Analysis of Woodlands Village's Wastewater Treatment Facility and Why O&M Manuals for WWTFs Rarely Meet Operators' Needs

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Analysis of the Decentralized Wastewater Treatment System at Woodlands Village

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Abstract

Operating and maintaining the decentralized wastewater treatment system (WWTS) serving Woodlands Village at Hickory Hills Lake consumes nearly one third of the condominium's annual budget. After analyzing the costs associated with the existing system, five potential cost-saving measures were designed and evaluated for cost-effectiveness. Seven alternative treatment systems and connecting into Lunenburg's sewer system were also evaluated to determine if the replacing the existing system could reduce the expenses associated with treating waste at Woodlands Village.

Acknowledgements

This project would not have been possible without the help of our advisors, Professor LePage, Professor Kmiotek, Professor Madan, and Professor Bergendahl. We would like to thank the Woodlands Village, especially Jack Brush, Bob Pease, and Ed Weksner, for allowing our team to perform our evaluation on their WWTS and providing us with an informative and challenging MQP. Another special thanks to Wayne Bates of Tighe & Bond and Joe Goodwill of St. Francis University for their engineering expertise. Finally, we would like to thank Worcester Polytechnic Institute for an incredible project experience that will greatly benefit our careers in the future.

Capstone Design Statement

This project focuses on analyzing potential wastewater treatment systems (WWTS) for use in the Woodlands Village Condominium Development in Lunenburg, Massachusetts. To fulfill the ABET engineering requirements, WPI requires a Capstone Design portion of the Major Qualifying Project. All solutions were found through the constraining aspects of a real-world solution, including: economic, environmental, social, political, ethical, health and safety, constructability, and sustainability constraints.

Economic

When analyzing the potential WWTS solutions for Woodlands Village, their yearly budget and current WWTS expenses were considered. Proposed systems and retrofits were lower than annual costs of operation, and were economically feasible for the community. Any systems with costs greater than the current expenses of the community were noted and discussed as unfeasible options.

Environmental

The current WWTS at Woodlands Village is bordering wetlands and is near Hickory Hills Lake. Since the influent total nitrogen concentration in the community's wastewater is above the groundwater discharge permit limit, a denitrification system must be used to protect the nearby environment. This caused our team to only analyze denitrification systems.

Social

Since Woodlands Village is a condominium development, the project addressed the needs of the entire community. The final presentation was conducted in front of the community, to create a platform for a community-wide discussion on the next steps the condominium development may take.

Political

The WWTS at Woodlands Village is managed by the Facilities Committee in the condominium development, and because of this, we maintained contact throughout the project with the committee to ensure any future decisions were well informed. Using the decision-making body as a reference also provided our team with valuable information that was used to create our cost analysis.

Ethical

Throughout our project we did not perform any tasks that compromised the confidentiality of community members and checked with community members before submitting official documents. Our team did not engage in any activities that were considered dishonest and we avoided any actions that would jeopardize our standings with both the Woodlands Village and the WPI community. All decisions made throughout the project never infringed on the ASCE (American Society of Civil Engineer) Code of Ethics or the AIChE (American Institute of Chemical Engineers) Code of Ethics

Health and Safety

All retrofits and alternative systems have been proven safe to operate, and do not cause damage to the environment. Therefore, all suggestions maintain a healthy and safe environment for the community to live in. Any systems and retrofits being considered that were unsafe for the community were ruled out.

Constructability

All suggestions made by our team to the community account for constructability. Our decision on the best options to consider were based on the cost, size of the system, and amount of construction. These parameters helped our team find the most feasible options for the community.

Sustainability

Another factor that shaped the group’s decision was the longevity of options. Easier operation and maintenance helps the system continue working, which helps prevent the need for repairs. The longer a system lasts, the more sustainable wastewater treatment will be in the community.

Professional Licensure

Professional engineers greatly influence the engineering community and are imperative to protecting the health and safety of community members that will be influenced by real world projects. Achieving a professional engineering license is a long and educational process, meant to ensure that recipients of the licensure are trained to "shoulder the responsibility for not only their work, but also for the lives affected by that work and must hold themselves to high ethical standards of practice" (National Society of Professional Engineers, 2017).

To apply for a professional engineering license, one must graduate from an accredited engineering school and pass the fundamentals of engineering exam. Then four years of engineering experience must be completed and finally pass the Principles and Practice of Engineering exam (National Society of Professional Engineers, 2017).

Obtaining a professional engineering license is an important step for the continued learning and progression of any engineer. It is a valuable goal for an engineer to obtain a license because it allows for an engineer to progress in the workforce and achieve higher levels of success. By completing this project, our team has taken an important introductory step into the world of engineering and learned important skills needed for successful engineering careers.

Authorship

The following report consists of work from Julia Bushell, Sierra Fowler, Matthew Houghton, Abbegail Nack, and Christopher Xavier. All group members contributed equally to the report and required presentations to complete the project. The following authorship shows the primary author and editor for each section in the report.

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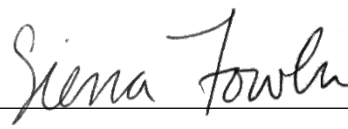

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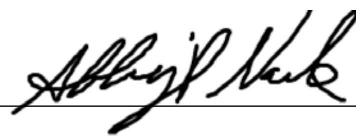

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Section	Author	Primary Editor
Abstract	JB	CX, AN
Capstone Design Statement	MH	SF
Professional Licensure	MH	SF
Executive Summary	AN, MH	All
1. Introduction	JB	MH
2. Background	-	
2.1 Woodlands Village Condominium Development	SF	AN
2.2 Overview of Decentralized Wastewater Treatment	SF	AN
2.3 Wastewater Treatment in Massachusetts	SF	AN
2.4 Wastewater Treatment in Lunenburg	MH	AN
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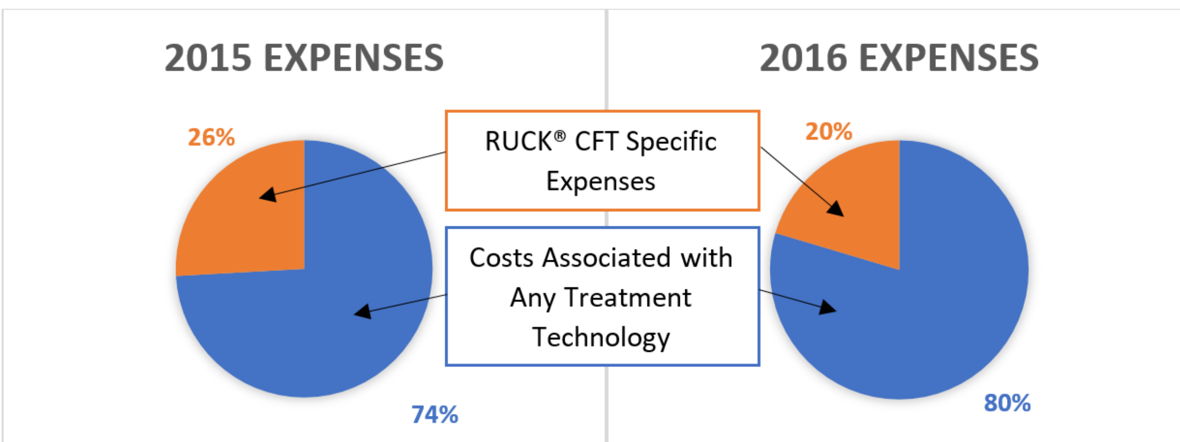
3. Methodology	-	-
3.1 Researched the Existing RUCK CFT System	JB	SF
3.2 Performed a Financial Analysis of the RUCK® CFT System	JB	SF
3.3. Investigated Ways to Improve the Current System	JB	SF
3.4. Identified Alternative Wastewater Treatment Systems	JB	SF
3.5. Selected a Feasible Alternative System for Woodlands Village	JB	SF
3.6. Presented Final Recommendations to the Community at Woodlands Village	JB	SF
4 Results and Findings	-	-
4.1. Analysis of Existing RUCK CFT System	AN	JB
4.2. Analysis of Costs Associated with the Existing RUCK Treatment System	AN	JB
4.3 Evaluation of Potential Retrofits and Cost-Cutting Actions	AN	JB
4.4 Description of Alternative Wastewater Treatment Systems	CX	MH

4.5. Evaluation of Alternative Wastewater Treatment Systems	CX, MH	MH, CX
5. Recommendations and Conclusion	All	All
6. Appendices	SF, MH	CX

Executive Summary

Woodlands Village at Hickory Hills Lake is a lake-side condominium development in Lunenburg, Massachusetts. Woodlands Village consists of four four-unit buildings, five duplexes, and numerous single-family dwellings. The condominium uses a decentralized wastewater treatment system to treat all of the community's waste. The system is a 12,500 gpd RUCK® CFT system, which employs trickling filters containing sand filter media. While currently effective, the system consumes almost a third of the development's annual budget. The Facilities Committee, which advises the Board of Trustees on the wastewater treatment system (WWTS), asked our team to analyze the costs associated with the system, find potential cost-saving measures, and select alternative treatment systems that the community could pursue in the future.

The expenses of the existing wastewater collection and treatment system were determined by analyzing the condominium's financial records for 2015 and 2016. Woodlands Village spent $94,467 and $107,014 on the treatment system in 2015 and 2016, respectively. The most significant finding from the cost analysis was that approximately 74-80% of the costs associated with Woodlands Village's WWTS would remain the same regardless of the treatment technology in place. Costs that would remain the same include expenses due to lift station repairs, contracting an operator, lab testing, engineering services, and permits. These findings are illustrated in the figure below.



Since the maximum annual savings that could be achieved by installing a different system amount to only $22,000, the best way to reduce costs is **not** by replacing the existing system. As a result, we identified and evaluated five potential cost-saving measures:

1. Automating the methanol dosing system;
2. Automating the sodium bicarbonate dosing system;
3. Hiring different maintenance and operating companies;
4. Improving community awareness about wastewater treatment systems; and
5. Assessing the need for heating the effluent.

Woodlands Village recently implemented Cost-Saving Measure 3. In January 2017, Woodlands Village's operator switched from WhiteWater, Inc. (for lift station maintenance) and Wastewater Environmental Management (for treatment system operation) to Small Water Systems Services (for both services). Barring any significant repairs, this change in operating companies is projected to save Woodlands Village approximately $12,000 based on last year's financial data.

It was initially proposed that fully-automated methanol and sodium bicarbonate ($NaHCO_3$) dosing systems would reduce Woodlands Village's chemical expenses. "Fully-automated" means that the amount of methanol or ($NaHCO_3$) added to the system is continuously adjusted according to the wastewater flow rate and nitrate or ammonia concentration. The cost to fully-automate the methanol and sodium bicarbonate systems (Cost-Saving Measures 1 and 2) was compared to the anticipated savings on chemical purchases. Our team found that fully-automating either dosing system is not cost-effective and therefore, not worth pursuing.

Although a fully-automated sodium bicarbonate feed is not cost-effective, we do recommend a basic retrofit for the $NaHCO_3$ system. Currently, 50 lbs. of powdered $NaHCO_3$ are added to the system three times each week, resulting in large fluctuations in the concentration of $NaHCO_3$. In this retrofit, sodium bicarbonate would be continuously added to the system as a solution. The retrofit would cost approximately $1,500 and should save on the amount of ($NaHCO_3$) that must be purchased by Woodlands Village each year.

Baby wipes, feminine hygiene products, pharmaceuticals, coffee filters, and grease should not enter the wastewater treatment system because they damage and corrode pipes and equipment (King County, 2016). Improving community awareness about what is safe to pour down drains or flush down toilets (Cost-Saving Measure 4) can reduce costs related to pump repairs, which is the largest expense associated with the Woodlands Village's WWTS.

In the RUCK ® CFT System, effluent is heated to ensure that its temperature is warm enough to encourage microbial processes. In 2016, the community spent about $2,700 on natural gas for equipment within the treatment building. A substantial, but unknown portion of that fuel was used by a furnace system to heat the effluent. However, heating of the effluent is not required at most treatment facilities because the temperature of the incoming raw wastewater is usually warm enough, regardless of the ambient temperature (Mount Hope Engineering, 2013). Therefore, the operator should assess the need for heating the effluent (Cost-Saving Measure 5). If the system is able to maintain warm effluent temperatures without use of the furnace, the condominium could save on their natural gas bill.

Our team also researched alternative systems that would be appropriate for Woodlands Village and have lower operational costs than the RUCK ® CFT system. Of the 31 MassDEP approved wastewater treatment technologies, seven alternative technologies were identified as meeting the needs of Woodlands Village. The available costs acquired for five of the systems are described in the following table.

Item	Removal	Construction	Total Capital Cost	Upkeep per Year
Bioclere	$ 250,800	$ 360,000	$ 610,800	$ 91,409
Clean Solution Treatment System		$ 366,000	$ 616,800	$ 88,616
Amphidrome System		$ 403,400	$ 654,200	N/A
Bio-Microbics MicroFAST		$ 337,500	$ 588,300	N/A
Smith & Loveless FAST System		$ 340,000	$ 590,800	N/A

Based on the information provided by companies, the cost to install any alternative system combined with the cost of removing the existing system exceeds any savings achieved by lower operating costs of an alternative system. Therefore, it is impractical for Woodlands Village to switch to a new WWTS at this time.

The final option considered by our team was the possibility of connecting Woodlands Village into Lunenburg's city sewer system. If completed, the total cost of installing new pipe lines and removing the current system would be around $1,123,750. With the added cost of removing the RUCK system, the total capital cost of the system would be $1,374,550. The cost of operating the sewer system would be significantly less than the annual cost of the RUCK ® CFT system, at $61,972. Unfortunately, the current Lunenburg city sewer system is not adjacent to Woodlands Village and there are no plans to expand the sewer system close to the condominium. Therefore, the city sewer system is not a feasible option for Woodlands Village to pursue.

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Acronyms

Acronym	**Meaning**
AICHE	American Institute of Chemical Engineers
ASCE	American Society of Civil Engineers
BOD	Biological Oxygen Demand
CWMP	Comprehensive Wastewater Management Plan
DEP	Department of Environmental Protection
DMR	Discharge Monitoring Report
EPA	Environmental Protection Agency
FET	Flow Equalization Tank
GPD	Gallons per day
IMA	Inter-municipal agreement
MQP	Major Qualifying Project
NHESP	Natural Heritage & Endangered Species Program
NOI	Notice of Intent
O&M	Operations and maintenance
PLC	Programmable logic controller
SAS	Soil absorption system
TS	Total solids
WWTS	Wastewater Treatment Systems
VOC	Volatile organic compound

1. Introduction

The Woodlands Village MQP analyzed the decentralized wastewater treatment system at a condominium development in Lunenburg, MA. The development, known as Woodlands Village, consists of single-family homes, duplexes, and four-unit buildings for a total of 46 units. Currently, wastewater from the condominium is treated by a RUCK® CFT System that was installed in 1998. The system has been modified multiple times since installation due to noncompliance with the Department of Environmental Protection (DEP) standards for effluent discharge.

Denitrification is an essential process for WWTS near water bodies. Effluent from WWTS should have low levels of nitrogen to prevent algae blooms and plant overgrowth in the lake, a process known as eutrophication. The effluent must also have low BOD levels. High BOD and nitrogen levels lead to a reduction in the dissolved oxygen in a waterbody, which can cause the death of aquatic organisms (United States Geological Survey, 2017). Since Woodlands Village borders Hickory Hills Lake, prevention of eutrophication and preservation of the lake's water quality is essential to maintaining the property values of surrounding area. The current solution for the community is their current denitrification WWTS, the RUCK system. Although effective, the RUCK® CFT System consumes about 33% of the condominium development's budget each year. With fewer houses built than initially expected, the burden of the system is much larger on each individual household. The cost of the system and maintenance of the grounds in the development have become an encumbrance on condominium owners and has made resale difficult (Lunenburg MQP Team, 2016). To address these problems, our team performed a cost-analysis on the current system and each alternative system at the present number of homes, as well as, research into growth feasibility. This information was presented at the Woodlands Village monthly board meeting on April 13, 2017 and a cost analysis report was provided for the community and board members.

2. Background

The Background provides an overview of Woodlands Village at Hickory Hills Lake condominium located in Lunenburg, Massachusetts. It then discusses general wastewater treatment principles used in small communities, MassDEP regulations regarding wastewater treatment, and wastewater treatment in Lunenburg, MA. The Background concludes with a description of Woodlands Village's WWTS, the RUCK ® CFT System.

2.1. The Woodlands Village Condominium Development

Woodlands Village at Hickory Hills Lake Condominium is located in Lunenburg, Massachusetts, which is approximately 46 miles northwest of Boston. Woodlands Village covers 74.4 acres fronting Hickory Hills Lake, which is a shallow man-made, dammed lake (Lunenburg MQP Team, 2016). The Woodlands Village condominium was initially designed and permitted in the 1980s to be larger than the 46 units currently built (Mount Hope Engineering, 2013). Woodlands Village condominium consists of four four-unit buildings, five duplexes, and 25 single-family dwellings. At Woodlands Condominium, residents own the title to their individual unit space, but the house structure, lawn, and surrounding land belong to the stakeholders who own the complex. The community has a board of trustees that make decisions regarding changes to the complex and oversee committees run by members who live in the complex. Committees include the Waterfront, Social, Finance, and Facilities Committee. The Facilities Committee advises the trustees on the wastewater treatment system in place at the complex (Lunenburg MQP Team, 2016).

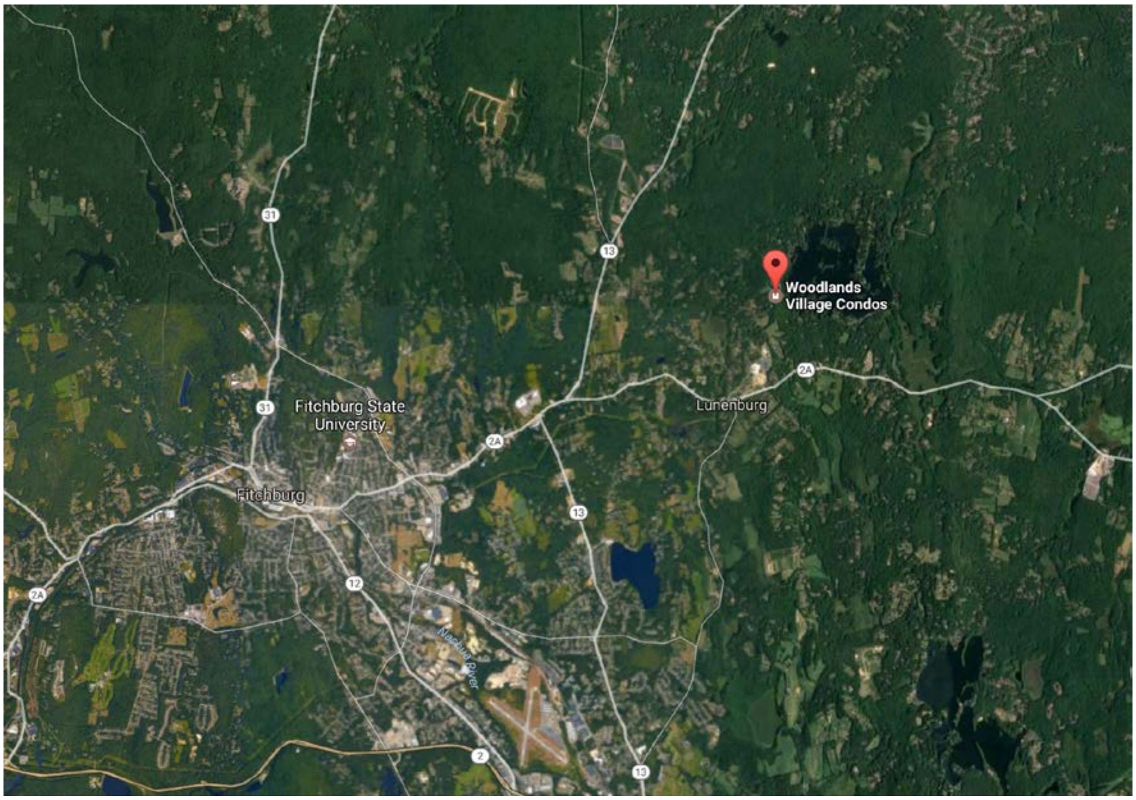

Figure 1: Google Maps Image of Woodlands Village

2.2. Overview of Decentralized Wastewater Treatment

Decentralized wastewater treatment is a broad term that describes the collection, treatment and dispersal of wastewater from individual dwellings, industries, institutions, or small communities. Decentralized wastewater treatment systems use a variety of approaches and are installed near the point of wastewater generation. Decentralized wastewater treatment systems can be grouped into two categories: septic systems and advanced treatment units (U.S. EPA)

2.2.1. Individual/Shared Septic Systems

The traditional septic tank allows for settling of solids by gravity at the bottom of a tank. The effluent then passes through a screen at the outlet of the tank before being dispersed into the soil absorption field where final treatment occurs.

A non-traditional septic system uses pumps or advanced treatment in order to improve effectiveness. These systems are broken down into two major parts, pretreatment components and final treatment and dispersal components. These two components are selected based on the site conditions of the system and the level of treatment soil conditions can handle. Pretreatment components include septic tanks, trash tanks, and processing tanks. Final treatment and dispersal components include gravity flow, low pressure, subsurface drip, and spray distribution systems. The latter three are designed to function in difficult areas where pressurized systems can overcome site limitations through even distribution of wastewater. Gravity flow distribution systems are the most commonly used due to low costs and maintenance, yet require proper soil conditions. Even advanced septic tanks will not typically meet strict standards required for some groundwater discharge permits. Thus, septic tanks are used as a pretreatment step before a more advanced process like aerobic treatment units or media filters. Once these more advanced technologies are added, the septic tank becomes merely an intermediate step in a larger processing system.

2.2.2. Advanced Decentralized Wastewater Systems

Advanced decentralized wastewater treatment systems use more complex and mechanized approaches to treat domestic waste from multiple buildings. Since these treatment systems collect wastewater from multiple units, a collection system is required. After collection, wastewater typically undergoes primary treatment, followed by secondary treatment. Occasionally tertiary or advanced treatment follows secondary treatment. Lastly, the treated wastewater is then discharged into to soil or nearby surface waters. The following section provides an overview of wastewater collection, primary treatment, secondary treatment, and discharge of treated effluent to the ground. The section delves into two specific processes that occur during secondary treatment: nitrification and denitrification.

Primary Treatment

The goal of primary treatment is to remove floating and readily settleable solids by physical operations (Metcalf & Eddy, 2003). Primary treatment, also known as primary sedimentation, reduces the concentration of suspended solids in the wastewater. To remove solids, effluent is held in a large settling tank, or primary clarifier, for long periods of time. As wastewater moves slowly through the settling tank, heavier solids sink by gravity and collect at the bottom of the tank, forming sludge. Lighter solids float to the surface. Periodically, the sludge must be pumped out of the tank and the floatables must be skimmed off the water’s surface. A portion of the solids removed contain organic matter. In wastewater, organic matter is measured by its biochemical oxygen demand (BOD), which is the amount of oxygen microorganisms have to consume in order to breakdown the organic material in the wastewater. According to Metcalf & Eddy, a well-designed primary settling tank will remove 50-70% of the suspended solids and 25-40% of the BOD. At Woodlands Village, primary treatment takes place in settling tank and is followed by secondary treatment.

Wastewater Collection Systems

Wastewater collection systems are used to gather wastewater from homes in a community and deliver the waste to a treatment plant. These systems usually use gravity as the primary method of transportation; however, force mains powered by pumps are also used to convey wastewater when the force of gravity is insufficient. Gravity sewers are typically designed to produce a flow velocity of about 5 feet per second, but a velocity 2.5 feet per second is ideal **(**New Mexico State University Water Utilities Assistance Program, 2007). Sewer systems are made up of building sewers, lateral/branch sewers, main sewers, trunk sewers, and intercepting sewers (NMSU WUAP, 2007). Force mains are primarily used to combat rises in elevations along the sewer line. In this system, lift stations raise the effluent from low elevations to higher elevations. There are two types of lift stations, drywell and wetwell. Drywell lift stations contain two chambers; one is used for wastewater and the other is for pumps, motors, valves, and auxiliary equipment and electrical controls. Wetwell lift stations have one chamber where the pumps are located either above the wastewater or in the walls (NMSU WUAP, 2007).

Secondary Treatment

Secondary treatment removes dissolved and suspended biodegradable organic matter. This is accomplished through a biological process in which microbes (primarily bacteria) consume organic matter as fuel for growth and reproduction, producing water and carbon dioxide as byproducts (Metcalf & Eddy, 2003). There are two main categories of biological processes used in secondary treatment: suspended growth and attached growth (Metcalf & Eddy, 2003). In suspended growth treatment processes, microorganisms are held in suspension. Suspended growth processes are usually aerobic processes, although anaerobic suspended growth reactors are used in some applications. The most common suspended growth processes used to treat municipal wastewater is the activated-sludge process. The activated sludge process takes place in an aeration tank. In the tank, effluent and microorganisms are mixed by aeration devices that bring oxygen into the mixture. The mixture then flows into a clarifier to remove the microorganisms, some of which can be recycled back into the aeration tank.

In attached growth processes, microorganisms are attached to media such as rock, sand, plastic, and other synthetic materials (Metcalf & Eddy, 2003). Attached growth processes can be aerobic or anaerobic. Aerobic systems require a forced or natural introduction of oxygen to the media chamber. The most common aerobic attached growth process is the trickling filter. In trickling filters, also known as biofilters, water is evenly distributed over the top of basins filled with media. Microorganisms grow on the media as an attached biofilm. As wastewater runs over the media, microorganisms consume organic material as energy for the growing biofilm. After passing through the media, treated wastewater collects in an underdrain. Any excess film material that separates from the media is caught in a secondary clarifier or filter. Finally, rotating biological contactors (RBCs) are another common attached growth process. In an RBC, microorganisms grow on rotating plastic discs that are partially submerged in flowing wastewater. Because the discs are only partially submerged, the aeration occurs when the microorganisms are exposed to the atmosphere. This process is also typically followed by a clarifier. Both attached growth processes are vulnerable in cool climates because microorganisms are exposed to the atmosphere; at low temperatures inactivity of the microbes causes poor system performance. Proper insulation and dispersion technologies have been effective in handling these climate issues; however, some systems require external heaters.

Besides the removal of BOD, secondary treatment can also be used to remove harmful nitrogenous compounds from wastewater. High levels of organic nitrogen from dead cells, proteins, urea, and nucleic acid are found in human waste. Much of this organic nitrogen is decomposed into ammonia by naturally-occurring bacteria in the wastewater. Domestic sewage typically contains between 25 mg/L and 45 mg/L of organic and ammonia nitrogen (Metcalf & Eddy, 2003). If ammonia is not treated and is released into the environment, it will kill fish and wildlife, deplete dissolved oxygen in the water supply, and cause eutrophication (Metcalf & Eddy, 2003). Nitrates, another nitrogen-based compound commonly found in wastewater, can also have a dangerous effect on the environment and on the safety of drinking water. Fortunately, harmful nitrogenous compounds such as ammonia and nitrate can be converted to harmless nitrogen gas via nitrification and denitrification. Nitrification and denitrification are especially important for wastewater treatment facilities located in nitrogen-sensitive areas where the release of ammonia and nitrates would be especially harmful to environment.

Nitrification

Nitrification is the two-step process in which microorganisms oxidize ammonia to nitrite (NO_2^-) and then nitrate (NO_3^-) (Metcalf & Eddy, 2003). The ammonia in wastewater is converted by autotrophic nitrifying bacteria that make organic molecules by consuming ammonia or nitrite as an energy source. Nitrification is an aerobic process that can occur in both suspended growth and attached growth biological processes during secondary treatment (Metcalf & Eddy, 2003). The first step is the oxidation of ammonia (NH_4^+) to nitrite (NO_2^-), which can be seen in equation below (Metcalf & Eddy, 2003):

$$2NH_4 + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O$$

The second step in the nitrification process includes oxidation of nitrites into nitrates according to equation below:

$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

The overall reaction can be shown as:

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$

In order to maintain a stable population of nitrifying bacteria, the system should be aerobic, around the temperature of 30°C, have a pH between 7.2 and 8.0, and have relatively low concentrations of carbonaceous BOD. The process of nitrification also requires alkalinity. Nitrification precedes denitrification in the removal process of nitrogen from wastewater (ECOS Environmental Consultants, 2013).

Denitrification

Denitrification is the biological conversion of nitrate to nitrogen gas, which can be released safely into the atmosphere. Denitrification is typically performed in anaerobic conditions by heterotrophic bacteria that consume organic matter (BOD). This process can occur before or after nitrification, which are termed pre-anoxic denitrification and post anoxic denitrification, respectively. Pre-anoxic denitrification consists of an anoxic tank followed by an aeration basin. Nitrates that are produced in the aeration basin via nitrification must be recycled back into the anoxic tank. In post-anoxic denitrification, the anoxic tank follows the aeration basin. However, in this setup, much of the naturally-occurring organic matter will be consumed in the aeration basin before reaching the anoxic tank. Therefore, a carbon source such as methanol must often be added to the system to provide sufficient BOD for the denitrifying bacteria to function. Post-anoxic denitrification can occur in both suspended and attached growth systems (Metcalf & Eddy, 2003).

Denitrification that relies on methanol (CH_3OH) as a carbon source is shown as:

$$NO_3^- + \frac{5}{6}CH_3OH \rightarrow \frac{1}{2}N_2 + \frac{5}{6}CO_2 + \frac{7}{6}H_2O + OH^-$$

Overall, the denitrification process is necessary in conjunction with nitrification to allow safe, inert nitrogen to exit the process and prevent nitrate from entering the environment and causing dangerous effects.

Discharge to Groundwater

In many systems, after secondary treatment, effluent is conveyed to a leaching field. Leaching fields, or soil absorption systems, allow effluent to be safely discharged into the surrounding soil and are vital parts of almost any wastewater treatment system. A leaching field is an array of underground perforated pipes that are used to help disperse treated effluent as it is introduced to the soil. The perforated pipes are situated in trenches containing porous material, such as gravel. Once in the ground, some of the wastewater evaporates at the surface; however, most percolates through the soil and combines with groundwater aquifers. This recharges the groundwater supply. The size of leaching fields is determined by two main factors, the amount of wastewater that it will have to handle, and the soil absorption rate (The Engineering Toolbox, n.d.). This affects the number and size of trenches housing the pipes. The trenches are covered in a layer of soil to prevent surface runoff. A percolation test can be done to determine how well the wastewater can pass through the soil and away from the field.

2.3. Wastewater Treatment in Massachusetts

The Massachusetts Department of Environmental Protection (MassDEP) sets requirements and standards to protect water quality and the environment. Under MassDEP's regulations, there are two major categories of wastewater treatment facilities, which are based on the facility's sewage design flow rate and effluent characteristics. Wastewater treatment systems either fall under a Title V Permit or require a Groundwater Discharge Permit.

2.3.1 Title V

Title V classification only applies to on-site collection and treatment of sewage (314 CMR 15.004). Typically, these systems are meant to only receive a maximum of 10,000 gpd. If the system exceeds this amount, it must be filed under a Groundwater Discharge Permit, with the exception of some facilities treating between 10,000 - 15,000 gpd. Title V systems are not meant to handle oil, hazardous waste, medical waste, and radioactive waste (314 CMR 15.004). These systems are managed by the local Board of Health (MassDEP, 2017b), although MassDEP is involved in approving technologies, shared systems, variance requests, and larger systems (MassDEP, 2017b).

If a community plans to share a Title V system, a separate application must be filed that includes a proposed operation and maintenance plan, forms of ownership for each part of the system, and a description of financial data supporting the long-term operation of the system (314 CMR 15.290). Under Title V, no new construction or increase in design flow is allowed unless a variance is submitted.

2.3.2. Groundwater Discharge Permit

Groundwater Discharge Permits are created and filed for any sanitary wastewater system above a flow rate of 10,000 gpd and any industrial waste systems ((MassDEP, 2017a). However, some sanitary wastewater treatment systems with design flows between 10,000 - 15,000 gpd may be allowed to operate under Title V without a Groundwater Discharge permit provided that the system is not in a nitrogen sensitive area. The permit can be applied for after the completion of a hydrogeographical investigation on the effects of a proposed system on the groundwater and surface water in the area. The permit is applied for by the owner of the system, and cannot be issued without an engineering report, certification from a Massachusetts professional engineer, and professional review of the hydrogeographical report (314 CMR 5.09).

Under the groundwater discharge permit, the system must be properly maintained, have an alternative power system, and monitored through samples and measurements (314 CMR 5.16). Permits will also contain discharge limits to prevent the impairment of nearby groundwater and surface water bodies (314 CMR 5.10.3). The permit must be renewed and approved by MassDEP every five years (314 CMR 5.12.9).

2.4 Wastewater Treatment in Lunenburg

Lunenburg has developed a CWMP to prepare for wastewater in the town through 2036 (Wright Pierce, 2016, pg. ES-1). The plan was initially created because there was growing concern over the ability of on-site wastewater treatment to adequately treat waste from a growing population and the limited ability of the town to send wastewater to nearby treatment facilities in other cities (Wright Pierce, 2016, pg. ES-1).

In the plan, sections of Lunenburg are identified to be connected to city sewer that gets treated at Fitchburg's and Leominster's municipal wastewater treatment systems. Lunenburg and Leominster established an IMA for treatment of up to 500,000 gpd (Wright Pierce, 2016, pg. 3-5). Another nearby treatment facility is the Shirley WWTS. To send wastewater to from Lunenburg to Shirley's WWTS, IMAs would need to be created between Lunenburg, Shirley, and Devens. Through the CWMP and IMAs created with nearby towns, Lunenburg has the ability to expand its sewer system. The plan highlights the existing sewer systems and the proposed expansion areas in Figure 2.

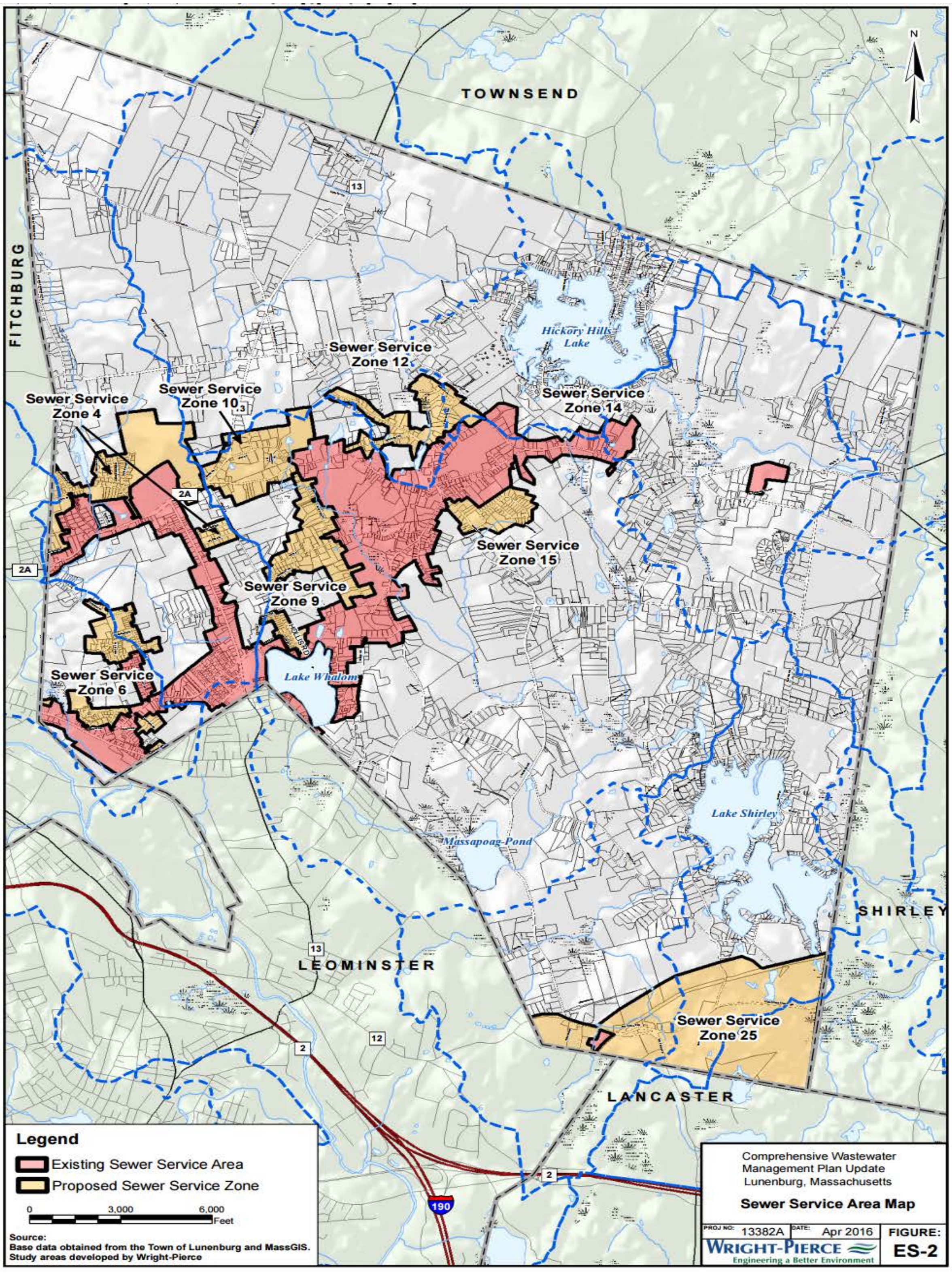

Figure 2: Sewer Service Area Map for Lunenburg, MA (Wright Pierce, 2016, pg. ES-5)

Along with municipal sewer hookups, the CWMP suggests alternatives for wastewater treatment that can be used throughout Lunenburg in the future. The CWMP describes four major options the area could pursue. These are:

1. Conventional Title V septic systems
2. Innovative/Alternative systems for additional nutrient treatment
3. Decentralized wastewater treatment systems
4. Regional treatment alternatives through either the Shirley/Devens or Leominster wastewater treatment facilities.

The areas surrounding Hickory Hills Lake are labeled as Sewer Service Zone 14. During the analysis of the area in the CWMP, Zone 14 was labeled as a secondary area that needed further analysis (Wright Pierce, 2016, pg. 3-5). Zone 14 borders a "Squannassit Area of Critical Environmental Concern and is a NHESP priority and an estimated habitat area (on the eastern side of the lake)" (Wright Pierce, 2016, pg. 2-3). The CWMP suggests that Zone 14 utilizes decentralized wastewater treatment because the "town currently does not plan to support requirements in addition to Title 5" (Wright Pierce, 2016, pg. 3-5). Currently Woodlands Village's wastewater treatment system is consistent with the recommendation of the CWMP because they are using a decentralized wastewater treatment system. The condominium uses a RUCK CFT system, which provides secondary treatment of the wastewater produced at the condominium and discharges the treated wastewater to the ground. The general principles of wastewater collection, secondary treatment, and discharge associated with Woodlands Village onsite sewage treatment system and the applicable environmental regulations are described below.

2.5. Decentralized Wastewater Treatment at Woodlands Village

The following section provides a brief history of wastewater treatment at Woodlands Village, an overview of the RUCK CFT treatment technology, and a description of the facility's groundwater discharge limits. The section concludes with a discussion of Facilities Committee concerns, which engendered this project.

2.5.1. History of Wastewater Treatment at Woodlands Village

When the first several homes were designed and constructed at Woodlands Village in the 1980s, the community was not large enough to necessitate a decentralized wastewater treatment system. Under Title V, until the sewage design flow of the community exceeded 10,000 gpd, the treatment fell under the jurisdiction of the local Board of Health. (310 CMR 15.003 (2)). According to Title V, the sewage design flow for multiple and single family dwellings is 110 gpd/bedroom (310 CMR 15.302). Therefore, until the bedroom count at the condominium exceeded 90, the system fell under jurisdiction of the Lunenburg Board of Health. During this period, the Lunenburg Board of Health only required the installation of septic tanks for individual homes or groups of dwellings.

Once Woodlands Village's bedroom count exceeded 90, the system fell under much more stringent MassDEP regulations. Woodlands Village was then required to obtain a Groundwater Discharge Permit and install a more robust decentralized wastewater treatment system that produced effluent meeting the State's groundwater standards in 314 CMR 5.00.

All 46 units within the condominium are connected to the decentralized wastewater treatment system. The current bedroom count is 104. Based on the 110 gpd/bedroom standard, the sewage design flow is 11,440 gpd. However, the maximum allowable flow rate under the system's Groundwater Discharge Permit # 3-362 is 12,500 gpd. Theoretically, at the existing permit limit of 12,500 gpd, 9 additional bedrooms could be built while remaining within the permit limits.

The existing RUCK® CFT system was not the first decentralized wastewater treatment system installed at Woodlands Village. Originally, a larger treatment system using a rotating biological contactor (RBC) was installed. However, the RBC system was never used because the capacity of the system was too large for the condominium's purposes. The RUCK® CFT system was subsequently installed and began operation in 1998. The unused RBC treatment equipment remained in the treatment building until it was sold in 2004. Since the existing treatment building was sized for the much larger RBC system, there is substantial unused space within the treatment building.

RUCK CFT System

The commercial RUCK technologies were invented by Rein Laak Ph.D. and developed by Michael B. McGrath in the mid-1980s. The RUCK CFT system is available for piloting use under Title V and can be installed under a Groundwater Discharge Permit. The RUCK CFT system is an aerobic treatment system designed to handle flows that range from 2,000 gpd to 9,999 gpd. The RUCK CFT system can provide nitrogen removal upwards of 90%.

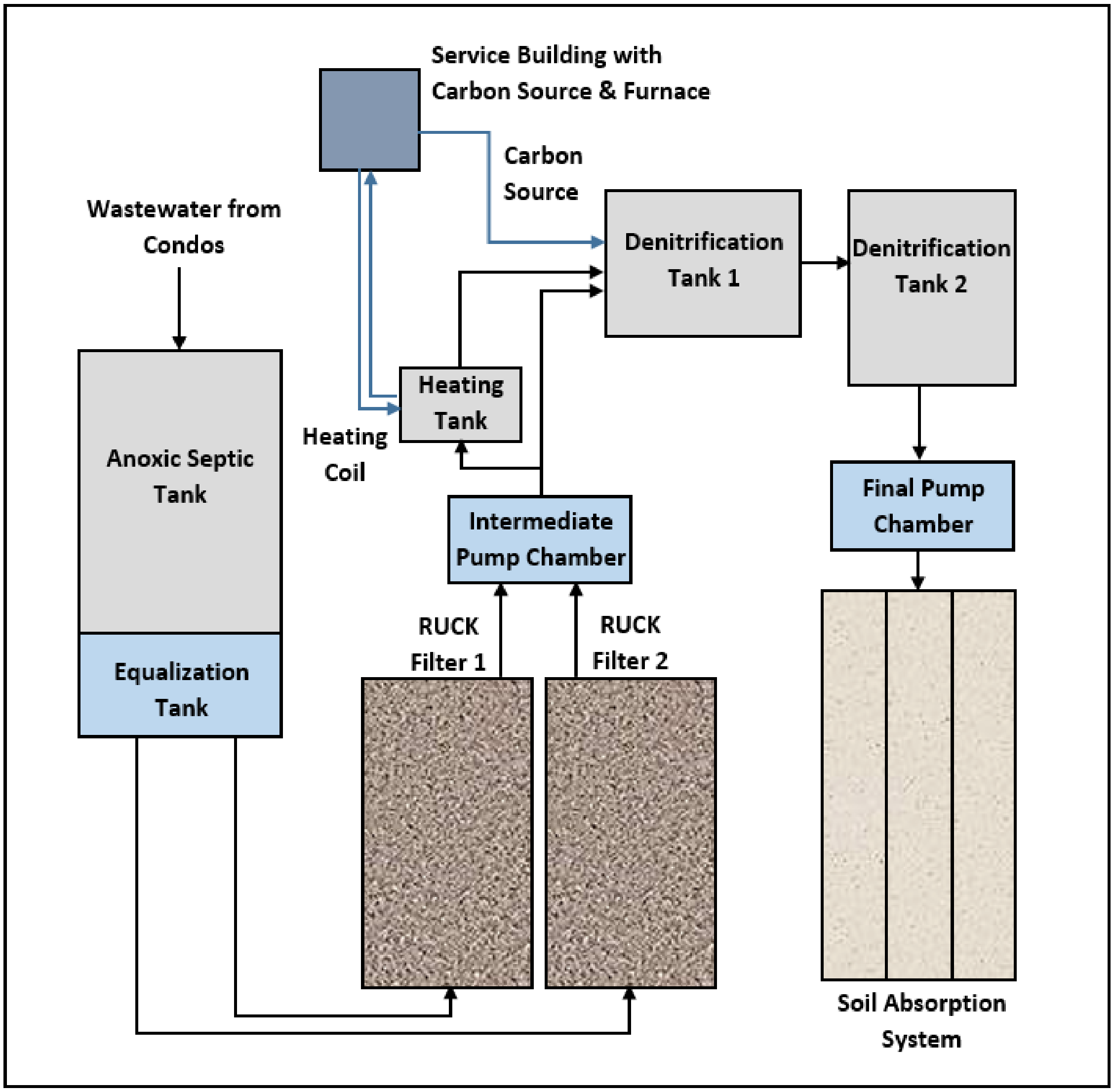

Figure 3: Diagram of Existing RUCK® CFT System

At Woodlands Village, effluent is conveyed through two force mains from the homes and their associated septic tanks to the treatment facility. At the facility, wastewater is first received by a large, anoxic settling tank, which removes settleable and floatable solids. The settling tank is connected to a flow equalization tank (FET) by an interior baffle. Sodium bicarbonate is added in the FET to provide alkalinity. The FET attenuates variation in flow by periodically pumping wastewater to the two RUCK modified sand filters. Microorganism living in the trickling filters consume organic matter (remove BOD) and convert ammonia into nitrates (nitrification). Once effluent passes through the filters, it collects in an underdrain beneath the filters. Effluent then flows by gravity to an interim pump chamber. The pump chamber conveys wastewater to the first of two denitrification tanks, which are set in series. A portion of the effluent fed to the denitrification tanks is heated in the winter. Microorganisms in the denitrification tanks convert nitrates to nitrogen gas. Methanol is added to the first denitrification tank to provide "food" for denitrifying bacteria. The final pump chamber pumps treated effluent from the second denitrification tank to the leaching field. A more detailed inventory of the decentralized wastewater treatment system at Woodlands Village can be found in Section 4.1.

Woodlands Village Groundwater Discharge Permit #3-362

According to 314 CMR 5.02, the Massachusetts Department of Environmental Protection is authorized to issue permits that regulate the discharge of pollutants to the ground. The following table summarizes Woodlands Village's effluent criteria.

Table 1: Groundwater Discharge Permit Effluent Limits

Flow	12,500 gpd
BOD_5 (5 day at 20C)	30 mg/l
Total Suspended Solids (TSS)	30 mg/l
Nitrate Nitrogen	10 mg/l
Total Nitrogen (NO2 + NO3 + TKN)	10 mg/l
Oil & Grease	15 mg/l
Surfactants	1.0 mg/l
pH	May not be less than 6.5, may not be more than 8.5, nor greater than 0.2 standard units outside naturally occurring range
Discharge of effluent shall not result in any demonstrable adverse effect on groundwater or violate any water quality standards	
Monthly average conc. Of BOD and TSS shall not exceed 15% of monthly average conc. of BOD and TSS in the influent into wastewater treatment system.	
Permittee must submit a report if average annual flow exceeds 80% of permitted flow limitations	

The groundwater discharge permit also requires that the treatment facility is operated by a Grade 4 or higher Massachusetts Certified Wastewater Treatment system operator. Currently, the treatment facility contracts a third-party to operate the system: Small Water System Services. The operator comes to the treatment facility five days a week for two hours, except on holidays. According to the discharge permit, the operator must periodically monitor and record the quality of the influent, effluent, and monitoring wells samples. The quality of the influent and effluent must be reported to MassDEP in a monthly discharge monitoring report (DMR). The operator also uses the results of in-house testing of alkalinity, BOD, and COD to adjust the dose of methanol and alkalinity to the system. Since the operator does not visit the site on weekends, flow rates over the weekend are approximated. The operator keeps handwritten records of flow and effluent characteristics; only a few documents have been digitized.

2.5.2 Concerns of Woodlands Village's Facilities Committee

In 2013 and 2015, Woodlands Village was issued two Administrative Consent Orders with Penalty (ACOPs) for non-compliance with MassDEP regulations. The first ACOP was issued for failure to record daily effluent flow rate, for allowing waste to bypass the treatment system, for failure to report breakout within 24-hrs, and for improper maintenance of effluent tee filters (Notice of Enforcement Conference, 2013). As a consequence of noncompliance, Woodlands Village was also fined $2000 (Executive Office of Energy and Environmental Affairs, 2013). MassDEP also required Woodlands Village to update the facility's plans and operations and maintenance (O&M) manual. Since 2013, Woodland Village's O&M manual has undergone several revisions. A report on the challenges of producing and revising O&M manuals for domestic wastewater treatment facilities can be found as a supplemental document. The report is titled, "Dust-Covered Operations and Maintenance Manuals: Why O&M Manuals for Wastewater Treatment Facilities Rarely Meet Operators' Needs."

In 2015, a second Administrative Consent Order with Penalty was issued to Woodlands Village for failure to comply with several of the treatment facility's Groundwater Discharge Permit limits. The effluent's monthly biological oxygen demand (BOD), total nitrogen (TN), total suspended solids (TSS), and nitrate-nitrogen content exceeded the effluent discharge limits for one or more months. For these violations, Woodlands Village was fined $5,565. Since these administrative consent orders were issued, Woodlands Village has made several modifications to their wastewater treatment system in order to improve the system's ability to comply with the Groundwater Discharge Permit and enhance the system's efficiency. After facing MassDEP fines, the board of trustees also created the Facilities Committee to oversee the RUCK® CFT System. Despite several notable improvements to the treatment facility's operation and maintenance, the Facilities Committee has identified several aspects of the wastewater treatment system that still need improvement. Currently, methanol is added to the system in relation to effluent flow rate, but not the concentration of ammonia in the influent or the concentration of nitrate in the effluent leaving the RUCK filters. Alkalinity is corrected by the manual addition of 50-lb bags of sodium bicarbonate to the flow equalization tank, independent of the mass of ammonia entering the system. Flow rates are calculated by hand and all records are kept as hard copies, with a limited number of documents available in a user-friendly, accessible format.

Currently, a substantial portion of the community's budget (about 33%) is spent on the wastewater treatment system. Due to deviations from the original design of the condominium, there is a stretch of unused road leading to the wastewater treatment system, which is expensive to maintain (Lunenburg MQP Team, 2016). The Facility's Committee would like to reduce the expenses associated with the wastewater treatment system and maintaining the road because homeowner's fees are excessive and negatively impacting the resale value of homes (Lunenburg MQP Team, 2016). To defray the high costs of maintaining both the treatment facility and the unused stretch of road, the community is considering the potential of expansion onto the limited undeveloped land in the complex. By adding additional units, the costs of maintaining the road and WWTS would be shared amongst more homeowners. As a result, the Facilities committee wanted to assess the feasibility of expansion through assessing the capacity of the existing wastewater treatment system and the availability of land for development. In addition, the Facilities Committee wanted to investigate the potential savings associated with automation of the methanol and sodium bicarbonate dosing processes or the installation of alternative treatment technologies.

3. Methodology

The goal of the Lunenburg MQP was to provide wastewater treatment options for the Woodlands Village Condominium Development in order to help them reduce high community expenses, maintain environmental standards, and plan for future expansion. To achieve the overall goal of this project, several steps were taken to gain the knowledge and background needed to formulate solutions. To do this the team:

1. Researched the current RUCK system in place
2. Performed a financial analysis on the RUCK system
3. Investigated ways to improve the current system in place
4. Identified alternative systems for the project site
5. Provided a feasible wastewater treatment alternative for the community at Woodlands Village
6. Delivered findings to the board members and community at Woodlands Village and provided a final recommendation for the Woodlands Village site

The steps above were divided up into two paths, as shown in Figure 4. Steps 2 and 3 were completed through path 1, and step 4 was completed through path 2.

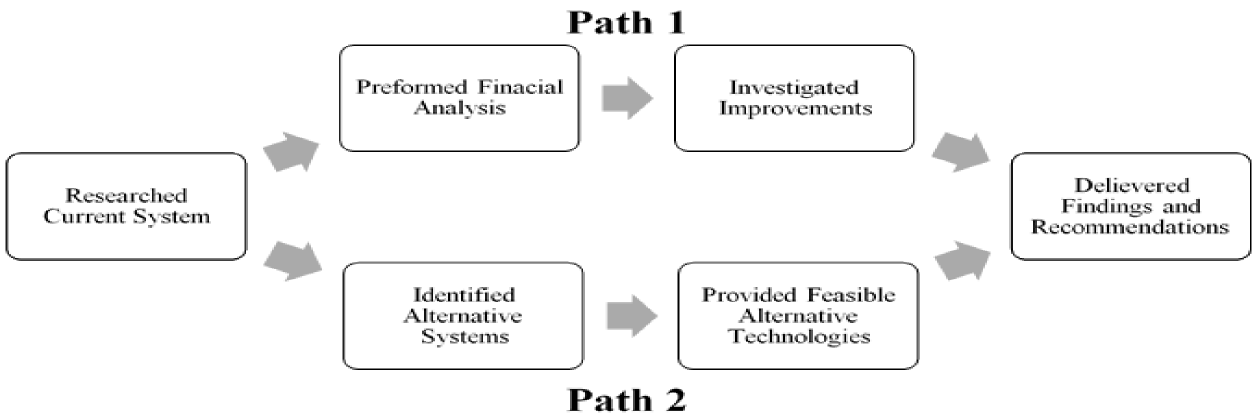

Figure 4: Methods Map for Project Including Two Paths of Investigation

3.1. Researched the Existing RUCK® CFT System

The first project objective was to learn more about the RUCK system already in place at Lunenburg. Therefore, we visited the Woodlands Condominium Development and completed a site visit report, found in Appendix A. During the visit, we walked through the community and discussed its relationship to the Hickory Hills Lake, which provided information on why they need a reliable effluent stream leaving the RUCK system. We examined the RUCK system to gather information that differed from the schematic plans. Lastly, we collected information on areas of concern and talked about potential problems from the stakeholders that highlighted the areas of focus in the project. Along with the site visit, the group conducted research on the current system in place. We looked at documents and specifications on the RUCK system provided by the sponsors to understand past issues of noncompliance, past problems with the system, and current successes of the system documents included the O&M manual, DMRs, and the Mount Hope Engineering's *Evaluation of Wastewater Facilities for Woodlands Village at Hickory Hills*.

3.2. Performed a Financial Analysis of the RUCK® CFT System

After looking at the current system we then looked at the financial situation. We were allowed access to the condominium's budget and finances. We compiled and calculated the past three years' worth of expenses, and made estimations for the coming year based on previous costs and changes that had already made to the system. From there expenses could be categorized based on whether they could be decreased, eliminated, or if they would remain the same regardless of changes to the system.

3.3. Investigated Ways to Improve the Current System

After we felt that we had a more complete understanding of the system and its subsequent cost we were able to examine areas in need of improvement. We looked at the possibility of increasing or decreasing the system size to reduce cost. We investigated places in which the RUCK was not efficient and what could be done to improve them, as well as, the feasibility of their current number of units.

In order to identify cost-cutting retrofits, we looked at the financial analysis and focused on the costs that could be changed, or eliminated and researched ways to incorporate these action in our recommendations They were critiqued based on the feasibility of implementation, possibility of savings, and their need for change. This was the first path the group investigated in order to provide sufficient recommendations for our sponsor.

3.4. Identified Alternative Wastewater Treatment Systems

Project Objective 4 started us on the second path of our methods, where we researched other available wastewater treatment technologies with potential to be suitable for the Woodlands site. The process of researching other wastewater treatment started with understanding the needs of the condominium. Conditions such as type of soil, surrounding environment, process volume, EPA regulations, and effluent requirements were used as criteria when looking at new technologies. Research was done on various existing and emerging systems. The positives and negatives of each new system was then compared to Woodlands' needs, then the systems were evaluated based on operating costs, installation costs, feasibility of installation, and availability of operators in the Lunenburg Area if the information was available.

3.5. Selected a Feasible Alternative System for Woodlands Village

We then looked at the comparisons of the different technologies, and how they compared to one another as well as to the current system. It was imperative to determine how much the system would cost and the breakdown of that cost. To do this we contacted companies over the phone and through email. We also looked at what cost could be eliminated if we kept parts of the old system, and what the cost of removal would be roughly. Essentially the group investigated whether it was feasible to install another system as opposed to keeping the RUCK at Woodlands Village.

3.6. Presented Final Recommendations to the Community at Woodlands Village

The final objective was to educate the Woodlands Village community and the Facilities Committee on the findings of the project. There were two ways in which we presented the project findings to the community and board members. One was through an oral presentation conducted at the Facilities Committee's monthly meeting which occurred on April 13, 2017. The group also presented preliminary findings and discussed feedback with the Facilities Committee on January 26, 2017. This provided the community with the opportunity to listen to our recommendations and ask questions that interest or concern them. Thus, it provided opportunity for them to understand the impact this project had on their homes and community. The other presentation of findings came in the form of a cost analysis report. The report outlines multiple alternatives along with the benefits and negatives of each system. It also provided the final recommended which we feel is the best fit for the Woodlands Development. This final recommendation incorporated and addressed concerns brought about in the presentation to the board and community. The cost analysis is a standalone product, which can be found in the Results section of the report. It provides stakeholders with information on the systems without the need of the full report.

Overall, the six objectives work towards the goal of reducing high community wastewater treatment expenses and plan for future expansion in the development by providing information on the current RUCK system, determining its efficacy, examining other alternatives to wastewater treatment, analyzing the cost and treatment effectiveness of these systems, determining the effect of expansion of the development, and educating the community on the findings (Carlson and others 2013).

4. Results and Findings

After having researched and analyzed the current system, the surrounding areas, different wastewater treatment technologies and possible retrofits, the Woodlands Village MQP team was able to provide analysis and results in order to provide recommendations. This section outlines our findings involving cost analyses, design descriptions, and possible areas for improvement within the current system.

4.1. Analysis of Existing RUCK CFT System

The following sections provide an inventory of the existing RUCK CFT wastewater treatment system at Woodlands Village and an evaluation of the potential for infiltration and inflow into the RUCK system. The RUCK CFT system began operation 1998 and continues to be the only method of wastewater treatment utilized by Woodlands Village.

4.1.1. Inventory and Description of System

Septic Tanks

The wastewater treatment system at Woodlands Village is atypical because at least 20 of the 46 units share or have their own septic tanks. These 1,500, 2,000, and 4,000-gallon septic tanks are remnants from the original onsite treatment systems required by the local Board of Health.

The single-family homes on Iris Ct. share one 4,000-gallon septic tank. Seven of the eight detached units on Trillium Ct. and the single-family dwelling at 130 Royal Fern Dr. have their own septic tanks. Four of the duplexes have their own septic tanks, but the locations of only three septic tanks are known. The Facilities Committee is in the process of locating the other septic tank with the help of the Nashoba Health District. Septic tanks of known locations are pumped annually. Since a portion of the solids in the wastewater settles in septic tanks, influent to the wastewater treatment system (WWTS) is unusually rich in ammonia due to a large proportion of urine in the blackwater.

Lift Stations

Effluent flows by gravity either directly from homes or from septic tanks to raw lift (pump) stations. Since the condominium is situated on relatively flat ground, four lift stations are needed to convey wastewater from low-lying areas within the community through two force mains to the treatment facility. Based on their location, the four lift stations are referred to as the 108 Royal Fern Dr. Pump, the Iris Ct. pump, the Wintergreen Ct. pump, and the 130 Royal Fern Dr. pump. Each pump station has its own electric meter.

Figure 5: Main Lift Station

The Iris Ct. lift station conveys effluent from multiple units to the 108 Royal Fern Dr. station. There is a septic tank preceding the pump station to collect solids before wastewater reaches it. The pump station contains two submersible pumps. The level of wastewater in the pump chamber is controlled by float switches, which turn the pumps on and off. A high-water level alarm will sound if the water level in the chamber becomes too high due to pump failure.

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The Wintergreen Ct. Pump station conveys effluent from multiple homes to the 108 Royal Fern Dr. station. This lift station is a Purestream pneumatic ejector system that utilizes two pots. Once effluent fills one pot, it is discharged from the pot via compressed air into the sewer collection system. No known septic tanks precede the Wintergreen Ct. pump station. This lift station has a natural gas-fired backup generator.

The 108 Royal Fern Pump Station receives wastewater from the Wintergreen Ct. and Iris Ct. pump stations as well as other units. Some of the units feeding directly to the 108 Royal Fern Dr. pump station have septic tanks. This pump station is the final lift station that conveys wastewater from all but one of the 46 units to the treatment facility. The station has dual 5 HP submersible pumps, which are controlled by float switches. A high-water level alarm will sound in the event of pump failure. This raw lift station is equipped with a natural gas-fired emergency generator.

The fourth pump station located at 130 Royal Fern Dr. serves a detached single family unit. Wastewater is pumped directly from the single-family home to the WWTS via a pipe separate from the main wastewater pipe. A septic tank is located before this pump station. The 130 Royal Dr. station contains two 5-HP submersible pumps, which are controlled by float switches. A high-water level alarm will sound in the event of pump failure.

30,000-Gallon Anoxic Tank and Flow Equalization Tank

In the wastewater treatment system, wastewater is received into a 30,000-gallon anoxic septic/pre-treatment tank (Description of Woodlands Wastewater Treatment System, 2016). In the first portion of the concrete tank, primary settling of solids and removal of floatable solids occurs (Holmes and McGrath, 2016). The sludge that accumulates on the bottom of the settling tank is pumped periodically and disposed of offsite (Holmes and McGrath, 2016).

Figure 6: Covers on the Anoxic Tank and FET

An 11,000-gallon flow equalization tank (FET) is connected to the settling tank by an interior baffle (Holmes and McGrath, 2016). Since the amount of wastewater produced by the Woodlands Village community varies throughout the day, the purpose of the FET is to attenuate fluctuations in effluent flow rate. The FET contains two 7.5 HP submersible pumps that periodically and evenly distribute flow to two RUCK filters. These pumps are controlled by two float switches that turn the pump on and off. A third flow switch will set off an alarm if the water level within the FET becomes too high. Typically, each valve pumps to one of the RUCK filters. In the event of pump failure or maintenance, valves can be used to redirect flow through the other pump to the opposite RUCK filter.

To adjust alkalinity and prevent a reduction in the effluent pH during the treatment process, sodium bicarbonate is added to the flow equalization tank (Description of Woodlands Wastewater Treatment System 2016). The operator adds one 50-lb bag of sodium bicarbonate to the FET three times each week.

RUCK Filter

From the flow equalization tank, wastewater is evenly distributed to two RUCK® CFT filters that operate in parallel. The two filters are located underground, beneath a mowed grass field. They are approximately 43' by 95' in size (Holmes and McGrath, 1999).

Figure 7: The RUCK Filters

In the RUCK filters, effluent trickles downward through alternating layers of sand and stone with a plastic insert between each layer (Holmes and McGrath, 2016). These modified sand filters act as trickling filters, which contain microbial communities that consume organic matter (BOD) and convert ammonia (NH_4^+) to nitrate (NO_3^-). To perform these processes, the bacteria need oxygen. Consequently, the filters are vented in eight locations to provide an oxygenated environment for the biological oxidation and nitrification processes (Holmes and McGrath, 1999). After passing through the filter media, effluent collects in the filter underdrain on an impermeable membrane and flows by gravity to the interim pump chamber. There are inspection ports at the end of each RUCK filter in the connection line leading to the interim pump chamber, which allow the operator to collect samples of effluent leaving the RUCK filter.

Filter #2 failed in 2009 and therefore both filters were rebuilt. (Description of Woodlands Wastewater Treatment System, 2016). There have not been any issues with the filters since their replacement due to more regular maintenance of the filters.

Interim Pump Chamber

Effluent flows by gravity from the filters into the 2,500-gallon interim pump chamber (Holmes and McGrath, 2016). There are two 1.0 HP submersible pumps in the chamber that feed effluent to the denitrification tanks. These pumps are controlled by float switches (Mount Hope Engineering, 2013). A high water-level alarm will sound in the event of pump failure. There is a flow totalizer on the discharge line from the interim pump chamber that is used to record the total daily flow rate through the system (Mount Hope Engineering, 2013).

Heating Tank

A portion of the effluent from the interim pump station is first diverted to the 1,500-gallon heating tank before flowing to the first denitrification tank (Mount Hope Engineering, 2014; Description of Woodlands Wastewater Treatment System 2016). For denitrification to occur properly, the effluent temperature in the denitrification tanks must be maintained above 58°F to keep the denitrifying bacteria active and healthy (Holmes and McGrath, 2016). As a result, the diverted effluent stream is typically heated from October through April in the heating tank by a heating coil. The furnace, which heats the coil, is located inside the chemical feed control room. The furnace turns on at 65°F then turns off at 75°F (Holmes and McGrath, 2016). The flow rate of effluent that is diverted to the heating tank cannot be controlled. Instead, the temperature within the following denitrification tanks is controlled by adjusting the furnace heating coil temperature (Mount Hope Engineering, 2013).

Denitrification Tanks

Effluent flows from the heating tank and directly from the interim pump chamber to the first of two 4,000-gallon denitrification tanks (Holmes and McGrath, 2016). The anoxic denitrification tanks are set in series and contain a plastic fixed film media, Denite, which provides a surface for the growth of denitrifying bacteria (Mount Hope Engineering, 2014). In the absence of oxygen, denitrifying bacteria convert nitrates (NO_3^-) to harmless nitrogen gas (N_2), which can then be vented to the atmosphere. A 20% methanol solution is added to the first denitrification tank to supply food (carbon) to the bacteria via a small peristaltic metering pump (Holmes and McGrath, 2016). MicroC was originally used as a carbon source. However, adjusting the levels of MicroC to maintain appropriate concentrations of nitrogen and BOD in the effluent proved too difficult. In March 2015, the carbon source was switched to 20% methanol. Initially, methanol was fed to the first denitrification tank continuously, independent of the effluent flow rate and nitrate concentration. As of 2017, the methanol feed pump only operates when the interim pump chamber is on, which ties the dose of methanol to the flow rate of effluent into the denitrification tanks. The methanol is stored in 55-gallon drums in a spill containment area inside the treatment building (Holmes and McGrath, 2016). This storage system is located 20 feet from any potential ignition source (live wires, etc.) to prevent chemical fires.

Over time, excess bacteria will slough off and accumulate as sludge in the bottom of the denitrification tanks. The level of sludge within the tank must be monitored so that it does not exceed one-third the depth of the tank. Filters at the end of the denitrification tanks are used to prevent solids (sloughed off bacteria) from entering the effluent. These filters are power-washed monthly.

Final Pump Chamber

The treated wastewater flows by gravity from the second denitrification tank to the final effluent pump chamber. There are two 1.0-HP submersible pumps within the final pump chamber that are controlled by float switches. A high water-level alarm is also located in the final pump chamber. Although the effluent tee filters in the denitrification tanks trap most solids, solids can still settle within the pump chamber. Therefore, the final pump chamber must be monitored for the accumulation of solids (Mount Hope Engineering, 2013). The final pump chamber stores and periodically discharges the treated effluent to the soil adsorption system (leaching fields) (Holmes and McGrath, 2016).

Soil Adsorption System

From the final pump chamber, effluent is pumped to a subsurface leaching (soil adsorption) system. The subsurface leaching fields contain four 152-foot lines of deep concrete leaching galleys surrounded by four feet of stone on each side. The galleys are set in a gravel bed and are vented to the atmosphere. The final effluent pumps evenly distribute effluent to two of the four galleys at a time. Effluent flows through 2-inch pipes in the center of each galley that have "T" sections every six to eight feet to allow effluent to evenly distribute along the length of the trench. Treated effluent then percolates outward through the gravel and surrounding soil, replenishing the groundwater in the underlying area.

Wastewater Treatment Building

Control panels for the treatment system's pumps are located in the lab/control room of the treatment building along with a bench for reporting and field testing. In case of power failure, there is a gas generator in the main room of the WWTS building to provide backup power. In the main room, there is also a bathroom, methanol storage, and a methanol spill containment area. The methanol feed pump, the flow meter display, heating tank furnace, and the intermediate control panel are located in the chemical feed room at the rear of the treatment building.

Other Components

The facility has a cellular alarm system that monitors for high water conditions, room temperature, and intrusions. Although there are seven pumps at the WWTS, only two pumps have hour meters to indicate how long the pump has been running. Since most of the pumps operate in tandem, it is difficult to determine when a pump has failed when there is no hour meter on the pump.

Effectiveness of System

Currently the RUCK ® CFT System is currently working and has not had any issues with non-compliance since 2015. Therefore, the system is effective and successful. The issues surrounding the system involve the high operation and maintenance costs. If Woodlands Village continues to use the RUCK ® CFT System, they would not be in danger of non-compliance.

4.1.2 Infiltration and Inflow

A concern raised by the Woodlands Community was the possible influence of infiltration and inflow into the wastewater treatment system. Based on the weather through 2015, there was no correlation found. This implies that infiltration and inflow do not have any significant impact on the monthly and daily flows of the system. An example of this can be seen through the month of June, shown in Table 2, which had the highest precipitation with a total of 6.2 inches. June had the lowest recorded total gallons entering the system, with a total of 88,000 gallons.

Table 2: Precipitation versus how many gallons entering the WWTS tanks per month in 2015 (The Weather Company, 2017)

Month in 2015	Total Precipitation (in.)	Gallons Entering WWTS
January	2.77	110,430
February	2.29	91,380
March	1.74	114,466
April	2.3	118,857
May	0.86	96,023
June	6.19	87,572
July	2.31	96,215
August	1.92	102,252
September	4.77	166,039
October	1.95	90,436
November	2.44	89,949
December	4.81	93,044

4.2. Analysis of Costs Associated with the Existing RUCK Treatment System

The expenses of the existing wastewater collection and treatment system at Woodlands Villages were determined by analyzing the condominium's financial records from January 2015 through December 2016. For this analysis, it was assumed that all invoices paid by the facility were included in the expense reports. Some invoices from the last few months of 2016 that were paid after January 2017 may not be included. Table 3 provides an itemized list of all major RUCK facility expenses associated with collection of the wastewater, treatment, and sludge disposal in 2015 and 2016. The expense items are listed according to 2016 expenses from greatest to least.

Table 3: Total cost each year broken down by type and amount for WWTS at Woodlands Village

	Percent of Total Cost Each Year	
Expense	**2015**	**2016**
Pump Repairs/Maintenance	15.3%	21.3%
Contracted Operations	10.9%	17.8%
Lab Testing/Analysis	8.2%	10.7%
Engineering Services	2.9%	9.1%
Electricity	10.3%	8.7%
DEP Permits	8.8%	7.8%
RUCK Repairs	9.5%	6.3%
Methanol	3.7%	3.9%
Replacement Reserve	4.2%	3.7%
Alarms/Fire Suppression/Security	7.8%	3.4%
Gas	3.0%	3.3%
Sodium Bicarbonate	0.9%	2.2%
Mowing Field over Ruck	1.1%	1.0%
Septic Pumping	3.0%	0.8%
Treatment Building Expenses	0.0%	0.0%
Telephone Lines	1.0%	0.0%
MicroC	1.9%	0.0%
DEP Fines	5.9%	0.0%
Switch to Methanol	1.5%	0.0%
Total Cost	**$ 94,467**	**$ 107,014**

The total cost of operating and maintaining the WWTS in 2015 determined using the facility's financial records was approximately $94,467. However, according to the Woodlands Wastewater Expense Comparative (1/23/17) prepared by Woodlands Village, the total costs associated with the wastewater conveyance and treatment system was $107,090. Discrepancies in these values may be due to the fact that:

1. For convenience, the cost of electricity for the street lights (about 12% of the electric costs or $1,300 per year) is included the Wastewater Expense Comparative;
2. Not all invoices may be included in the financial reports; and
3. In the calculations, expenses were organized according to the invoice date rather than the payment date (i.e. some large expenses that were billed in 2014 may have been paid in 2015, but were not included in our calculations).

However, our projected total cost for 2016 of $107,014 more closely aligns with the total 2016 cost of $104,563 from the Woodlands Wastewater Expense Comparative (1/23/17) document. The following sections discuss the expenses associated with the RUCK system in 2015 and 2016.

For the cost analysis, current expenses associated with Woodlands Village WWTS were grouped into two categories: those that are specific to the RUCK® CFT technology and those that are independent of the treatment technology used. A third group of expenses are no longer applicable to Woodlands Village. The following diagram illustrates which expenses would remain the same regardless of the treatment technology used by the facility.

4.2.1. RUCK® CFT Specific Expenses

Six categories of expenses are specific to the RUCK® CFT technology: repairs to the RUCK system, chemicals,~48% of the electricity bill,~77% of the gas bill, mowing over the RUCK filters, and treatment building expenses. Table 4 summarizes the RUCK-specific expenses in 2016.

Table 4: RUCK costs in 2015 broken down by expense type

RUCK Specific Expenses (2016)	% of Total Expenses	Cost
RUCK Repairs	6.3%	$ 6,724
Chemicals	6.1%	$ 6,511
RUCK Electric Use	4.5%	$ 4,819
RUCK Gas Use	2.5%	$ 2,703
Mowing over RUCK Filters	1.0%	$ 1,050
Treatment Building Expenses	0.0%	$ 18
Total	**20.4%**	**$21,825**

In 2015 and 2016, RUCK-specific expenses accounted for about 26% and 20% of the total costs, respectively. These six categories are discussed in further detail below, from greatest to least expensive.

RUCK Repairs

In 2015, repairs to the RUCK system cost Woodlands Village $8,962 or 9% of the total cost associated with the wastewater treatment system. Repairs to the RUCK system included repairs to the boiler, flow equalization tank, manhole covers, and generator as well as the installation of sensors, a thermocouple lines, and a backflow preventer.

In 2016, repairs to the RUCK system cost Woodlands Village $6,724 (6% of the total cost in 2016). This sum includes repairs to the generator, maintenance on a junction box, a new thermocouple, a new level float, and replacement tubing.

The repairs needed to the RUCK system in 2015 and 2016 were relatively minor. No major piece of equipment failed and needed replacing. However, in 2009, after one of the RUCK filters failed, both filters were rebuilt for $161,000. When analyzing the expenses associated with repairing and maintain the RUCK CFT technology, it is important to consider the potential for major costs associated with equipment failure of the RUCK system. However, no matter the treatment technology in place, repairs to the system are inevitable.

Chemicals

Two chemicals are frequently added to the wastewater treatment system: methanol and sodium bicarbonate. Methanol is added to the first denitrification tanks to provide "food" for denitrifying bacteria. Sodium bicarbonate ($NaHCO_3$) is added to the flow equalization tank to protect against a reduction in pH due to the frequent addition of acids. The quantity of methanol and sodium bicarbonate that must be added to Woodland Village WWTS depends on the chemical reactions that take place in the system, which in turn depend on the treatment technology. As a result, this expense category is characterized as RUCK-specific. However, it is likely that other treatment technologies would require the addition of a carbon source (i.e. methanol) or alkalinity (i.e. sodium bicarbonate). Overall, chemical purchases cost Woodlands Village $6,104 in 2015 and $6,856 in 2016 (7% of the total expenses for both years). The two chemicals are discussed separately below.

Carbon Additive

In March 2015, the system switched from Micro C to methanol as a source of carbon for denitrifying bacteria. Therefore, MicroC is no longer an expense of the system (although it is recommended that Woodland Village disposes of the Micro C that remains on-site). Switching to methanol required the purchase and installation of a methanol pump, flammability signs, and a spill containment system, resulting in a one-time-expense of $1,406 in 2015.

Figure 8: Methanol Tanks at Woodlands Village

Since switching to methanol, Woodlands Village has purchased on average two 55-gallon drums of 20% methanol solution for $346 total each month. Occasionally four drums were purchased in a month, while in other months, none were purchased at all. In 2016, Woodlands Village spent $4,180 on methanol (4% of the total WWTS expenses).

Sodium Bicarbonate

Beginning in September of 2015, Wastewater Environmental Management began adding one 50 lb. bag of sodium bicarbonate three times a week to the 11,000-gal flow equalization tank (FET) at the WWTS to provide alkalinity. Alkalinity in wastewater helps resist changes in pH from the addition of acids (Metcalf & Eddy 2003, pg. 59). It is essential that the wastewater at Woodlands Village can resist changes in pH since, according to Woodland Village's groundwater discharge permit, the pH of the effluent must be between 6.5 and 8.5 at all times.

Sodium bicarbonate costs approximately $0.43 per pound. Since September 2015, Woodlands Village has spent approximately $214 each month on sodium bicarbonate. In 2016, the condominium purchased 109 50-lb bags of sodium bicarbonate for $2,331. This accounted for 2% of the total system expenses.

Electric Use of RUCK System

Five separate electricity accounts service the wastewater collection and treatment system. Four electricity accounts are associated with each of the four lift stations. The fifth account is associated with the treatment facility pumps and building. In 2015, the cost of electricity for the five accounts was $6,501 (10% of total costs). This expense increased to $9,276 (9% of total expenses) in 2016.

In 2016, 48% of the electricity was consumed by the equipment, alarm system, and lights located at the treatment site. The cost of electricity used at the treatment building and by the RUCK system in 2016 was $4,819.

Gas Use of RUCK System

Three gas accounts are associated with the RUCK treatment system. Two accounts are associated with the emergency generators located at two of the raw lift stations. One account is associated with the Peerless furnace and emergency generator located in the treatment building. In 2015, gas cost the treatment facility $2,871 (3% of total costs). In 2016, this expense rose to $3,491, but still contributed to 3% of the total system expenses.

In 2016, approximately 77% of the gas costs were associated with equipment within the treatment building. RUCK-specific gas use cost Woodlands Village $2,703 in 2016.

Mowing the Field over the RUCK Filter

During the 2013 inspections of the treatment facility by MassDEP, the inspector discovered that the ground covering the RUCK filters contained deep depressions, animal burrows, and excessive vegetative growth. Since that time, Woodlands Village has hired Moisan Bros Landscaping to mow the fields over the RUCK filters during the summer. In 2015 and 2016, mowing cost the condominium $1,075 and $1,050, respectively. This expense contributed to 1% of the total system expenses in 2015 and 2016.

Mowing is characterized as a RUCK-specific expense because maintaining the ground over the RUCK filters is important for the successful operation of the filters. Other treatment technologies may not require such maintenance.

Treatment Building Expenses

Expenses associated with maintaining and repairing the treatment building are characterized as RUCK-specific because if another treatment system were installed, a much smaller treatment building could be constructed. A smaller treatment building would be much less expensive to maintain. Due to the placement of RUCK controls on two ends of the large building, the existing structure must remain while the RUCK system is in place. Fortunately, there were no significant expenses associated with maintaining the treatment facility building in 2015 and 2016. However, it is important to note that there are occasionally significant expenses associated with painting, replacing siding, re-shingling, and repairing the treatment building itself. Due to permit constraints, the building cannot be used for other purposes, such as storage for lake-related equipment.

4.2.2 Expenses Associated with Any Treatment Technology

Ten categories of expenses are not specific to the RUCK® CFT technology: repairs to the lift stations, hiring an operator, lab testing and analysis of the wastewater, engineering services, MassDEP permits,~51% of the electricity bill, the RUCK replacement reserve, alarms/suppression/and security costs,~23% of the gas bill, and septic tank pumping. Table 5 summarizes the expenses that would be associated with any treatment technology in 2016.

Table 5: Treatment technology costs broken down by expense type

Any Treatment Technology Expenses (2016)	% of Total Expenses	Cost
Lift Station Repairs/Maintenance	21.3%	$22,838
Contracted Operations	17.8%	$19,008
Lab Testing/Analysis	10.7%	$11,475
Engineering Services	9.1%	$9,739
DEP Permits	7.8%	$8,320
Lift Station Electric Use	4.2%	$4,457
Replacement Reserve	3.7%	$4,000
Alarms/Fire Suppression/Security	3.4%	$3,657
Lift Station Gas Use	0.7%	$788
Septic Pumping	0.8%	$861
Total	**79.6%**	**$85,142**

In 2015 and 2016, RUCK-specific expenses accounted for about 74% and 80% of the total costs, respectively. These ten categories are discussed in further detail below, from greatest to least expensive.

Lift Station Repairs

Repairs to the four lift stations are the most significant expense associated with the wastewater treatment system at Woodlands Village. In 2015, repairs and maintenance to the lift stations, performed exclusively by Whitewater Inc., cost Woodlands Village $14,483 (15% of the total costs). This expense rose significantly to $22,838 in 2016 (21% of the total costs).

Regardless of the treatment technology used at Woodlands Village, lift stations are needed to convey wastewater uphill to the treatment facility. Unfortunately, high costs associated with pump repairs are unavoidable. Pumps fail frequently because they contain several moving parts. In fact, pumps fail so frequently that almost all are installed in duplicate. As a result, pump maintenance and repairs must be conducted often.

Cost of Contracting an Operator

A Grade 4 wastewater treatment system operator visits Woodland Village WWTS every weekday (except holidays) to record effluent flow, monitor operating conditions, collect samples for lab analysis, and perform in-house testing (Holmes and McGrath, 2016). In 2015, the cost of hiring an operator through Waste Water Environmental Management, Inc. was $10,281 (11% of the total costs). At the start of 2016, Waste Water Environmental Management increased their costs by almost 75%, partly due to an increase in staffing hours. This increase in staffing hours was stipulated by the newly revised O&M manual dated Oct. 29th 2015. As a result, in 2016, the cost of hiring operations rose to $19,008 or about 18% of the facility's total costs.

According to 314 CMR 12.04(3), all wastewater treatment facilities must be staffed with adequate operation personnel to ensure that the system is properly operated at all times. The minimum number of shifts and personnel per shift is determined by the facility, but must be reviewed and approved by the MassDEP. Table 6 describes the minimum number of coverage hours recommended by the MassDEP for small wastewater treatment facilities in good operating condition (Massachusetts Department of Environmental Protection Division of Watershed Permitting, 2014.).

Table 6: Minimum coverage required by Woodlands Village WWTS shown by plant grade and treatment process

Minimum Coverage at Permitted WWTS		
Plant Grade	**Treatment Process (assumes denitrification & disinfection)**	**Min. coverage (hrs./month)(1)**
3	No denitrification or disinfection requirement	20 (2)
4	Rotating Biological Contactor	40
4	Membrane Biological Reactor	40
4	Sequencing Batch Reactor	40
4	FAST™ Treatment	40
4	Bioclere™ Treatment	40
4	Amphidrome™ Treatment	40
4	Ruck™ Treatment	40
	Any process with Reclaimed Water Operations	50
5 or higher		50
(1) Does not include routine labor work not requiring operator certification.		
(2) 25 hours if disinfection is required		

As shown in Table 6, all Grade 4 treatment systems providing denitrification or disinfection should have at least 40 hours of operator coverage per month. Since Woodlands Village requires a WWTS that provides denitrification, any feasible alternative treatment system would require approximately the same level of operator coverage as the existing RUCK® CFT system. Therefore, it is unlikely that replacing the RUCK system could reduce the expenses associated with contacting an operator. However, the MassDEP guidance recommends an increase in operator coverage of 10-20% for facilities that are more than 15 years old due to increased need for preventative maintenance. As a result, added expenses corresponding to the operation of an aging facility may be avoided by the installation of a new system.

Lab Testing and Analysis

In 2015, lab testing and analysis for the WWTS, performed by Wastewater Environmental Management, Inc. cost Woodlands Village approximately $7,776 total (8% of total 2015 costs). In 2016, lab testing and analysis expenses rose nearly 50% to $11,475, accounting for 11% of the total expenses. This drastic increase in laboratory expenses was partly due to an increase in the number of tests performed by the operator. Beginning in September 2016, Wastewater Environmental Management began performing extra testing as stipulated in the newly revised O&M manual dated Oct. 29, 2015.

Monitoring and reporting of the quality of the influent and quality and quantity of the effluent is required by Woodland Village's groundwater discharge permit. According to the permit, the $BOD_{5,}$ TSS, Total Solids (TS), and Ammonia content of the influent must be sampled monthly; the flow and pH of the effluent must be recorded daily; the $BOD_{5,}$ TSS, Total Solids (TS), Ammonia, Nitrate, Total Nitrogen, Oil and Grease, Surfactants, and Fecal Coliform content in the effluent must be tested monthly; and the VOCs in the effluent must be monitored annually. (Groundwater Discharge Permit). Additionally, the permit requires sampling of upgradient and downgradient monitoring wells. The pH, Static Water Level, Specific Conductance in the wells must be recorded monthly; Nitrate and Total Nitrogen must be recorded quarterly; and VOCs must be recorded semiannually. These monitoring and reporting requirements would likely remain the same, regardless of the Grade 4 treatment system in place at Woodlands Village.

Engineering Services

In 2013, Mount Hope Engineering was hired to revise Woodland Village's Operations & Maintenance (O&M) Manual. This service was required because the MassDEP requested that Woodlands Village provide an updated version of the O&M Manual following a site inspection (Pease, personal communication, December 12, 2016). This revision process took several years. In 2015, Mount Hope Engineering charged the condominium $2,765 for conversations with MassDEP and revisions to the manual. In 2016, Mount Hope's engineering services cost Woodlands Village another $540.

The application to renew Woodland Village's groundwater discharge permit was due on 1/22/17. During 2016, the engineering firm, Holmes and McGrath, Inc. was hired to prepare the application as well as a new Operations and Maintenance (O&M) manual. These engineering services from Holmes's & McGrath cost Woodlands Village $9,163. In 2016, the condominium spent $9,739 to hire engineering consultants, which contributed 9% of the total expenses.

Fortunately, according to the current groundwater discharge permit, a permit term lasts 5 years. (The last permit term was extended by four years due to Permit Extension Act signed by Governor Patrick in 2012 (MassDEP, personal communication, October 21, 2012). Therefore, engineering services to renew the groundwater discharge permit will not be needed for at least five years. Additionally, once the O&M manual is approved by MassDEP, Woodlands Village will stop incurring expenses associated with revising the O&M manual. In the future, the manual should be updated by the operator as part of his day-to-day services, which should not result in additional expenses.

DEP Permits/Annual Compliance Fees

Wastewater Treatment Facilities in Massachusetts must pay annual compliance fees, which provide MassDEP with adequate resources for the state's inspection and monitoring programs (Groundwater Discharge Permits: Frequently Asked Questions, 2017). The cost of these fees depends on the type and size of the facility. Facilities with permits authorizing a groundwater discharge between 10,000 – 50,000 gpd (exclusive) must pay an annual fee of $8,320 (*Annual Compliance Assurance Fees*, 2017). This compliance fee accounted for 9% of the total cost of the system in 2015 and contributed to 8% of the total costs in 2016. No matter the treatment technology installed at Woodlands Village, the condominium will still have to pay this fee.

On 7/21/2017, Woodlands Village current groundwater discharge permit (#362-3) will expire and must be renewed. The cost to renew the groundwater discharge permit using form BRP WP 12 is $890 (*Schedule of Permit Application Fees and Timelines*, 2017). During the years that a permittee must pay a renewal application fee, the permittee does not need to pay the $8,320 annual compliance fee. As a result, the condominium will save $7,430 in 2017. However, in subsequent years, Woodlands Village must continue to pay the annual compliance fee.

Electric Use of Lift Stations

Regardless of the treatment technology in place, the four lift stations will require energy to convey wastewater uphill to the treatment facility. In 2016, the four lift stations consumed 52% of the electricity used by the entire treatment system and cost Woodlands Village $4,457.

Replacement Reserve Costs

As outlined in the groundwater discharge permit, the permittee must have at least $40,000 available for emergency repairs or replacements for failing wastewater treatment units. This emergency supply must be in the form of a backup fund or a letter of credit from an approved financial institution in Massachusetts. Additionally, the permit requires that Woodland Village maintains a capital reserve account for necessary modifications to the treatment system. As a result, Woodlands Village is required to make annual contributions of $4000 to the cash reserve. In 2015 and 2016, this expense contributed 4% and 3% of the total expenses for their respective years.

Alarms, Fire Suppression, and Security

In 2015, a new alarm system was installed at Woodlands Village wastewater treatment system. This system is equipped with multiple alarms that notify the operator of equipment malfunctions or breakdowns. The treatment facility also contains an automated sprinkler system. In the event of pump failure, power failure, sprinkler flow, sprinkler tamper, low sprinkler pressure, or low temperature, the operator will be automatically called via the alarm system. According to 314

CMR 12.04, all alarms at the treatment facility must be operable and tested semiannually. In 2015, Woodlands spent $7,357 (8% of the total costs) on the installation, service, and testing of the alarm and sprinkler systems. In 2016, these expenses decreased to $3,657 or (3% of the total 2016 expenses). In the upcoming years, expenses associated with alarms, fire suppression, and security are expected to stay approximately the same as in 2016.

Gas Use of Lift Stations

In 2016, gas for the emergency generators for two of the raw lift stations accounted for 23% of the total gas bill. Gas was used only periodically test the emergency generators. Since so little gas is used by the generators, the majority of the gas bill for these two accounts is due to the minimum charge set by National Grid. In 2016, gas for the two generators cost Woodlands Village $788.

Septic Pumping

In 2015, Woodlands Village spent $2,863 for pumping and disposal of sludge from septic tanks by Wind River Environmental and Whitewater, Inc. (3% of total costs). In 2016, septic tank pumping and sludge disposal cost $861, a mere 0.8% of the system's total expenses. No matter the treatment technology used at Woodlands Village, primary settling of solids is unavoidable and therefore the disposal of sludge will be necessary.

Eliminated Expenses

In 2015, the Woodlands Village facility was non-compliant with MassDEP regulations and was required to pay $5,565 in fines. As long as the facility remains compliant with their groundwater discharge permit, this will be a one-time expense. After the installation of a new security system in 2015, the facility's Verizon phone lines were disconnected, eliminating an average monthly expense of approximately $78.

4.2.3 The Main Take-Away

The most significant conclusion from analyzing Woodlands Village's financial reports is that several of the largest expenses associated with operating the system will not change through the replacement of the existing wastewater treatment system. Regardless of the treatment technology used, lift stations are needed to convey wastewater uphill, laboratory testing is required by the MassDEP, and operating costs are associated with all systems. In 2015 and 2016, approximately 74 - 80% of the costs associated with Woodland Village's wastewater conveyance and treatment system would remain the same, regardless of the treatment technology in place.

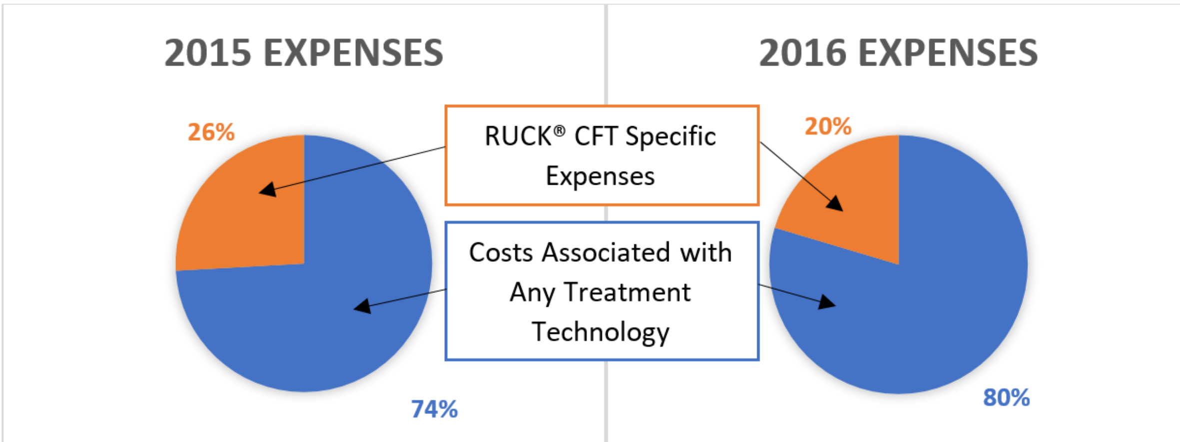

Figure 9: Woodlands Village's WWTS Expenses in 2015 and 2016

Therefore, if the new system did not need repairs, used no electricity or gas, and required no additional chemicals, the maximum potential savings that could be achieved by switching treatment technologies is about $22,000 annually. It is important to note that any new technology installed will need electricity, will incur repairs, and will likely require chemicals and gas. Therefore, the actual savings that would be achieved through switching from RUCK®CFT technology to alternative treatment system would be much less. Any newly installed technology would also include a large installation fee, which would inhibit savings until the installation was paid off.

4.3 Evaluation of Potential Retrofits and Cost-Cutting Actions

Since nearly 80% of the expenses associated with Woodland Village's wastewater collection and treatment system are independent of the treatment technology in place, it appears that the best way to reduce costs is not by replacing the RUCK® CFT Technology. As a result, the possible cost-saving retrofits and actions were investigated. Unfortunately, there are not many aspects of the treatment system that can be modified to reduce expenses. Through analysis of the financial reports and system conditions the following five potentially cost-cutting measures were identified and evaluated:

1. Automation of methanol dosing system.
2. Automation of sodium bicarbonate dosing system.
3. Contracting a cheaper lift station maintenance company or operating company.
4. Increased community awareness regarding what is "flushable" to reduce lift station repairs.
5. Assess the need for heating effluent.

During the course of this project, the Facilities Committee enacted one of our cost-cutting measures by contracting a cheaper operating company.

4.3.1 Measure #1: Automated Methanol Feed

A 20% methanol dilution (a form of organic carbon) is added to the treatment system in the first denitrification tank to provide "food" for denitrifying bacteria. An external carbon source must be added to the system because negligible amounts of organic carbon remain in the effluent following nitrification, which occurs in the RUCK filters (Metcalf & Eddy). Currently, the dose of 20% methanol only depends on the flow rate of wastewater entering the denitrification tank. The following section evaluates the potential savings associated with installing a fully automated methanol dosing system, which would continuously adjust the flow rate of methanol according to the flow rate of wastewater and nitrate concentration. These potential savings are then compared to the cost of installing the retrofit.

Existing Methanol Dosing System

During 2015 and 2016, methanol was added continuously to the first denitrification tank, *independent* of the influent flow rate or nitrogen concentration. On average, two 55-gallon barrels of methanol were purchased each month during this time period. Occasionally four barrels were purchased in a month, while in other months, no methanol was purchased. In 2016, Woodlands Village spent $4,680 on methanol.

The continuous addition of methanol, without regard to the nitrogen content or wastewater flow rate is not efficient. As described in the Operations and Maintenance Manual, the required dose of methanol should be “monitored and adjusted accordingly” and the methanol feed pumps should be “adjusted to deliver the appropriate amount of methanol as required” (Holmes and McGrath, 2016). In January 2017, the operation of the methanol dosing pump changed. The methanol pump is now plugged into the same circuit as the interim pump so that the methanol pump only operates when the interim pump turns on. This way, methanol is only added to the denitrification tanks when influent is also being pumped into the tanks. As a result, the dose of methanol now depends on the flow of wastewater through the system.

However, this method of methanol dosing still does not take into consideration variations in the nitrogen content of the influent. The nitrogen concentration in the wastewater entering the system changes considerably from month-to-month. From January 2015 – December 2016, the monthly average ammonia concentration in the influent ranged from 21.8 mg/L to 48.1 mg/L. Using the current methanol dosing method, if the dose of methanol were calibrated to an influent ammonia concentration of 48.1 mg/L and the actual concentration fell as low as 21.8 mg/L, nearly twice as much methanol would be added as needed.

It is reasonable to suspect that more methanol is being added to the system than is required. If the exact amount of methanol needed for denitrification were added to the system, nearly all of the methanol would be consumed by denitrifying bacteria, resulting in negligible BOD in the effluent. Figure 10 shows that the concentration of BOD in the effluent from July 2014 through August 2016 is not negligible. Therefore, it is likely that excess methanol is being added to the system.

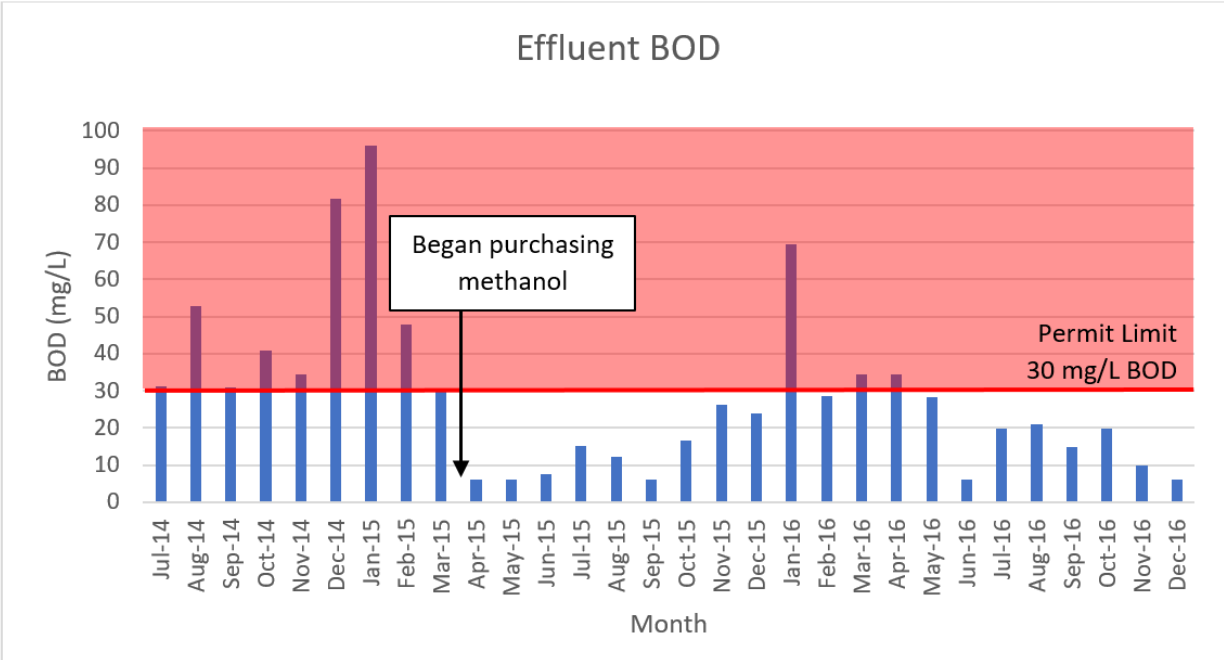

Figure 10: BOD in Effluent between July 2014 and December 2016

Improved control and automation of the methanol dosing system would more closely relate the dose of methanol to the quantity of nitrogen that must be removed. An automated system that delivers a more precise quantity of the methanol would minimize the addition of excess methanol, reducing methanol expenses.

Potential Savings of Automated Methanol Dosing

The potential savings gained by installing an automated system were determined by comparing the theoretical quantity of methanol that should have been added to the system to the amount of methanol purchased by Woodlands Village.

The theoretical amount of methanol that should have been added to the system from January 2016 through December 2016 was determined from the total amount of ammonia that entered the treatment system (Holmes and McGrath, 2016). The mass of ammonia that entered the system each month was found from the total volume of wastewater that passed through the system and the average concentration of ammonia in the influent. According to Tim Holmes and McGrath of Holmes and McGrath, 4 mg/L of methanol should be added per mg/L of nitrogen to be removed. Based on this dosing relationship, the total amount of 20% diluted methanol that should have been added to the system each month was calculated. Including shipping and taxes, the methanol purchased from Callahan Chemical Company costs $3.15 per gallon. At this price, the total cost of methanol, if an automated dosing system were installed, was calculated. Appendix C shows the sample calculation that was used to find how much 20% methanol was needed for January 2016 and the associated cost. Given a 24-hour composite NH_4-N concentration of 39.2 mg/L in the influent, the required concentration of methanol (CH_4) was 158.4 mg/L of CH_4. The required volume of 20% methanol per liter of effluent was $1.00*10^{-3}$ liters. The total volume of 20%

methanol needed for January 2016 was 166 gallons. The total cost of methanol in January 2016 would have been: $524.28

In order to calculate the savings that could be achieved by only adding as much methanol as needed via an automated system, the following assumptions were made:

1. Methanol is currently used at the rate at which it is purchased.
2. The ammonia concentration found using a 24-hr composite sample in the monthly DMR is truly representative of how much ammonia enters the system. However, from January 2015 through December 2016 ranged between 22 mg/L – 48 mg/L. It is possible that the 24-hr composite sample is not a true monthly average.
3. The influent flow rate equals the effluent flow rate.

Table 7 compares Woodlands Village's actual methanol expenses to how much the association would have paid for methanol if the chemical were added by a fully-automated dosing system.

Table 7: Methanol costs for the first year of operation and for 2016

	First Year (Mar. '15 – Mar. '16)	2016 (Jan. '16 – Dec. '16)	Annualized Total (Mar. '15 – Dec. '16)
Purchased Methanol	$ 4,503	$ 4,180	$ 4,587
Methanol Added as Needed	$ 3,902	$ 4,347	$ 4,460
Savings	$ 601	$ (167)	**$ 127**

Assuming that the condominium used methanol as quickly as they purchased it, in the first year that Woodlands Village began purchasing methanol, the condominium would have saved approximately $650 by adding methanol in proportion to the amount of ammonia entering the system. However, in 2016, Woodlands Village purchased less methanol, resulting in no savings if an automated system were installed. It is likely that the condominium purchased excess methanol in 2015 and therefore did not need to purchase as much in 2016. Therefore, the annual savings of **$127** since Woodlands Village began using methanol best reflects the expected savings on methanol from adding an automated system. These savings calculations assume a constant ammonia concentration for an entire month. If the flow of methanol was adjusted continuously using an automated system, the savings could be even greater.

It is important to note that the savings were calculated based on Woodland Village's purchase of methanol in 2016, when the methanol dose was not tied to the effluent flow rate. Now that the methanol dose corresponds to the effluent flow rate, it is likely that Woodlands Village will add less and therefore purchase less methanol. Consequently, the annual savings achieved by installing an automated system may be less than $127.

However, adding only as much methanol as needed using an automated system reduces the potential for the facility's effluent to violate the groundwater discharge permit. If not enough methanol is added to the system, the total nitrogen content in the effluent may be too high. If too much is added, organic content (BOD) may be too high. If Woodlands Village were to violate the groundwater discharge permit limit, the association could incur a fine from MassDEP of about $5,565 (the penalty from the last Administrative Consent Order).

Automated Methanol Dosing System Design

In order to fully automate the methanol dosing process, the following items would need to be purchased and installed:

1. A programmable logic controller (PLC) and its electrical connections/software,
2. A nitrate sensor, and
3. A new peristaltic methanol feed pump and associated piping (may be required).

In this design, the dose of methanol would depend on the concentration of nitrate (NO_3^-) exiting the RUCK® CFT filters instead of the ammonia concentration in the influent. Like the existing design, the methanol pump would only deliver methanol into the denitrification tank when the interim pump chamber is pumping wastewater. Since the flow rate of effluent leaving the interim pump chamber is fixed, synchronized operation of the interim pump chamber and methanol dosing pump effectively ties the methanol dose to effluent flow rate. As a result, the dose of methanol only needs to vary with changes in nitrate concentration. According to Metcalf & Eddy, for post-anoxic attached growth denitrification processes, the methanol to NO_3-N ratio should be between 3.0 and 3.5 kg methanol per kg NO_3-N (Metcalf & Eddy 2003, pg. 962). Using this dosing relationship, the flow of methanol that should be added to the denitrification tanks was determined.

This nitrate-based configuration is preferable because an ammonia-based system is more susceptible to variations within the treatment process that could affect the dosing ratio. Ammonia must first be converted into nitrate in the RUCK filters before being converted to N_2 in the denitrification tanks. If the ammonia is not completely converted to nitrate in the RUCK filters, then the 4 mg/L methanol per mg/L ammonia dosing ratio will not be accurate. As a result, the system could provide more methanol to the system than needed. The nitrate-based system directly measures the chemical compound (NO_3^-) that is consumed in the denitrification reaction requiring methanol, reducing the likelihood of error in the dosing relationship.

In this retrofit, a nitrate sensor would be installed in the interim pump chamber to continuously record the nitrate concentration of the effluent from the RUCK filters. A programmable logic controller (PLC), which is a small industrial computer, would continuously receive signals from the nitrate sensor. Using a custom program, the PLC would then calculate how much methanol must be added to the denitrification tank. The calculation used by the PLC to adjust the methanol flow rate can be found in Appendix D. According to this calculation, the PLC would continuously send signals to the methanol feed pump to adjust the flow rate of methanol delivered to the denitrification tank. A new peristaltic pump will be needed if the existing pump cannot be connected to a PLC. A diagram of the retrofit can be seen in Figure 11.

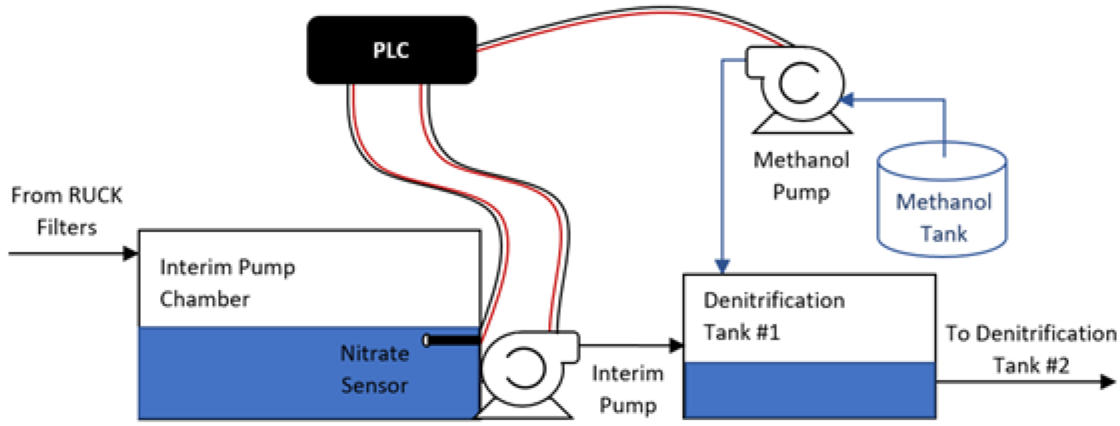

Figure 11: Methanol Dosing System Diagram

To install the equipment, Woodlands Village will need to hire a plumber and electrician/programmer. The plumber would install the nitrate probe, which may require the purchase of special fittings, piping, tubing, and/or electrical parts. This installation may take two men working up to four hours each. The electrician/programmer would install and program the PLC. He or she would also run the wires from the nitrate sensor to the PLC and from the PLC to the pump. This would take approximately eight hours of labor. The nitrate probe would need replacing about every six months; each cartridge costs $989.

More detailed information regarding the equipment that was used to obtain costs for the automated methanol system can be found in Appendix E. The installation costs for the nitrate-based automated methanol feed pump are summarized in Table 8:

Table 8: Costs of extra items for WWTS including labor rates for repairs

Item	Unit Cost	Unit	# Units	Min. Cost	Max. Cost
Nitrate Sensor	$7,218	per item	1	$7,218	$7,218
Ammonia Sensor Controller	$1,733 - $1,907	per item	1	$1,733	$1,907
PLC	$95 - $125	per item	may share 1	$-	$125
PLC Software	$395	per item	may share 1	$-	$395
Peristaltic Pump	$890 - $1,043	per item	1	$890	$1,043
Plumber Labor Rate	$92	per hour	8	$736	$736
Electrician Labor Rate	$50 - $80	per hour	8	$400	$640
Misc. Fittings/Tubing/Electrical Parts				$100	$100
			Total	$11,077	$12,164

This retrofit would cost between $11,077 and $12,164. With this design, given an average annual savings of $127, it would take 87 to 96 years for the savings to outweigh the initial investment of installing the retrofit. This does not take into account the cost of replacing the nitrate cartridge twice a year for $1,978; taking into consideration this expense, the savings gained from fully automating the methanol dosing system would never outweigh the expense of the retrofit. We do not recommend this retrofit.

4.3.2 Measure #2: Automated Sodium Bicarbonate Feed

The process of nitrification in the RUCK® CFT filters consumes alkalinity, which makes the wastewater more susceptible to fluctuations in pH. During nitrification, every gram of ammonia (as N) converted to nitrate requires 7.07 g of alkalinity (as $CaCO_3$) (Metcalf & Eddy, p. 613). This is corroborated by the O&M Manual, which states that “general alkalinity is required at a ratio of 7 to 1 of alkalinity to NH_4 for proper nitrification to occur and go to completion.” Some alkalinity is restored to wastewater during denitrification. According to Metcalf & Eddy, approximately 3.57 g of alkalinity (as $CaCO_3$) is produced per g of nitrate (as N) reduced to nitrogen gas. Therefore, about half of the alkalinity removed from nitrification is restored through denitrification. Currently, the addition of sodium bicarbonate is not closely related to the mass of ammonia entering the system. The following section evaluates the potential savings associated with installing a fully automated sodium bicarbonate dosing system, which would continuously adjust the flow rate of sodium bicarbonate according to the wastewater and ammonia concentration. These potential savings are then compared to the cost of installing the retrofit.

Existing Sodium Bicarbonate Dosing System

To provide alkalinity, WasteWater Environmental Management began adding sodium bicarbonate ($NaHCO_3$) to the flow equalization tank (FET) in September 2015. Currently, one 50-lb bag of sodium bicarbonate is manually poured into the inlet end of the 11,000-gallon FET three times per week (O&M Manual).

Through analysis of the discharge monitoring reports (DMR), it is evident that the addition of alkalinity is needed at the Woodlands Village treatment facility. Prior to the use of sodium bicarbonate, the average monthly pH of the effluent consistently violated the discharge permit limit ($6.5 < pH < 8$). While using sodium bicarbonate, the average monthly pH measured in the effluent has been within the permit limits for all but one month as seen in Figure 12.

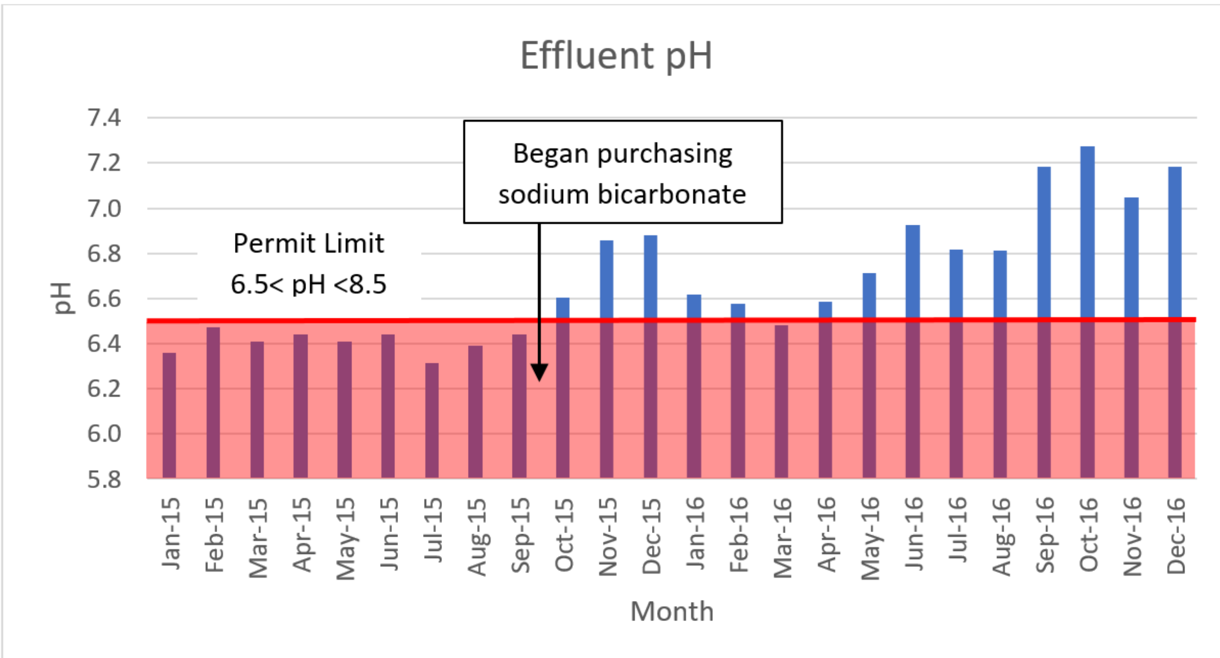

Figure 12: pH of Effluent from January 2015 Through December 2016

However, by adding sodium bicarbonate in pulses rather than continuously, it is possible that the operator at Woodlands Village is adding more sodium bicarbonate than needed. If the FET were a perfectly mixed system, the initial concentration of sodium bicarbonate would be 545 mg/L. This is nearly double the concentration of sodium bicarbonate that is needed for the highest recorded ammonia concentration in the last two years. In reality, because the tank is not well-mixed, the concentration in the FET would be greater in some regions and less than others.

In a perfectly continuously mixed system (CSTR), it would take nearly 30 days for the sodium bicarbonate to be essentially flushed out of the anoxic tank. Therefore, if the system behaved like an ideal CSTR and sodium bicarbonate were added to the system every three days, sodium bicarbonate would quickly accumulate in the anoxic tank. Since there is no evidence that sodium bicarbonate is accumulating in the flow equalization tank, the FET has plug flow-like behavior. This means that by the time another bag of sodium bicarbonate is added to the FET, the concentration of sodium bicarbonate is nearly zero. As a result, the concentration of sodium bicarbonate fluctuates drastically between 0 mg/L and upwards of 545 mg/L every two to three days. Therefore, the ability of Woodland Village's wastewater to resist changes in pH is not constant.

Improved control and automation of the sodium bicarbonate dosing system would more closely relate the dose of $NaHCO_3$ to the reduction in alkalinity caused by the removal of a certain quantity of ammonia. An automated system that delivers a more precise quantity of sodium bicarbonate would minimize the addition of excess $NaHCO_3$, saving Woodlands Village money on sodium bicarbonate.

Potential Savings of Automation

According to Droste (1997), "automatic pH control is often the most economical means of pH control because less chemicals are consumed" (p. 627). The potential savings gained by installing an automated sodium bicarbonate system was determined by comparing the theoretical quantity of $NaHCO_3$ that should have been added to the system to the amount purchased by Woodlands Village between October 2015 and December 2016.

The total amount of sodium bicarbonate that should have been added to the system between October 2015 and December 2016 can be determined from the amount of ammonia (NH_4^{+}) entering the flow equalization tank (FET). The mass of ammonia that entered the tank each month was found from the total volume of wastewater that passed through the FET and the average concentration of ammonia in the influent. Based on the 7:1 dosing ratio of ammonia to alkalinity (as $CaCO_3$), the total amount sodium bicarbonate that should have been added to the system each month was calculated. Although some alkalinity is restored during denitrification, it is more conservative to add alkalinity according to the amount that is consuming during nitrification. Including shipping and taxes, the methanol purchased through Wastewater Environmental services cost $0.43 per pound. At this price, the total cost of sodium bicarbonate if an automatic dosing system were installed was found. Appendix C has the sample calculations used to determine how much sodium bicarbonate was needed for January 2016 and the associated cost. Given a 24-hour composite NH_4-N concentration of 39.2 mg/L in the influent, the required concentration of alkalinity was 280.0 mg/L as $CaCO_3$. The required mass of sodium bicarbonate ($NaHCO_3$) per liter of effluent was 235 mg/L of $NaHCO_3$. The total mass of $NaHCO_3$ needed for January 2016 was 326 lbs. The total cost for January 2016 would have been: $140.20

In order to calculate the savings that could be achieved by installing an automated sodium bicarbonate system, the following assumptions were made:

1. Sodium bicarbonate is currently used at the rate at which it is purchased.
2. The ammonia concentration found using a 24-hr composite sample in the monthly DMR is truly representative of how much ammonia enters the system. However, from January 2015 through December 2016 ranged between 22 mg/L – 48 mg/L. It is possible that the 24-hr composite sample is not a true monthly average.

3. The influent flow rate equals the effluent flow rate.

The following table compares how much Woodlands Village has spent on sodium bicarbonate to how much the association would have paid if sodium bicarbonate were added to the FET using an automated system.

Table 9: Cost of sodium bicarbonate for first 6 months of RUCK operation, 2016, and the annualized total

	First 6 Months (Sept. ’15 – Feb. ’16)	2016 (Jan. ’16 – Dec. ’16)	Annualized Total (Sept. ’15 – Dec. ’16)
Purchased Sodium Bicarbonate	$ 1,304	$ 2,331	$ 2,569
Sodium Bicarbonate Added as Needed	$ 454	$ 1,162	$ 1,118
Savings	$ 850	$ 1,168	**$ 1,451**

As shown in the table above, Woodlands Village could save approximately $1,122 on a yearly basis by adding sodium bicarbonate more closely in relation to the influent flow rate and ammonia concentration. However, this assumes a constant ammonia concentration for an entire month. If the flow of sodium bicarbonate was adjusted continuously using an automatic system, the savings could be even greater.

Assuming that the condominium used sodium bicarbonate as quickly as they purchased it, in the first six months that Woodlands Village began purchasing sodium bicarbonate, the savings would be approximately $850 by adding $NaHCO_3$ in proportion to the amount of ammonia entering the system. In 2016, Woodlands Village would have saved $1,168 if an automated system were installed. It is likely that the condominium purchased excess sodium bicarbonate in 2015 and therefore did not need to purchase as much in 2016. Therefore, the annual savings of $1,451 best reflects the expected savings on sodium bicarbonate expenses from installing an automated system. These savings calculations assume a constant ammonia concentration for an entire month. If the flow of $NaHCO_3$ was adjusted continuously using an automated system, the savings could be even greater.

Proposed Automated Sodium Bicarbonate Dosing System

In order to fully automate the sodium bicarbonate dosing process, the following items are needed:

1. A programmable logic controller (PLC) and its electrical connections,
2. A new sodium bicarbonate feed pump and associated tubing,
3. A water level sensor,
4. An ammonia sensor,
5. A 55-gallon drum, and
6. An electric mixer (may be required).

This automated system would be similar to the methanol dosing system. First, the sodium bicarbonate would be mixed into a solution at a fixed concentration. The solution would be highly concentrated (approximately 60 g/L), but below the solubility limit of sodium bicarbonate to minimize precipitation of $NaHCO_3$. To create the solution, the operator would pour less than half of 50-lb bag of sodium bicarbonate into a 55-gallon drum and add water until the solution is at the appropriate concentration. For example, 20.0 lbs. of $NaHCO_3$ must be added to 40 gallons of water. An electric mixer may be needed to periodically mix the sodium bicarbonate solution.

The same PLC that is installed for the automated methanol dosing system can be used for the automated sodium bicarbonate system. A water level sensor would be installed in the flow equalization tank (FET) to measure the height of wastewater in the tank. By recording the rate at which the level of wastewater in the FET changes, the flow rate of wastewater into the FET can be determined. An ammonia sensor would also be installed in the flow equalization tank. The water level and ammonia sensors would then relay signals to a programmable logic controller (PLC). The PLC would use the volumetric flow rate of wastewater into the FET and the ammonia concentration to calculate the total mass flow rate of ammonia entering the FET., during nitrification, for every gram of ammonia (as N) converted to nitrate, 7.07 g of alkalinity (as $CaCO_3$) is needed. Using this dosing relationship, the PLC would then calculate how much sodium bicarbonate must be added. Based on this calculation, the PLC would send a signal to the sodium bicarbonate feed pump to increase or decrease the flow rate of $NaHCO_3$ to the desired level. Diagrams of the setup (not to scale) are shown in Figures 13 and 14.

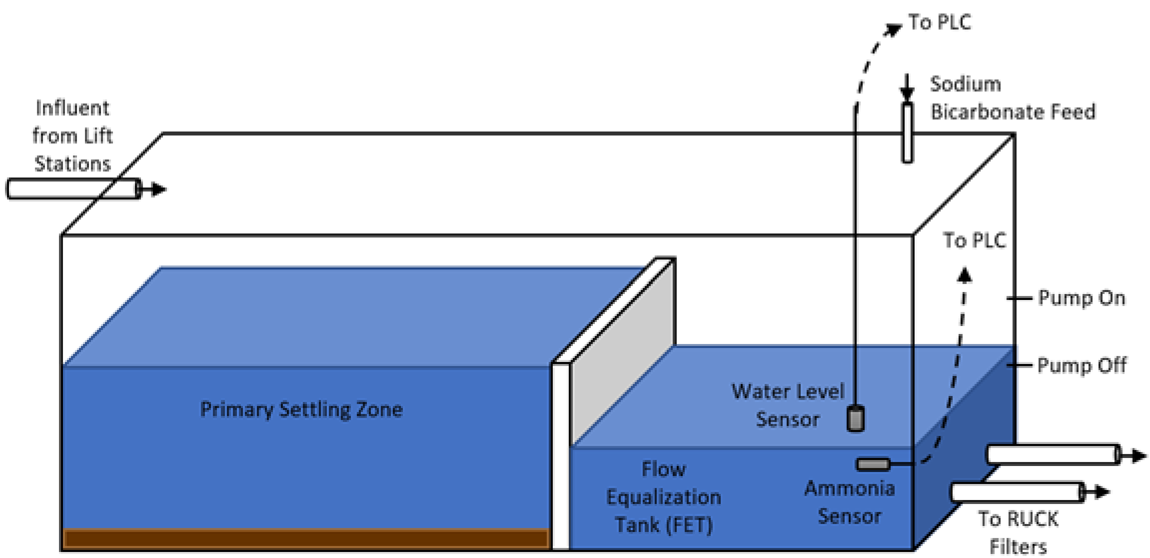

Figure 13: Anoxic Tank and FET with Sodium Bicarbonate Retrofit

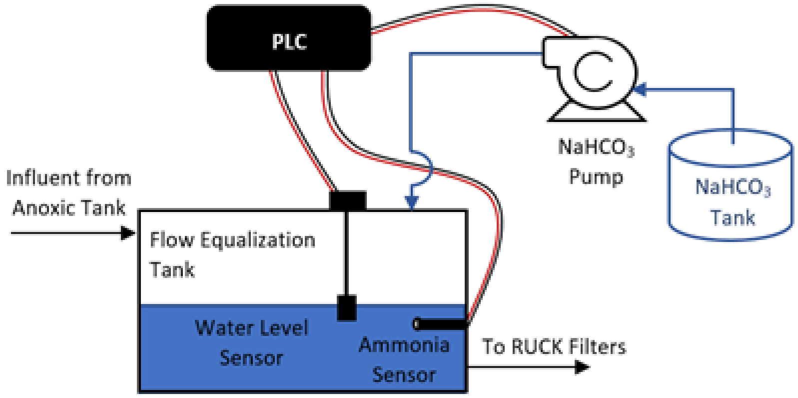

Figure 14: Sodium Bicarbonate Retrofit Setup

To install the equipment, Woodlands Village will need to hire a plumber and electrician/programmer. The plumber would install the ammonia probe and water level sensor, which may require the purchase of special fittings. This installation may take two men up to four hours each. The electrician/programmer would install and program the PLC. He or she would also run the wires from the sensors to the PLC and from the PLC to the pump. This would take approximately eight hours of labor. The ammonia probe would need replacing about every six months whereas the water level sensor would need infrequent replacing. The replacement cartridge for the ammonia sensor costs $989. If this system were installed at the same time as the methanol dosing system, labor costs would not be duplicated.

More detailed information regarding the equipment that was used to obtain costs for the automated sodium bicarbonate system can be found in Appendix E. The installation costs for the sodium bicarbonate dosing system are itemized in Table 10.

Table 10: Costs for sodium bicarbonate dosing system including labor rates

Item	Unit Cost	Unit	# Units	Min. Cost	Max. Cost
Ammonia (NH4) Sensor	$7,428.00	per item	1	$7,428	$7,428
Ammonia Sensor Controller	$1,733 - $1,907	per item	1	$1,733	$1,907
Water Level Sensor	$1,055 - $1,150	per item	1	$1,055	$1,150
PLC	$95 - $125	per item	may share 1	$-	$125
PLC Software	$395	per item	may share 1	$-	$395
Peristaltic Pump	$890 - $1,043	per item	1	$893	$1,043
55-Gallon Drum	$74	per item	1	$74	$74
Electric Mixer	$175	per item	may need 1	$-	$175
Plumber Labor Rate	$92	per hour	8	$736	$736
Electrician Labor Rate	$50 - $80	per hour	8	$400	$640
Misc. Fittings/Tubing/ Electrical Parts				$100	$100
			Total	**$12,419**	**$13,773**

This retrofit would cost between $12,419 and $13,773. Given an approximate annual savings of $1,450 on sodium bicarbonate from installing an automated dosing system, it would take 8.6 to 9.5 years for the savings on sodium bicarbonate to outweigh the initial investment of the retrofit. This does not take into account the cost of replacing the ammonia cartridge twice a year for $1,978; taking into consideration this expense, the savings gained from fully automating the sodium bicarbonate dosing system would never outweigh the expense of the retrofit. The cost of the ammonia cartridges alone is double the potential savings of installing the automated sodium bicarbonate feed. Because of this, we do not recommend this retrofit for the community.

Modification of the Automated Sodium Bicarbonate System

Although we do not recommend installing a fully-automated sodium bicarbonate system, we do recommend the installation of a retrofit that more continuously adds sodium bicarbonate to the FET rather than periodically adding large doses. As previously discussed, the concentration of sodium bicarbonate fluctuates drastically between 0 mg/L and upwards of 545 mg/L every two to three days. This negatively impacts the ability of Woodland Village’s wastewater to resist changes in pH. A constant feed of a solution of sodium bicarbonate would maintain a more stable concentration of sodium bicarbonate in the FET, improving the wastewater's ability to maintain a constant pH.

This basic retrofit would require the purchase of a 55-gallon drum, a new peristaltic pump, tubing for the pump, a hose to fill the drum with water, and possibly an electric mixer. Like the fully-automated $NaHCO_3$ dosing system, the operator would pour powdered sodium bicarbonate into a 55-gallon drum and add water until the solution is at the appropriate concentration. The solution would be highly concentrated (approximately 60 g/L), but below the solubility limit of sodium bicarbonate to minimize precipitation of $NaHCO_3$. An electric mixer may be needed to periodically mix the sodium bicarbonate solution. Woodlands Village may need to hire a plumber to install the retrofit. However, the retrofit is basic; the operator may be able to install the retrofit during his daily visit to the site. A diagram of the basic sodium bicarbonate feed system is shown in Figure 15 below.

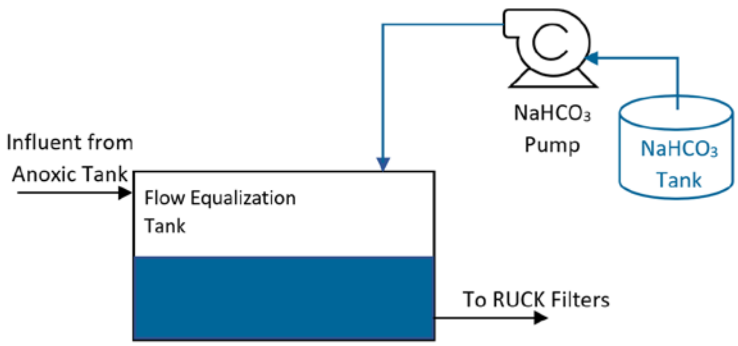

Figure 15: Basic Sodium Bicarbonate Feed Retrofit

To install this retrofit, the following items from the previously described retrofit are needed:

Table 11: Costs of proposed design retrofit to automated sodium bicarbonate system

Item	Unit Cost	Unit	# of Units	Min. Cost	Max. Cost
Peristaltic Pump	$890 - $1,043	per item	1	$893	$1,043
55-Gallon Drum	$74	per item	1	$74	$74
Electric Mixer	$175	per item	may need 1	$-	$175
Plumber Labor Rate	$92	per hour	4	$-	$368
Misc. Fittings/Tubing/ Electrical Parts				$100	$100
			Total	**$ 1,067**	**$ 1,760**

This retrofit would only cost between $1,067 and $1,760. This retrofit should save on the amount of sodium bicarbonate that must be purchased by Woodlands Village. However, since this retrofit does not add sodium bicarbonate in direct proportion to the amount of ammonia entering the system, these potential savings cannot be calculated. The operator should experiment with different flow rates of sodium bicarbonate to determine the appropriate average dose of the NaHCO3 solution. To determine the appropriate flow rate of sodium bicarbonate, it is recommended that the operator start with a high dose of sodium bicarbonate and slowly reduce the solution's flow rate until the effluent pH begins to drop; a flow rate greater than this critical value should be used.

4.3.3 Measure #3: Less Expensive Operations & Maintenance Contracts

Starting in 2017, Woodlands Village switched their operational services from WhiteWater, Inc. to Small Water Systems Services. Previously WhiteWater handled the pump repairs in the community, while Wastewater Environmental Management provided lab testing and contracted operations. Small Water Systems Services offers both services, which provides an outlet to Woodlands Village for savings. The combination of both Wastewater Environmental Management and WhiteWater accounted for 34% of the budget at $32,540 in 2015, while growing to 50% of the budget at $53,504. Small Water Systems Services were quoted at $33,400 for the year of 2017, in which they cover both the contracted operations and pump repairs. Lab testing would have an additional fee of $8,352 throughout the year, creating a total of $41,752. This saves the community almost $12,000 from the year prior, barring any major unforeseen repairs that may be needed during the year.

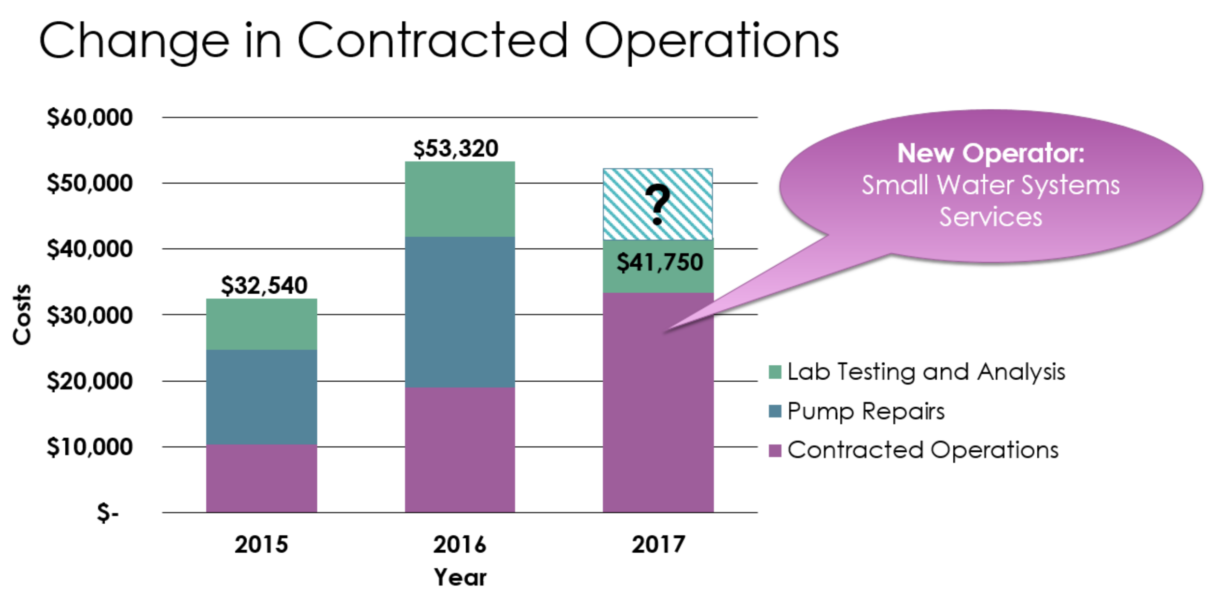

Figure 16: Savings Achieved by Switching Operation/Maintenance Companies

Small Water Systems Services, who are based in Littleton, MA, offers flexibility in their services. They have the ability to work on FAST systems, Amphidrome Systems, and Bioclere systems (Small Wastewater Systems Services, 2017). The company also provides system design and installation, and services regarding groundwater discharge permits (Small Wastewater

Systems Services, 2017). This wide-ranged expertise provides the community with a viable operating company in the future if the system is changed.

4.3.4 Measure #4: Community Education to Reduce Lift Station Repairs

Creating a document for distribution in the community to educate them on septic tank and wastewater treatment system maintenance could be a potential cost saving measure. This document would include information about what types of household products and trash should not be introduced to the system. Products such as baby wipes, feminine hygiene product, coffee filters, grease, and pharmaceuticals should not be flushed down the toilet or washed down the drain (Bhakta, 2013). These along with other items can clog or corrode pipes and tanks, and damage equipment (King County, 2016). Pharmaceuticals that enter the sewage system can enter the groundwater and eventually water bodies, such as Hickory Lake, and affect aquatic life (Bound, 2005). Even products that claim to be "flushable" should not be disposed of into the sewer systems. The Washington Post printed an article about issues with clogging that "flushable" wipes are causing in septic systems across the country (Ehrenfreund, 2013). If the community could be encouraged to minimize their disposal of harmful items into the sewer system, it could potentially reduce maintenance cost on the pipes, and pumps at the lift stations.

4.3.5 Measure #5: Assess the Need for Heating the Effluent

There are many ways in which temperature can affect wastewater treatment. Because the wastewater treatment in the RUCK system uses a biological fixed film media, temperature has an effect on the organism's growth and activity. There is theoretically an optimal condition for the organisms where the growth rate and activity are most effective for the wastewater treatment system. This effectiveness is not only driven directly by temperature, it is also dependent on factors that altering the temperature may affect such as electron donor or acceptor availability, the form of the substrate, sensitivities to inhibitors, and efficiency of enzymes. With the wide range of factors that could be affected by the temperature change, there has been a wide range of results when examining optimal conditions of systems. The result of the majority of studies, however, found that growth rate of the denitrification bacteria increases with temperature before leveling off around 35°C. The range of temperatures that growth occurs was found to be between 4°C and 45°C. It was also found that activity of the bacteria increases with temperature before plateauing at approximately 30°C. This provides essentially a similar range and optimization point as growth rate temperatures.

A study focusing on an autotrophic denitrification reactor with OBBs as media, varied temperatures from 10°C to 30°C at 2°C intervals and determined denitrification rates at varying constant flow rates between 50 and 500 mL/min. The study's data was able to demonstrate that there was a significant impact on denitrification above temperatures of 16°C. As shown in the chart below, there is an approximately 10,000 mg/m^3h nitrogen removal difference between the 14°C and 16°C trials at the optimal load rate of 80,000 mg/m^3h of NO_3-N. This suggests that the bacteria activity is nearly dormant and certainly is ineffective below temperatures of 16°C. The study also illustrates that as temperature rises, the nitrogen removal also increases significantly. At the highest temperature of 30°C, the difference between the nitrogen removal at 16°C is about 10,000 mg/ m^3h at the load rate of 80,000 mg m^3h of NO_3-N. This is a 33% increase in effectiveness (Iswar, et al).

This study illustrates that heating the effluent can have major effects on the efficiency of the system. Any effluent below 16°C or 61°F should have an external heater for the media chamber. Above this temperature, more external heating should be considered if the denitrification is not sufficient to meet regulations. However, this external heating does come at a cost. In order to determine the necessity of a heater, the temperature must be collected in the media chamber during the cold months of the year. If insulation on the chamber is able to effectively keep temperatures above 16°C, the heater may be an unnecessary expenditure. Further research should be done to examine if there is a true potential for cost savings from not heating the media chamber.

4.4 Description of Alternative Wastewater Treatment Systems

There are 31 approved technologies by the MassDEP for wastewater treatment. Out of these, 19 technologies are septic tanks or alternative SAS technologies. Because of the pre-existing, effective leaching field and septic tanks as Woodlands Village, these technologies can be considered as not applicable for the community. Four of the remaining 12 systems on the list are either sand filters or too small for the community's 12,500 gpd flow rate. Sand filter systems are specifically designed for areas with poor soil quality that causes an inability to handle the effluent discharge WWTS. Sand filters also can be negatively affected by colder climates, since sand filters run the risk of freezing. At the Lunenburg site, the quality of the soil is ideal for typical effluent discharge and the seasonal differences in climate cause sand filter systems to be unfeasible options for Woodlands Village This elimination of non-compatible systems leaves eight wastewater treatment systems to be analyzed, including the current RUCK technology in place. The seven technologies, not including the RUCK system described in the previous section, are listed in Table 12:

Table 12: MassDEP Alternative Systems Considered for Woodlands Village

Technology	Company
Advantex Treatment System	Orenco Systems, Inc.
Amphidrome System	F.R. Mahony & Associates, Inc.
Bioclere	Aquapoint
Bio-Microbics MicroFAST	Bio-Microbics, Inc.
Clean Solution Treatment System	Wastewater Alternative, Inc.
Hoots Aerobic Systems	Hoot Systems, LLC.
Smith & Loveless FAST System	Smith & Loveless, Inc.

4.4.1. Advantex Treatment System by Orenco Systems, Inc.

The Advantex Treatment System by Orenco Systems, Inc. is a module system that utilizes a packed bed filter technology. The system is similar in configuration to a recirculating sand filter and was designed in the 1970s. It has been installed in about 17,000 residencies and 2,300 commercial locations since 2000. A schematic system can be seen in Figure 17. The Advantex System operates through the use of a recirculation tank that receives influent from a septic tank. The influent then flows into the AX100 Pods where pumps micro-dose the textile media packed bed filter at regular increments. This process treats the wastewater to reduce levels of BOD and total nitrogen. Once the process concludes, the effluent is discharged from the pods to a polishing tank. In the polishing tank, the effluent is treated a final time in the AX100 Pods to produce a final discharge that is up to 98% cleaner than the influent.

This process is efficient and reliable for all levels of flow. A major benefit of the system is its modular nature. Because the system is made up of pods, the system can be expanded at any time. This allows Woodland Village the luxury of expanding the system to meet future needs of a possible growing complex. These modules can also be installed above ground, which reduces installation cost and maintenance costs (AdvanTex Treatment System).

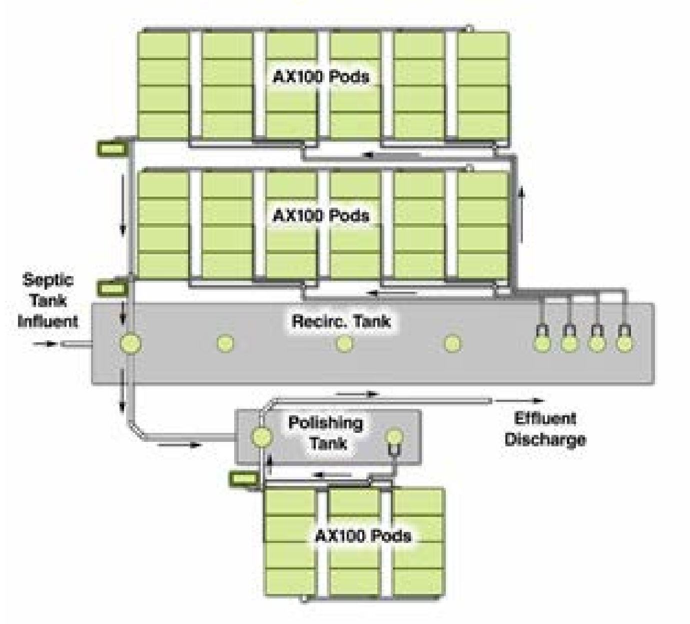

Figure 17: Advantex System Diagram (AdvanTex Treatment System)

4.4.2. Amphidrome System by F.R. Mahony & Associates, Inc.

The Amphidrome System is a sequence of batch reactors that utilize a biologically active filter. Due to a high fixed film biomass concentration, the system is able to maintain a small footprint while still being effective for varying flow rates. Over the past 15 years, over 110 systems have been successfully installed for larger projects. The system provides BOD reduction, nitrification, denitrification, and filtration of solids through a five-chamber process. The influent enters the anoxic septic tank where decomposition first occurs. The waste then enters the Amphidrome Reactor containing bacteria for the nitrification and denitrification processes. The treated waste moves into a clearwell, where it becomes an odorless, colorless effluent. The effluent then passes through a Plus Reactor that polishes the wastewater and reduces levels of BOD and nitrogen further. The effluent moves to a final holding tank before being discharged. This process is energy efficient while maintaining superior treatment in a small footprint (Amphidrome – F.R. Mahony & Associates, Inc.).

Figure 18: Amphidrome Technology Diagram (Amphidrome – F.R. Mahony $ Associates, Inc)

4.4.3. Bioclere by Aquapoint

Bioclere is a trickling filter system that has been modified to be constructed over a clarifier. Benefits of this system are its ability to treat wastewater varying in organic and nutrient concentrations, its stable and simple fixed film media, and its low operation and maintenance costs. The Bioclere system operates through the use of a primary settling and recirculation tank that accepts the influent entering the system. The tank allows for the decomposition and settling of solids. The effluent then leaves the tank and is piped to the top of a dosing array that distributes the effluent over a biological filter. The effluent trickles through the filter and collects at the bottom of a second tank. A recycling pump brings the effluent back to the top and repeats the process. After the effluent is fully treated, it is discharged out of the system. The Bioclere filter bed is self-regulating and purging, meaning the bacteria on the filter does not require cleaning or replacement. This is beneficial when examining the cost of maintenance for the system (Bioclere Wastewater Treatment Systems).

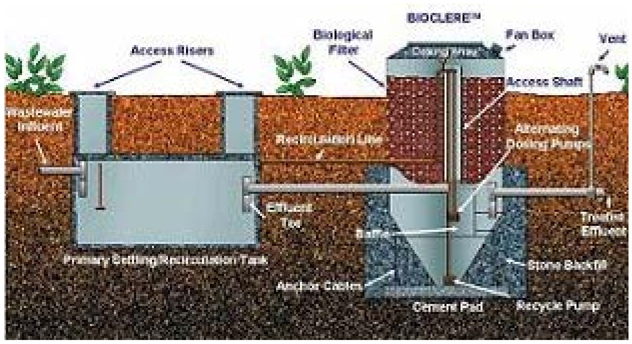

Figure 19: Bioclere Technology Diagram (Bioclere Wastewater Treatment Systems)

4.4.4. Bio-Microbics MicroFAST by Bio-Microbics, Inc.

The Bio-Microbics MicroFAST system operates by having influent enter a primary settling tank, where natural separation occurs of the liquids and solids. The liquid then moves to the treatment module. In the module, oxygen is introduced via a blower, which facilitates circulation through the media inside. Bacteria is fixed to this media and metabolize the waste, treating it until the waste is clear and odorless. This waste is then discharged from the system. The system is able to continue microbial growth despite varying flow. It is also easy to maintain and reliable for treatment (MicroFAST Wastewater Treatment Systems).

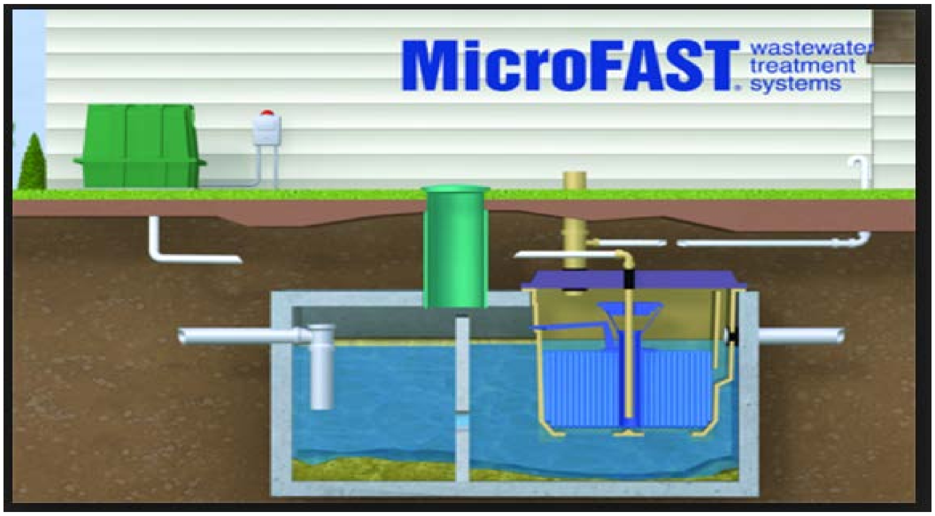

Figure 20: Bio-Microbics Technology Diagram (MicroFAST Wastewater Treatment Systems)

4.4.5. Clean Solution Treatment System by Wastewater Alternative, Inc.

The Clean Solution Treatment System is an aerobic treatment system that is both low maintenance and affordable. The system operates by having the influent enter a pretreatment tank that lets solids settle and anaerobic decomposition to begin. The wastewater then moves to the aerobic chamber where oxygen is pumped in through a compressor. This chamber treats the effluent with bacteria on plastic media and sends it to a final chamber. The effluent leaves this final chamber clean and odorless. The only moving part in the system is the compressor, causing maintenance costs to be low and infrequent. The simple system could utilize the current leaching fields and be an affordable solution for the Woodlands Village site (Wastewater Alternatives Inc.).

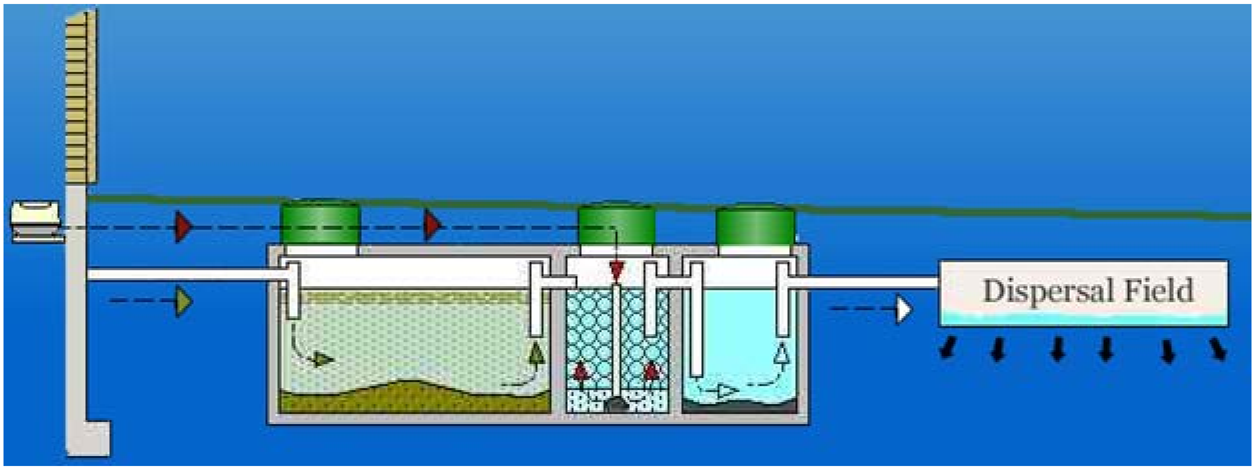

Figure 21: Clean Solution Treatment System Diagram (Wastewater Alternatives Inc.)

4.4.6. Hoot Aerobic Systems by Hoot Systems, LLC.

The Hoot Aerobic System is designed as a five-component system. The influent enters a pretreatment tank and is anaerobically decomposed. The fluid then moves to the aeration chamber, where the sewage is mixed with a bacteria population and oxygen that is pumped into the chamber. These bacteria reduce the organic material and nitrifying bacteria changes ammonia to nitrate. The effluent then moves to the clarifier chamber. Any activated sludge present then settles to the bottom and is reintroduced in the aeration chamber. The effluent that is now clear and odorless moves to the anoxic media cell. A carbon source additive is pumped into the cell to cause further denitrification. The final effluent enters the pump tank and leaves the system. The Hoot system reduces effluent nitrogen levels by 85% and can be customized to fit the needs of Woodlands Village. The controls system of the unit also provides lower operation costs and an effective treatment of influent at multiple flow rates (Residential Products).

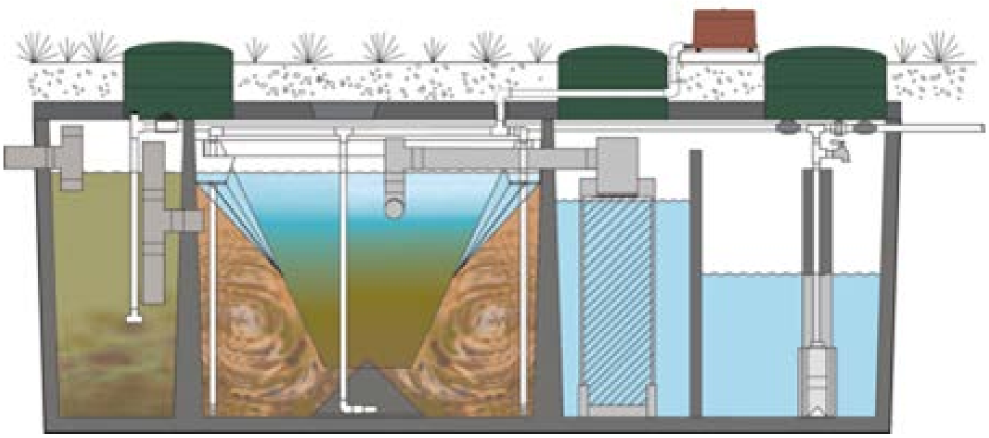

Figure 22: Hoot Aerobic Systems Diagram (Residential Products)

4.4.7. Smith & Loveless FAST System by Smith & Loveless, Inc.

The Smith & Loveless FAST System uses fixed activated sludge treatment. The system operates by sending influent from a septic tank into the Modular FAST system. Once it enters, the waste is treated by a fixed media that holds bacteria. The fixed media has a high surface area-to-volume ratio that allows for larger amounts of bacteria that can metabolize waste. This allows for a continuous high level of treatment. There is a solids collection zone in the modular that collects sludge from the process and ensures effective circulation of the effluent. A blower introduces oxygen to the system and is the only moving part of the system. The result of the modular is an odorless effluent with low BOD and nitrogen levels. This system has a small footprint and is easy to install. The maintenance is also low on the system due to the lack of complex moving parts (Treatment Systems).

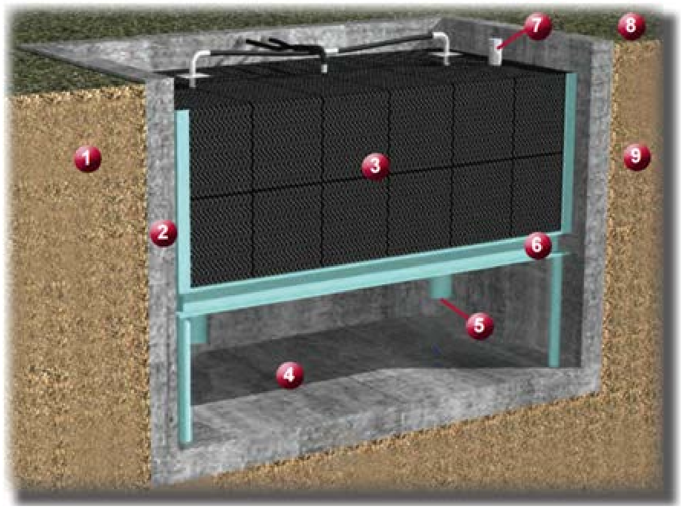

Figure 23: Smith & Loveless FAST System Diagram (Treatment Systems)

4.5. Evaluation of Alternative Wastewater Treatment Systems

When discussed with professionals in the field, switching to an alternative technology was seen as a non-viable solution if the current system in place is functional and meeting discharge requirements. However, the system in place is currently almost 20 years old. Most systems similar to RUCK systems have an estimated lifespan of approximately 25 years. This places Woodlands Village in a position to begin to evaluate potential options if the system is to fail. This path of switching to an alternative technology is an examination of the costs of operation and installation of the seven approved DEP systems. The systems have the potential to provide a solution for the high costs of operation currently faced in the RUCK system. Appendix G contains preliminary design plans of systems that the size information was available.

4.5.1. Cost of Removal

The removal or replacement of a wastewater treatment system has several costs associated with the process. The first major cost to consider is the equipment and labor involved to remove the soil and physical system from the site. The next major cost is the disposal of the actual system due to its hazardous contents. There is also a cost associated to filling the site after replacing the system and replacing the grass at the site. Another cost is the installation of the new system that is separate from the purchasing the system. While all of this construction occurs over an estimated 16-week period, the community also requires a temporary system that costs roughly 25 cents a gallon. All of these costs are listed in Table 13 according to an estimated budget for demolition by Pride Environmental. Those values have a 20% increase in order for the construction company to pay for overhead and make a profit. This provides an estimated total of $565,200 for the replacement process of the RUCK system to an alternative system.

Table 13: Costs to Change WWTS

Item	Cost
Removal and Backfill Equipment and Labor	$ 104,000.00
Disposal of System	$ 50,000.00
Replacement Fill	$ 30,000.00
Loam and Seed	$ 25,000.00
Installation of 12,500 GPD System	$ 150,000.00
Temporary System Pumping (16 weeks)	$ 112,000.00
Total Cost for Construction Company	**$ 471,000.00**
Total Cost for Client (20% for Overhead and Profit)	**$ 565,200.00**

4.5.2. Constraints of Systems

Woodlands Village's property consists of 74 acres, however not all of the land is buildable. Multiple sections of wetland areas stretch across the property, and these areas can influence future development. The Wetlands Protection Act created by MassDEP specifies that a 100-foot buffer must be present around wastewater treatment facilities (310 CMR 10.02). Of the 74-acre property, wetlands protection areas constitute 31 acres. This cuts the amount of readily buildable land on the property nearly in half. A map of the surrounding wetland buffer zones is located on the next page.

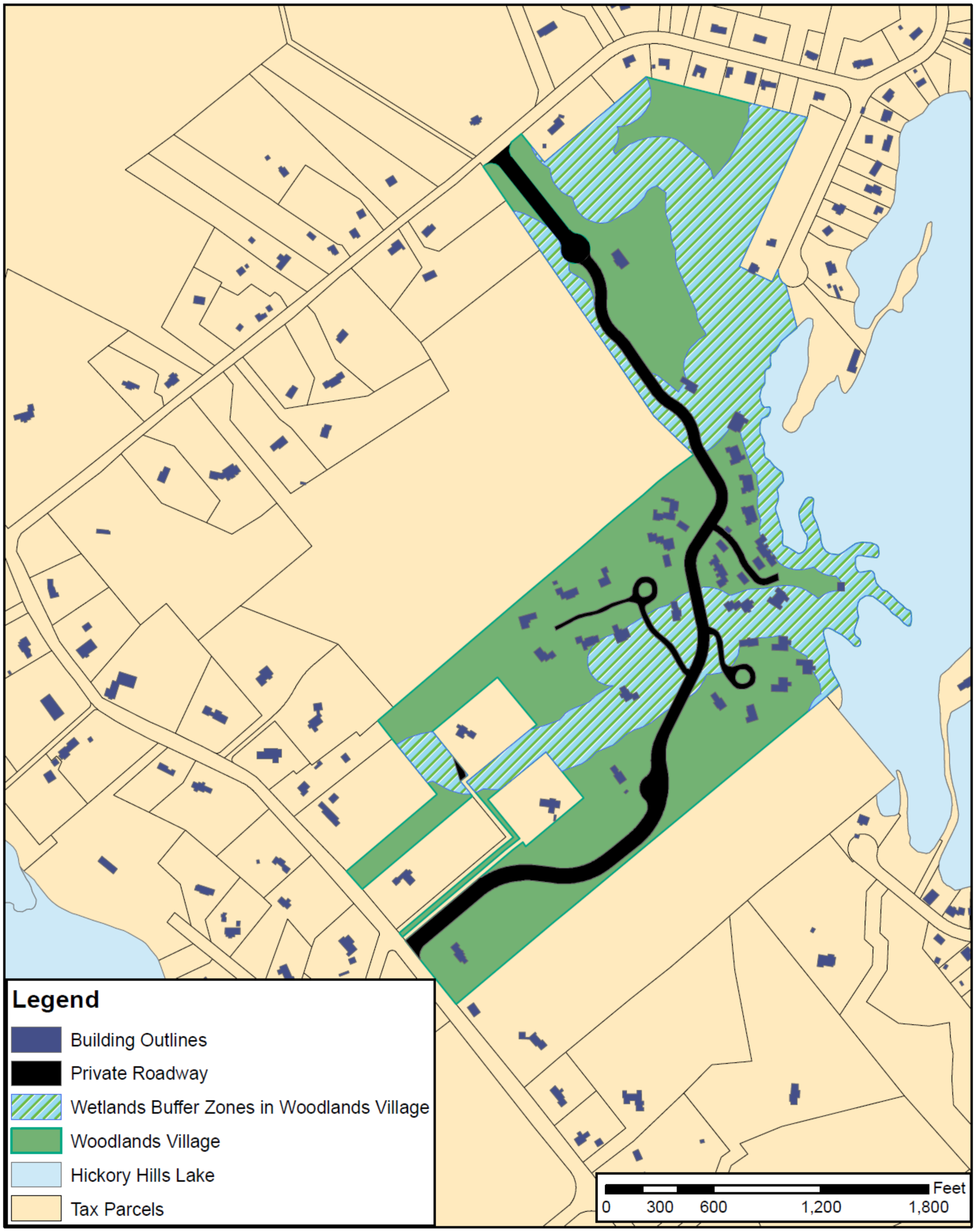

Figure 24: Zoning Map for Woodlands Village

Handling Wetlands Constraints

MassDEP outlines two options an entity must go through when attempting to build in wetlands protection areas. They are listed below:

1. A Request for a Determination of Applicability must be submitted to the local Conservation Commission.
2. A Notice of Intent (NOI) must be submitted to the local Conservation Commission.

As the NOI is completed and submitted, the applicant must notify all abutting properties of the work that will be done (310 CMR 10a). Once the application is received, the mitigation techniques in the NOI will be analyzed to ensure that the work's negative effects on the environment are properly removed or reduced (310 CMR 10a).

Although much of the Woodlands Village property falls under the Wetlands Protection Act, the wastewater treatment system is not affected by these areas. This allows for easier adjustment if the community decides to alter or replace the current RUCK system. A map of the wetlands protection areas bordering the treatment facility are shown in Figure 25.

Figure 25: Map of wetland zones at Woodlands Village

4.5.3. City Sewer Pricing in Lunenburg

Although pursuing a municipal sewer system is unfeasible in the present time, it is an option that can be looked at in the future if the sewer system is extended onto Gilchrest Street and Valley Road. In the Lunenburg CWMP, estimated construction costs for a municipal system are given and were compiled into Table 14 below (Wright Pierce, 2016, pg. 4-29).

Table 14: Unit costs of sewer pipe installation

Description	Unit	Unit Cost
8"-12" PVC Gravity Sewer Pipe	LF	$375
4"-6" DI Force Main Pipe	LF	$300
Common Trench Installation (cost for both types of pipe)	LF	$400
Typical Pump Station	EA	$400,000
Land Acquisition	Acre	$175,000
1-1/2"-3" PVC Low Pressure	LF	$225
Grinder Pump Unit	EA	$12,000

Since the majority of the community is already connected through force mains and existing pump stations, the community would only require approximately 1,160 feet of piping installed. This would result in only the requirement of trench installation for force main pipe. The total estimated cost of the work would amount to $899,000. With the required engineering design estimated by Wright Pierce in the CWMP to amount to 25% of the total cost, the price would rise to $1,123,750. In adding the cost for removing the RUCK system found in Table 13, the total capital costs would amount to about $1,374,000. The calculations for these estimates can be found in Appendix F.

Figure 26: Map of Hypothetical City Sewer Line Installation

Along with the capital costs of $1,374,000, an annual sewer connection cost would be added by the town. Tighe & Bond, a consulting engineering firm, conducted a survey in 2014 across Massachusetts on the typical sewer connection costs in all towns and cities. In Lunenburg, the estimated annual cost for a household connecting to the sewer system was $718 (Tighe and Bond, 2014). For the current sized community in Woodlands Village, this would incur an estimated cost of $61,972, including the electricity costs associated with the pumping stations. If the community expanded to 55 units, the estimated cost would increase to $68,434. The calculations for these estimates are found in Appendix F.

4.5.4. MassDEP Certified Alternative Wastewater Technologies Cost Analysis

The costs for the MassDEP certified systems were acquired through contact with local vendors in the area that supply each system. Acquisition of pricing for all the systems was not obtained due to the inability to receive the necessary information from all companies. For the remaining systems, a cost analysis was performed to determine the system that best meets the needs of Woodlands Village. Below is a table of the seven systems with pricing information for each system. The systems listed with information "Not Available" were the systems that pricing information was unavailable for.

Table 15: Alternative technologies broken down by cost and company

Technology	Company	Cost of System
Advantex Treatment System	Orenco Systems, Inc.	Not Available
Amphidrome System	F.R. Mahony & Associates, Inc.	$163,400
Bioclere	Aquapoint	$120,000
Bio-Microbics MicroFAST	Bio-Microbics, Inc.	$97,500
Clean Solution Treatment System	Wastewater Alternative, Inc.	$126,000
Hoots Aerobic Systems	Hoot Systems, LLC.	Not Available
Smith & Loveless FAST System	Smith & Loveless, Inc.	$100,000

4.5.5. Cost of an Amphidrome System

The Amphidrome system was quoted to cost $125,000 for an 8,000 gallon per day system. Using scaling of the cost, the 12,500 GPD system was estimated to cost $163,400. This makes Amphidrome one of the most expensive systems researched. The cost of electricity to operate the system is $935 a year. This is a reduction of $3,884 per year from the current electricity costs or an estimated $97,100 savings over the 25-year life span of the Amphidrome system. The system has controls that optimize performance and can track the flow rates of the system for easy compilation of data This information could provide better maintenance and efficiency of the system that could reduce costs. Further information must be gathered from the supplier on maintenance costs in order to obtain a proper cost savings estimate.

4.5.6. Cost of a Bioclere System

The overall cost of the Bioclere system is $120,000. However, the lack of complex parts leads to a reduction in repair costs. The repair costs were estimated at about $11,900 for the lifetime of the system. The system also has a self-regulating and purging filter bed. This means that it does not require cleaning, unlike the current RUCK filters. The RUCK filters were replaced before because of improper maintenance at a cost of $125,000. The reduced maintenance and higher reliability may lead to cost reductions in the future and prevent an incident similar to the failure of the RUCK system. The cost of electricity required to operate the Bioclere system is estimated at about $5,800 per year. This is a cost increase of $973 per year on electricity or a $24,300 increase over the lifespan of the system. The system does not require an external heater for the fixed film media. This eliminates the cost associated with gas that is typically spent on heating. However, it is not possible to determine the cost savings due to the inability to separate the gas that goes to the external heater and the gas that goes towards heating the building itself. This is an added benefit that could not be quantified into the cost analysis. Retiring the system after 25 years would save Woodlands Village about $131,900 in maintenance and electrical costs. Looking at the costs per year, the savings is $5,275 per year. Although there is a savings over the RUCK system, the cost of demolition and replacement is estimated at $565,000. The system is only feasible then if the current system fails and needs to be decommissioned and replaced.

4.5.7. Cost of a Bio-Microbics STAAR 13.5D System

The Bio-Microbics STAAR 13.5D system is a 13,500 gpd system. This was chosen over the 12,000 gpd system because the 13,500 gpd system is cheaper. The cost of the STAAR 13.5 system is $97,500. The electrical cost and maintenance cost of the system was unable to be acquired. Further information must be given from Bio-Microbics to calculate a final savings.

4.5.8. Cost of a Clean Solution Treatment System

The Clean Solution Treatment System is an aerobic treatment system. This system has one moving part in the air compressor. The cost of the Clean Solution Treatment System is $126,000. The repairs on the system were estimated at $22,800 over the life of the system. This is a savings of $145,300 over 25 years or $5,800 a year. The lack of moving parts also reduces the cost of operations in terms of electricity. The electrical cost of the system is estimated at $2,562. This is an annual savings of $2,257 or lifetime savings of $56,425. The system does not require an external heater for the fixed film media. This eliminates the cost that is typically spent on heating. However, it is not possible to determine the cost savings due to the inability to separate the gas that goes to the external heater and the gas that goes towards heating the building itself. This is an added benefit that could not be quantified into the cost analysis. Examining the system with a lifespan of 25 years, the Clean Solution Treatment System provides a savings of $201,713 on electricity and maintenance. Splitting up the cost over the 25 years, the annual savings is $8,070. Although there is a savings over the RUCK system, the cost of demolition and replacement is estimated at $565,000. The system is only feasible then if the current system fails and needs to be decommissioned and replaced.

4.5.9. Cost of a FAST System

The FAST system is a 12,500 gpd system. This was chosen over the 12,000 gpd system to accommodate the needs of Woodlands. The cost of the system is $100,000. The electrical costs and maintenance costs of the system each year was not able to be acquired for the system. Further information must be given from Bio-Microbics to calculate a final savings.

5. Recommendations and Conclusion

Based on information researched and discovered throughout the project, specific recommendations were formulated based on the two paths identified in the Methodology.

Path 1

Our team identified and evaluated the following five retrofits and cost-saving actions:

1. Automating the methanol dosing system;
2. Automating the sodium bicarbonate dosing system;
3. Hiring different maintenance and operating companies;
4. Improving community awareness about wastewater treatment systems; and
5. Assessing the need for heating the effluent.

Woodlands Village has implemented Cost-Saving Measure #3. In January 2017, the Facilities Committee hired a new company, Small Water Systems Services, to operate both the treatment facility and maintain the lift stations. Excluding the costs for labor beyond the contracted two hour per weekday and for repair parts, the switch to Small Water Systems Services is predicted to save Woodlands Village approximately $11,600 annual based on 2016 financial data.

Unfortunately, fully-automating the methanol and sodium bicarbonate feed systems (Measures #1 and #2) is not cost-effective. Just the cost to replace the nitrate and ammonia sensors every six months exceeds the savings that would be achieved by reducing the amount of methanol and sodium bicarbonate added to the system. However, a simpler retrofit to the sodium bicarbonate feed system is recommended. In this retrofit, sodium bicarbonate would be continuously pumped into the flow equalization tank rather than added in 50-lb batches of powder every two to three days. By adding sodium bicarbonate as a solution continuously, fluctuations in pH would be minimized. A more consistent effluent pH is optimal for the downstream processes that require microbial activities. The continuous sodium bicarbonate feed would cost between $1,067 and $1,760 to install. Although the actual savings on sodium bicarbonate cannot be calculated without knowing the exact dose of sodium bicarbonate fed to the flow equalization tank, the retrofit should reduce the amount that must be purchased each year. To maximize the savings on sodium bicarbonate purchases, the operator should experiment with varying sodium bicarbonate flow rates. The operator should determine the lowest dose of sodium bicarbonate that is needed to maintain a steady pH in the wastewater throughout the entire treatment process.

The community should also provide community-wide education on proper waste disposal in the development (Measure #4). Baby wipes, feminine hygiene products, pharmaceuticals, coffee filters, and grease should not enter the wastewater treatment system because they damage and corrode pipes and equipment (King County, 2016). Preventing these harmful materials from entering the wastewater conveyance system will protect the infrastructure from damage, thus reducing the costs required for lift station repairs and maintenance.

Woodlands Village should also assess the need for heating the effluent prior to denitrification using the natural-gas furnace (Measure #5). Currently the community spends close to $2,700 each year on natural gas used at the treatment building, a substantial portion of which is used to heat the effluent. Our research indicated that other systems which utilize carbon sources do not require heat. Although the RUCK ® CFT System may require heated effluent for optimal performance, research should be conducted in the future to determine the actual need for the heat. If the system is able to maintain effluent temperatures warm enough for microbial activities without use of the furnace, the condominium could on the cost of natural gas.

Path 2

Path 2 examined the implementation of alternative systems to lower costs associated with Woodlands Village WWTS. 31 MassDEP approved systems were evaluated and 8 systems were selected for further analysis based on suitability for Woodlands Village. City sewer was also examined as an alternative system to reduce costs. The compilation of acquired costs from vendors and research can be seen in Table 16.

Table 16: Summary of Alternative WWTS

Item	Removal	Construction	Total Capital Cost	Upkeep per Year
RUCK Filter Replacement	$ -	$ 160,000	$ 160,000	$ 107,014
Bioclere	$ 250,800	$ 360,000	$ 610,800	$ 91,409
Clean Solution Treatment System		$ 366,000	$ 616,800	$ 88,616
Amphidrome System		$ 403,400	$ 654,200	N/A
Bio-Microbics MicroFAST		$ 337,500	$ 588,300	N/A
Smith & Loveless FAST System		$ 340,000	$ 590,800	N/A
City Sewer System	$ 250,800	$ 1,123,750	$ 1,374,550	$ 61,972

For the 8 systems considered, Bio-Microbics MicroFAST provides the most affordable option for the community; however, Clean Solution Treatment System provides the most cost effective system. Despite the savings associated with the Clean Solution Treatment System, the capital cost and installation of the system outweighs any cost savings. Also, the removal of the RUCK system would cost over $250,000. This makes removal and replacement of the RUCK system impractical for Woodlands Village at this time. Replacing the RUCK system with a new technology would be a feasible option should the current system fail.

In terms of yearly operational costs, connecting to city sewer is the cheapest option out of all alternatives. However, the installation of city sewer would cost around $1,123,750 including engineering costs. The removal of the RUCK system would cost over $250,000 as well, which would result in a total capital cost of about around $1,374,550. As a result the city sewer connection would be the most expensive system to install. Connection, however, would provide savings of nearly $45,000 a year for Woodlands Village. This savings makes city sewer the best financial option for Woodlands Village. However, connection to city sewer at this time is not possible because the system does not reach the public roads near Woodlands Village. Until an extension of the city sewer system occurs, the connection is unfeasible.

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Appendix A: Proposal

10/13/2016

Wastewater Treatment in a Growing Lakeside Community

Lunenburg MQP Proposal

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Abstract

The goal of the Lunenburg MQP is to provide alternative wastewater treatment system options (WWTS) for the Woodlands Condominium Development to help reduce high community expenses, maintain environmental standards, and plan for future expansion of the condominium. The proposal outlines the current status of the development and site conditions, provides typical procedural steps on the analysis of a WWTS, and details the methodology of this project.

Capstone Design

This project focuses on the sizing and planning of a wastewater treatment system (WWTS) in Woodlands Village in Lunenburg, Massachusetts. The current RUCK® CFT filter system is a large expense to the community, and has had a history of being noncompliant with MassDEP regulations. Eventually, the community would like to expand to the intended original size of 100 units. To ensure that the current system and any new recommendations will meet the needs of a 100-unit community, the project will use population projections and current effluent information from the community to properly size a new system.

The group will use both GIS and AutoCAD to draw potential WWTS solutions for the community, while considering the current infrastructure and plans to reduce the total cost. Soil properties, design constraints specified by MassDEP, and local zoning laws will be considered in developing the most appropriate solution for the wastewater treatment issues in the community.

Throughout the project, design constraints will be considered to provide a feasible solution that benefits the community. The new system will be economically affordable, but also environmentally conscious in protecting the water quality of Hickory Hills Lake. The final decision on the type of system used at Woodlands Village will ultimately be decided by the community through their political system, which will ensure that the system is socially acceptable to the community. The recommended WWTS will be safe for the community and feasible to construct. The designs will cause no harm to the environment or people in the area and will be sustainable for the community for many years in the future.

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1. Introduction

The Lunenburg MQP analyzes the decentralized wastewater treatment system at a condominium development in Lunenburg, MA. The Woodlands Village condominium development consists of single-family homes, duplexes, and four-unit buildings for a total of 47 units. Currently, wastewater from the condominium is treated by a RUCK® CFT System that was installed in 1998. The system has been modified multiple times since installation due to non-compliance with EPA standards for effluent discharge. The current design uses a continuously added supply of methanol as the carbon source for denitrification (Brush and Weksner 2016).

Nitrogen levels in the effluent are an important consideration at the site. Since Woodlands Village is a lakeside community, the effluent should have low levels of nitrogen to prevent algae blooms and plant overgrowth in the lake. The effluent must also have low biological oxygen demand (BOD) levels. Both high BOD and nitrogen levels lead to a reduction in the dissolved oxygen in a waterbody. Low dissolved oxygen levels cause the death of aquatic organisms (United States Geological Survey). Prevention of eutrophication and preservation of the lake's water quality is essential to maintaining the property values of surrounding properties. These concerns are addressed through an assessment of the current wastewater treatment system and exploration of alternative systems.

The RUCK® CFT System consumes about 33% of the condominium development's budget each year. With fewer houses built than initially expected, the burden of the system is much larger on each individual household. The cost of the system and maintenance of the grounds in the development have become an encumbrance on condominium owners and has made resale difficult (Brush and Weksner 2016). To address these problems, a full cost-analysis will be done on the current system and each alternative system at the present number of homes, as well as, at multiple levels of increased development. The analysis will then provide recommendations for the system to be used at varying levels of added development. This information will be presented at the Woodlands Village monthly board meeting and a cost-analysis report will be provided to the community and board members.

2. Background

This chapter outlines information about the Woodlands Village Condominium Development and their current wastewater treatment system. It describes how to approach analyzing a wastewater treatment facility and our qualifications for completing this project.

2.1 Woodlands Condominium Development

The Woodland Condominium complex is located in Lunenburg, Massachusetts, which is approximately 46 miles north of Boston. Woodlands Village covers 74 acres surrounding Hickory Hills Lake, which is a shallow man-made, dammed lake (Brush and Weksner 2016). The Woodlands Village condominium was initially designed to consist of 100 units, but only 47 were built. Due to deviations from the original design of the condominium, there is a mile of unused road leading to the wastewater treatment facility, which is expensive to maintain (Brush and Weksner 2016).

Figure 1: Satellite Image of Woodlands Village Area

2.1.1 Private Wastewater Treatment System

Septic tanks were originally installed at Woodlands Village for individual units or groups of units. However, as the community grew in size, changes to the existing system were necessary to meet MassDEP regulations. In order to accommodate the wastewater from an anticipated 100 units, a conventional wastewater treatment system using a rotating biological contactor was installed (Brush and Weksner 2016). This design required a groundwater discharge permit. However, since only 47 units were constructed, the conventional WWTS exceeded the needs of the development. As a result, the original system was sold prior to operation and replaced with a RUCK® CFT System wastewater treatment system in 1998 (Brush and Weksner 2016). The community is looking to expand because there is an abundance of undeveloped land, however this cannot happen until the current WWTS is evaluated and other technologies are investigated.

Figure 2: View of the RUCK filter system at Woodlands Village

2.1.2 Governance

At Woodlands Condominium, residents own the title to their individual unit space, but the house structure, lawn, and surrounding land belong to the stakeholders who own the complex. The community has a board of trustees that make decisions regarding changes to the complex and oversee committees run by members who live in the complex. Committees include the Waterfront, Social, Finance, and Facilities Committee. The Facilities Committee oversees the wastewater treatment system in place at the complex (Brush and Weksner 2016).

2.1.3 Wastewater Treatment Issues

The Woodlands Village wastewater treatment system was non-compliant with MassDEP regulations multiple times. Initially, the RUCK® CFT System was not maintained properly. For example, the filter at the effluent to the 30,000-gal tank was not cleaned monthly, as required. This was likely due to insufficient training and/or insufficient operating instructions. Additionally, Woodland's Village was cited for negligence because the flowrate, BOD level, and nitrogen content of the WWTS effluent exceeded their permit standards for eight months (Brush and Weksner 2016).

Figure 3: Woodlands Village Wastewater Treatment Building

After facing MassDEP fines, the board of trustees created the Facilities Committee to oversee the RUCK® CFT System. The Facilities Committee has identified several aspects of the wastewater treatment system that need improvement. Currently, methanol is added to the system continuously, independent of the effluent flow rate. Alkalinity is corrected by the addition of 40lb bags of bicarbonate to the 30,000-gal anoxic tank. Flow rates are calculated by hand and all records are kept as hard copies, with a limited number of documents available in a user-friendly, accessible digital format. Most importantly, about 33% of the community's budget is spent on the system, which is excessive. (Brush and Weksner 2016).

2.2 Ruck Technology

RUCK CFT Systems are designed to treat 2,000-9,999 gallons of wastewater per day (Innovative RUCK Systems 2016). Typically, the system consists of a septic tank, a pump chamber, a RUCK® filter(s), a mixing chamber, a detention tank, and a soil absorption system (Massachusetts Department of Environmental Protection 2012). Wastewater from the residential units first flows to the septic tank where solids settle out of the wastewater. Effluent then flows to a pump chamber, which pressure doses the RUCK filter. The filter consists of alternating layers of stone and sand, with plastic inserts in the sand layers. The filter is also surrounded by an impermeable liner and is vented to the atmosphere. Filtered effluent collects in the filter underdrain and flows to the mixing chamber. In the mixing chamber, a carbon source is added to provide nourishment for denitrifying bacteria and allow denitrification to take place. After denitrification, nitrogen reduced effluent flows to a detention tank and then the soil absorption system (SAS) (Innovative RUCK Systems 2016). A simplified schematic of the RUCK CFT system is shown in Figure 4.

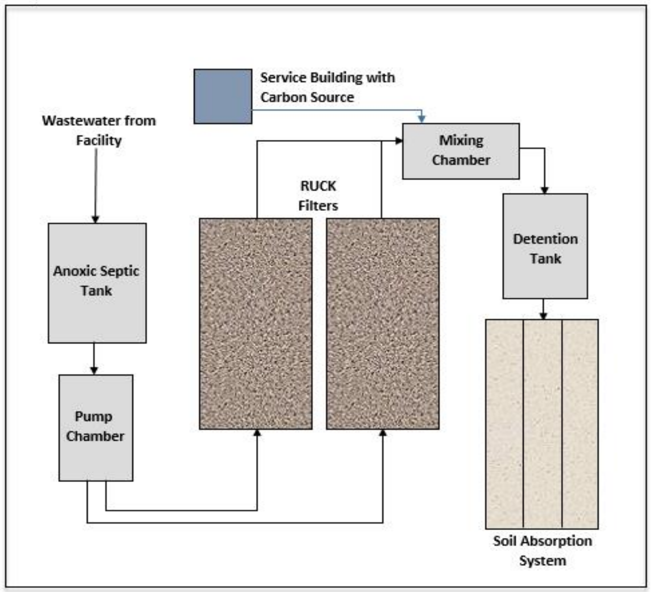


Figure 4: General Schematic of a RUCK ® CFT System

The RUCK® CFT System installed at Woodlands Village in 1998 was the first RUCK CFT System installed in Massachusetts. Four other RUCK CFT systems have been installed since 2003 to treat wastewater from both residential and institutional facilities (Innovative RUCK Systems 2016). RUCK CFT systems provide tertiary treatment with a nitrogen removal rates upwards of 90%. RUCK CFT systems are advantageous because they replenish groundwater and can run mostly unattended. However, RUCK CFT systems require a part-time operator, provide very little operational control, and the addition of the carbon source must be precise.

2.2.2 Woodlands WWTP Design

The RUCK CFT System at Woodlands Village has a design capacity of 12,400 gpd, just under the facility's permit limit of 12,500 gpd (Mount Hope Engineering 2014). The wastewater treatment system at the condominium is atypical because 41% of the 47 units have septic tanks. Since a portion of the solids in the wastewater settles in the septic tanks, influent to the wastewater treatment plant (WWTP) is unusually rich in ammonia due to a large proportion of urine in the blackwater. Since the condominium is situated on relatively flat ground, four pump ("lift") stations convey wastewater through two force mains to the treatment facility. Of the four pump stations in the complex, three are used to convey effluent from multiple homes. The fourth pump serves only the last house constructed at the condominium. All but one pump station has a septic tank before the pump to catch solids.

At the wastewater treatment facility, wastewater is received by a 30,000-gallon anoxic septic/pre-treatment tank (Description of Woodlands Wastewater Treatment System 2016). To adjust alkalinity, sodium bicarbonate is added to the wastewater in this underground, concrete pre-treatment tank (Description of Woodlands Wastewater Treatment System 2016). Description of Woodlands Wastewater Treatment System 2016). A portion of the anoxic septic tank consists of a 10,000-gallon flow equalization tank, which contains two submersible pumps that periodically and evenly distribute flow to two RUCK filters.

The WWTP has two RUCK filters that operate in parallel. Filter #1 was part of the original instillation whereas filter #2 failed and was rebuilt in 2009 (Description of Woodlands Wastewater Treatment System 2016). The filters are vented in eight locations to provide an oxygenated environment for the nitrification process (Holmes and McGrath 1999). Within the filter, ammonia (NH_4) is converted to nitrate (NO_4). Nitrified effluent collects in the filter's underdrain on an impermeable membrane and flows to the interim pump chamber.

A portion of the effluent from the interim pump station is first diverted to the 1,500-gallon heating tank before flowing to the first denitrification tank (Mount Hope Engineering 2014); Description of Woodlands Wastewater Treatment System 2016). The remaining portion of the effluent flows directly to the first of two 4,000-gallon denitrification tanks, which are set in series (Mount Hope Engineering 2014). For denitrification to occur properly, the effluent temperature in the denitrification tanks must be maintained above 50°F to keep the denitrifying bacteria active and healthy. As a result, the diverted effluent stream must be heated for approximately ⅔ of the year. The anoxic denitrification tanks contain a fixed film media, Denite, to provide a surface for the growth of denitrifying bacteria (Mount Hope Engineering 2014). Methanol is continuously added to the first denitrification tank to supply food (carbon) to the bacteria. The denitrifying bacteria convert nitrates to nitrogen gas, which can then be vented to the atmosphere. The treated water flows through the second denitrification tank to the final effluent pump.

The final effluent pump chamber stores and periodically discharges the treated effluent to the soil adsorption system (leaching fields). The subsurface leaching field contains four 154-foot lines of deep concrete leaching galleys surrounded by four feet of stone on each side. The galleys are set in a gravel bed and are vented to the atmosphere. The final effluent pumps evenly distribute effluent to two of the four galleys at a time. Pumps in the final chamber alternate between dosing two of the four 154-foot leaching galleys with effluent at a time.

2.3 General Procedure to Analyze a Wastewater Treatment System

Although wastewater treatment systems have varied throughout the years, a general process for analysis can be formed through the past projects. State and provincial departments have utilized the general processes to create plans that help guide planners and designers towards a standardized method of wastewater treatment analysis. The guidelines have multiple ideas in common, that can be further divided into six major steps.

Figure 5: General Process for Developing Wastewater Treatment Options

2.3.1 Step 1: Analysis of Current Conditions

The first major task a group should undertake when retrofitting or redesigning a wastewater treatment system is to inventory the current system in place. The Oregon Department of Environmental Quality states that the analysis must include all wastewater collection, treatment, and disposal facilities in the area (Carlson et al. 2013). Performing an inventory on the current system will help determine the current flow from the community, the types of pipes in the ground, and the systems used for treatment. Another major factor to be considered is the area available for the treatment system. The Wisconsin Department of Natural Resources specifies that the planning area is important if any potential changes to the system result in a larger design area (Wisconsin Department of Natural Resources). Another design criterion that should be considered is the inventory of energy efficient appliances in the community to determine how much the flow can be decreased in each household (Province of Manitoba).

2.3.2 Step 2: Investigate the Current Wastewater Treatment System

Once the current conditions are fully inventoried, the treatment system can be analyzed. When evaluating the system in place, a major factor that must be considered is the utilities required for the system to function (Carlson and others 2013). Knowledge of the facility's utilities will provide limitations for upgrades and replacement of the system. Another factor to consider is the current cost of the system. When determining the effectiveness of the system, the cost must be compared to the functionality as part of the analysis (Province of Manitoba). An efficient design that encompasses a significant portion of the community's budget will be worse than a functioning system that saves the community money each year.

2.3.3 Step 3: Projected Needs of the Community

Most communities are never completely stagnant. The population changes as people move, and some communities expand as new houses are built. In a changing community with a wastewater treatment system, planning for increased flow rates in the system is imperative for a well-functioning community. When a system is being either upgraded or replaced, future projections of the population of the community will help with the planning and design of the wastewater treatment system (Wisconsin Department of Natural Resources). Using population trends, a projected flow rate can be estimated based on the average flow rates created by community members. These flows allow for the planning of a system design that will accommodate future growth in the community (Province of Manitoba).

2.3.4 Step 4: Identify Potential Wastewater Treatment Options Available to the Community

Based on the projected flow rates of the community, alternative wastewater treatment systems should be researched as the next step in the planning process. A properly sized treatment system should be designed to accommodate the current population and future growth of the community. Specific types of wastewater treatment can be analyzed according to the existing site conditions determined in the first step of the planning process. The decision should also include land use patterns in the area, development direction and densities, and changes that occur when the system is installed and functioning (Province of Manitoba). Finally, any alternative designs must be checked to ensure that they do not violate any local and state laws regarding wastewater treatment and discharge (Carlson et al. 2013).

2.3.5 Step 5: Final Comparison of Wastewater Treatment Systems

Once the alternative design options are completed, a final decision must be made on the type of system to pursue. The decision should encompass costs of construction, maintenance, and operation (Province of Manitoba). Once the factors are compared, the ability of each system to handle the community's projected future waste will be used to determine how effective the systems will be in the future (Carlson et al. 2013). Oregon's Department of Environmental Quality suggests using a triple bottom line analysis when making the decision about the best system to pursue (Carlson et al. 2013). A triple bottom line analysis is "an accounting framework that incorporates three dimensions of performance: social, environmental and financial" (Slaper and Hall 2011, 4). Utilizing this decision-making plan will allow for the community to incorporate public opinion, environmental concerns, and financial limitations in the final decision.

2.3.6 Step 6: Final Recommendations

Based on the community's income and ability to afford a new project, the best system will be chosen as the final recommendation (Carlson et al. 2013). If the triple bottom line analysis is used in the decision making, the final recommendation will be a combination of price, limitation of environmental impacts, and acceptance by the community (Slaper and Hall 2011, 4-5). The final decision will also include important documents like an environmental impact analysis report and information still needing additional research (Carlson et al. 2013). Upon making a decision, the community can continue the process and begin the design and implementation phases.

2.4 Qualifications

The students from Worcester Polytechnic Institute who will be working on this project as their Major Qualifying Project (MQP) are Julia Bushell, Sierra Fowler, Matthew Houghton, Abbegail Nack, and Chris Xavier. Julia Bushell is a Chemical Engineering Major and has experience in managing risk in HVAC systems in the pharmaceutical industry. Sierra Fowler, a Chemical Engineering major as well, has worked for city and government environmental departments including the Worcester Water Filtration Plant where she tested filter efficiency. Matthew Houghton is a Civil Engineering major who has performed a cost analysis report for solar panels in the Santo Domingo Pueblo in Santa Fe, NM. He has also inspected municipal wastewater conveyance systems, has experience in AutoCAD and GIS, and has taken classes in wastewater treatment. Abbegail Nack is a Chemical Engineering and Professional Writing Double Major, who has class experience in water treatment. Christopher Xavier is another Chemical Engineering major, with experience in process design and analysis.

3. Methodology

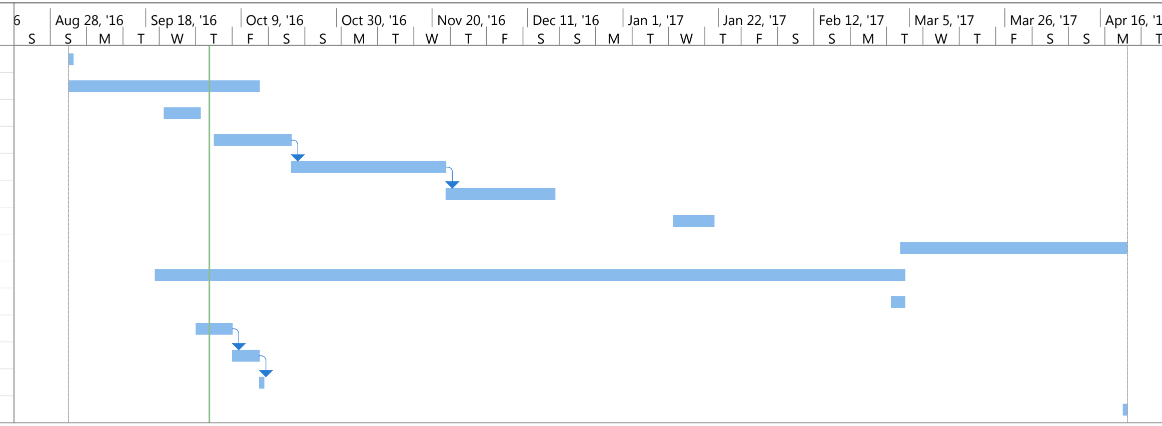
The goal of the Lunenburg MQP is to provide different wastewater treatment options for the Woodlands Condominium Development to help them reduce high community expenses, maintain environmental standards, and plan for future expansion. In order to achieve the overall goal of the project, several steps must be taken to gain the knowledge and background needed to formulate solutions. We will:

1. Create a schedule for the project
2. Learn more about the current RUCK system in place
3. Determine the effectiveness of the RUCK system in place
4. Learn about other available wastewater treatment technologies
5. Provide a feasible wastewater treatment alternative for the community at Woodlands Village
6. Deliver findings to the board members and community at Woodlands Village and provide a final recommendation for the Woodlands Village site

3.1 Create a Schedule for the project

The Gantt Chart on the following page is a detailed plan for completion of the project goals. The scheduled dates provide structure for successful fulfillment of each objective.

ID		Task Mode	Task Name	Duration	Start	Finish
1			Start	1 day	Thu 9/1/16	Thu 9/1/16
2			Background Research	31 days	Thu 9/1/16	Wed 10/12/16
3			Project Proposal	6 days	Thu 9/22/16	Thu 9/29/16
4			RUCK System Analysis	14 days	Mon 10/3/16	Wed 10/19/16
5			WWTS Options	24 days	Thu 10/20/16	Tue 11/22/16
6			Conduct Cost Analysis	18 days	Wed 11/23/16	Fri 12/16/16
7			Winter Presentation	7 days	Thu 1/12/17	Fri 1/20/17
8			Final Presentation	36 days	Fri 3/3/17	Fri 4/21/17
9			MQP Report	120 days	Tue 9/20/16	Fri 3/3/17
10			eCDR	3 days	Wed 3/1/17	Fri 3/3/17
11			Project Proposal Edits	6 days	Thu 9/29/16	Thu 10/6/16
12			Project Proposal Final Edits	5 days	Fri 10/7/16	Wed 10/12/16
13			Project Proposal Final Submittal	1 day	Thu 10/13/16	Thu 10/13/16
14			End	1 day	Fri 4/21/17	Fri 4/21/17



Project: MQP Schedule
Date: Sun 10/2/16

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

3.2 Learn more about the current RUCK system in place

The first project objective is to learn more about the current RUCK system in place at Lunenburg. To complete this objective, we must perform a site visit to the Woodlands Condominium Development to better understand the current system. A walk through of the community and its relationship to the Hickory Hills Lake, will provide information on the need for a reliable effluent stream leaving the RUCK system. Examination of the RUCK site must be done to gather information that may differ from schematic plans. Lastly, collecting information on areas of concern and potential problems from the stakeholders will highlight the areas of focus of the project.

3.3 Determine the effectiveness of the RUCK system in place.

In order to suggest improvements or modifications, the efficacy of the RUCK technology and septic system present at the facility must be determined. An analysis of the documents and specs on the RUCK system given to us by the sponsors will be done to understand past issues of noncompliance, past problems with the system, and current successes of the system. An examination of the effluent tests on BOD and nitrogen levels must also be performed in order to gather information on how well the RUCK system is treating the wastewater. Lastly, with all this information we must compare the actual performance of the system with the desired performance. This will tell us any short comings of the system and how effective the system is at performing its desired task.

3.4 Learn about other available wastewater treatment technologies

Project objective three is to learn about other available wastewater treatment technologies that may be suitable for the Woodlands site. The process of discovering other wastewater treatment starts with understanding the needs of the condominium. Conditions such as type of soil, surrounding environment, process volume, EBA regulations, and effluent requirements must be determined to provide base expectations for a new technology. Research can be done on various existing and emerging systems. The positives and negatives of each new system can then be compared to Woodlands' needs. We can then report our findings and move on to objective four.

3.5 Provide a feasible wastewater treatment alternative for the community at Woodlands Village

The fourth objective is to fully understand the implications of implementing each of these technologies and determine the system that is feasible for the present and future needs of Woodlands Condominium. To accomplish this objective, we must estimate the future expenses of all wastewater systems. These estimates need to account for two possible scenarios, no growth in the Woodlands Development and expansion of the development. It is imperative to determine how much the system will cost with the present side of the condominium complex and to determine if the costs can be lowered through the addition of units. We need to examine the effect different levels of expansion would have on the wastewater treatment in system operations. Once the effect on operations is known, the cost of the systems at each level can be estimated. This will provide a comparison model between the different systems at a no growth, low expansion, medium expansion, and high expansion level. These models will provide an ideal cost-benefit analysis for deciding the most suitable system and expansion level of the Woodlands site.

3.6 Deliver findings to the board members and community at Woodlands Village and provide a final recommendation for the Woodlands Village site

The final objective is to educate the Woodlands Village community and board members on the findings of the project. There are two ways in which we plan on presenting the project findings to the community and board members. One is through an oral report conducted at the board's monthly meetings. This will provide the community with the opportunity to listen to our recommendations and ask questions that interest or concern them. Thus, it provides opportunity for them to understand the impact on their homes and community. The other presentation of findings will come in the form of a cost analysis report. The report will outline the cost at multiple levels of expansion and multiple alternatives along with the benefits and negatives of each system. It will also provide the final recommended solution that we see best fit for the Woodlands Development. This final recommendation will incorporate and address concerns brought about in the presentation to the board and community. The cost analysis will be a standalone product that provides stakeholders with the necessary information on the systems without the need of the full report.

Overall, the five objectives work to the goal of reducing high community wastewater treatment expenses and plan for future expansion in the development by educating us on the current RUCK system, determining its efficacy, examining other alternatives to wastewater treatment, analyzing the cost and treatment effectiveness of these systems, determining the effect of expansion of the development, and educating the community on the findings (Carlson and others 2013).

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Appendix A: 9/16/16 Site Visit Report

Site Visit at Woodlands Village 9/16/16

Introduction

On Friday September 16, 2016 our MQP group (Julia Bushell, Sierra Fowler, Matt Houghton, Abbey Nack, and Chris Xavier) visited Woodlands Village. We were accompanied by our advisors Suzanne LePage and Jose Alvarez Corena. We met with Jack Brush, Bob Pease, and Ed Weskner from Woodlands Village. Our site visit provided invaluable, first-hand knowledge of the facility layout and resulted in fruitful discussions with our contacts at the condominium development. The information we obtained is discussed below.

Areas Visited

Our tour of Woodlands Village began at Jack Brush's duplex unit (100 Royal Fern Drive) overlooking Hickory Hills lake. From there, we walked to the wastewater treatment facility (WWTP). On our walk, we stopped at the final pump station that conveys wastewater from the majority of the units to the facility. We also identified a pump station used solely to convey wastewater from the last unit constructed and a stormwater detention pond. Once at the WWTP, we explored the inside of the building which houses the back-up generator, heater, carbon source pump, carbon source, and various other equipment. We also explored the area surrounding the WWTP building to identify the locations of the 30,000 gal septic tank, RUCK Filters, leaching field, and other parts of the treatment system. Most of this external equipment was located underground. After gaining insight into the layout of the facility, we walked back past Jack's unit to another pump station. At this point, we concluded the tour.

Woodlands Village

Facility Layout

Woodlands Village consists of 5 buildings with 2 units, 5 structures with 4 units, and 17 single-family homes. Each unit has two bedrooms and 3-4 baths. All 47 units are under condominium ownership, which means that homeowners own from the walls of their unit inward, but the actual structure of the buildings and grounds are communal. Woodlands Village is supplied with town water and has a storm drainage system separate from the wastewater treatment system. Storm water flows through a drainage system into a detention pond that is surrounded by a dike. Originally, the community was intended to consist of 100 units. However, the remaining 53 units were never built.

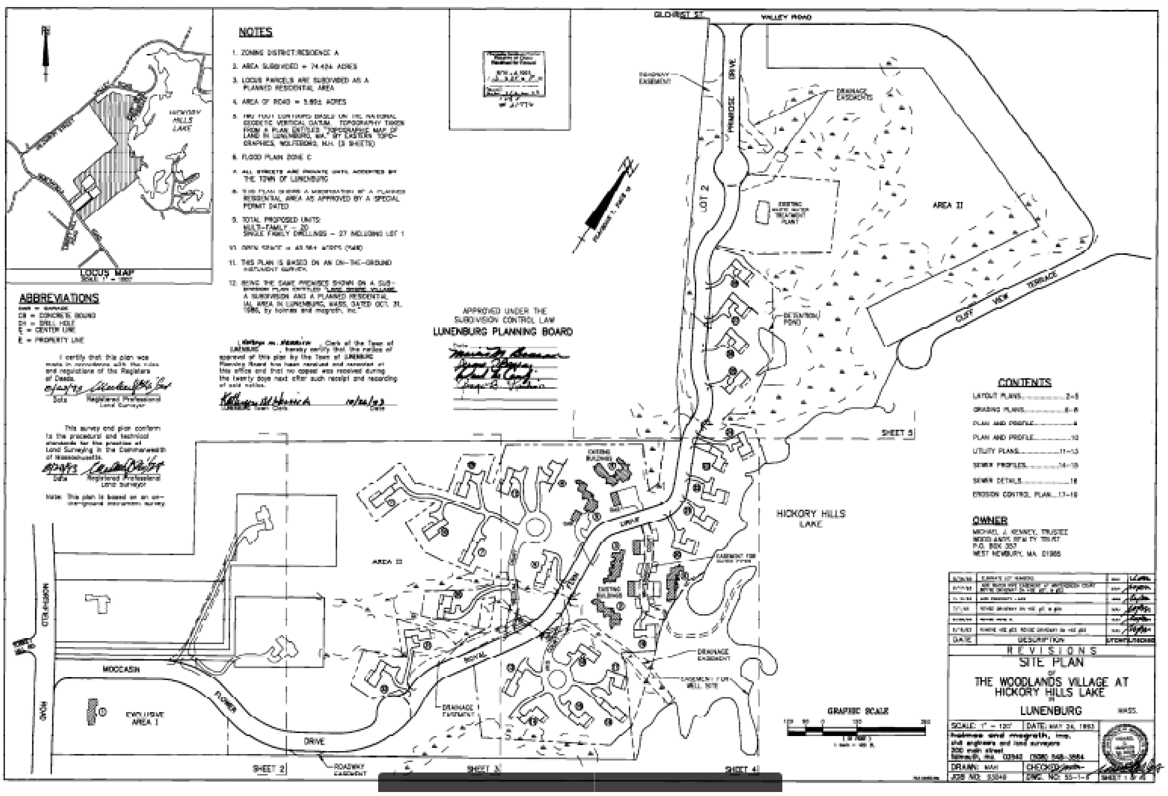

Figure 1: Layout of Woodland Village

Facility Maintenance

During our discussion two maintenance issues in the facility were discussed. They are listed below:

1. The pond is currently overgrown and is in need of maintenance.
2. Consequently, there is approximately a mile of road that is not used, but still requires maintenance. To cover the cost of this unused road, homeowners' monthly fees are almost double what they would had been if all of the units were constructed.

Administration

The condominium is controlled by a 5-member board of trustees, which includes Ed Weskner and Bob Pease. The trustees created several proactive committees to oversee different aspects of the condominium, such as a social committee, waterfront committee, and facilities committee. The facilities committee is responsible for overseeing the operation of the RUCK facility. Ed Weskner, Bob Pease, and Jack Brush are all members of the facilities committee. Ed and Bob are also on the finance committees. Our primary contact is Jack Brush; he can be reached by cell at 508-816-3361.

Hickory Hills Lake

The condos are situated on a man-made, dammed lake called Hickory Hills Lake. There is one inflow from the Mulpus Brook and the depth ranges from approximately 8 to 12 feet. The bottom of the lake consists of glacial till. Hickory Hills Lake is a private beach under active lake management by Hickory Hills Landowners, Inc. The organization oversees the 3 beaches, and is actively combating fanwort, an invasive species. Hickory Hills Landowners, Inc. contracts out dive teams to use a DASH unit to remove and strip the fanwort. They are considering the use of an herbicide to eliminate the invasive species.

Figure 2: View of Hickory Hills Lake

There are about 500 homes surrounding the lake, but Woodlands Village is the only condominium complex. Each homeowner at Woodland Village receives a dock for their use. Woodlands Village also has a 100-foot stretch of beach for patrons' use. The lake is used for recreational purposes, but there are restrictions on boat size and the use of watercraft that have been used elsewhere. The lake is also occasionally used for helicopters and amphibious vehicles. The town has a pump house located in an easement on the condominium's property, because the lake is a tertiary emergency reservoir. As a result, the condominium must ask permission to make modifications to the area surrounding the easement. Currently, the inlet pipe from the lake to the pump house is laden with manganese. Therefore, it is unlikely that the pump house will be used to provide drinking water to the Town of Lunenburg in the near future.

Wastewater Treatment

WWTP History

From its inception, Woodlands Village has used Holmes and McGrath out of Falmouth, MA for their wastewater services. Originally, a conventional wastewater treatment system sufficient for 100 units was installed. The system included a Rotating Biological Contactor (RBC). This expensive system, which would require an operator 24/7, exceeded the needs of the 47-unit condominium. Therefore, the original system was sold prior to its operation and RUCK system was installed between 1998 and 1999. During the switch, oxygenated filters and denitrification tanks were also installed. Unfortunately, the building housing the wastewater treatment system controls and aboveground equipment was sized for the original equipment. Now, the building contains a lot of wasted space.

Figure 3: View of the Wastewater Treatment Building

Current WWTP System

The condominium is permitted by MassDEP to treat 12,500 gpd of wastewater. Although the wastewater treatment system is designed for a maximum flow rate of 10,000 gpd, typical effluent flow rates are half of this upper limit. The flow rate is extremely variable. This is a product of the community living at Woodlands Village. Many homeowners are elderly or “empty-nesters” who have family visit on the weekends or throughout the summer. This may contribute to the variable flow rate.

Septic Tanks

Septic tanks, installed as part of the original treatment system, are still used in the current system. The septic tanks were installed when the first homes were built because they community did not reach the gallon limit required for a larger scale operation and fell under Title V. The WWTP now falls under MassDEP jurisdiction. 41 % of the units in Woodlands Village have septic tanks. The single family homes in the Iris Court each have their own septic tanks, which are pumped every year. Four of the duplexes have their own septic tanks, but only the location of one tank is known. The facilities committee is in the process of trying to locate the other three septic tanks with the help of the Nashoba Health District. Septic tanks of known location are pumped annually. Since some of the solids in the wastewater settle in the septic tanks, influent to the WWTP is ammonia rich due to the large proportion of urine in the blackwater.

Pump Stations

Effluent from the homes is fed to a 30,000 gal tank near the RUCK facility. Since most of Woodlands Village is situated on flat ground, the wastewater cannot be gravity fed. Therefore, there are four pump stations in the complex. Of the four pump stations in the complex, three are used to convey effluent from multiple homes. The fourth pump serves only the last house constructed at the condominium. This 5-HP pump conveys wastewater directly from the home to the WWTP via a pipe separate from the main wastewater pipe.

The main pump station has a gas backup generator. This main pump is the final pump that conveys wastewater from 46 of the units to the WWTP. Two of the pumps are submerged 5 HP pumps. Wastewater from 6 of the single family homes go to one of these traditional 5 HP pumps. One pump takes strictly greywater, while the other two take sludge as well. It costs about $24,000 to clean the pumps. Each pump station has its own electric meter.

Figure 4: Main Pump Station

One of the pumps serving multiple homes is a pneumatic system that utilizes two pots. The effluent flows into the pot until it is full, which causes a valve to close. The pressure in the pot is used to force the effluent to another pump station via compressed air. However, this pneumatic pump is not functioning properly. Currently, the pressure in the pneumatic pump only builds to 6 psi because one side of the dual pump is not operational. This pressure is sufficient enough to convey the effluent, but is by no means efficient.

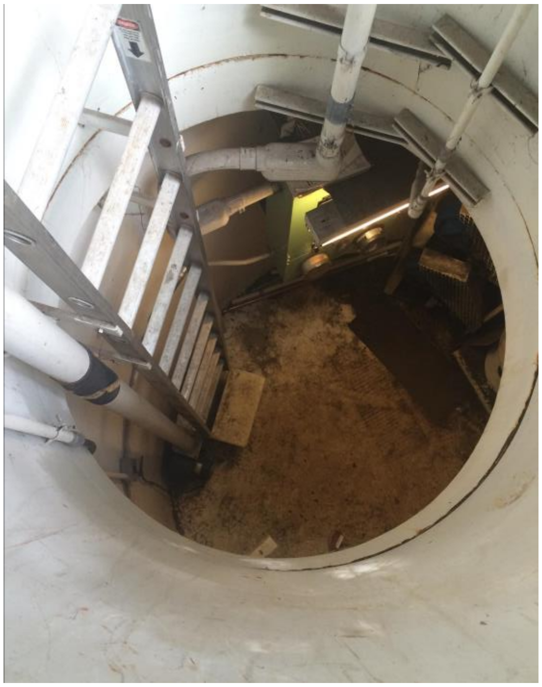

Figure 5: Pneumatic Pump Station

Originally, WhiteWater Inc., the pump operator, neglected to inform Woodlands Village that the pneumatic pump station was malfunctioning. WhiteWater Inc. will not fix the pump nor will they provide Woodlands Village with enough information about the pumps to take their business to another company. Despite the difficulties of working with WhiteWater, Woodlands Village continues to use the pump operator because WhiteWater is the only company in the area that provides the services they require. The next closest operating company is Pride Environmental, which is based in Cape Cod. Due to the costs associated with travel from Cape Cod, the use of this company is not feasible for Woodlands Village.

30,000 Gallon Anoxic Tank and Flow Equalization Chamber

There are two different force mains that convey wastewater to the 30,000-gallon anoxic tank. Baffles are built into the anoxic tank. To adjust alkalinity, the operator pours 40 lb. bags of bicarbonate into the 30,000-gal tank three times a week. Wastewater is fed from the 30,000-gallon tank to the Flow Equalizer Chamber (FEC), which pumps effluent to the RUCK. There are manual controls in the FEC, in case of pump failure.

Figure 6: Septic Tank in the WWTS

RUCK Filter

The physical RUCK filter consists of alternating layers of a plastic waffle-like structure covered in landscaping cloth. There are layers of sand and crushed rock between the layers of plastic filters. The filters are vented, which oxygenates the filters. Approximately 15 years ago the filters failed and were replaced. There have not been any issues with the filters since their replacement.

Figure 7: RUCK Filter Media

Denitrification

Effluent flows from the RUCK filters to the denitrification tanks. For denitrification to occur properly, the effluent must be heated for ⅔ of the year to keep the denitrifying bacteria active and healthy. This is done through recirculating liquid that acts like a radiator. The heater maintains the effluent at a temperature of 62-75 °F from October through April. Filters at the end of the denitrification tanks are used to prevent scum from entering the effluent. These filters are power-washed monthly.

A 20% methanol solution is added to one of the denitrification tanks as a carbon source for the denitrifying bacteria. They use two barrels of methanol each month. MicroC was originally used as a carbon source. However, adjusting the levels of MicroC to maintain appropriate concentrations of nitrogen and BOD in the effluent proved too difficult. While the methanol is effective at maintaining effluent characteristics within MassDEP limits, methanol costs $1000 more per year than MicroC. Their methanol use used to be based off of flow rate, but the methanol injection pump is currently operating 24/7 as per the recommendation of the treatment plant operator. In the future, this may be problematic; too much methanol can increase BOD, but too little can cause too high nitrogen levels. Adding methanol 24/7 is also likely wasteful since varying flow rates require different levels of methanol.

To comply with MassDEP regulations, the methanol is stored on special platforms with secondary containment systems to combat spills. This storage system is in the main room of their facilities located 100 feet from any potential ignition source (live wires, etc.) to prevent the chemical from starting a fire. This required the modification of a power outlet in the storage room.

Figure 8: Methanol Barrels in the Wastewater Treatment Building

Leach Fields

After denitrification, effluent is pumped to the leach field. At the final pump station, a scum pump keeps effluent agitated before it goes to the leaching fields. The leach field consists of four concrete trenches containing 2-inch pipes down the length of the trench. Effluent from the WWTP flows through the pipes that have “T” sections every six to eight feet to allow effluent to evenly distribute along the length of the 150-ft trench. The leach fields are tested through inspection ports. To check the flow-level in the leach field, the operator removes the plug from the inspection port and inserts a clear plastic pipe into the trench. The height of effluent in the clear column can be used to determine the flow. Woodlands Village’s facilities committee is not worried about the leach fields failing.

Monitoring and Recordkeeping

The plant is operated by a man named Hugh (often referred to as Smokey). The operator keeps handwritten records of flow and effluent characteristics; only a few documents have been digitized. Three monitoring wells are located upstream of the WWTP and two are located downstream. The operator performs in-house testing of alkalinity, BOD, and COD and decides how to proceed with some operations based on the test results. The operator visits the site every weekday morning to record flow, monitor operating conditions, and perform testing. The operator does not visit the site on weekends. Consequently, flow rates over the weekend are approximated from a flow meter located at an intermediate pump in the WWTP. Ideally, the facilities committee would like to install a data recorder so that information can be recorded automatically each day and stored digitally.

Figure 9: Methanol Pump

The facility has a cellular alarm system that monitors for high water conditions, room temperature, and intrusions. The intrusion alarm was turned off due to several false alarms. Although there are seven pumps at the WWTP, only two pumps have hour meters to indicate how long the pump has been running. Since most of the pumps operate in tandem, it is difficult to determine when a pump has failed if there is no hour meter on the pump. The flowmeter on the control panel is not connected to the central alarm system. In case of power failure, there is a gas generator in the WWTP building to provide backup power. This generator, designed for the original conventional treatment plant, is too large for the current RUCK system.

Cost of the System

The biggest problem the condo association faces is the cost associated with operating their WWTP system under capacity. The homeowners' monthly fees are fairly high because about one third of Woodlands Village's budget goes into the RUCK system. It costs about $100,000 to maintain the RUCK system annually. Since there are fewer units than originally intended, a greater financial burden is placed on each homeowner to cover the costs of maintaining the system. Consequently, the high homeowners' fees impact the resale values of their homes.

Non-Compliance

About 3 years ago, the condominium and the WWTP operator was fined $3000 for negligence. The WWTP did not have an operating flowmeter because of miscommunication between the managing company and the operator. The operator was unaware of the filter at the end of the denitrification tank, which needed to be cleaned once a month. Additionally, the operator was not inspecting the leaching fields. When the MassDEP investigator visited the site, the fields were overgrown and one of the inspection ports was not closed properly. As a result, effluent had flowed into the field above the RUCK system and into the neighboring wetlands. The MassDEP informed the trustees that they are responsible for non-compliance issues. Since then, they have become more involved in the wastewater treatment system and formed the facilities committee.

Woodlands Village was also in violation of MassDEP regulations at the end of 2014 because they did not meet discharge permit standards for several months in a row. They were over the effluent permit limits for BOD, TSS, and nitrogen content. After these infractions, the facilities committee rewrote the operating manual and their operating company changed hands. The manual still has some inaccuracies, but they have not had any issue with their new WWTP operator since the change in ownership.

Potential Improvements Suggests by Facilities Committee

The Woodlands Village's trustees must consider many factors in looking to improve their wastewater treatment system. At first, the trustees considered hooking Woodlands Village into the Town of Lunenburg's sewer system. However, this option would be costly and faces political opposition from homeowners living around the lake. The current wastewater treatment system replenishes the groundwater supply. Homeowners are opposed to a centralized wastewater treatment system that would remove water from the area surrounding Hickory Hills Lake.

Woodlands Village's discharge permit allows for 94 bedrooms. However, the condominium actually has 104 bedrooms and their assessment says they have 114. Ideally, the trustees would like to increase the number of permitted bedrooms to 120 in order to reduce the cost of the system for each homeowner through construction of new units. Alternatively, the trustees hope to return to governance under Title V instead of the MassDEP. The trustees suspect that the actual flow rate of effluent is small enough to be under Title V.

Project Outcomes and Potential Recommendations

From our site visit, we identified the following possible project outcomes, deliverables, and recommendations for Woodlands Village:

1. We will prepare a report detailing alternatives to RUCK technologies, the costs associated with each technology, and justifications for switching to alternative technologies.
2. We will also present the results of our findings to the board of trustees, the facilities committee, and/or homeowners.
3. We will likely recommend that the facility disposes of old MicroC.
4. We will offer to create or revise their current operating manual. Although the facility now has an operating manual on-site, the manual still needs revisions.
5. We may offer to update the facility's plans. There are several issues with the facilities plans. For example, the WWTP plans depict the flow of wastewater through the treatment plant incorrectly.
6. We may propose uses for the unused space in the WWTP building to help mitigate costs of maintaining the structure.

Questions and Items Needing Clarification

- Why the septic tanks were originally installed?
- Why can't the RUCK filters be backwashed?
- At which point exactly is the carbon source added?
- Should the RUCK filter be oxygenated?

Appendix B: Cost Analysis Calculations

2015 & 2016 WWTS Expenses							
Item	Total 2015	Total 2015 (%)	Total Jan - Jun 2016	Monthly Average 2015	Monthly Average 2016	Total 2016	Total 2016 (%)
Contracted Operations	$ 10,281.00	10.9%	$ 8,448.00	$ 856.75	$ 1,584.00	$ 19,008.00	17.8%
Lab Testing/Analysis	$ 7,776.00	8.2%	$ 3,797.00	$ 648.00	$ 956.25	$ 11,475.00	10.7%
Pump Repairs/Maintenance	$ 14,483.09	15.3%	$ 8,242.40	$ 1,206.92	$ 1,557.11	$ 22,837.64	21.3%
Engineering Services	$ 2,765.00	2.9%	$ 870.00	$ 230.42	$ 811.54	$ 9,738.50	9.1%
Alarms/Fire Suppression/Security	$ 7,357.34	7.8%	$ 3,262.18	$ 332.47	$ 613.11	$ 3,657.12	3.4%
Telephone Lines	$ 936.26	1.0%	$ 46.51	$ 78.02	$ 3.88	$ 46.51	0.0%
Mowing Field over Ruck	$ 1,075.00	1.1%	$ 600.00	$ 89.58	$ 87.50	$ 1,050.00	1.0%
Gas	$ 2,871.27	3.0%	$ 2,490.09	$ 239.27	$ 276.11	$ 3,490.60	3.3%
Electricity	$ 9,700.67	10.3%	$ 6,501.00	$ 808.39	$ 928.71	$ 9,275.67	8.7%
Methanol	$ 3,464.10	3.7%	$ 2,078.46	$ 346.41	$ 384.90	$ 4,180.29	3.9%
MicroC	$ 1,759.77	1.9%	$ -	$ 146.65	$ -	$ -	0.0%
Sodium Bicarbonate	$ 880.21	0.9%	$ 916.47	$ 220.05	$ 184.21	$ 2,330.89	2.2%
Septic Pumping	$ 2,863.24	3.0%	$ 238.60	$ 599.50		$ 861.44	0.8%
DEP Permits	$ 8,320.00	8.8%	$ -	$ 693.33		$ 8,320.00	7.8%
DEP Fines	$ 5,565.00	5.9%	0	$ 463.75		$ -	0.0%
RUCK Repairs	$ 8,962.81	9.5%	$ 395.00	$ 746.90		$ 6,723.53	6.3%
Switch to Methanol	$ 1,406.00	1.5%	$ -	$ 117.17	$ -	$ -	0.0%
Replacement Reserve	$ 4,000.00	4.2%	$ -	$ 333.33	$ -	$ 4,000.00	3.7%
Treatment Building Repairs	$ -	0.0%	$ -			$ 18.48	0.0%
Total	$ 94,466.76	100%	$ 37,885.71	$ 8,156.92	$ 7,387.32	$ 107,013.67	100.0%

Cost of Operator and Maintenance Companies				
	2015	2016	2017	Savings
Contracted Operations	$ 10,281	$ 19,008	$ 33,400.00	
Pump Repairs	$ 14,483	$ 22,838	$ -	
Lab Testing and Analysis	$ 7,776	$ 11,475	$ 8,352.00	
Total	$ 32,540	$ 53,321	$ 41,752	**$ 11,569**

2015 & 2016 WWTS Expenses by Percentage		
Item	**2015**	**2016**
Total Cost	$ 94,466.76	$ 107,013.67
Pump Repairs/Maintenance (Whitewater)	15.3%	21.3%
Contracted Operations	10.9%	17.8%
Lab Testing/Analysis	8.2%	10.7%
Engineering Services	2.9%	9.1%
Electricity	10.3%	8.7%
DEP Permits	8.8%	7.8%
RUCK Repairs	9.5%	6.3%
Methanol	3.7%	3.9%
Replacement Reserve	4.2%	3.7%
Alarms/Fire Suppression/Security	7.8%	3.4%
Gas	3.0%	3.3%
Sodium Bicarbonate	0.9%	2.2%
Mowing Field over Ruck	1.1%	1.0%
Septic Pumping	3.0%	0.8%
Treatment Building Expenses	0.0%	0.0%
Telephone Lines	1.0%	0.0%
MicroC	1.9%	0.0%
DEP Fines	5.9%	0.0%
Switch to Methanol	1.5%	0.0%
Expenses that would remain the same	74.1%	79.6%
Expenses Associated with Any Treatment Technology	**$ 70,012.09**	**$ 85,187.14**
RUCK CFT Specific Expenses	**$ 24,454.67**	**$ 21,826.53**

RUCK Specific Expenses (2016)			
Item	**% of Usage**	**% of Total Expenses**	**Cost**
Chemicals	100%	6.1%	$ 6,511.18
RUCK Repairs	100%	6.3%	$ 6,723.53
RUCK Electric Use	52%	4.5%	$ 4,819.04
RUCK Gas Use	77%	2.5%	$ 2,702.68
Mowing	100%	1.0%	$ 1,050.00
Treatment Building Repairs		0.0%	$ 18.48
Total		**20.4%**	**$ 21,824.91**

Any Treatment Technology Expenses (2016)			
Item	**% of Usage**	**% of Total Expenses**	**Cost**
Lift Station Repairs/Maintenance		21.3%	$ 22,837.64
Contracted Operations		17.8%	$ 19,008.00
Lab Testing/Analysis		10.7%	$ 11,475.00
Engineering Services		9.1%	$ 9,738.50
DEP Permits		7.8%	$ 8,320.00
Lift Station Electric Use	48%	4.2%	$ 4,456.63
Replacement Reserve		3.7%	$ 4,000.00
Alarms/Fire Suppression/Security		3.4%	$ 3,657.12
Lift Station Gas Use	23%	0.7%	$ 787.92
Septic Pumping		0.8%	$ 861.44
Total		**79.6%**	**$ 85,142.25**

Total RUCK-Specific and Any Treatment Tech Expenses			$ 106,967.16
Expenses No Longer Applicable			$ 46.51
Total			$ 107,013.67

Gas Bills									
Account/Invoice Date	**Dec-14**	**Jan-15**	**Feb-15**	**Mar-15**	**Apr-15**	**May-15**	**Jun-15**	**Jul-15**	**Aug-15**
47214-13810	$ 85.08	$ 93.96	$ 68.93	$156.47	$555.68	$487.84	$ 81.30	$ 45.13	$ 44.32
47214-19240	$ 42.82	$ 46.96	$ 37.29	$ 41.44	$ 44.20	$ 47.97	$ 47.60	$ 40.06	$ 39.99
47214-13870	$ 24.06	$ 27.28	$ 22.17	$ 24.06	$ 24.45	$ 23.16	$ 25.25	$ 21.72	$ 21.72
Total	$ 151.96	$168.20	$ 128.39	$221.97	$624.33	$558.97	$154.15	$106.91	$106.03

Division of Gas Bill (RUCK Specific vs. Any WWTS)			
	2015 - 2016	**2016**	**2016**
Pump Stations	25%	23%	$ 787.92
Treatment Building & Pumps	75%	77%	$2,702.68

Gas Costs Breakdown	
Year 2015	$2,871.27
Jan-June 2016	$2,490.09
Total 2016	$3,490.60
Monthly Average 2015	$ 239.27
Monthly Average 2016	$ 276.11
Winter Monthly Average	$ 342.83
Summer Monthly Average	$ 208.23

Gas Bills

Account/Invoice Date	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16
47214-13810	$ 58.27	$ 63.73	$ 74.59	$337.13	$319.94	$267.82	$594.00	$477.88	$355.00	$ 82.28	$ 63.00
47214-19240	$ 43.40	$ 38.68	$ 42.82	$ 48.34	$ 42.82	$ 37.29	$ 45.58	$ 42.82	$ 40.06	$ 44.23	$ 44.20
47214-13870	$ 23.63	$ 20.88	$ 24.46	$ 26.39	$ 24.40	$ 20.70	$ 25.80	$ 23.50	$ 22.03	$ 23.94	$ 24.64
Total	$125.30	$123.29	$141.87	$411.86	$387.16	$325.81	$665.38	$544.20	$417.09	$150.45	$131.84

Gas Bills									
Account/Invoice Date	**Aug-16**	**Sep-16**	**Oct-16**	**Nov-16**	**Dec-16**	**2015 & 2016 Total**	**%**	**Total 2016**	**%**
47214-13810	$16.30	$36.40	$ 42.90	$ 65.41	$381.75	$ 4,770.03	75%	$2,702.68	77%
47214-19240	$40.76	$38.68	$ 45.58	$ 38.68	$ 45.58	$ 1,025.03	16%	$ 506.28	15%
47214-13870	$21.79	$21.14	$ 26.07	$ 21.58	$ 26.05	$ 566.81	9%	$ 281.64	8%
Total	$78.85	$96.22	$114.55	$125.67	$453.38	$ 6,361.87	100%	$3,490.60	100%

Electric Bills						
Location	**Acct. #**	**Dec-14**	**Jan-15**	**Feb-15**	**Mar-15**	**Apr-15**
Royal Fern Dr. (Treatment Building & Pumps)	3024851-3018578	$ 571.96	$ 554.27	$ 1,059.40	$ 582.57	$ 476.69
130 Royal Fern Dr. Sewer Pump	3110865-3089046	$ 13.90	$ 14.17	$ 27.19	$ (0.29)	$ 13.24
Wintergreen CT Pump	3024877-3018600	$ 52.35	$ 46.93	$ 88.85	$ 0.42	$ 36.61
Royal Fern Dr Pump	3024879-3018602	$ 147.88	$ 558.88	$ 1,092.68	$ 165.73	$ 317.41
Iris Ct Sewer Pump	3118857-3069866	$ 18.09	$ 17.05	$ 31.83	$ 0.35	$ 17.64
Total		$ 804.18	$ 1,191.30	$ 2,299.95	$ 748.78	$ 861.59

Electric Costs Breakdown	
Total 2015	$ 9,700.67
Total 2016	$ 9,275.67
Total Jan-June 2016	$ 6,501.00
Monthly Average 2015	$ 808.39
Monthly Average 2016	$ 928.71
Winter Monthly Average	$ 1,137.87
Summer Monthly Average	$ 498.81

Division of Gas Bill (RUCK Specific vs. Any WWTS)			
	2015 - 2016	**2016**	**2016**
Pump Stations	49%	48%	$ 4,456.63
Treatment Building & Pumps	51%	52%	$ 4,819.04

Electric Bills							
Location	**May-15**	**Jun-15**	**Jul-15**	**Aug-15**	**Sep-15**	**Oct-15**	**Nov-15**
Royal Fern Dr. (Treatment Building & Pumps)	$ 300.41	$ 183.05	$ 159.92	$ 167.02	$ 181.75	$ 271.12	$ 336.46
130 Royal Fern Dr. Sewer Pump	$ 15.03	$ 13.32	$ 11.33	$ 11.33	$ 10.00	$ 11.10	$ 10.89
Wintergreen CT Pump	$ 18.56	$ 28.37	$ 175.87	$ 349.24	$ 355.63	$ 284.93	$ 345.71
Royal Fern Dr Pump	$ (72.92)	$ 11.14	$ 66.18	$ 65.31	$ 72.33	$ 88.88	$ 96.14
Iris Ct Sewer Pump	$ 14.53	$ 14.67	$ 14.86	$ 14.86	$ 33.78	$ 21.24	$ 14.19
Total	$ 275.61	$ 250.55	$ 428.16	$ 607.76	$ 653.49	$ 677.27	$ 803.39

Electric Bills								
Location	**Dec-15**	**Jan-16**	**Feb-16**	**Mar-16**	**Apr-16**	**May-16**	**Jun-16**	**Jul-16**
Royal Fern Dr. (Treatment Building & Pumps)	$ 388.95	$ 860.16	$ 498.70	$ 431.69	$ 388.01	$ 306.97	$ 172.94	$ 167.89
130 Royal Fern Dr. Sewer Pump	$ 13.10	$ 26.01	$ 12.82	$ 13.20	$ 12.49	$ 12.95	$ 12.20	$ 12.37
Wintergreen CT Pump	$ 372.61	$ 754.49	$ 410.24	$ 393.24	$ 416.62	$ 396.32	$ 225.72	$ 24.99
Royal Fern Dr Pump	$ 113.55	$ 245.25	$ 140.30	$ 116.86	$ 109.62	$ 98.99	$ 65.08	$ 57.95
Iris Ct Sewer Pump	$ 14.61	$ 30.65	$ 14.20	$ 15.00	$ 15.00	$ 14.55	$ 13.58	$ 13.95
Total	$ 902.82	$ 1,916.56	$ 1,076.26	$ 969.99	$ 941.74	$ 829.78	$ 489.52	$ 277.15

Electric Bills									
Location	**Aug-16**	**Sep-16**	**Oct-16**	**Nov-16**	**Dec-16**	**Total**	**%**	**Total 2016**	**%**
Royal Fern Dr. (Treatment Building & Pumps)	$ 221.76	$ 234.83	$ 330.34	$ 506.92	$ 698.83	$ 10,052.61	51%	$ 4,819.04	52%
130 Royal Fern Dr. Sewer Pump	$ 12.00	$ 12.00	$ 11.19	$ 11.76	$ 11.24	$ 324.54	2%	$ 160.23	2%
Wintergreen CT Pump	$ 49.98	$ 47.77	$ 38.85	$ 32.63	$ 22.59	$ 4,969.52	25%	$ 2,813.44	30%
Royal Fern Dr Pump	$ 57.95	$ 59.91	$ 100.58	$ 96.23	$ 138.28	$ 4,010.19	20%	$ 1,287.00	14%
Iris Ct Sewer Pump	$ 14.74	$ 13.95	$ 13.74	$ 15.52	$ 21.08	$ 423.66	2%	$ 195.96	2%
Total	$ 356.43	$ 368.46	$ 494.70	$ 663.06	$ 892.02	$ 19,780.52	100%	$ 9,275.67	100%

Chemical Expenses							
Chemical		**Feb-15**	**Mar-15**	**Apr-15**	**May-15**	**Jun-15**	**Jul-15**
Methanol	Invoice Date		3/23/2015		5/26/2015		7/15/2015
	Methanol Cost		$ 346.41		$ 346.41		$ 346.41
	Methanol Units		2		2		2
	Methanol Total Gallons		110		110		110
	Methanol Total Lbs		878.9		878.9		878.9
Sodium Bicarbonate	Invoice Date						
	Sodium Bicarbonate Cost						
	Bicarbonate Units						
	Sodium Bicarbonate Total Lbs						
Micro C	Invoice Date	2/4/2015					
	Micro C Cost	$1,759.77					
	Micro C Gal	265					

Chemical Expenses									
Chemical		Aug-15		Sep-15		Oct-15	Nov-15	Dec-15	Jan-16
Methanol	Invoice Date	8/6/2015	8/28/2015	9/21/2015	Sep-15	10/20/2015	11/18/2015	12/17/2015	1/11/2016
	Methanol Cost	$346.41	$ 346.41	$ 346.41	$346.41	$ 346.41	$ 346.41	$ 346.41	$ 346.41
	Methanol Units	2	2	2	2	2	2	2	2
	Methanol Total Gallons	110	110	110	110	110	110	110	110
	Methanol Total Lbs	878.9	878.9	878.9	878.9	878.9	878.9	878.9	878.9
Sodium Bicarbonate	Invoice Date			9/13/2015					1/13/2016
	Sodium Bicarbonate Cost			$ 880.21					$ 342.89
	Bicarbonate Units			43					16
	Sodium Bicarbonate Total Lbs			2150					800

Chemical Expenses								
Chemical		**Feb-16**		**Mar-16**	**Apr-16**	**May-16**		**Jun-16**
Methanol	Invoice Date	2/4/2016	2/29/2016	3/24/2016	4/14/2016	5/27/2016		
	Methanol Cost	$ 346.41	$ 346.41	$ 346.41	$ 346.41	$ 346.41		
	Methanol Units	2	2	2	2	2		
	Methanol Total Gallons	110	110	110	110	110		
	Methanol Total Lbs	878.9	878.9	878.9	878.9	878.9		
Sodium Bicarbonate	Invoice Date	2/24/2016		3/22/2016		5/10/2016	5/19/2016	6/24/2016
	Sodium Bicarbonate Cost	$ 80.68		$ 107.15		$ 85.72	$ 128.58	$ 171.45
	Bicarbonate Units	4		5		4	6	8
	Sodium Bicarbonate Total Lbs	200		250		200	300	400

Chemical Expenses								
Chemical		Jul-16		Aug-16	Sep-16	Oct-16	Nov-16	Dec-16
Methanol	Invoice Date	7/5/2016	7/27/2016	8/22/2016	9/12/2016	10/17/2016	11/29/2016	
	Methanol Cost	$346.41	$ 346.41	$ 346.41	$ 346.41	$ 346.41	$ 369.78	
	Methanol Units	2	2	2	2	2	2	
	Methanol Total Gallons	110	110	110	110	110	110	
	Methanol Total Lbs	878.9	878.9	878.9	878.9	878.9	878.9	
Sodium Bicarbonate	Invoice Date	7/8/2016		8/2/2016	9/20/2016		11/11/2016	12/6/2016
	Sodium Bicarbonate Cost	$278.60		$ 278.60	$ 364.32		$ 342.89	$ 150.01
	Bicarbonate Units	13		13	17		16	7
	Sodium Bicarbonate Total Lbs	650		650	850		800	350

Summary Chemical Expenses and Usage				
Month	Methanol Cost	Gallons Methanol	Sodium Bicarb Cost	Bags Sodium Bicarb
Mar-15	$ 346.41	110		
Apr-15	$ -			
May-15	$ 346.41	110		
Jun-15	$ -			
Jul-15	$ 346.41	110		
Aug-15	$ 692.82	220		
Sep-15	$ 692.82	220	$ 880.21	43
Oct-15	$ 346.41	110	$ -	
Nov-15	$ 346.41	110	$ -	
Dec-15	$ 346.41	110	$ -	
Jan-16	$ 346.41	110	$ 342.89	16
Feb-16	$ 692.82	220	$ 80.68	4
Mar-16	$ 346.41	110	$ 107.15	5
Apr-16	$ 346.41	110	$ -	
May-16	$ 346.41	110	$ 214.30	10
Jun-16	$ -		$ 171.45	8
Jul-16	$ 692.82	220	$ 278.60	13
Aug-16	$ 346.41	110	$ 278.60	13
Sep-16	$ 346.41	110	$ 364.32	17
Oct-16	$ 346.41	110		
Nov-16	$ 369.78	110	$ 342.89	16
Dec-16			$ 150.01	7
Monthly Average 2015	$ 346.41		$ 220.05	
Monthly Average 2016	$ 384.90		$ 184.21	
Total 2016	$ 4,180.29	1320	$ 2,330.89	109
Total Jan - June 2016	$ 2,078.46		$ 916.47	
Sum 2015	$ 3,464.10	1100	880.21	
Total	$ 7,644.39	2420	$ 3,211.10	152
Overall Monthly Average	$ 364.02		$ 214.07	

Chemical Cost per Unit (Includes Shipping & Tax)		
Methanol	$ 3.15	per gallon
Micro C	$ 6.64	per gallon
Sodium Bicarbonate	$ 0.43	per lb

Theoretical Amount of Methanol Needed							
Month	24-hr composite monthly average Ammonia Influent (as N) (mg/L)	Needed Methanol (mg/L)	Needed 20% Diluted Methanol (L meth solution/L effluent)	Total Effluent Flow Rate (gal)	Total Effluent Flow Rate (liter)	Methanol Needed (gal)	Methanol Cost
Jan-15	39.2	156.8	9.91E-04	110430	418022	109	
Feb-15	38.4	153.6	9.71E-04	91380	345910	89	
Mar-15	31.8	127.2	8.04E-04	114466	433300	92	$ 289.84
Apr-15	33.5	134	8.47E-04	118857	449921	101	$ 317.04
May-15	37.8	151.2	9.56E-04	96023	363485	92	$ 289.01
Jun-15	37.8	151.2	9.56E-04	87572	331495	84	$ 263.58
Jul-15	48.1	192.4	1.22E-03	96215	364212	117	$ 368.50
Aug-15	47.9	191.6	1.21E-03	102252	387065	124	$ 389.99
Sep-15	21.8	87.2	5.51E-04	166039	628524	92	$ 288.22
Oct-15	41.7	166.8	1.05E-03	90436	342336	95	$ 300.28
Nov-15	40.2	160.8	1.02E-03	89949	340493	91	$ 287.92
Dec-15	39.4	157.6	9.96E-04	93044	352209	93	$ 291.90
Jan-16	39.6	158.4	1.00E-03	166272	629406	166	$ 524.28
Feb-16	33.4	133.6	8.45E-04	109746	415433	93	$ 291.87
Mar-16	39.5	158	9.99E-04	105704	400132	106	$ 332.46
Apr-16	39.5	158	9.99E-04	106404	402782	106	$ 334.66
May-16	40.6	162.4	1.03E-03	86409	327093	89	$ 279.34
Jun-16	46.5	186	1.18E-03	70272	266008	83	$ 260.19
Jul-16	48.4	193.6	1.22E-03	108546	410890	133	$ 418.32
Aug-16	44.7	178.8	1.13E-03	166272	629406	188	$ 591.80
Sep-16	42.8	171.2	1.08E-03	103807	392951	112	$ 353.77
Oct-16	42.4	169.6	1.07E-03	98246	371900	105	$ 331.69
Nov-16	41.2	164.8	1.04E-03	108011	408865	113	$ 354.34
Dec-16	32.3	129.2	8.17E-04	106604	403539	87	$ 274.17
Max	48.4	193.6	1.22E-03	166272	629406	203	$ 640.79
Min	21.8	87.2	5.51E-04	70272	266008	39	$ 121.98
Methanol Density	0.7915	g/ml					
Must assume effluent flow rate = influent flow rate							

Savings of Methanol Automation					
	First 6 mo.	First Year	2016	Total	Annualized Total
Purchased Methanol	$ 1,732	$ 4,503	$ 4,180	$ 7,644	$ 4,587
Methanol Added as Needed	$ 1,918	$ 3,902	$ 4,347	$ 7,433	$ 4,460
Savings	$ (186)	$ 601	$ (167)	$ 211	$ 127

Theoretical Amount of Sodium Bicarbonate Needed					
Month	Needed Alkalinity (mg/L)	Sodium Bicarbonate Needed (mg/L)	Total Effluent Flow Rate (liter)	Sodium Bicarbonate Needed (lb)	Sodium Bicarbonate Cost
Jan-15	277.1	232.6	418022	214.4	
Feb-15	271.5	227.8	345910	173.8	
Mar-15	224.8	188.7	433300	180.2	
Apr-15	236.8	198.8	449921	197.2	
May-15	267.2	224.3	363485	179.7	
Jun-15	267.2	224.3	331495	163.9	
Jul-15	340.1	285.4	364212	229.2	
Aug-15	338.7	284.2	387065	242.5	
Sep-15	154.1	129.4	628524	179.2	
Oct-15	294.8	247.4	342336	186.7	$ 80.30
Nov-15	284.2	238.5	340493	179.1	$ 76.99
Dec-15	278.6	233.8	352209	181.5	$ 78.06
Jan-16	280.0	235.0	629406	326.0	$ 140.20
Feb-16	236.1	198.2	415433	181.5	$ 78.05
Mar-16	279.3	234.4	400132	206.8	$ 88.90
Apr-16	279.3	234.4	402782	208.1	$ 89.49
May-16	287.0	240.9	327093	173.7	$ 74.70
Jun-16	328.8	275.9	266008	161.8	$ 69.58
Jul-16	342.2	287.2	410890	260.1	$ 111.86
Aug-16	316.0	265.2	629406	368.0	$ 158.26
Sep-16	302.6	254.0	392951	220.0	$ 94.60
Oct-16	299.8	251.6	371900	206.3	$ 88.70
Nov-16	291.3	244.5	408865	220.4	$ 94.75
Dec-16	228.4	191.7	403539	170.5	$ 73.32
	342.2	287.2	629406	398.5	$ 171.35
	154.1	129.4	266008	75.9	$ 32.62

Savings of Sodium Bicarbonate Automation				
	First 6 mo.	Total	Annualized Average	2016
Purchased Sodium Bicarbonate	$ 1,303.78	$ 3,211.10	$ 2,568.88	$ 2,330.89
Sodium Bicarbonate Added as Needed	$ 453.60	$ 1,397.76	$ 1,118.21	$ 1,162.41
Savings	$ 850.18	$ 1,813.34	$ 1,450.67	$ 1,168.48

Waste Water Environmental Management Operator		
Invoice Date	Operations Date	$
12/16/2014	11/30/14-12/13/14	$ 414.00
12/30/2014	12/14/14-12/27/14	$ 410.00
1/13/2015	12/28/14-1/10/15	$ 410.00
1/27/2015	1/11/15-1/24/15	$ 410.00
2/10/2015	1/25/15-1/7/15	$ 410.00
3/10/2015	2/22/15-3/7/15	$ 410.00
3/24/2015	3/8/15-3/21/15	$ 410.00
4/7/2015	3/22/15-4/4/15	$ 410.00
4/21/2015	4/5/15-4/18/15	$ 405.00
5/5/2015	4/19/15-5/2/15	$ 410.00
6/15/2015	5/31/15-6/13/15	$ 410.00
6/2/2015	5/17/15-5/30/15	$ 410.00
5/19/2015	5/3/15-5/16/15	$ 410.00
6/3/2015	6/14/15-6/27/15	$ 410.00
7/14/2015	6/28/15-7/5/15	$ 410.00
8/11/2015	7/26/15-8/8/15	$ 405.00
7/28/2015	7/12/15-7/25/15	$ 405.00
8/25/2015	8/9/15-/22/15	$ 405.00
9/8/2015	8/23/15-9/5/15	$ 405.00
9/22/2015	9/6/15-9/19/15	$ 410.00
10/6/2015	9/20/15-10/3/15	$ 410.00
10/20/2015	10/4/15-10/17/15	$ 404.00
10/25/2015	10/18/15-10/31/15	$ 404.00
11/11/2015	11/1/15-11/14/15	$ 404.00
12/7/2015	11/15/15-12/5/15	$ 606.00
12/7/2015	12/7/15-12/18/15	$ 404.00
1/4/2016	12/21/15-1/1/16	$ 704.00
1/18/2016	1/4/16-1/15/16	$ 704.00
2/1/2016	1/18/16-1/29/16	$ 704.00
2/15/2016	2/1/16-2/12/16	$ 704.00
2/29/2016	2/15/16-2/26/16	$ 704.00
3/14/2016	2/29/16-3/11/16	$ 704.00
3/28/2016	3/14/16-3/25/16	$ 704.00
4/11/2016	3/28/16-4/8/16	$ 704.00
4/25/2016	4/11/16-4/22/16	$ 704.00
5/9/2016	4/25/16-5/6/16	$ 704.00
5/23/2016	5/9/16-5/20/16	$ 704.00
6/6/2016	5/23/16-6/3/16	$ 704.00
6/20/2016	6/6/16-6/17/16	$ 704.00
7/4/2016	6/20/16-7/1/16	$ 704.00
7/18/2016	7/4/16-7/15/16	$ 704.00
8/1/2016	7/18/16-7/29/16	$ 704.00
8/15/2016	8/1/16-8/12/16	$ 704.00
8/29/2016	8/15/16 - 8/26/16	$ 704.00
9/12/2016	8/29/2016-9/9/16	$ 704.00
9/14/2016	8/29/16-9/9/16	$ 704.00
9/26/2016	9/12/16-9/23/16	$ 704.00
10/10/2016	9/26/16-10/7/16	$ 704.00
10/24/2016	10/10/16-10/21/16	$ 704.00
11/17/2016	10/24/16-11/4/16	$ 704.00
11/21/2016	11/7/16-11/18/16	$ 704.00
12/5/2016	11/21/16-12/2/16	$ 704.00
12/19/2016	12/5/16-12/16/16	$ 704.00

Total Jan - June 2016	$ 8,448.00
Total 2016	$ 19,008.00
Monthly Average 2016	$ 1,584.00
Total 2015	$ 10,281.00
Monthly Average 2015	$ 856.75

Waste Water Environmental Management Lab Testing		
Invoice Date	Description.	Amt.
12/30/2014	WWTF analysis	$ 262.00
12/16/2014	WWTF and Wells 11/12-14/14	$ 400.50
1/13/2015	WWTF and Wells 12/10-15/14	$ 851.50
1/27/2015	WWTF and Wells 1/8-9/15	$ 400.50
3/10/2015	WWTF	$ 275.50
4/7/2015	WWTF and Wells	$ 1,526.50
4/21/2015	WWTF	$ 31.00
5/5/2015	WWTF and Wells	$ 400.50
6/2/2015	WWTF and wells	$ 400.50
6/30/2015	WWTF	$ 306.50
7/14/2015	Wells	$ 345.00
8/11/2015	WWTF and Wells	$ 400.50
9/8/2015	Wells	$ 125.00
9/22/2015	WWTP and Wells	$ 320.00
10/6/2015	WWTF and Wells	$ 1,373.00
11/11/2015	WWTF and wells	$ 400.50
12/24/2015	WWTF 11/11/15-11/12/15, Wells 11/13/15	$ 619.50
1/26/2016	WRRF 12/15/16, Wells 12/23/15	$ 668.50
2/13/2016	WWRRF 1/13-14/2016, Wells 1/15/16	$ 400.50
2/26/2016	WRRF 2/4-5/16	$ 275.50
3/4/2016	Wells 2/8/18	$ 125.00
3/29/2016	WRRF 3/9-10/16	$ 306.50
4/5/2016	Wells 3/14/16	$ 1,220.00
5/3/2016	WRRF 4/13-14/16	$ 275.50
5/12/2016	Wells 4/18/16	$ 125.00
5/23/2016	WRRF 5/5-6/16	$ 262.00
5/31/2016	WRRF 5/10/16	$ 13.50
6/7/2016	Wells 5/16/16	$ 125.00
7/1/2016	WRRP &/-10/16	$ 306.50
7/12/2016	Wells 6/13/16	$ 545.00
8/9/2016	WRRF	$ 13.50
8/13/2016	WRRF 7/27-28/18	$ 362.00
8/19/2016	WRRF 8/4-5/2016	$ 289.00
8/23/2016	Wells	$ 110.00
9/13/2016	Extra Weekly Sample	$ 2,064.00
10/1/2016	WRRF 9/21-22/16	$ 446.00
10/2/2016	Extra Weekly Sample	$ 192.00
10/11/2016	Wells 9/26/16	$ 972.00
11/1/2016	Extra Weekly Sample	$ 192.00
11/1/2016	WRRF 10/18-19/16 and Wells 10/24/16	$ 480.00
11/8/2016	WRRF and Wells 10/24/16	$ 110.00
11/25/2016	WRRF and Wells 11/15-18/16	$ 631.50
12/1/2016	Extra Weekly Sample	$ 192.00
12/13/2016	WRRF and Wells 12/8-8/2016	$ 740.00
12/27/2016	WRRF 12/14	$ 32.50

Total Jan - June 2016	$ 3,797.00
Total 2016	$ 11,475.00
Monthly Average 2016	$ 956.25
Total 2015	$ 7,776.00
Monthly Average 2015	$ 648.00

Pump Repairs			
Invoice Date	Company	Description.	Amt.
12/12/2014	WhiteWater	Pump Repairs	$ 194.55
12/31/2014	WhiteWater	Pump Repairs	$ 536.89
1/13/2015	Wind River Environmental	Dig Up Pipe	$ 2,550.00
1/15/2015	WhiteWater	Pump Repairs	$ 719.85
2/10/2015	WhiteWater	Pump Repairs	$ 88.48
5/3/2015	WhiteWater	Pump Repairs	$ 331.20
5/22/2015	WhiteWater	Pump Repairs	$ 2,304.91
6/12/2015	WhiteWater	Pump Repairs	$ 559.31
7/10/2015	WhiteWater	Pump Repairs	$ 720.73
7/21/2015	WhiteWater	Pump Repairs	$ 547.63
9/6/2015	WhiteWater	Pump Repairs	$ 3,020.80
10/4/2015	WhiteWater	Pump Repairs	$ 699.38
11/5/2015	WhiteWater	Pump Repairs	$ 860.80
12/18/2015	WhiteWater	Pump Repairs	$ 2,080.00
1/4/2016	WhiteWater	Pump Repairs	$ 547.63
1/19/2016	WhiteWater	Pump Repairs	$ 1,784.60
2/19/2016	WhiteWater	Pump Repairs	$ 339.48
3/11/2016	WhiteWater	Pump Repairs	$ 3,385.00
3/15/2016	WhiteWater	Pump Repairs	$ 2,032.91
5/11/2016	WhiteWater	Pump Repairs	$ 152.78
7/5/2016	WhiteWater	Pump Repairs	$ 4,971.00
7/5/2016	WhiteWater	Pump Repairs	$ 875.00
7/21/2016	WhiteWater	Pump Repairs	$ 558.58
8/4/2016	WhiteWater	Pump Repairs	$ 1,327.50
8/24/2016	Pride Environmental & Construction	Inspect Pump Stations	$ 935.00
9/6/2016	WhiteWater	Pump Repairs	$ 218.75

Total Jan - June 2016	$ 8,242.40
Total 2016	$ 22,837.64
Monthly Average 2016	$ 1,557.11
Total 2015	$ 14,483.09
Monthly Average 2015	$ 1,206.92

Engineering Services			
Invoice Date	Company	Description.	Amt.
2/12/2015	Mount Hope Engineering	DEP conversation	$ 320.00
4/1/2015	Mount Hope Engineering	DEP O&M	$ 780.00
11/5/2015	Mount Hope Engineering	revisions to O&M	$ 1,395.00
12/8/2015	Mount Hope Engineering	)&M conversation	$ 270.00
1/5/2016	Mount Hope Engineering	Engineering Services	$ 540.00
3/1/2016	Holmes and McGrath	Project management/research	$ 330.00
8/22/2016	Holmes and McGrath	Project management/research	$ 2,800.00
10/19/2016	Holmes and McGrath	?	$ 907.50
11/21/2016	Holmes and McGrath	Prepare O&M Manual and DEP Appl	$ 4,000.00
12/20/2016	Holmes and McGrath	Project Management/DEP correspo	1,125
12/23/2016	Bob Pease	Nashoba Health Bd copies	$ 28.00
12/24/2016	Bob Pease	Minute Man press copies	$ 8.00

Total Jan - June 2016	$ 870.00
Total 2016	$ 9,738.50
Monthly Average 2016	$ 811.54
Total 2015	$ 2,765.00
Monthly Average 2015	$ 230.42

Security/Alarms/Fire System			
Invoice Date		Description.	Amt.
12/3/2014	Jasonics Security Corp	Annual Fee	$ 288.00
5/1/2015	Jasonics Security Corp	pump wire relay broken	$ 150.00
8/8/2015	Lunenburg Fire Dept.		$ 50.00
10/19/2015	Tyco Simplex Grinnel	repairs to backflow	$ 720.00
11/17/2015	Security Alarms Systems	worm on system	$ 3,159.39
11/4/2015	Tyco Simplex Grinnel	filter	$ 2,035.00
12/11/2015	Tyco Simplex Grinnel	Alarm Testing	$ 400.00
12/7/2015	Security Alarms Systems	Service Call	$ 147.50
12/8/2015	Jasonics Security Corp	Annual Fee	$ 288.00
12/9/2015	Security Alarms Systems	Test Pumps	$ 142.50
12/11/2015	Security Alarms Systems	Alarm Testing	$ 95.00
12/11/2015	Security Alarms Systems	Installed Horn/strobe	$ 169.95
1/25/2016	Security Alarms Systems	Sprinkler Service	$ 486.46
1/25/2016	Security Alarms Systems	Sprinkler Service	$ 833.91
1/25/2016	Security Alarms Systems	Sprinkler Service	$ 1,236.89
2/2/2016	Security Alarms Systems	Service Call	$ 554.95
6/21/2016	Security Alarms Systems	Cell Fire	$ 149.97
9/21/2016	Security Alarms Systems	Cell Fire	$ 149.97
11/4/2016	Security Alarms Systems		$ 95.00
11/22/2016	Security Alarms Systems	Cell Fire	$ 149.97

Total Jan - June 2016	$ 3,262.18
Total 2016	$ 3,657.12
Monthly Average 2016	$ 332.47
Total 2015	$ 7,357.34
Average 2015	$ 613.11

Ruck System Repairs			
Company	Invoice Date	Description.	Amt.
12/9/2014	OG Croteau P	Boiler Repairs	$ 157.50
12/11/2014	Merrimac	Pump Sensor	$ 861.62
1/2/2015	Wastewater I	repair FET Tank 12/18/14	$ 469.00
1/14/2015	Ruel Electric	Sensor	$ 250.00
1/20/2015	Merrimac	Thermocouple material	$ 353.31
2/3/2015	Ruel Electric	Septic Tank Temp Sensor	$ 1,210.80
3/13/2015	OG Croteau P	Backflow Preventer	$ 90.00
4/10/2015	Bigelow Elec	Generator Service	$ 450.00
5/3/2015	Wastewater I	manhole repairs	$ 51.33
5/19/2015	Wastewater I	FET Tank repairs	$ 960.00
5/24/2015	John H Espos	burying thermocouple line/push back brush	$ 600.00
5/31/2015	Wastewater I	manhole repairs	$ 66.33
6/17/2015	Wastewater I	FET Tank repairs	$ 836.00
6/21/2015	Wastewater I	FET Tank repairs	$ 1,436.04
7/10/2015	Bigelow Elec	Generator Service	$ 450.00
8/12/2015	OG Croteau P	Boiler Shut Down	$ 90.00
10/7/2015	John H Espos	PVC Vent Line	$ 1,650.00
1/21/2016	Croteau Plum	cleared septic tank blockage	$ 395.00
7/14/2016	Bigelow Elect	Generator Repair	$ 760.00
7/15/2016	Bigelow Elect	Generator Repair	$ 450.00
7/16/2016	Bigelow Elect	Generator Repair	$ 340.00
9/16/2016	Waste Water	new level float	$ 84.81
11/4/2016	OG Croteau P	Replaced Thermocouple	$ 236.55
11/15/2016	Wastewater I	Replacement Tubing	$ 74.64
11/16/2016	Pride Environ	Junction Box Work	$ 4,356.00
12/23/2016	Bob Pease	Soil Probe	$ 26.53

Total Jan - June 2016	$ 395.00
Total 2016	$ 6,723.53
Monthly Average 2016	$ 560.29
Total 2015	$ 8,962.81
Monthly Average 2015	$ 746.90

Switching Over to Methanol			
Company	Invoice Date	Description.	Amt.
Graves Fire Protection	8/5/2015	Flammability signs	$ 90.14
IPI	8/31/2015	Drum Containment	$ 185.00
Global Industrial	9/11/2015	Oil Spill Kit	$ 152.14
IPI	12/3/2015	drum containment pallets	$ 334.56
Wastewater Environmental	10/8/2015	Purchase & Install methanol pump	$ 644.16
		Total 2015	$ 1,406.00
		2015 Monthly Average	$ 117.17

Verizon	
Invoice Date	Amt.
1/14/2015	$ 46.55
1/14/2015	$ 44.11
2/14/2015	$ 46.98
2/15/2015	$ 44.51
3/14/2015	$ 46.59
3/14/2015	$ 44.14
4/14/2015	$ 46.65
4/14/2015	$ 44.53
5/14/2015	$ 44.56
5/14/2015	$ 47.11
6/14/2015	$ 44.19
6/14/2015	$ 46.70
7/14/2015	$ 45.21
7/15/2015	$ 47.77
8/14/2015	$ 45.00
8/15/2015	$ 47.58
9/14/2015	$ 45.37
9/15/2015	$ 21.60
10/14/2015	$ 44.99
11/14/2015	$ 46.06
12/14/2015	$ 46.06
1/14/2016	$ 46.51
Total 2015	$ 936.26
2015 Monthly Average	$ 78.02
Total 2016	$ 46.51
2016 Monthly Average	$ 3.88

Moisan Bros Landscaping		
Invoice Date	Description.	Amt.
Jun-15	cut RUCK field	$ 125.00
6/28/2015	cut RUCK field	$ 200.00
7/29/2015	cut RUCK field	$ 150.00
8/31/2015	cut RUCK field	$ 200.00
9/28/2015	cut RUCK field	$ 200.00
11/30/2015	cut RUCK field	$ 200.00
6/1/2016	cut RUCK field	$ 200.00
6/27/2016	cut RUCK field	$ 200.00
7/26/2016	cut RUCK field	$ 200.00
10/5/2016	cut RUCK field	$ 300.00
12/5/2016	cut RUCK field	$ 150.00

Monthly Average Summer 2016		$ 150.00
Monthly Average Summer 2015		$ 179.17
Total Jan - Jun 2016		$ 600.00
Total 2016		$ 1,050.00
Monthly Average 2016 over year		$ 87.50
Total 2015		$ 1,075.00
Monthly Average 2015 (over year)		$ 89.58

Permits/Annual Compliance Fee		
Notice Date	Description.	Amt.
11/7/2015	Medium Groundwater Discharge Permit	$ 8,320.00
	Fines	$ 5,565.00

Treatment Building Repairs		
Date	Description.	Amt.
12/23/2016	treatment building repair	$ 18.48
	Total 2016	$ 18.48

Wind River Environmental Septic Pumping		
Invoice Date	Amt.	Quantity (gal)
1/13/2015	1256.74	
5/19/2015	$ 346.94	
5/19/2015	$ 410.56	1500-2000
5/19/2015	$ 599.50	4000
5/19/2015	$ 249.50	1500
5/31/2016	$ 599.50	
12/27/2016	$ 261.94	
2015 Total	$ 2,863.24	
2015 Monthly Average	$ 238.60	
Jan - June 2016 Total	$ 599.50	
2016 Total	$ 861.44	

Appendix C: Methanol and Sodium Bicarbonate Calculations

Methanol Dosage Calculation

Given a 24-hour composite NH_3-N concentration of 39.2 mg/L in the influent, the required concentration of methanol (CH_4) was:

$$39.6\ mg\frac{NH_3}{L} * \frac{4\frac{mg\ CH_4}{L}}{\frac{NH_3}{L}} = 158.4\ \ \frac{mg\ CH_4}{liter\ effluent}$$

The required volume of 20% methanol per liter of effluent was:

$$158.4\ \ \frac{mg\ CH_4}{L\ effluent} * \frac{1\ g}{1000\ mg} * \frac{1\ mL\ CH_4}{0.791\ g\ CH_4} * \frac{1\ L}{1000\ mL} * \frac{5\ L\ diluted\ CH_4}{1\ L\ CH_4}$$

$$= 1.00 * 10^{-3} L\ diluted\ CH_4\ per\ liter\ effluent$$

The total volume of 20% methanol needed for January 2016 was:

$$\frac{1.00 * 10^{-3} gal\ diluted\ CH_4}{gal\ effluent} * 166{,}272\ gal\ effluent = 166\ gal\ diluted\ CH_4$$

The total cost of methanol in January 2016 would have been:

$$166\ gal\ diluted\ CH_4 * \frac{\$3.15}{gal} = \$524.28$$

Sodium Bicarbonate Calculations

Given a 24-hour composite NH_4-N concentration of 39.2 mg/L in the influent, the required concentration of alkalinity as $CaCO_3$ was:

$$39.6\ mg\frac{NH_3}{L} * \frac{7.07\ mg\ CaCO_3}{1\ mg\ NH_4} = 280.0\ \frac{mg\ CaCO_3}{liter\ effluent}$$

The required mass of sodium bicarbonate ($NaHCO_3$) per liter of effluent was:

$$280.0\ \frac{mg\ CaCO_3}{L\ effluent} * \frac{1\ mmol\ CaCO_3}{100.1\ mg\ CaCO_3} * \frac{1\ mmol\ NaHCO_3}{1\ mmol\ CaCO_3} * \frac{84.01\ mg\ NaHCO_3}{1 mmol\ NaHCO_3} = 235\ mg\ NaHCO_3\ per\ liter\ effluent$$

The total mass of $NaHCO_3$ needed for January 2016 was:

$$\frac{235\ mg\ NaHCO_3}{L\ \ effluent} * 166{,}272\ gal\ effluent * \frac{3.7854\ L}{1\ gal} * \frac{1\ mg}{453{,}592\ lb} = 326\ lb\ NaHCO_3$$

The total cost for January 2016 would have been:

$$326\ lb\ NaHCO_3 * \frac{\$0.43}{lb} = \$140.20$$

Appendix D: PLC Calculations for Methanol and Sodium Bicarbonate Feeds

Automated Methanol Feed PLC Equation Calculations

The mass flow rate of nitrate ($\dot{m}_{NO3}$) in g/s exiting the interim pump chamber is:

$$\dot{m}_{NO3} = [NO_3](t) * Q_{effluent}$$

Where:

- $Q_{effluent}$ = the flowrate of wastewater [L/s] exiting the interim pump chamber, which is essentially constant when the pump is on
- $[NO_3](t)$= the concentration of nitrate [g/L] as a function of time

For every gram of NO_3-N leaving the RUCK filters, between 3.0 and 3.5 g of methanol should be added to the denitrification tank

$$\dot{m}_{methanol} = \frac{3.5\ g\ methanol}{1\ g\ NO_3 - N} \dot{m}_{NO3}$$

$$\dot{m}_{methanol} = Q_{20\%\ methanol} * C_{20\%\ methanol}$$

Where:

- $Q_{20\%\ methanol}$ = flowrate of 20% methanol entering the first denitrification tank [g/s]
- $C_{20\%\ methanol}$= concentration of methanol [g/L] in a 20% by volume solution of methanol in water

$$\left(\frac{3.5\ g\ methanol}{1\ g\ NO_3 - N}\right) * \dot{m}_{NO3} = Q_{20\%\ methanol} * C_{20\%\ methanol}$$

$$\left(\frac{3.5\ g\ methanol}{1\ g\ NO_3 - N}\right) * [NO_3](t) * Q_{effluent} = Q_{20\%\ methanol} * C_{20\%\ methanol}$$

$$Q_{20\%\ methanol} = \frac{\left(\frac{3.5\ g\ methanol}{1\ g\ NO_3 - N}\right) * [NO_3](t) * Q_{effluent}}{C_{20\%\ methanol}}$$

The concentration of methanol in a 20% solution is 158.3 g/L. As a result:

$$Q_{20\%\ methanol} = \frac{\left(\frac{3.5\ g\ methanol}{1\ g\ NO_3 - N}\right) * [NO_3](t) * Q_{effluent}}{158.3\ \frac{g\ methanol}{L}}$$

Given the flowrate and nitrate concentration of the wastewater leaving the interim pump, the flowrate of 20% methanol must be calculated by the PLC using the following equation:

$$Q_{20\%\ methanol} = 0.0221 \frac{L}{g\ NO_3 - N} * [NO_3](t) * Q_{effluent}$$

Automated Sodium Bicarbonate Feed PLC Equation Calculations

The surface area (SA) in m[3] and volume of the flow equalization tank (V_{FET}) in m^3 is:

$$SA = l * w$$

$$V_{FET} = l * w * h$$

$$V_{FET} = SA * h$$

$$V(h)_{FET} = SA * h$$

Where:

- SA = surface area[m^2], which is constant
- l = length of the FET [m]
- w= width of the FET [m]
- V_{FET} = volume of wastewater in the FET [m^3]
- h = height of wastewater
- $V(h)_{FET}$ = volume of wastewater in the FET as a function of the wastewater height [m^3]

When the flow equalization tank pumps are not operating, the volume of wastewater in the flow equalization tank increases. While the FET is filling, for a period of time Δt in seconds, the mass of ammonia (Δm_{NH4^+}) in g entering the flow equalization tank (FET) is:

$$\frac{\Delta m_{NH4^+}}{\Delta t} = [NH_4](t) * \frac{\Delta V(h)_{FET}}{\Delta t} * 1000 \frac{L}{m^3}$$

$$\frac{\Delta m_{NH4^+}}{\Delta t} = [NH_4](t) * \frac{\Delta h_{FET}}{\Delta t} * SA * 1000 \frac{L}{m^3}$$

Where:

- $[NH_4](t)$= the concentration of ammonia [g/L] in the FET as a function of time

For a constant concentration of the sodium bicarbonate feed solution ($[NaHCO_3]$), the mass of sodium bicarbonate (Δm_{NaHCO3}) entering the FET for a given period of time (Δt) is:

$$\frac{\Delta m_{NaHCO3}}{\Delta t} = [NaHCO_3] * \frac{\Delta V_{NaHCO3}}{\Delta t}$$

Where:

- $\frac{\Delta V_{NaHCO3}}{\Delta t}$= the volume of sodium bicarbonate entering the FET [L/s]

For every gram of ammonia that enters the system, 7.07 g of alkalinity as $CaCO_3$ are required:

$$\frac{\Delta m_{NaHCO3}}{\Delta t} = \frac{\Delta m_{NH4^+}}{\Delta t} * \frac{7.07\ g\ CaCO_3}{1\ g\ NH_3} * \frac{84.01 \frac{g}{mol}\ NaHCO_3}{100.1 \frac{g}{mol}\ CaCO_3} = 5.934 * \frac{\Delta m_{NH4^+}}{\Delta t}$$

$$[NaHCO_3] * \frac{\Delta V_{NaHCO3}}{\Delta t} = 5.934 * \frac{\Delta m_{NH4^+}}{\Delta t}$$

The flow rate of sodium bicarbonate (Q_{NaHCO3}) in L/s is:

$$[NaHCO_3] * \frac{\Delta V_{NaHCO3}}{\Delta t} = 5.934 * [NH_4](t) * \frac{\Delta h_{FET}}{\Delta t} * SA * 1000 \frac{L}{m^3}$$

$$\frac{\Delta V_{NaHCO3}}{\Delta t} = \frac{5.934 * [NH_4](t) * SA}{[NaHCO_3]} * \frac{\Delta h_{FET}}{\Delta t} * 1000 \frac{L}{m^3}$$

$$\frac{dV_{NaHCO3}}{dt} = \frac{5{,}934 * SA * [NH_4](t)}{[NaHCO_3]} * \frac{d(h_{FET})}{dt}$$

$$Q_{NaHCO3} = \frac{dV_{NaHCO3}}{dt}$$

Given the surface area of the FET, the ammonia concentration in the FET, the rate at which the height of wastewater it the FET changes, and the concentration of the sodium bicarbonate solution, the flow rate of sodium bicarbonate must be calculated by the PLC using the following equation when the pumps are off:

$$Q_{NaHCO3} = \frac{5{,}934 * SA * [NH_4](t)}{[NaHCO_3]} * \frac{d(h_{FET})}{dt}$$

When the flow equalization tank pumps are operating, the volume of wastewater in the flow equalization tank decreases, even though some wastewater may be flowing in to the FET. The flow rate of effluent into the tank ($Q_{effluent}$) in L/s is:

$$\frac{\Delta V(h)_{FET}}{\Delta t} = IN - OUT$$

$$\frac{\Delta V(h)_{FET}}{\Delta t} = Q_{effluent} - Q_{effluent,pump}$$

$$Q_{effluent} = \frac{\Delta V(h)_{FET}}{\Delta t} * 1000 \frac{L}{m^3} + Q_{effluent,pump}$$

$$Q_{effluent} = \frac{\Delta h_{FET}}{\Delta t} * SA * 1000 \frac{L}{m^3} + Q_{effluent,pump}$$

Assuming the concentration of ammonia in the streams entering and exiting the FET is the same as the concentration within the tank, the mass of ammonia entering the FET is:

$$\frac{\Delta m_{NH4^+}}{\Delta t} = [NH_4](t) * [\frac{\Delta h_{FET}}{\Delta t} * SA * 1000 \frac{L}{m^3} + Q_{effluent,pump}]$$

Where

- $Q_{effluent,pump}$ = the flow rate of effluent pumped out of the FET [L/s], which is constant
- $Q_{effluent}$ = the flow rate of effluent entering the FET [L/s]

For a constant concentration of the sodium bicarbonate feed solution ($[NaHCO_3]$), the mass of sodium bicarbonate (Δm_{NaHCO3}) entering the FET for a given period of time (Δt) is:

$$[NaHCO_3] * \frac{\Delta V_{NaHCO3}}{\Delta t} = 5.934 * \frac{\Delta m_{NH4^+}}{\Delta t}$$

$$[NaHCO_3] * \frac{\Delta V_{NaHCO3}}{\Delta t} = 5.934 * [NH_4](t) * [\frac{\Delta h_{FET}}{\Delta t} * SA * 1000 \frac{L}{m^3} + Q_{effluent,pump}]$$

$$\frac{\Delta V_{NaHCO3}}{\Delta t} = \frac{5.934 * [NH_4](t)}{[NaHCO_3]} * [\frac{\Delta h_{FET}}{\Delta t} * SA * 1000 \frac{L}{m^3} + Q_{effluent,pump}]$$

$$\frac{dV_{NaHCO3}}{dt} = \frac{5.934 * [NH_4](t)}{[NaHCO_3]} * [\frac{d(h_{FET})}{dt} * SA * 1000 \frac{L}{m^3} + Q_{effluent,pump}]$$

$$Q_{NaHCO3} = \frac{dV_{NaHCO3}}{dt}$$

Given the surface area of the FET, the ammonia concentration in the FET, the rate at which the height of wastewater it the FET changes, the flow rate of effluent leaving the FET, and the concentration of the sodium bicarbonate solution, the flow rate of sodium bicarbonate must be calculated by the PLC using the following equation when the pumps are on:

$$Q_{NaHCO3} = \frac{5.934 * [NH_4](t)}{[NaHCO_3]} * [\frac{d(h_{FET})}{dt} * SA * 1000 \frac{L}{m^3} + Q_{effluent,pump}]$$

Appendix E: Automated Methanol and Sodium Bicarbonate Equipment Pricing

Prices for the automated methanol and sodium bicarbonate feed systems were obtained using the equipment shown in the following documents.

Equipment for the Automated Methanol Feed System

- Nitrate Sensor
- Nitrate Sensor Controller
- PLC
- PLC Software
- Peristaltic Pump

Equipment for the Automated Sodium Bicarbonate Feed System

- Ammonia Sensor
- Ammonia Sensor Controller (same as nitrate sensor controller above)
- Water Level Sensor
- PLC (same as above)
- PLC Software (same as above)
- Peristaltic Pump (same as above)
- 55-Gallon Drum
- Electric Mixer

Online Sensors and Controllers: Ammonium Sensors » A-ISE sc Sensors

A-ISE sc Sensors

Talk to an Expert

Gallery

Hach's digital, ion-selective A-ISE sc probe is designed for the determination of ammonium concentration directly in the medium. Calibration-free with automatic potassium compensation. The sensor features easy handling and low maintenance due to Cartrical sensor cartridge. A-ISE sc is particularly cost-effective in terms of installation and operation, even for small wastewater treatment plants.

A-ISE sc Sensors can be connected to all SC controllers, providing versatile output options including 4-20 mA Output, Modbus RS485, Profibus, or Hart.

Prognosys is a predictive diagnostic system that allows you to be proactive in your maintenance, by alerting you to upcoming instrument issues. Know with confidence whether changes in your measurements are due to changes in your instrument or your water.

Print PDF Page

Compare Selected (0) Clear Selected

Part Number	USD Price	
LXV440.99.10002 Compare	$7,428.00	
LXV440.99.10012 Compare	$7,428.00	

Home » Flow & Level » Level Switches & Transmitters » Continuous Capacitive Level Tr... » LV3000 and LV4000 Series

Capacitance Continuous Level Measurement Probes

LV3000 and LV4000 Series

Capacitance Continuous Level Measurement Probes and Switch

See All Models Below

Be the first to review this product

- Can Operate at High Temperatures and Pressure
- Unaffected by Coating Media or Aggressive Products
- Accurate and Reliable Measurement
- Easy Economical Installation
- Rugged Construction
- No Moving Parts
- Compatible with Both Conductive and Non-Conductive Media
- Wide Range of Applications/Industries (e.g., Water, Oils, Corrosives)

Level Switches & Transmitters - View related products

Description

The LV3000/LV4000 Series continuous level measurement probes are flexible, cost-effective solutions for applications involving liquids, pastes, and some solids. The built-in (one-piece) electronic module provides a 4 to 20 mA output (2-wire) signal that is proportional to the process level. Zero and span adjustment helps account for various media, tank dimensions, rod lengths, and positions of installation.

OMEGA® offers these probes in several different models. The user must choose the probe that suits his or her application and install it in the proper location. When submerged, the probe must be able to produce enough capacitance variance. The probe's success depends on these important factors:
A) Conductive materials can cause a short circuit between a bare stainless steel probe and the tank wall. For this situation, we recommend using PTFE sleeving on the rod surface.
B) Material buildup affects the accuracy of RF capacitive measurements. Additional adjustment to the probe's sensitivity is therefore recommended.

Housings must be compatible with the requirements for hazardous, washdown, wet, or dusty environments. For explosion-proof environments, the housing may need to be certified. In addition, the active probe might need to be intrinsically safe or have an intrinsic safety barrier.

The electronic circuitry of the probe performs several functions, such as rectifying and filtering the incoming power, generating the radio frequency signal, and measuring the changes in current flow.

SPECIFICATIONS (LV3000 SERIES)
Accuracy: 0.5%
Repeatability: ±1 mm
Level Indication: Bar graph, 0 to 1000%
Process Connection: ¾ to 1½ NPT, tri-clamp or flange

Wetted Material: 316 SS or PTFE
Enclosure Material: Aluminum die cast
Max Pressure: 290 psi (20 bar)
Operating Temperature: -10 to 120°C (14 to 248°F)
Class Protection:
LV3000: NEMA 4 (IP65)
LVCN410: IP40
Max Probe Length: 1.8 m (6')
Dimensions:
Aluminum Die-Cast Head: 89 W x 108 mm H (3.5 x 4¼")
Diameter of Probe: 16 mm (5/8")
Electrical Connection: Cable gland with ½ NPT conduit

Note: *The LV3000 Series probes require a LVCN400 Series controller.*

SPECIFICATIONS (LV4000 SERIES)
Accuracy: 0.5%
Repeatability: ±1 mm
Operating Voltage: 12 to 30 Vdc
Adjustment: Zero and span (potentiometer)
Range of Sensitivity: 100 to 5500 pF
Frequency Oscillation: 400 kHz
Output: 4 to 20 mA (2-wire)
Process Connection: ¾ to 1½ NPT, tri-clamp or flange
Wetted Material: 316 SS or PTFE
Enclosure Material: Glass-filled nylon or aluminum die cast
Max Pressure: 290 psi (20 bar)
Operating Temperature: -10 to 120°C (14 to 248°F)
Class Protection: NEMA 4 (IP65)
Max Probe Length: 1.8 m (6')
Dimensions:
Nylon Head: 89 W x 64 mm H (3.5 x 2.5")
Aluminum Die-Cast Head: 89 W x 108 mm H (3.5 x 4.25")
Diameter of Probe: 16 mm (5⁄8")
Electrical Connection: Cable gland with ½ NPT conduit

Note: *The LV4000 Series probes require a galvanic isolator, LI-420.*

SPECIFICATIONS (LI-420)
Input Current from the Evaluation Instrument: 4 to 20 mA
Input Voltage: 22 to 24 Vdc
Output Current: 4 to 20 mA
Output Voltage to the Transducer at 20 mA: 12.5 V
Output Voltage to the Transducer at 4 mA: 15.5 V
Resistance per Conductor: 15 Ω
Testing Voltage Input/output circuit: 2000 V_{eff}
Domestic Current Demand: 300 ±60 µA
Ambient Temperature: -20 to 70°C (-4 to 158°F)
Enclosure Dimensions: 44 W x 82 H x 110 mm L (1¾ x 3¼ x 4⅜)

SPECIFICATIONS (LVCN410 SERIES)
Operating Voltage: 24 Vdc, 110 or 240 Vac (50/60 Hz)
Current Consumption: 4 mA
Adjustment: Zero and span (potentiometer) and 2 switch point (potentiometer)
Range of Sensitivity: 50 to 1000 pF
Output: 4 to 20 mA and 2-relay SPDT
LVCN411/LVCN412: 73 W x 110 H x 110 mm L (2⅞ x 4⅜ x 4⅜")

Place Order
(Specify Model Number)

What Other People Bought: When you see this icon, click on it to expand a list of products that other people have bought when they purchased this model.

Most Popular Models!

Show Only Stocked Items

Part Number		Description	RoHS	Qty
LV4012-38 $1,355.00	1 In Stock	96.5 cm (38") long probe with 3/4 NPT connection, with aluminum die cast head with 1/2 NPT conduit entry	?	0
LV4042-60 $1,575.00	Available In 8 Weeks	152.4 (60") long probe with 1 1/2" Tri-Grip™ connection, with aluminum die cast head with 1/2 NPT conduit entry	✓	0
LV4111-24 $1,055.00	1 In Stock	60 cm (24") long probe with 3/4" NPT connection, with PTFE coating and nylon head	✓	0
LV4121-36 $1,150.00	1 In Stock	90 cm (36") long probe with 1" NPT connection, with PTFE coating and nylon head	✓	0
LV4121-48 $1,245.00	1 In Stock	1.2 m (4') long probe with 1" NPT connection, with PTFE coating and nylon head	✓	0
LV4121-60 $1,340.00	Available In 8 Weeks	1.5 m (5') long probe with 1" NPT connection, with PTFE coating and nylon head	✓	0
LV3123-48-HT $1,130.00	Available In 8 Weeks	Remote electronics required LVCN410 Series 1.2 m (4') long probe with 1 NPT connection, with PTFE coating and aluminum die cast head, 177°C (350°F)	✓	0
LV3125-48-HT $3,815.00	Available In 8 Weeks	Remote electronics required LVCN410 Series 1.2 m (4') long probe with 1 NPT connection, with PTFE coating and aluminum die cast head, 177°C (350°F)	?	0
LVCN411 $815.00	4 In Stock	24 Vdc powered controller with relay and 4 to 20 mA output for LV3000 Series only	✓	0
LVCN412 $845.00	4 In Stock	115 Vac powered controller with relay and 4 to 20 mA output for LV3000 Series only	✓	0
Accessories				
CNI16D33 $280.00	13 In Stock	1/16 DIN Dual Display with two 3 A relays and 24 Vdc Excitation	✓	0
TX4-100 $35.50	12 In Stock	30 m (100') spool of 4 conductor wire	✓	0
FPW-15 $97.00	More Than 25 In Stock	15 Vdc power supply	✓	0
LI-420 $400.00	5 In Stock	Loop isolator	✓	0

Order By Part Number

Part Number	Qty	Part Number	Qty

† ***All amounts shown in USD***

Note: Comes complete with operator's manual.

LV4000 Series length is not recommended below 24" due to dielectric strength.

For High Temperature PTFE Sleeving 200°C (392°F), add suffix "-HTPTFE" to model number, add $150 per unit and $660 per foot to price.

Ordering Example: (1) **LV4111-24** 60 cm (24, **$1,055.00**

Part Number Builder

Build Your Part Number Below

(1) (2) (3) (4) (5)

LV 4 ▾ 0 ▾ 1 ▾ 1 ▾ - L ▾

Contact our sales team for pricing: sales@omega.com

Option Descriptions:

(1) Capacitance System *select from:*
4 for standard capacitance system
3 for remote capacitance system

(2) Insulation Connection *select from:*
0 for 316 SS rod
1 for ECTFE/ETFE sleeve

(3) Process Connection *select from:*
1 for 3/4 NPT thread
2 for 1 NPT thread
3 for 1.5 NPT thread
4 for 1.5 in Tri-Grip
5 for 2 in ANSI flange 15016 316 SS

(4) Enclosure *select from:*
1 for glass-filled nylon with 1/2 NPT conduit entry and cable gland
2 for aluminum die cast with 1/2 NPT conduit entry-LV4000
3 for aluminum die cast with cable gland entry-LV4000
4 for aluminum die cast with 1/2 NPT conduit entry-LV3000
5 for aluminum die cast with cable gland entry-LV3000

(5) Length *select from:*
L for length in inches -72 inches max

Note: All combinations may not be valid, check spec sheet for valid part numbers.

Product Manuals:

Download LV4000 Series - Continuous Level Measurement Probes

Download LVCN410 and LV3000 Series - Continuous Level Measurement

Reviews

★★★★★

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’9

Home | Pumps | Peristaltic Pumps | Complete Pump Systems | Digital Variable-Speed Peristaltic Pumps

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Digital Variable-Speed Peristaltic Pumps

STENNER

Exceptional reliability and ease of service reduce maintenance and cost

$893.00 - $1,043.00 USD / EACH

- Polycarbonate corrosion-resistant housing
- 24/7 continuous duty cycle
- Mount pumps vertically or horizontally

NOTE: The skus from 74208-00 to -35 are Digital Variable-Speed Peristaltic Pumps w/o 4 to 20 mA input. The pumps with a 4 to 20 mA signal input are 74208-40 to -75 skus. Digital Variable-Speed Peristaltic Pumps With and Without 4 to 20 mA feature a

16 PRODUCT OPTIONS

item	Max Flow Rate (GPH)	Max Pressure (PSI)	Power (VAC)	Availability	Pricing
 EW-74208-00 Mfr # SVP1H1A1SUAA	0.21	100	115	**Usually Ships in 6 Days**	**$893.00** USD / EACH

item	Max Flow Rate (GPH)	Max Pressure (PSI)	Power (VAC)	Availability	Pricing
 EW-74208-05 Mfr # SVP1H1C1SWAA	0.21	100	230	**Usually Ships in 7 Days**	**$893.00** USD / EACH
 EW-74208-10 Mfr # SVP1H2A1S2AA	0.71	100	115	**Usually Ships in 7 Days**	**$893.00** USD / EACH
 EW-74208-15 Mfr # SVP1H2C1SWAA	0.71	100	230	**Usually Ships in 7 Days**	**$893.00** USD / EACH
 EW-74208-20 Mfr # SVP1H7A1SUAA	1.67	100	115	**Usually Ships in 7 Days**	**$893.00** USD / EACH
 EW-74208-25 Mfr # SVP1H7C1SWAA	1.67	100	230	**Usually Ships in 7 Days**	**$893.00** USD / EACH
 EW-74208-30 Mfr # SVP1L5A1SUAA	3.54	25	115	**Usually Ships in 7 Days**	**$893.00** USD / EACH

item	Max Flow Rate (GPH)	Max Pressure (PSI)	Power (VAC)	Availability	Pricing
 EW-74208-35 Mfr # SVP1L5C1SWAA	3.54	25	230	**Usually Ships in 12 Days**	**$893.00** USD / EACH
 EW-74208-40 Mfr # SVP4H1A1SUAA	0.21	100	115	**Usually Ships in 7 Days**	**$1,043.00** USD / EACH
 EW-74208-45 Mfr # SVP4H1C1SWAA	0.21	100	230	**Usually Ships in 7 Days**	**$1,043.00** USD / EACH
 EW-74208-50 Mfr # SVP4H2A1SUAA	0.71	100	115	**Usually Ships in 7 Days**	**$1,043.00** USD / EACH
 EW-74208-55 Mfr # SVP4H2C1SWAA	0.71	100	230	**Usually Ships in 7 Days**	**$1,043.00** USD / EACH
 EW-74208-60 Mfr # SVP4H7A1SUAA	1.67	100	115	**Usually Ships in 7 Days**	**$1,036.00** USD / EACH

item	Max Flow Rate (GPH)	Max Pressure (PSI)	Power (VAC)	Availability	Pricing
 EW-74208-65 Mfr # SVP4H7C1SWAA	1.67	100	230	**Usually Ships in 7 Days**	**$1,036.00** USD / EACH
 EW-74208-70 Mfr # SVP4L5A1SUAA	3.54	25	115	**Usually Ships in 9 Days**	**$1,043.00** USD / EACH
 EW-74208-75 Mfr # SVP4L5C1SWAA	3.54	25	230	**Usually Ships in 7 Days**	**$1,043.00** USD / EACH

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You are looking at: Programmable Controllers > DirectLogic Series P... > **DirectLogic 05 (Micro Brick PLC)**

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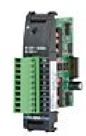
DirectLogic 05 (Micro Brick PLC)

Programmable logic controllers have to reliably execute the logic operations and communication requests that automated facilities/machines require. The DirectLOGIC 05 controller offers reliable, time-tested hardware with the software features needed for many industrial automation projects.


PLC Units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*Direct*LOGIC Micro Programmable Logic Controller (DL05 PLC)

Would a ***$125.00*** micro PLC with incredible features solve your application's discrete and process control problems?

The DL05 and the DL06 DirectLOGIC product lines are a family of micro PLCs designed to fit more applications than any other PLC family in their class. Starting with the DL05 at 8 inputs/ 6 outputs, all the way up to the fully expanded 100 I/O DL06 PLC, these PLCs are a standard that can grow with the changing needs of your machine or process control applications.

The inexpensive *Direct*LOGIC DL05 PLC offers many features including:

- Eight built-in inputs and six built-in outputs, expandable to 30 I/O total
- Eight combinations of AC or DC powered PLC units with AC, DC and relay I/O
- 6 KB program and data memory
- Two communication ports
- Supports MODBUS RTU master/slave, DeviceNET slave, Proibus slave and Ethernet networking
- 129 instructions, including four PID loops
- Powerful functions like FOR/ NEXT loops, subroutines, and drum sequencers
- Smallest I/O cards in the micro class
- Removable terminal block connectors
- Compatible with ***AutomationDirect*** *ZIP*Link wiring connection systems for 16-point discrete versions

Complete DL05/06 Overview

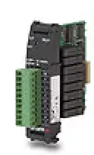
BUY WITH CONFIDENCE: All ***AutomationDirect*** PLCs include **Free Technical Support** and a **30-Day Money-Back Guarantee!**


From ***$125.00***

DL05 PLC Units

The DL05 micro PLC line includes eight PLC units, each with 8 built-in discrete inputs, 6 discrete outputs. One option slot adds analog or discrete I/O, additional communications or a memory module with real-time clock and battery back-up.

- **Eight units:** 100-240 VAC or 12-24 VDC powered
- **AC-powered I/O combinations:** AC-in/AC-out, AC-in/DC-out, AC-in/relay-


Starting at ***$41.00***

Discrete I/O

Discrete I/O option modules allow the DL05 PLC to expand with the needs of industrial control applications for just a few dollars more.

- 8-in, 110 VAC
- 10-in, 12-24 VDC
- 16-in, 20-28 VDC
- 10-out & 16-out 12-24 VDC
- 4 relay outputs, 5-30 VDC or 5-125 VAC
- 8 relay outputs, 6-27 VDC or 6-240 VAC

HACH Ammonia and Nitrate Sensor Pricing Conversations

Nathan W.: Hi, my name is Nathan W.. How may I help you?

Abbegail Nack: I'm looking to install an ammonia sensor in a wastewater treatment tank to continuously measure ammonia concentration and send a signal directly to a PLC. Will this sensor work for that application?

Nathan W.: Yes, provided your ammonia residual is always above 0.1

Nathan W.: We have either the AN-ISE or the AMTAX for that application.

Abbegail Nack: How long can you expect the sensor to last?

Nathan W.: The sensor cartridges are replaced every 6 months (sometimes earlier as needed). With regular maintenance in municipal waste water, 5 years is a conservative estimate. The warranty is only 1 year.

Abbegail Nack: How much do the cartridges typically cost?

Nathan W.: $989

Nathan W.: The advantage of AN-ISE probes is the initial cost, the disadvantage is they need to be calibrated and maintained regularly.

Abbegail Nack: Is there a probe that only monitors NO3?

Abbegail Nack: And, does the AMTAX require replacement cartridges less frequently?

Nathan W.: The Amtax is an analyzer, so a stream is sent to the unit. It calibrates automatically and doesn't have cartridges.

Abbegail Nack: Oh, I see. Thank you, that was very helpful!

Linda R.: Hi, my name is Linda R.. How may I help you?

Abbegail Nack: Hi! I'm looking into installing a A-ISE sc Sensor into a wastewater treatment system to continuously monitor the ammonia concentration in a tank. How does the A-ISE sc Sensor differ from the AN-ISE sc? Can I connect the A-ISE sensor directly to a PLC?

Linda R.: Both the A-ISE or the AN-ISE sensors need to connect to our sc200 or sc1000 controllers first for power and programming needs. The sc controller then has the 4-20 mA outputs that can be taken to the PLC. If the PLC cannot accept 4-20 mA, we need to know what communication it does accept. We also have modbus, profibus and Hart communication modules as other options for outputs to PLC>

Abbegail Nack: How frequently will the A-ISE sensor need to be replaced?

Linda R.: The A-ISE sensor measures ammonium while the AN-ISE sensor measures ammonium AND nitrate.

Linda R.: Here is the recommended maintenance for the ISE sensors:

Linda R.: Clean the probe - every 30 days

Linda R.: Replace sensor cartridge - every 6 months

Linda R.: Check probe for damage - every 30 days

Linda R.: Compare the measured value with a ref laboratory analysis and correct the values as required via a matrix correction - every 30 days

Linda R.: All maintenance depends on the actual application also.

Abbegail Nack: How much does the sensor cartridge cost?

Linda R.: PN LZY694 - US Retail Price $989.00

Linda R.: Here is a link to the User Manual which includes all maintenance and frequency plus part numbers. The warranty is one year on these sensors.

Linda R.: https://www.hach.com/asset-get.download-en.jsa?id=10070775050

Abbegail Nack: Can I connect two different A-ISE sensors to the same sc200 controller to send two outputs to a PLC?

Linda R.: Yes, you can do that. We have 2 inputs available on the sc200 - just order as 2 digital inputs. There are automatically 2x 4-20 mA outputs available in the controller as well.

Abbegail Nack: Thank you! That was very helpful!

Linda R.: You are very welcome. Did you get my email from earlier also? Sorry about losing you on Chat.

Linda R.: Let us know if you need anything else and feel free to call in directly too.

Abbegail Nack: Oh no, I didn't see that. No worries, I think it was my fault. Thank you so much and have a wonderful day!

Hi, my name is Leisha H.. How may I help you?

Abbegail Nack: Hi, on your website, for the AN-ISE, it says the sensor measures NH4-N (under parameters) and the A-ISE doesn't say. Do these sensors measure NH4-N or NH3-N?

Leisha H.: The A-ISE measures NH4-N and the AN-ISE measures NH4-N and NO3-N.

Abbegail Nack: Okay, so they both measure ammonia and not ammonium? I was confused by the website...Thanks!

Leisha H.: If you have additional questions, or I can be of further assistance to you, please let me know.

N-ISE sc Nitrate Sensors

Talk to an Expert

Gallery

Hach's digital, ion-selective N-ISE sc probe is designed for the determination of nitrate concentration directly in the medium. Calibration-free with automatic chloride compensation. The sensor features easy handling and low maintenance due to Cartrical sensor cartridge. N-ISE sc is particularly cost-effective in terms of installation and operation, even for small wastewater treatment plants.

N-ISE sc Sensors can be connected to all SC controllers, providing versatile output options including 4-20 mA Output, Modbus RS485, Profibus, or Hart.

Prognosys is a predictive diagnostic system that allows you to be proactive in your maintenance, by alerting you to upcoming instrument issues. Know with confidence whether changes in your measurements are due to changes in your instrument or your water.

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Compare Selected (0) Clear Selected

Part Number	Range	RFID	Parameters	USD Price	
LXV440.99.20012 Compare	0 - 1000 mg/L NO_3-N	No	NO_3-N	$7,218.00	
LXV440.99.20002 Compare	0 - 1000 mg/L NO_3-N	Yes	NO_3-N	$7,218.00	

Other Product Families

Nitratax sc Nitrate Sensors

Real Time Controls (RTC)

SC1000 Controller Probe Module

SC200 Controller

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PLASTIC DRUMS

UN RATED

Excellent for indoor or outdoor use. Corrosion free, dent-resistant polyethylene.

- **Open Top:** 30 gal. stores up to 395 lbs.; 55 gal., 450 lbs. of solids. Quick-lock lid (included) won't pop open during transit.
- **Closed Top:** 15 gal. stores up to 230 lbs.; 30 gal., 445 lbs.; 55 gal., 800 lbs. of liquids and solids. Two openings to pour and vent.
- Natural drums allow for easy viewing of contents.
- FDA compliant resins.
- **Recommended liners**: For 30 and 55 gallon open top use Round Bottom.

* AVAILABLE IN: Blue, Natural or Black

MODEL NO.	COLOR	TOP	CAPACITY	UN RATING	WT. (LBS.)	PRICE EACH 1	4	8+	ADD TO CART
S-19412	Blue	Closed	5 Gallon	1H1/Y1.8/150	3	$19	$18	$17	1 ADD
S-19413	Natural								1 ADD
S-17007	Blue	Closed	15 Gallon	1H1/Y1.8/100	7	41	39	37	1 ADD
S-19418	Natural								1 ADD
S-11860	Blue	Open	30 Gallon	1H2/Y180/S	16	74	71	67	1 ADD
S-19419	Natural								1 ADD
S-11861	Blue	Closed	30 Gallon	1H1/Y1.8/100	14	64	61	57	1 ADD
S-17008	Natural								1 ADD
■ S-9945	Specify*	Open	55 Gallon	1H2/Y250/S**	25	79	$74 each		Specify Color
■ S-10757		Closed		1H1/Y1.9/100	22	69	$65 each		Specify Color

** Natural UN Rating: 1H2/Y130/S

■ SHIPS VIA MOTOR FREIGHT

Online Sensors and Controllers: Controllers (Digital) » SC200 Controller

SC200 Controller

Talk to an Expert

Gallery

The SC200 Universal Controller is the most versatile controller on the market. It allows the use of digital and analog sensors, either alone or in combination, to provide compatibility with the broadest range of sensors. It replaces the Hach SC100 digital and GLI53 analog controllers with advanced features for easier operator use. The SC200 controller can be configured to operate two digital sensor inputs, two analog sensor inputs, or a combination of one digital and one analog input. Customers may add communication modules for a variety of protocols including Modbus 232/485, Profibus DPV1, and Hart.

Maximum Versatility
Ease of Use and Confidence in Results
Wide Variety of Communication Options

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Part Number	Power Options	Communication Capabilities	Digital / Analog	Sensor Input #1	Sensor Input #2	USD Price
LXV404.99.00552 Compare	100-240V AC, No Power Cord	2x 4-20 mA Out	Digital	Digital	Digital	$1,907.00
LXV404.99.00502 Compare	100-240V AC, No Power Cord	2x 4-20 mA Out	Digital	Digital	None	$1,733.00
LXV404.99.00102 Compare	100-240V AC, No Power Cord	2x 4-20 mA Out	Analog	Analog pH/ORP/DO	None	$1,311.00
LXV404.99.00202 Compare	100-240V AC, No Power Cord	2x 4-20 mA Out	Analog	Analog Conductivity	None	$1,311.00
LXV404.99.00112 Compare	100-240V AC, No Power Cord	2x 4-20 mA Out	Analog	Analog pH/ORP/DO	Analog pH/ORP/DO	$1,600.00
LXV404.99.70552 Compare	24 VDC	2x 4-20 mA Out	Digital	Digital	Digital	$2,127.00
LXV404.99.00222 Compare	100-240V AC, No Power Cord	2x 4-20 mA Out	Analog	Analog Conductivity	Analog Conductivity	$1,600.00
LXV404.99.00302 Compare	100-240V AC, No Power Cord	2x 4-20 mA Out	Analog	Analog Flow	None	Contact Hach
LXV404.99.01552 Compare	100-240V AC, No Power Cord	Modbus RS232/RS485	Digital	Digital	Digital	$2,273.00
LXV404.99.05502 Compare	100-240V AC, No Power Cord	Hart	Digital	Digital	None	$2,117.00

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Home > Drum & Bucket Accessories > Drum Mixers And Drum Tumblers > Power > Heavy-Duty Portable Mixer Blades For Power Drills > Mixer-blades-for-power-drills-55-gallon Drums > Swing T-Style Triple Mixer Blade for 55 Gallon TH Barrel-36" Shaft

Click to enlarge

Item Number: 8TMS-55-3

1+ pieces	$171.95 ea.
2 + pieces	$169.95 ea.

Regular price: $171.95

Quantity: 1 ADD TO CART

Swing T-Style Triple Mixer Blade for 55 Gallon TH Barrel-36" Shaft

- 3-Triple T-Style Cast aluminum mixing head
- Fits standard power drills with 1/2" chuck

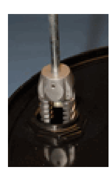
Baytec's heavy-duty portable mixers are the right choice for job-site mixing of heavy liquids and dry material, without introducing air into the mix.

Round-Style Mixers are ideal for dry materials, heavy coatings, glues, printing ink, resins, plaster, cement, and more.

The T-Style Mixer's has a triple use a swing-blade design that fits through Coarse Thread Bung Hole opening.
The Turbine-like teeth on the top and bottom produce a tornado-like mixing action and are ideal for less viscous fluids like latex paint or ink.

Features:
Container Size Use: Tight Head 55 Gallon Barrel or Drum
Dim. (head x shaft x length): 3-5 3/4" Mixer Head x 1/2" Shaft Diameter x 36" Shaft Length
Wt. (lbs.): 2 1/2 lb.

Additional Image(s) - Click To Enlarge



You May Also Need

Round Zinc Aluminum Mixer Blade for 55 Gal Barrel-40" Shaft

Barrel Mixer Blade for Tight Head 55 Gallon Barrel-36" Shaft

Swing T-Style Mixer Blade for 55 Gallon Tight Head Barrel-36" Shaft

In This Category

- Round Zinc Aluminum Mixer Blade for 55 Gal Barrel-
- Barrel Mixer Blade for Tight Head 55 Gallon Barrel-36"

Appendix F: City Sewer Calculations

Capital Costs

Force Main Pipe Costs:

$375*1,160 ft. =$435,000

Trench Installation:

$400*1160 ft. =$464,000

Total Cost:

$435,000+$464,000=$899,000

With Engineering Design:

1.25*$899,000=$1,123,750

With the removal of the RUCK System from Table 13:

$$\$1{,}123{,}750 + \$250{,}800 = \$1{,}374{,}550$$

Yearly Expenses

Current size

$718*46 units=$33,028

After Future Development

$718*55 units=$39,490

Required Expenses (2016)	**Cost**
Lift Station Repairs/Maintenance	$ 22,838
Lift Station Electric Use	$ 4,457
Lift Station Gas Use	$ 788
Septic Pumping	$ 861
Total	**$ 28,944**

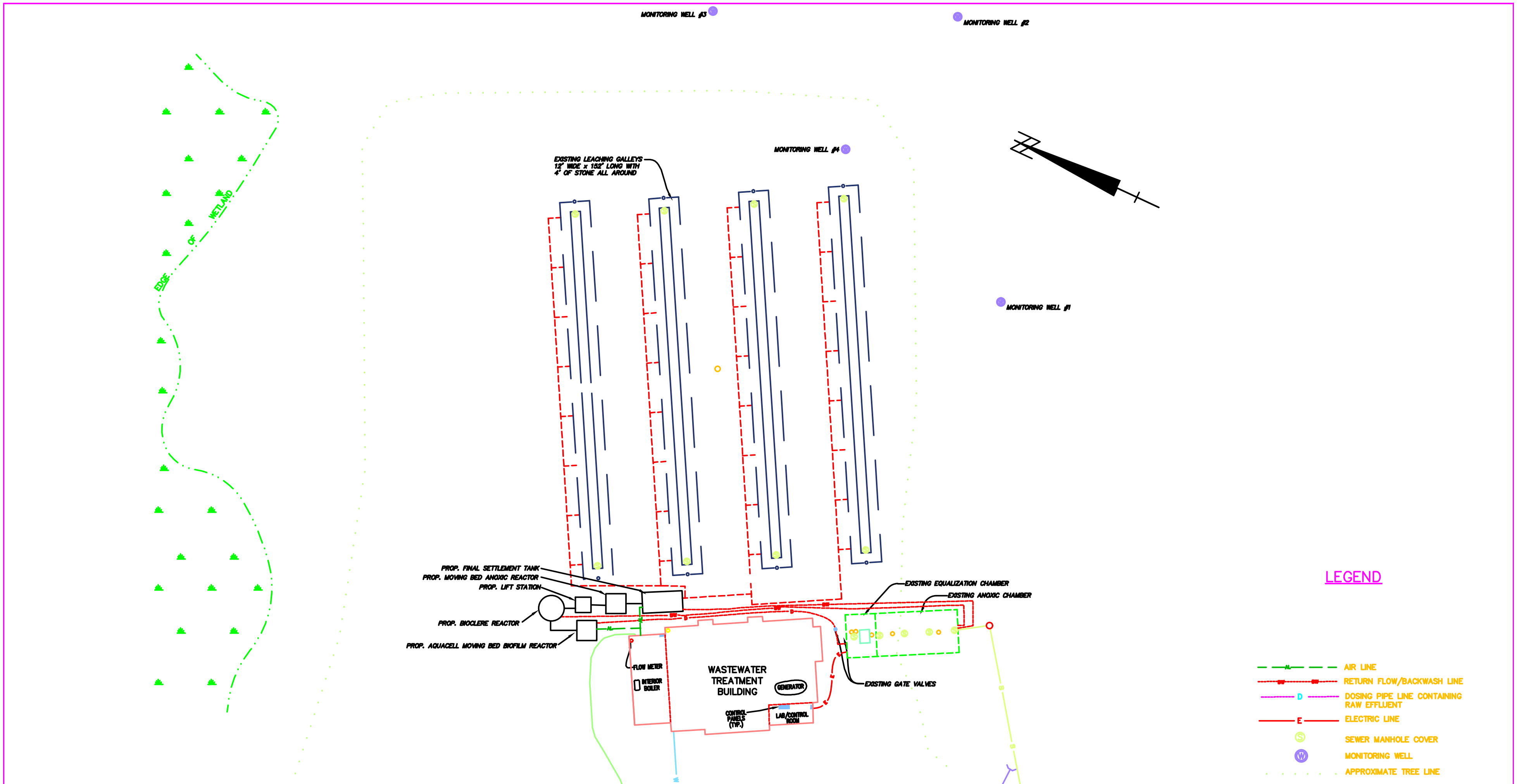
$28,944 in community expenses for transportation of the wastewater and electrical/pumping costs:
For 46 units:

$$\$33{,}028 + \$28{,}944 = \$61{,}972$$

For 55 units:

$$\$39{,}390 + \$28{,}944 = \$68{,}434$$

Appendix G: Alternative Systems Design Plans



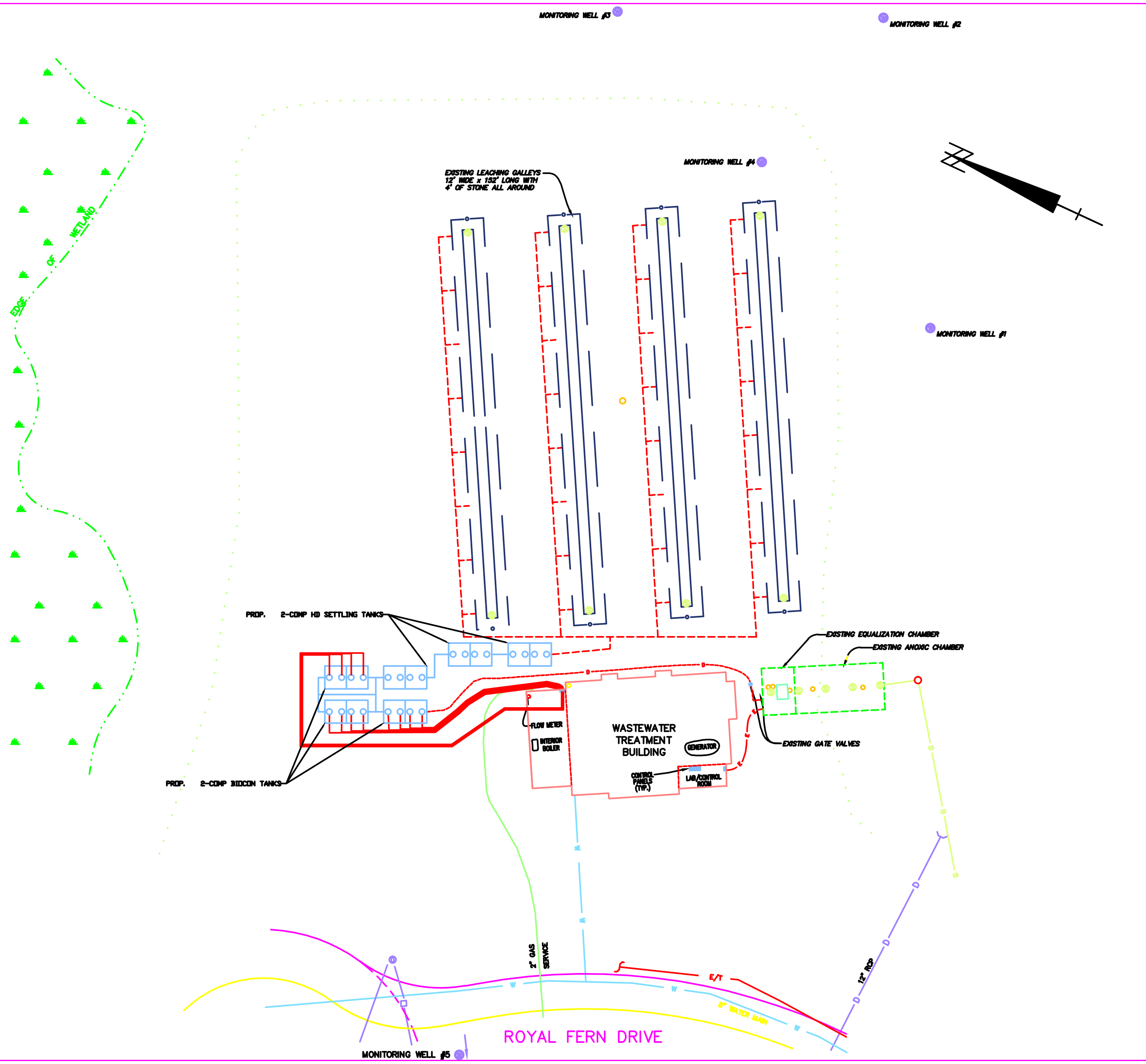
DATE	DESCRIPTION	Drawn	Checked
REVISIONS			

EXAMPLE SCHEMATIC
OF THE BIOCLERE SYSTEM

MODIFIED FROM ORIGINAL DESIGN PLANS CREATED BY HOLMES AND MCGRATH, INC.

SCALE: 1" = 40' | DATE: APRIL 19, 2017

LUNENBURG MQP TEAM
STUDENTS AT WORCESTER POLYTECHNIC INSTITUTE
100 INSTITUTE ROAD
WORCESTER, MA 01609



LEGEND

- EFFLUENT PIPE TO LEACHING FIELDS
- D — DOSING PIPE LINE CONTAINING RAW EFFLUENT
- ELECTRIC LINE
- S — SEWER MANHOLE COVER
- W — MONITORING WELL
- APPROXIMATE TREE LINE

DATE	DESCRIPTION	Drawn	Checked

R E V I S I O N S

EXAMPLE SCHEMATIC
OF THE CLEAN SOLUTION TREATMENT SYSTEM
AT
MODIFIED FROM ORIGINAL DESIGN PLANS
CREATED BY HOLMES AND MCGRATH, INC.

SCALE: 1" = 40' | DATE: FEBRUARY 22, 2017

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STUDENTS AT WORCESTER POLYTECHNIC INSTITUTE
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