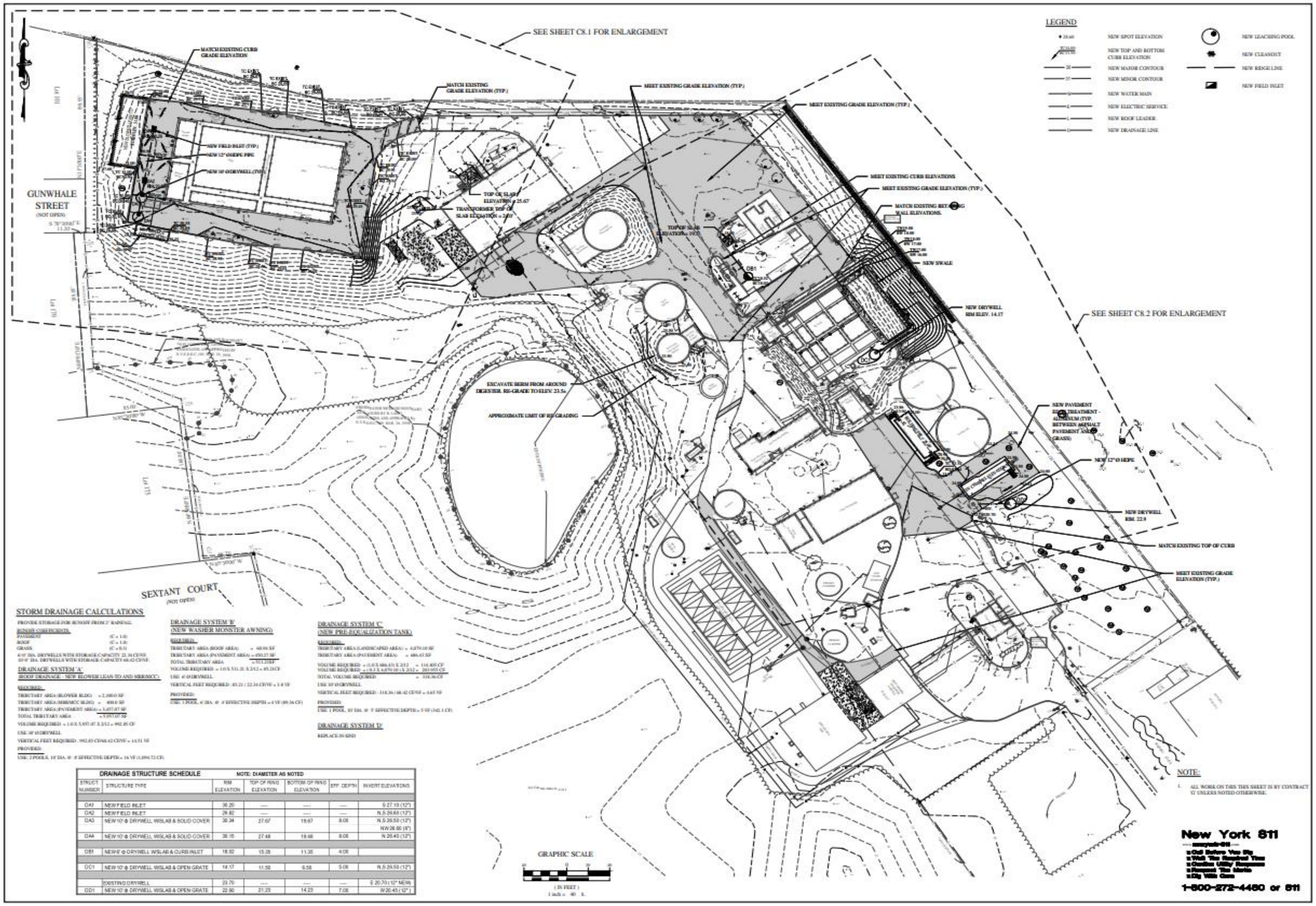
Grading and Drainage Site Plan



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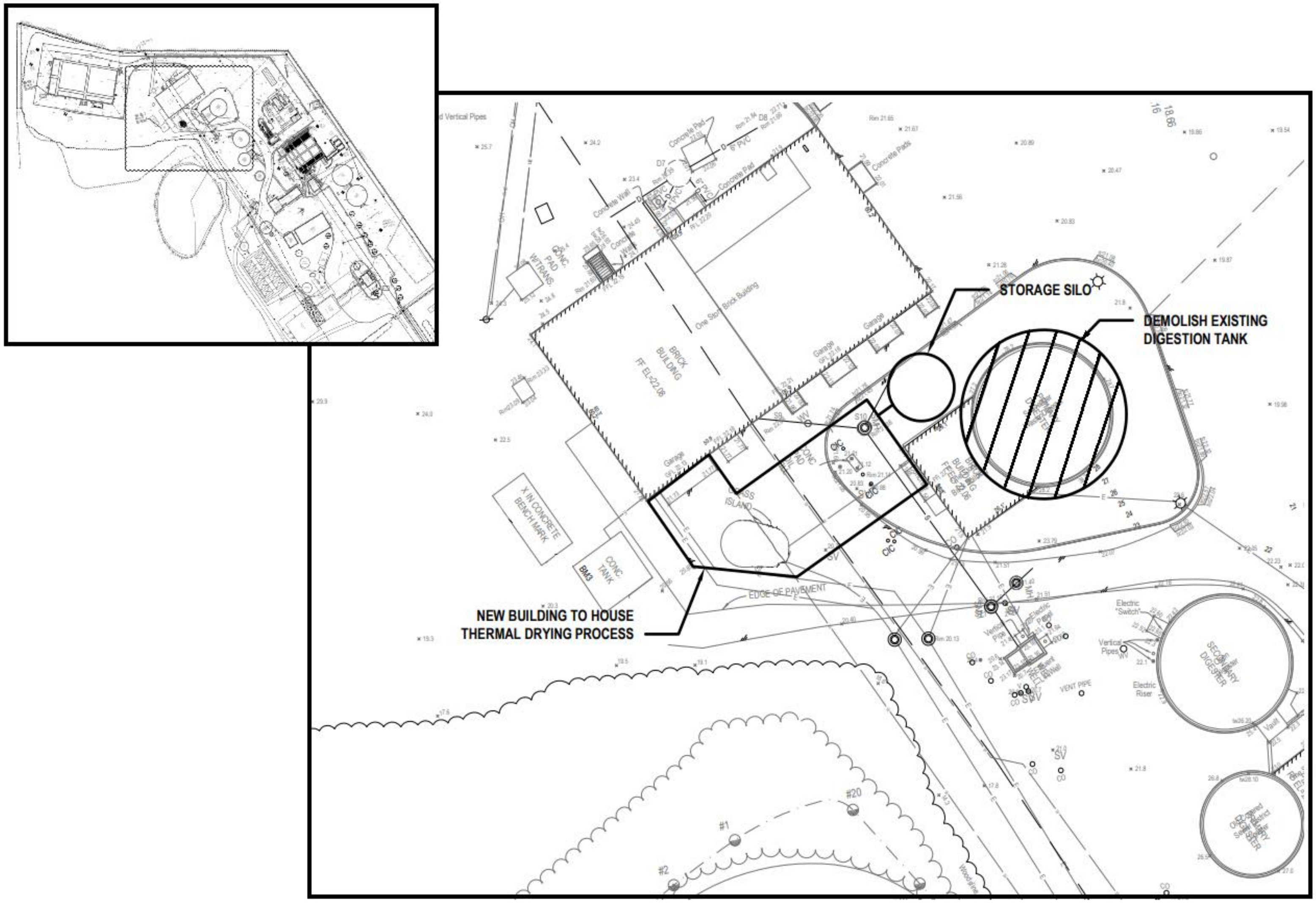
Appendix B - Design Alternative Site Plans
base site plan provided by H2M Engineering.

Thermal Drying



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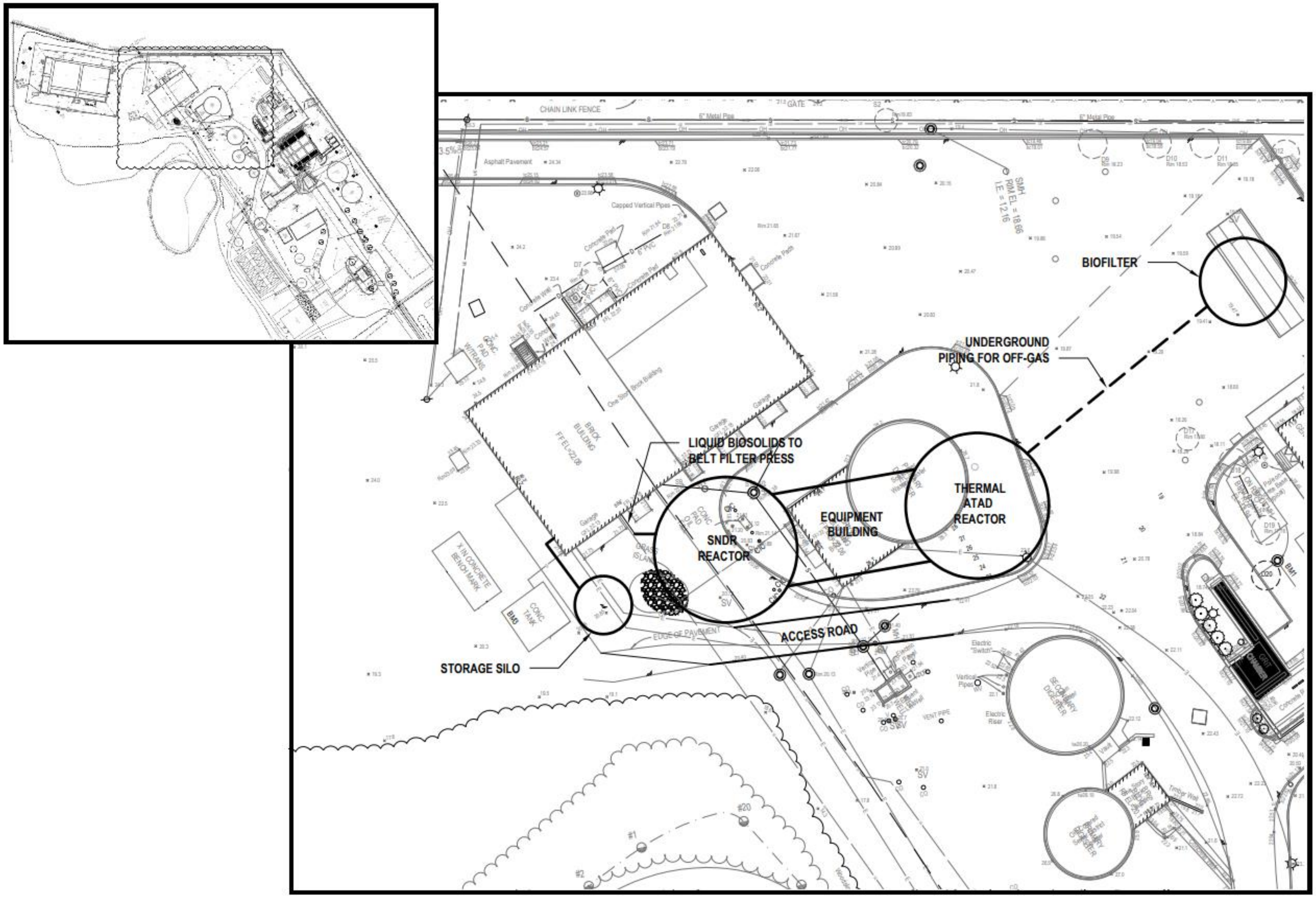
Autothermal Thermophilic Aerobic Digestion



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Appendix C – Calculations

Sludge Volume Calculations:

- Specific Gravity of Wet Sludge assuming $GS_s = 1.4$

$$GS_{sl} = \frac{1}{\left(\frac{\%\,solids}{GS_s} + \frac{\%\,water}{GS_W}\right)}$$ Source: Sludge Volume – Weight Relationships

  - At 15% solids

$$GS_{sl} = \frac{1}{\left(\frac{\%\,solids}{GS_s} + \frac{\%\,water}{GS_w}\right)} = \frac{1}{\left(\frac{0.15}{1.4} + \frac{0.85}{1}\right)} = 1.045$$

  - At 90% solids

$$GS_{sl} = \frac{1}{\left(\frac{\%\,solids}{GS_s} + \frac{\%\,water}{GS_w}\right)} = \frac{1}{\left(\frac{0.90}{1.4} + \frac{0.10}{1}\right)} = 1.346$$

- Volume of Sludge (based on 87.5 wet tons/week for current facility treatment flow)

$$V_{sludge} = \frac{W_{sl}}{\rho_w GS_{sl}}$$ Source: Sludge Volume – Weight Relationships

  - For 15% solids sludge

$$V_{sludge} = \frac{W_{sl}}{\rho_w GS_{sl}} = \frac{87.5\ tons/week(2200\ lbs/ton)}{(62.4\ lbs/ft^3)(1.045)} = 2952\ ft^3/week$$

  - For 90% solids sludge

$$V_{sludge} = \frac{W_{sl}}{\rho_w GS_{sl}} = \frac{87.5\ tons/week(2200\ lbs/ton)}{(62.4\ lbs/ft^3)(1.346)} = 2292\ ft^3/week$$

30 – Year Total O&M Cost based on a constant 2% yearly inflation rate

$$F = A[\frac{(1+i)^N - 1}{i}]$$ Source: (Blank & Tarquin 2018)

$$F = \$680{,}000\left[\frac{(1+0.02)^{30}-1}{0.02}\right] = \$27{,}586{,}000$$

Calculations for Design Alternatives:

- Cost for Installing a Natural Gas Line to the Site
  Assumptions: Cost for gas line = \$100/ft
  1400 ft. from Riverside Dr. to required location on site
  $1400\ ft\ x\ \$100/ft\ =\ \$140{,}000$

- Capital and Installation Cost for Centrifuge
  Capital Cost = \$500,000
  Installation Cost = $40\%\ capital\ cost\ =\ 40\%\ x\ \$500{,}000\ =\ \$200{,}000$
  Capital and Installation Cost = $\$500{,}000\ +\ \$200{,}000\ =\ \$700{,}000$

- Permit Cost
  Assume \$15,000 for each required permit
  2 required permits = $\$15{,}000\ x\ 2\ =\ \$30{,}000$

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Thermal Drying:

- Fuel Consumption and Associated Cost Calculations:

Assumptions: 1,450 BTUs of energy per pound of water removed

1 dry ton of biosolids (DTS) at 90% solids contains: $Ws = 0.90\ ton;\ Ww = 0.10\ ton$

1030 BTU/c.f. of natural gas

1 gal. oil = 135 c.f. of natural gas

\$3.00/gal. for oil, \$0.02/c.f. for natural gas

700 DTS/year sludge produced at facility

❖ 16% solids (current process by belt filter press)

For 1 wet ton of sludge (WTS) at 16% solids:

$$Ws = 0.16\ ton, Ww = 0.84\ ton$$

$0.90\ ton/0.16\ ton = 5.625\ WTS/DTS$

$(5.6250.84\ ton\ water) - 0.1\ ton\ water = 4.625\ ton\ water\ removed/DTS$

$\left(4.625\ ton\dfrac{water}{DTS} x\ 2{,}200\dfrac{lbs}{ton}\right) x\ 1{,}450\ BTUs/lb\ of\ water = 14{,}753{,}750\ BTUs/DTS$

$\dfrac{14{,}753{,}750\ BTUs/DTS}{1030\ BTU/c.f.} = 14{,}324\ c.f./DTS$

$14{,}324\ c.f./DTSx\ \$0.02/c.f. = \$286.48/DTS$

$\$286.48/DTS\ x\ 700\ DTS/year = \$200{,}536/year$

$\$200{,}536/\text{year}\ x\ 30\ years = \$6{,}016{,}080\ (30 - year\ cost\ for\ natural\ gas)$

$\dfrac{14{,}324\ c.f./DTS}{135\ c.f./gal} = 106.1\ gal/DTS\ of\ oil$

$106.1\ gal/DTS\ x\ \$3.00/gal\ of\ oil = \$318.30/DTS$

$\$318.30/DTS\ x\ 700\ DTS/year = \$222{,}810/year$

$\$222{,}810/\text{year}\ x\ 30\ years = \$6{,}684{,}300$ (30-year cost of oil)

❖ 25% solids (by centrifuge)

for 1 wet ton of sludge (WTS) at 25% solids:

$$Ws = 0.25\ ton, Ww = 0.75\ ton$$

$0.90\ ton/0.25\ ton = 3.6\ WTS/DTS$

$(3.6\ x\ 0.75\ ton\ water) - 0.1\ ton\ water = 2.6\ ton\ water\ removed/DTS$

$(2.6\ ton\ water/DTSx\ 2{,}200\ lbs./ton) x\ 1{,}450\ BTUs/lb.of\ water = 8{,}294{,}000\ BTUs/DTS$

$\dfrac{8{,}294{,}000\ BTUs/DTS}{1030\ BTU/c.f.} = 8{,}052\ cf/DTS$

$8{,}052\ c.f./DTS\ x\ \$0.02/c.f. = \$161.04/DTS$

$\$161.04/DTS\ x\ 700\ DTS/year = \$112{,}728/year$

$\$112{,}728/year\ x\ 30\ years = \$3{,}381{,}840\ (30 - year\ cost\ for\ natural\ gas)$

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$$\frac{8{,}052\ c.f./DTS}{135\ c.f./gal} = 59.64\ gal/DTS\ of\ oil$$

$59.64\ gal/DTS\ x\ \$3.00/gal\ of\ oil\ = \$178.92/DTS$

$\$178.92/DTS\ x\ 700\ DTS/year\ = \$125{,}244/year$

$125,244/year x 30 $years$ = $3,757,320 (30-year cost of oil)

❖ 35% solids (by centrifuge)

For 1 wet ton of sludge (WTS) at 25% solids:

$$Ws = 0.35\ ton, \qquad Ww = 0.65\ ton$$

$0.90\ ton/0.35\ ton = 2.57\ WTS/DTS$

$(2.570.65\ ton\ water) - 0.1\ ton\ water\ = 1.57\ ton\ water\ removed/DTS$

$$\left(1.57\ ton \frac{water}{DTS} \times 2{,}200 lbs/ton\right)\ x\ 1{,}450\ BTUs/lb\ of\ water\ = 5{,}000{,}300\ BTUs/DTS$$

$$\frac{5{,}000{,}300\ BTU/DTS}{1030\ BTU/c.f.} = 4{,}862\ c.f./DTS$$

$4{,}862\ c.f./DTS \times \$0.02/c.f. = \$97.24/DTS$

$\$97.24/DTS \times 700\ DTS/year\ = \$68{,}068/year$

$\$68{,}068/year \times 30\ years\ = \$2{,}042{,}040\ (30 - year\ cost\ for\ natural\ gas)$

$$\frac{4{,}862\ c.f./DTS}{135\ c.f./gal} = 36.0\ gal/DTS\ of\ oil$$

$36.0\ gal/DTS \times \$3.00/gal\ of\ oil\ = \$108.00/DTS$

$\$108.00/DTS \times 700\ DTS/year\ = \$75{,}600/year$

$\$75{,}600/year\ x\ 30\ years\ = \$2{,}268{,}000\ (30 - year\ cost\ for\ oil)$

❖ Capital costs and installation for Centrifuge and Gas Line based on 30-year bond.

$A = P\left[\frac{i(1+i)^N}{(1+i)^N-1}\right]$ Source: (Blank & Tarquin 2018)

$A = \$140{,}000\left[\frac{0.03(1+0.03)^{30}}{(1+0.03)^{30}-1}\right] x\ 30\ years = \$214{,}280$ for Gas Line

$A = \$700{,}000\left[\frac{0.03(1+0.03)^{30}}{(1+0.03)^{30}-1}\right] x\ 30\ years = \$1{,}071{,}400$ for Centrifuge

$A = \$840{,}000\left[\frac{0.03(1+0.03)^{30}}{(1+0.03)^{30}-1}\right] x\ 30\ years = \$1{,}285{,}700$ for Centrifuge & Gas Lines

➢ Cost Analysis Calculations:

❖ Capital Costs

- K-S provide equipment = $2,500,000
- Other required equipment = $500,000
- Centrisys centrifuge = $500,000
- 2,000 sq. ft. building = $2{,}000\ x\ \$300/sq\ ft\ = \$600{,}000$

Total capital cost = $\$2{,}500{,}000 + \$500{,}000 + \$500{,}000 + \$600{,}000 = \$4{,}100{,}000$

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- Construction and Installation

Assume 40% of Capital Cost = $40\%\ x\ \$4{,}100{,}000\ =\ \$1{,}640{,}000$

- Total Hard Costs

Capital Cost + Construction and Installation Cost = $\$4{,}100{,}000\ +\ \$1{,}640{,}000\ =\ \$5{,}740{,}000$

- Total Soft Costs

Includes Engineering Startup and Contingency
Assume 20% of Hard Costs = 20% x \$5,740,000 = \$1,148,000

- Total Upfront Project Cost

$P\ =\ \$5{,}740{,}000\ +\ \$1{,}148{,}000\ +\ \$140{,}000\ +\ \$30{,}000\ =\ \$7{,}048{,}000$

- Upfront Cost Based on a 30-year Bond at 3% interest.

$A = P\left[\frac{i(1+i)^N}{(1+i)^N-1}\right] = \$7{,}048{,}000\left[\frac{0.03(1+0.03)^{30}-1}{(1+0.03)^{30}-1}\right] = \$360{,}000/year$

30-year total =\$360,000/*year* x 30 *years* = \$10,800,000

- O&M and Consumables Cost

Total Power Usage = 1816 kWh/day

- 6-month Winter rate = \$0.14/kWh
  - $\$0.14/kWh\ x\ 1816\ kWh/day\ =\ \$254.24/day$
  - $\$254.24/day\ x\ 6\ months\ =\ \$46{,}400$
- 6-month Summer rate = \$0.18/kWh
  - $\$0.18/kWh\ x\ 1816\ kWh/day\ =\ \$326.88/day$
  - $\$326.88/day\ x\ 6\ months\ =\ \$60{,}000$
- Total Electric Costs = $\$46{,}000\ + \$60{,}000\ =\ \$106{,}000/year$

Fuel Cost = \$68,000/*year*

2 additional staff members = $2\ x\ \$100{,}000/year\ =\ \$200{,}000/year$

Maintenance and Replacement Cost = \$85,000/*year*

Total O&M Cost = $\$106{,}000\ +\ \$68{,}000\ +\ \$200{,}000\ +\ \$85{,}000\ =\ \$459{,}000/year$

- 30-Year Total O&M Cost based on a constant 2% yearly inflation rate

$F\ =\ A[\frac{(1+i)^N-1}{i}]$ Source: (Blank & Tarquin 2018)

$F\ =\ \$459{,}100\ \left[\frac{(1+0.02)^{30}-1}{0.02}\right] = \$18{,}625{,}000$

- Total Project Cost over a 30-Year Period

Total Project Cost = $\$10{,}800{,}000\ +\ \$18{,}625{,}000\ =\ \$29{,}425{,}000$

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Autothermal Thermophilic Aerobic Digestion:

- Cost Analysis Calculations:
  - Capital Costs

Note: Includes all equipment listed above as well as all the components of that equipment and the construction cost of installation.

ThermAer Installation Cost: Includes the Equipment and Equipment Installation
~ \$3 - 3.6 million = \$3.5 million

Building Construction Cost: Includes the Building Holding the Equipment
~ \$1.2 - 1.5 million = \$1.5 million

General Conditions: Includes Overhead, Insurance and Bonds for Construction
~ \$900,000 - \$1 million = \$1 million

Engineering Cost: Includes Engineering Design and Planning
~\$900,000

- Total Hard Costs

ThermAer + Building + General Conditions + Engineering Cost = Total
$\$3.5\ million\ +\ \$1.5\ million\ +\ \$1.0\ million\ +\ \$900{,}000\ =\ \$6.9\ million$

Total Hard Cost: \$6.9 million

Total Soft Costs/Contingency

Assume 20% of Hard Costs = $20\%\ x\ \$6{,}900{,}000\ =\ \$1{,}380{,}000$

Total Capital Costs: $\$6{,}900{,}000\ +\ \$1{,}380{,}000\ =\ \$8{,}280{,}000$

Based on a 30-year Bond at 3% interest:

$$A = F\left[\frac{i(1+i)^N-1}{(1+i)^N-1}\right] = \$8{,}280{,}000\left[\frac{(1+0.03)^{30}-1}{(1+0.03)^{30}-1}\right] = \$422{,}000/year$$

Total Capital Cost with 30-Year Bond: $(30\ years)\ x\ (\$422{,}000/year)\ =\ \$12{,}660{,}000$

- O&M and Consumables Cost

Electrical Costs* (Liquid Sludge/Not Including Dewatering):
*Average of \$0.16 per kWh was used in cost estimate.

Thermal Reactor:

Recirculation Pump	100hp	39kW/h
Blower	40hp	12kW/h

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SN/DR Reactor		
Recirculation Pump	50hp	18kW/h
Blower	40hp	4kW/h
Biofilter		
Off-Gas Fan	15hp	5kW/h
Polymer Systems		
Total	3hp	3kW/h
Total	<u>245hp</u>	<u>81kW/h</u>
		<u>1,839kW/day**</u>

1,839kW/day x $0.16/kWh x 365days/year = $110,000/year
***Total based on equipment daily running times*.

Operation*:

*With this process being mostly automated, new staff will likely not be required. for daily operation.

~ N/A

Maintenance and Consumables*:

*Includes oil, part replacement, biofilter media, belts and other consumables.

~ $65,000 - $70,000

Annual O&M Total: Electric Cost + Maintenance and Consumables = Total
$110,000/year + $70,000/year = $180,000/year

- O&M Cost After 30 Years: $(30\ years)\left(\frac{\$180{,}000}{year}\right) = \$5{,}400{,}000$
- 30-Year Total O&M Cost based on a constant 2% yearly inflation rate

$$A = F\left[\frac{(1+i)^N - 1}{i}\right] = \$180{,}000\left[\frac{(1+0.02)^{30} - 1}{0.02}\right] = \$7{,}302{,}000/year$$

- Total Project Cost over a 30-Year Period

Total Project Cost = $\$12{,}660{,}000\ +\ \$7{,}302{,}000\ +\ \$30{,}000\ =\ \$19{,}992{,}000$

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Appendix D – Manufacturer's Literature

Komline-Sanderson
12 Holland Av Peapack, NJ 07977-0257
908-234-1000 Fax: 908-234-9487
www.komline.com

[redacted]

To: [redacted]

Ref: [redacted]

Thank you for your interest in the Komline-Sanderson Paddle Dryer. Based on the information provided, Komline-Sanderson would propose the following drying system:

Process Conditions

Feed material:	Secondary Municipal Sludge Cake
Feed solids:	16 percent
Feed temperature:	Ambient
System Design Rate:	3,530 Wet Tons/year
	3,000 Wet lb/h assuming 45 h./week operation
Evaporation rate:	2,500 lb/h
Product:	92 % dry solids
Heating medium:	Thermal fluid
	500 gpm at 380 °F

Service Conditions

Plant power:	3 Ph, 60Hz, 440 Volts
Control voltage:	24 VDC, 110 VAC

Based on the provided information and K-S experience drying other anaerobically digested municipal sludges and food wastes, we have selected a K-S Paddle Dryer Model 9W-840 to handle the requirements as listed above.

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[redacted]

K-S TPG-7894
[redacted]

Scope of Supply

The following components are to be provided by Komline-Sanderson:

1. One (1) wet cake storage hopper with a 20 yd^3 volumetric capacity: The wet cake storage hopper will temporarily store the wet cake from the dewatering device. Materials of construction for the hopper will be stainless steel feed bin with a carbon steel hopper.
2. One (1) progressive cavity feed pump: Located directly below the wet cake hopper, the pump is provided to pump the sludge cake to the dyer. A second pump can be provided if desired. The pump is controlled by a variable frequency drive provided by others. The feed rate to the dryer is adjusted by changing the speed of the pump. Pump motor power is 15 hp.
3. One (1) K-S Paddle Dryer Model 9W-840: All process wetted parts are manufactured from stainless steel to protect the dryer against corrosion. To protect against abrasion, hard surfacing is applied to 2/3 of the paddles as well as the entire trough. The dryer has a 75 hp TEFC motor used to rotate the dual intermeshing shafts that mix, heat, and dry the product. As the material enters the final drying stages, the product temperature will start to rise. Komline-Sanderson's control system monitors the product temperature and can adjust a discharge weir at the back of the dryers to maintain a consistent product.
4. One (1) rotary valve between the K-S Paddle dryer and the product conveyor.
5. One (1) product cooling conveyor to cool and transport the dried product to further product handling by others.
6. One (1) Off-gas system: The systems will condense the evaporated water in a spray tower condenser. The condenser is fabricated from stainless steel and would cool and condense the dryer off-gas. The condenser effluent would need to be treated for odor. An exhaust fan is included to vent the non-condensable constituents to an odor control system provided by others, or alternatively, a liquid ring compressor can be provided to send the off-gas to an aeration basin.
7. One (1) 5 MMBTU/h thermal fluid heating system: The system includes a heater with natural gas or biogas fuel train and pilot train, burner controls with 7:1 turn down to modulate the heater firing rate to maintain a consistent thermal fluid temperature, combustion fan, thermal fluid recirculating pump, thermal fluid expansion tank, and control panel. All components are prewired and skid mounted with the exception of the expansion tank which must be bolted to the top of the skid in the field. A thermal fluid cooler heat exchanger is also provided for shut down operation.
8. Instrumentation and Controls: The system is controlled by an Allen Bradley panel mounted PLC with Operator Interface Terminal. The control panel will be a free standing NEMA 4X panel located near the dryer. MCC and VFD's are supplied by others.

9. System engineering: K-S will provide Process Flow Diagrams, Piping and Instrumentation Diagrams, General Equipment Layout Drawings, OEM Manuals for all equipment and instruments provided, as well as 30 days of start-up service and operator training per dryer system. Additional days can be offered as optional.

Exclusions:

The following equipment, material, and services are excluded from the Komline-Sanderson scope of supply.

- Wet cake transfer to our hoppers
- Dry product handling after our cooling conveyor
- Additional odor control equipment after our exhaust fan
- Plant water supply and return for cooling conveyor and condenser/scrubber
- Compressed Air for dryer shaft seals
- Building
- Any and all permits
- Insurance certificates
- Taxes of any kind
- Shipping
- Receipt and off loading of all equipment supplied
- Installation of equipment and re-assembly when required
- Supply and installation of interconnecting piping, fittings and all valves
- Gaskets and fasteners for the points of interface with ducts and piping supplied by others
- Piping isometric and installation drawings. Piping and Instrumentation line drawings are supplied.
- Supply and installation of external insulation. K-S will insulate the dryer. Client will install the K-S supplied dryer cover blanket.
- Design and supply of concrete supports
- Design, fabrication, and installation of equipment support steel not referenced
- Design, supply, and installation of interconnecting wire, cable, conduit tubing, etc.
- Operational consumables such as oil, grease, chemicals/reagents
- Field painting, including touch up paint
- Surety bond, if required
- Certified equipment tests
- Motor control center(MCC), motor starters and variable frequency drives (VFDs)
- Local disconnects and HOA stations if required
- Spare parts
- Any other equipment, material, or service not specifically identified within this quotation

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[redacted] K-S TPG-7894
[redacted]

[redacted]

If the above drying system is of interest, we should have some discussions with the plant manager and engineer to discuss various design details to solidify a system design that integrates well with the current operations of the plant.

Total for scope of supply listed is approximately $2,500,000.

Kind Regards,

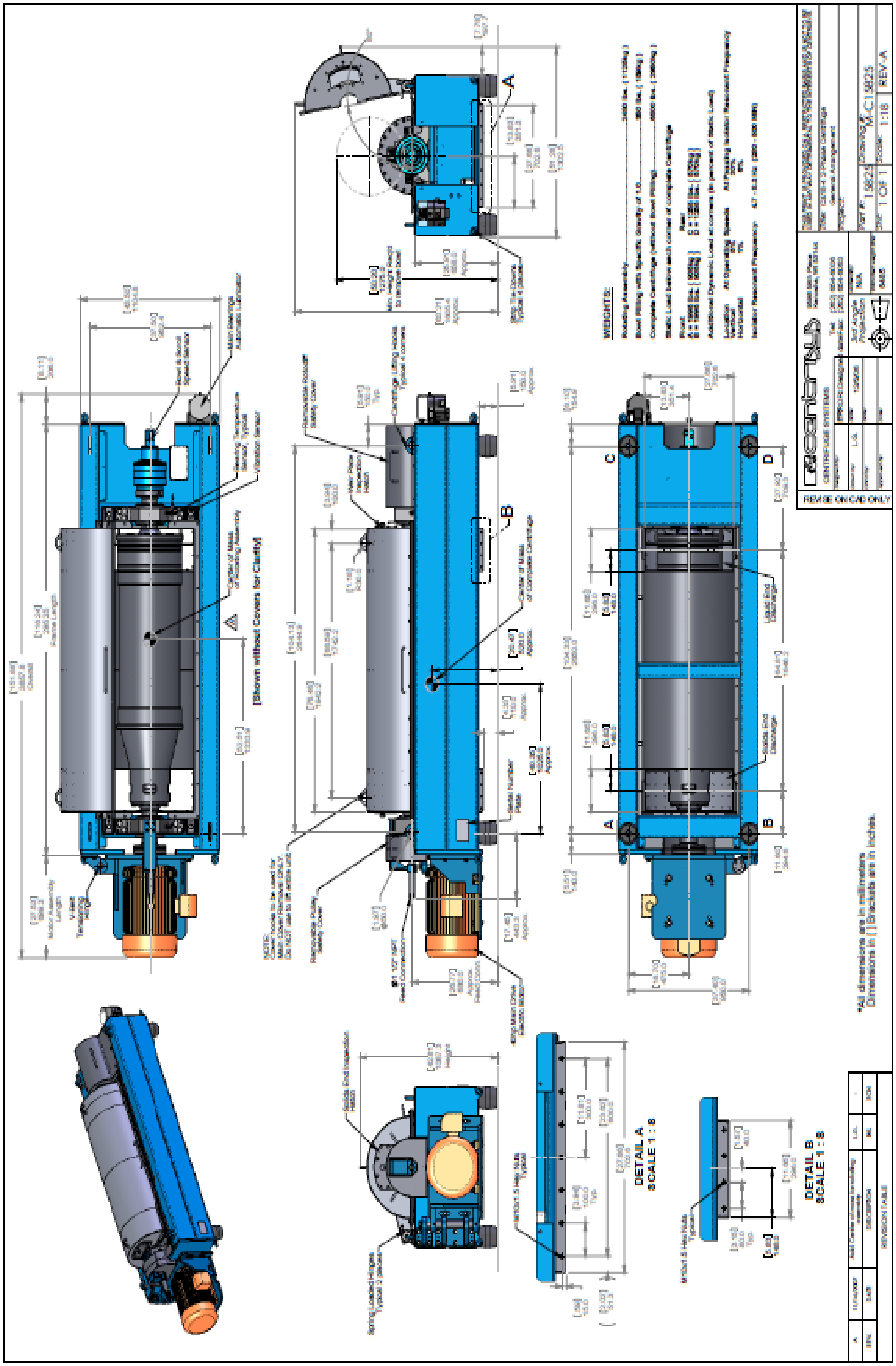
Brian T. Komline

Product Manager

Komline-Sanderson Corporation
12 Holland Avenue, Peapack, NJ 07977
Office: +1-908-234-1000 x317
Mobile: +1-908-229-1981
E-Mail: btkomline@komline.com
www.komline.com

GROUP NUMBER 01
FINAL REPORT
05/07/2021

CIV 440 Engineering



Appendix D

CIV 440 Engineering

Thermal Process Systems

[redacted]

[redacted]

Thermal Process Systems is pleased to offer the following proposal for the solids handling for your budgetary ATAD estimate based on the information provided by you. Note that TPS supplies only quality equipment and state-of-the-art technology in its patented ThermAer process. Please find attached the following:

- This Letter of Transmittal;
- ThermAer™ Budget Proposal;
- ThermAer™ Applications Reports;
- Thermal Process Systems' ThermAer™ Brochure;
- Thermal Process Systems' BiofiltAer™ Biofiltration Brochure; and
- Thermal Process Systems' Terms and Conditions.

We look forward to working with you on this project. Please feel free to contact me with questions and/or comments at (315) 440-9750 or by email ehaslam@thermalprocess.com.

Sincerely,

Eric Haslam

Eric Haslam
Cc: Cinar Akman, G.A. Fleet Associates, Inc.

CIV 440 Engineering

Thermal Process Systems

Thermal Process Systems is pleased to offer the following budgetary proposal and preliminary scope of supply for the solids handling and processing for your ATAD project. The following proposal explains the fundamental theory behind Thermal Process Systems' Class 'A' thermophilic aerobic digestor and the components involved in the successful operation of an autothermal thermophilic aerobic digestion (ATAD) process. Most of the attention is given to the TPS **ThermAer™** system, as our specific type of ATAD is substantially different from the other ATAD processes available in the market today. Additionally, information is provided on the ancillary components required for these types of high temperature processes. A scope of services and supply, and a budgetary estimate are provided for your review.

The Thermal Process Systems' **ThermAer™** will provide your project with a process capable of meeting the solids' aeration demands as well as provide a cost effective process for substantial volume reduction and a Class 'A' virtually pathogen and odor free, stabilized final material. TPS is an innovative provider of 2nd Generation ATAD process operations providing comprehensive thermophilic solids treatment for over sixteen years and sincerely appreciates the opportunity to work with you on this treatment project.

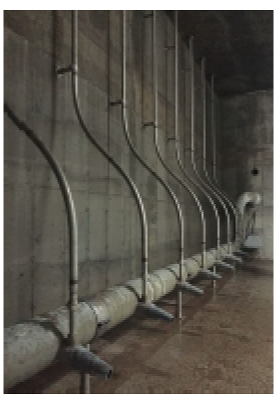
The ThermAer Process can provide state-of-the-art digestion to the current plant operations (see figure 1). This preliminary design incorporates the use of new concrete tanks for the ThermAer digestor system and SNDR. The patented **ThermAer™** system proposed here includes a process system capable of treating the waste activated sludge material transferred at an average of ~6% total solids at the average design load to the ThermAer Reactor.

Figure 1. New Construction of ThermAer Tank System, Franklin, IN

The SNDR reactor has the ability to nitrify and also denitrify the ThermAer solids prior to dewatering and/or land application operations. The addition of this aerated SNDR system is an important point to consider as it provides for additional storage prior to final dewatering activities. Tanks require fixed covers, to retain heat and control emissions and is assumed to be within the general contractor's scope of supply.

The following **ThermAer™** pricing includes the patented **ThermAer™** system, including jet aeration headers, jet motive pumps, blowers, foam control systems, process controls and control logic, and in-basin piping to operate the **ThermAer™** process reactor and the SNDR. This type of solids treatment process is very stable and requires only one actual process tank to complete the entire reaction (Reference Technical Papers, www.ThermalProcess.com). Accordingly, we have developed an operation and cost scenario that has been tailored to the facility's specific needs and provides for maximum flexibility.

Our design calculations are based upon the biological solids specific oxygen requirements. The 'gassing rate' (air/liquid ratio) in the jet system is the only parameter that may change drastically, and so this makes this particular digestion system even more operationally attractive given the complexities and uncertainties of many WTFs. The **ThermAer™** system requires a minimum of ~3.0% total solids but can easily process up to ~7% TS (2.5% to 7% VS). Our initial design calculations are based on the average month design loading of organic sludge solids at about 5% TS. Aeration is sized at the corresponding loading for operation on a 7- day per week loading schedule. TPS has several WWTPs operating under this type of design scenario. The **ThermAer™** aeration system is designed to meet 100% of the daily oxygen uptake requirement in the reactor.



The TPS process design incorporates jet aeration systems (figure 2). The ability to adjust both the liquid flow rate and air flow rate independently allows for the flexibility in this design to operate the system at a given temperature based on the actual solids loadings. Furthermore, this aeration system is designed to operate continuously throughout the daily dynamic process cycle. This digestion process has three basic steps in the process operation: waste, feed, and react. As mentioned previously, the cycle is set up to operate as a reverse draw, batch feed, and isolate and is never shut down, especially during the most critical time, the feeding (highest demand) period. The cycle begins by wasting the estimated daily feed volume from the ThermAer tank to the SNDR just prior to scheduled feeding, (approximately 1/12 (equal to the HRT in the system) the total volume for this (liquid burn reactor).

Figure 2. Interior of new ThermAer reactor with Jet Aeration Header, Blacksburg, VA

Wasting should occur in a fairly rapid fashion directly before the feed cycle begins to maximize the time under aeration during the subsequent reaction/isolation cycle. Feed material can be pumped directly into the reactor during the fill cycle as the waste solids are pumped from a holding tank (by others).

The pump and the blowers are equipped with variable frequency drives to provide the ability to vary the oxygen delivery capacity; to increase flows during high oxygen demand periods and also to decrease flows during low oxygen demand periods and thus conserve energy. This is an extremely important design consideration for this project. The daily cycles have large swings in the oxygen uptake requirement. Process control is based upon an oxidation-reduction potential (ORP) probe signal. This feature, along with the specially designed oxygen delivery system, offers the solids processing operation the ability to meet the high uptake demands that occur during the feed cycles and initial reaction phases and lower oxygen demands during the later reaction, pathogen destruction portion, of the cycle. In addition, this function can aid in the control of the reactors operating temperature throughout the process. This is accomplished by either conserving or wasting heat with the blower airflow rate. Evaporative and convective heat losses are the main method of heat control after attaining the appropriate temperature level from the volatile solids oxidation process. The ability to vary the liquid recycle rate and airflow delivery independently, in addition to the retention time provides the most effective method of reactor temperature control while maintaining optimum process metabolic conversion. The **ThermAer™** process is protected under US Patent Number 5,948,261. This installation is considered a single use license agreement.

TPS has designed this system as a semi-automated process, however, it can easily be operated as a completely automated process or manually. As such, a PLC processor package is included along with a PanelView™ operator interface touch screen. Outputs are provided to tie this local control system into an existing or proposed processor elsewhere in the plant. The instrumentation necessary to properly monitor the process is included and directed into the PLC for the convenience of the operations personnel. The primary function of the processor is to control the reactor mixing intensity and aeration delivery rate. This is accomplished by receiving the primary signal from an ORP probe mounted on the pump suction piping and 'fine-tuning' with secondary signals. The ORP signal (see figure 3) is read by the PLC and then appropriate settings are sent to the pump and blower VFDs and ultimately the pumps and blowers. During the feed cycle, the oxygen demand will increase. As oxygen demand increases, the oxidation-reduction potential decreases.

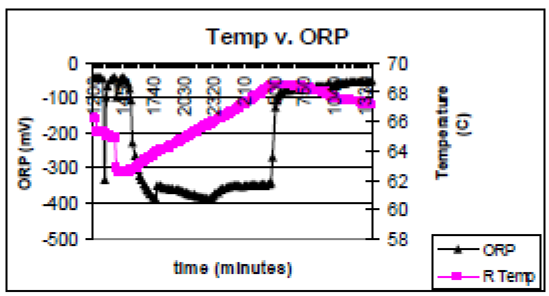


Figure 3. Actual temperature and ORP Response Curve Data (24 hr period)

This is read as a negative millivolt (electrical potential) value when the oxygen demand is not being met by the oxygen delivery system. The aeration system is designed with a maximum and a minimum setting. The maximum setting is based upon the highest requirement of oxygen uptake anticipated during the feed cycle. The purpose of this setting is to minimize the depth of the ORP dip as well as minimize the length of time the ORP signal remains at a low level, i.e., the systems' aerobic nature is maximized. The minimum setting is based upon the turn down capabilities of the process equipment and minimum design mixing intensity. Optimization of this process maximizes aerobic destruction efficiency and minimizes odor potential while minimizing utility electrical costs.

Oxygen demand is based upon the amount of soluble COD available to the microbial community as a food substrate. Therefore, process stability is at its highest when the feed cycle is extended over a relatively long period. The process is designed to be self-regulating and therefore is adaptable to several feed cycle protocols providing the instantaneous uptake demand does not exceed the maximum capability of the aeration equipment. Secondary signals are received from temperature probes mounted near the ORP probe and from our proprietary foam control monitoring system. Liquid and air-flows are controlled independently to sustain optimum reactor performance. This portion of the control process is patented with the U.S. Patent Office number 6,203,701.

The calculated oxygen requirement is based upon 60% VS destruction rate (mass balance) for secondary solids. The actual destruction may vary. The aeration system is designed with positive displacement blowers for the air delivery system. Positive displacement blowers have been selected because of their ability to operate with variable backpressure created by changing liquid depths and reactor temperature. The displacement of airflow is a direct correlation to blower rpm. The blower selected for this application will operate at ≈90% of maximum rpm at the design airflow. This design point offers a high degree of flexibility to turn the blower rpm up or down. Therefore, the system has the inherent capability of increasing O_2 delivery during unexpected high COD feed concentrations. An unusually high uptake or demand is detected by a low ORP reading and is met by increasing pump and blower speeds above the anticipated requirement. It also has the capability to decrease pump and blower speeds for energy and temperature conservation during periods of low solids feeding, unattended weekends, or inactivity.

A hydraulic foam control system is also included as part of our package. The foam layer is the upper reactor's insulation blanket. Foam suppression nozzles connected to a side stream off the jet pump supply the energy source. The pump is designed to operate at sufficient volume and pressure to recycle reactor contents which primary function is breaking down the foam. The foam bubbles are ruptured by the mixing intensity of the nozzle and return SplashCone™ unit. The system is operated when required and controlled by the foam level radar transmitter in the top of the reactor.

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The calculated oxygen requirement is based upon 60% VS destruction rate (mass balance) for secondary solids. The actual destruction may vary. The aeration system is designed with positive displacement blowers for the air delivery system. Positive displacement blowers have been selected because of their ability to operate with variable backpressure created by changing liquid depths and reactor temperature. The displacement of airflow is a direct correlation to blower rpm. The blower selected for this application will operate at ≈90% of maximum rpm at the design airflow. This design point offers a high degree of flexibility to turn the blower rpm up or down. Therefore, the system has the inherent capability of increasing O_2 delivery during unexpected high COD feed concentrations. An unusually high uptake or demand is detected by a low ORP reading and is met by increasing pump and blower speeds above the anticipated requirement. It also has the capability to decrease pump and blower speeds for energy and temperature conservation during periods of low solids feeding, unattended weekends, or inactivity.

A hydraulic foam control system is also included as part of our package. The foam layer is the upper reactor's insulation blanket. Foam suppression nozzles connected to a side stream off the jet pump supply the energy source. The pump is designed to operate at sufficient volume and pressure to recycle reactor contents which primary function is breaking down the foam. The foam bubbles are ruptured by the mixing intensity of the nozzle and return SplashCone™ unit. The system is operated when required and controlled by the foam level radar transmitter in the top of the reactor.

The SNDR is cooled and operated with 12 day HRT and below ~95°F to facilitate the introduction of a mesophilic culture and nitrification prior to dewatering and land application activities. The remaining existing tank can serve as a wide spot in the line, allowing for smaller dewatering operations as the material is either removed slowly each day, or campaign dewatered on daily or weekly batch runs. Well-digested biosolids release a portion of the entrained water within the cell structure in the reactor. Therefore, digested material has the ability to release a higher percentage of free water during dewatering. These high temperature processes denature and consume exopolymeric substances (EPS), a form of protein. These EPSs can bind water, up to 5 grams H_2O/gram EPS. As such, TPS **ThermAer™** units typically experience an increase of approximately 25-30% in cake solids as compared to undigested or classical aerobically digested WAS, depending on downstream unit processes. The increased cake solids in conjunction with the high TS destruction rate have a significant impact on the economics of this project. The combination of reducing the mass and increasing the cake solids will decrease the overall amount of material necessary to store and process in all downstream unit operations, material handling, and ultimately removal from site, typical volumetric reductions for dewatered materials result in fewer trucks out the gate reducing transportation costs significantly.

The two-stage **BiofiltAer™** odor control system is described below (figure 4). The initial portion of the odor control system includes the SNDR headspace for cooling/ammonia scrubbing using the recycled biosolid material. This unit serves two major functions for this application. Its primary function is to cool the hot air to assure conditions within the biofiltration media are conducive to mesophilic biological activity. Its secondary function is to effectively remove a high percentage of the ammonia and other soluble compounds contained in the off-gas (an indication of cell breakdown). Ammonia is water-soluble and easily removed with a properly designed scrubber unit. The typical design off-gas, concentration to the scrubber is 1,200 ppm. However, values may range from 500 to 1,500 ppm, throughout the digestion process. Design ammonia feed to the biofilter portion of the gas treatment system is less than 100 ppmv. As such, the SNDR design is based upon 70-80% ammonia removal and 95-100°F exit temperature to assure the proper temperature and nitrification-loading rate is introduced to a second stage biofilter. A back-up scrubber would be included for periods in which the SNDR exceeds 104°F or may need to be by-passed.

Figure 4. 15,000 SCFM Biofiltration Unit, Middletown, Ohio

[redacted] [redacted]

Thermal Process Systems provides process and design engineering and design support to the design engineer. Technical instructions for the ThermAer unit, start-up, as well as, operation and maintenance are also included. Thermal Process Systems' personnel will be there every step of the way to ensure a smooth transition to the **ThermAer™** process operation, from initial training and information sessions, access to design data, assistance in permitting, equipment shakedown, startup, operation, and trouble shooting.

Provide ThermAer™ treatment for Class A solids

Proposed design daily loading of 6,000 lbs/day of sludge material loaded on a 7 day work week.

ThermAer Package

Sludge Type	
WAS	6,000 lbs/day average design 7-day/week
Number of ThermAer Reactors	2
Number of SNDR Reactors	1
%TS Average	~5.0%
%TS Range	4 - 7%
%VS	75%

ThermAer Reactor Sizing

Two new concrete tanks– 32 ft. x 20 ft. x 24 ft. deep, with a proposed SWD of ~18 ft. (By contractor)

Two (2) ThermAer Reactors each complete with:

1) One (1) 60 HP, 52-14 ThermAer jet motive pump.
2) One (1) 25 HP positive displacement blower.
3) Two (2) Foam control SplashCone™ with assemblies.
4) One (1) in-basin FRP piping for the ThermAer system including the 12" liquid and 8" air jet aeration system header with 5 nozzles, pipe supports, connection hardware and anchor bolts for this piping.
5) One (1) Radar foam level sensor.
6) One (1) ORP probe and analyzer with temperature readout.
7) One (1) Vacuum gauge sensor.
8) One (1) Liquid level sensor with local readout.

SNDR Reactor Sizing

One new concrete tank– 40 ft. x 32 ft. x 24 ft. deep, with a proposed SWD of ~18 ft. (By contractor)

One (1) SNDR Reactor complete with:

1) One (1) 40 HP, 43-12 SNDR jet motive pump.
2) One (1) 25 HP positive displacement blower.
3) Two (2) Foam control SplashCone™ with assemblies.
4) One (1) in-basin FRP piping for the SNDR system including the 12" liquid and 8" air jet aeration system header with 6 nozzles, pipe supports, connection hardware and anchor bolts for this piping.
5) One (1) Radar foam level sensor.
6) One (1) ORP/pH probe and analyzer with temperature readout.
7) One (1) Vacuum gauge sensor.
8) One (1) Liquid level sensor with local readout.

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Additional Equipment
1) One (1) 25 HP positive displacement blower. (Spare)
2) One (1) 3" Magnetic flow meter and transmitter for feed control and monitoring.
3) One (1) 4" Magnetic flow meter and transmitter for intra-process control and monitoring.
4) Two (2) 15 HP, Transfer Pumps.
5) Five (5) 4" Actuated valves.
6) Four (4) 6" Actuated valves.
7) One (1) Heat Exchanger.
8) One (1) Pre-wired control panel complete with PLC, and system programming.
9) One (1) Battery backup system.

Included Spare Parts
1) One (1) ORP/pH Probe.
2) One (1) Blower Filter.
3) Four (4) Spare Belts one (1) set per pump/blower size.

BiofiltAer Odor Control Unit
One new concrete Biofilter tank – 24 ft. x 20 ft. x 12 ft. deep (By contractor)

One (1) Biofilters each complete with:
1) One (1) 15 HP 5,000 SCFM @ 9" WC Fan.
2) One (1) Scrubber.
3) One (1) Aluminum Biofilter Cover.
4) One (1) Lot, Biofilter plenum for even air flow distribution.
5) One (1) Lot, inorganic Biofilter media.
6) One (1) Lot, organic Biofilter media.
7) Two (2) RTD temperature sensor.
8) One (1) Biofilter instrument cabinet.

Electrical Package MCC/VFDs
MCC mounting arrangement with Allen Bradley 6 pulse VFDs.

1) Two (2) ThermAer Jet Motive Pumps 60 HP VFD.
2) Two (2) ThermAer PD blowers 25 HP VFD.
3) One (1) SNDR Jet Motive Pump 40 HP VFD.
4) One (1) SNDR PD blower 25 HP VFD.
5) One (1) Spare PD blower 25 HP VFD.
6) Two (2) Transfer Pumps 15 HP VFD.
7) One (1) Off Gas Fan 15 HP VFD.
8) One (1) 120/240 VAC Lighting Panel w/ 10 – 20 Amp Breakers.
9) One (1) Control Panel Power Monitor.
10) One (1) Control Panel Transformer.
11) One (1) Main Disconnect.

[redacted]

Total price for scope of supply is approximately $2,000,000.

Start-up services and O&M manuals are included in the above listed price. Tank construction, modification, covers, equipment installation, and electrical service to the facility control room are assumed to be provided by the general contractor. As stated above, we have included the **ThermAer™** patented facility and hardware and patented control logic system for the ThermAer reactors and the SNDR as well as the odor control unit. Copies of ThermAer Applications Reports, the **ThermAer™** brochure, and TPS Terms and Conditions are also included in the following sections of this package. This is a budget estimate, based on 'normally' encountered conditions.

Notes

1) Performance test labor, test equipment and laboratory services are to be Contractor or Owner supplied.
2) Purchased equipment such as electric motors, pumps, blowers, valves, gear reducers, instrumentation, etc. will be furnished with manufacturer's standard finish.
3) Prepaid truck freight to the job site is included.
4) These prices are correct for the next 120 days.
5) Price quoted is exclusive of any Local, State or Federal taxes.

Work and material not included

1) The Contractor shall provide the necessary pump, fan and blower pads, anchor bolts and leveling required for proper setting of all equipment associated with the ThermAer reactor(s), and SNDR.
2) The Contractor shall supply all connections, sample taps, drains, interconnecting spool pieces, and miscellaneous 'small' valves for each pump, blower and fan as shown on drawings.
3) The Contractor shall supply the seal water supply pipe, seal arrangements, pressure regulators, and flow control, drain and accessories for the ThermAer(s), SNDR, and foam control pumps, and coatings (if required by the Engineer).
4) The Contractor shall supply all tank penetrations,
5) The Contractor shall supply all covers for the ThermAer(s) as shown on the drawings.
6) The Contractor shall supply all the tank cover penetrations, flanges, seals, hatches and man ways as shown on the drawings.
7) The Contractor shall supply interconnecting bolts, gaskets, welds, and other miscellaneous fasteners.
8) The Contractor shall supply a communication cable from the ThermAer control panel to the VFDs.
9) The Contractor shall supply all conduits and interconnecting electrical wire for all motors, instruments, and controls.
10) The Contractor shall supply field welds for the in-basin and out-of-basin stainless steel supports associated with the liquid and air headers provided by the ThermAer supplier.
11) The Contractor shall supply all miscellaneous plant service water supply piping.
12) The Contractor shall supply any field installation including delivery point rigging, offloading and storage.
13) The Contractor shall supply all penetrations, nipples, and mounting accessories for field installed instruments and probes.
14) The Contractor shall supply any such items but not limited to as; structural steel, platforms, walkways, ladders, guards, handrails, gratings, supports, piping, valves, weirs, flexible connections, anchor bolts, starters, panel boards, field painting, insulation, or electrical work or material other than that specifically mentioned in the offering which may be required by site specific conditions, federal, state or local requirements.

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Appendix E - References

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