NORTHERN ARIZONA UNIVERSITY

Memorandum

TO: Jeffrey Heiderscheidt, Ph.D.

FROM: 2020 NAU WEF Capstone Team

DATE: May 5, 2020

SUBJECT: CENE 486C– Section 1

RE: Final Design Report

Hello Dr. Jeffrey Heiderscheidt,

Attached below is a team compiled Final Design Report for the Water Environment Federation and Arizona Water Student Design Competition for a wastewater facility. It contains an introduction and technical sections, consisting of the research on requirements, an introduction and assessment of alternative design technologies, and progress into the final design recommendations. If you have further questions, feel free to contact Jocelyn Ramirez at jr2677@nau.edu.

Thank you for the opportunity. We look forward to working with you again in the future.

Best,

WEF 20

Letter of Transmittal

2020 Northern Arizona University Water Environment Federation Student Design Competition Team

Prepared By: Khalid Abushousha, Shiqing Cai, Wes Levin, Jacob Mitten, Jocelyn Ramirez

Northern Arizona University

05/04/2020

AZ Water Association Judgement Panel

2020 Arizona Regional Competition

Dear AZ Water Association Judgment Panel,

The Northern Arizona University Student Design Team is proud to present the final design plan for the Kyrene Water Reclamation Facility: Rehabilitation and Startup project as part of the 2020 Water Environment Federation and AZ Water Student Design Competition. This design plan includes an assessment of the existing conditions of the plant, research and evaluation concerning the implementation of the chosen new and emerging treatment processes, proposed phasing of construction, and essential documentation which supports our claims. Overall objectives of this project revolve around creating a cohesive recommendation in order to reduce the influent flow, optimize treatment processes, and treat biosolids while producing class A+ effluent.

The Kyrene Water Reclamation Facility (KWRF) was designed to be a scalping plant which pulled a portion of wastewater from the Guadalupe Road Sewer Line. The facility opened in 1991, was expanded in 2006 to handle an average flow of 9 million gallons per day (MGD), and subsequently taken offline in 2010. Before the facility was shut down, the plant had an average capacity of 9 MGD and was able to produce Class A+ effluent. The City of Tempe plans on construction completion and site start-up by the year 2025. This start-up entails a projected average daily flow of 3.0 MGD of Class A+ effluent. Half of this effluent is planned on being used as irrigation for the Ken McDonald Golf Course and for cooling water at Salt River Project's Kyrene Generating Station while the remaining half is geared towards being available for groundwater recharge.

The retrofit of this facility was designed to be completed in a three-phase expansion. Phase 1 consists of the demolition and reconstruction of all necessary features for the plant to start-up. Phase 2 consists of the implementation and profiting of the biosolids system. Phase 3 consists of the addition of energy efficiency improvements regarding solar panels placed strategically around the facility in order to incorporate the use of green energy. The enclosed report consists of an existing technology assessment, influent and effluent analysis, proposed effluent usage, technology upgrade options, technology downsizing options, economic analysis, and future recommendations regarding the proposed technology improvements. Overall capital cost of equipment and implementation is approximately $18 million and an annual operations cost of approximately $1.4 million.

This final retrofitted design will include:

- Preliminary Treatment:
  - 2 VFD Dry Well Turbine Pumps
  - 2 Coarse Screens
  - Pista 360 Vortex Grit Chamber
- Primary Treatment
  - 3 VFD Submersible Impeller Pumps
  - Reduced Equalization Basin
  - ACTIFLO Pack-Ballasted Clarifier
- Secondary Treatment
  - 3 VFD Vertical Turbine Pumps
  - Anammox Reactor
- Advanced Treatment
  - 3 VFD Enclosed Impeller Turbine Pumps With 1 Pump Shelfed
  - VigorOX WWTII Chemical Usage
  - 4 UV Disinfection Banks
- Biosolids Handling
  - Synagro Bio-Fix

WEF and AZ Water Student Design Competition 2020 Report:

The Kyrene Reclamation Facility Rehabilitation and Startup

Prepared By: Khalid Abushousha, Shiqing Cai,
Jacob Mitten, Wes Levin, and Jocelyn Ramirez

Prepared For: Jeffrey Heiderscheidt, Ph. D, Senior Lecture

In Preparation For: The 2020 AZ Water Design Competition

Final Report

May 5, 2020

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List of Abbreviations

AA	Administrative Assistant
ADEQ	Arizona Department of Environmental Quality
APP	Aquifer Protection Permit
AZ	Arizona
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
BWCDD	Buckeye Water Conservation and Drainage District
COD	Chemical Oxygen Demand
CFU	Colony Forming Units
EIT	Engineer In Training
ENG	Engineer
EQ	Equalization
KWRF	Kyrene Water Reclamation Facility
NAU	Northern Arizona University
MBR	Membrane Bioreactor
MBMR	Moving Bed Media Reactor
MGD	Million Gallons per Day
N	Nitrogen
NPDES	National Pollutant Discharge Elimination System
PD	Partial Denitrification
PFR	Plug Flow Reactor
PSD	Particle Size Distribution
PVNGS	Palo Verde Nuclear Generating Station
RO	Reverse Osmosis
SENG	Senior Engineer
SBR	Sequence Batch Reactor
TSS	Total Suspended Solids
UASB	Upflow Anaerobic Sludge Blanket
UV	Ultraviolet
VFD	Variable Frequency Drive
WEF	Water Environment Federation
WWTP	Wastewater Treatment Plant

Acknowledgements

The 2020 Northern Arizona University Water Environment Federation Student Design Team expresses our full gratitude and appreciation to the individuals and companies whose guidance and help have allowed our team to succeed in the completion of this design report:

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1.0 Project Introduction

The purpose of this project is to retrofit the Kyrene Water Reclamation Facility (KWRF). The plant, located in Tempe, Arizona, opened in 1991, expanded in 2006 to operate a maximum month flow of 9 million gallons per day (MGD) for the City of Tempe. The criteria for the retrofitted plant include providing Class A+ reclaimed water effluent and reducing the capacity from 9MGD to an average of 3MGD. The City of Tempe plans to have construction completion and start-up of the KWRF by 2025. The new design of the plant takes into consideration biosolids handling and the energy efficiency of the plant to comply with the City of Tempe's goal to use 100% green energy by 2030 and to become carbon neutral by 2050. Half of the effluent generated will be available for irrigation at the Ken McDonald Golf Course and for use as cooling water at Salt River Project's Kyrene Generating Station. The other half of effluent is planned to be used for groundwater recharge.

1.1 Site Location

KWRF is located in Tempe, Arizona. Appendix A-1 shows the location in a state map. This rehabilitation and start-up are seen as the start of a new project located on a pre-existing interface. The KWRF sites on a 9.7 acre plot of land between Rural Road and Kyrene Road on Guadalupe Road in Tempe [1]. Due to lack of open usable area around all four sides of the site, there is no open space available for expansion. Appendix A-2 shows a layout of the whole plant as it is existing.

1.2 Constraints/Limitations

The constraints and limitations associated with this project revolve around the limited space on-site. The boundaries for the facility cannot be expanded so all renovations must consider that space is limited and that the addition of new structures must still allow for efficient and effective day to day operations. Another constraint/limitation is the cost associated with the rehabilitation and start-up of this facility.

1.3 Major Objectives and Unique Deliverables

The objectives and deliverables of this project consist of:

- Evaluation of historic wastewater flow rates and loading characteristic data
- Analysis and recommendation for use of effluent water
- Analysis of City of Tempe desired treatment capacity and required effluent water quality parameters
- Optimization of the process surrounding the overall treatment efficiency with regards to chemical and energy use
- Research and evaluation of existing and emerging treatment processes which meet water quality standards associated with Class A+ effluent and potential reuse applications
- Research and recommendations towards the handling and disposal of biosolids

1.4 Exclusions

A full design includes work that is excluded from this preliminary design effort. These exclusions are:

- Completion of Environmental Impact Statement or Environmental Impact Assessment
- Topographical survey of the area of the plant
- Geotechnical work of the land
- Acquisition of Permits
- Acquisition of Manual of Operations
- Conduction of lab/pilot studies
- Detailed and complete plan of construction

There are several reasons for these exclusions. First, a limit is placed on the team's access to KWRF itself and so technical work, such as surveys or geotechnical work, cannot be completed. Team members do not have proper engineering licensing and so are unavailable to obtain permits and manuals of operation. Further, a lack of resources and time eliminates the possibility of conducting lab/pilot studies and completing a full construction plan.

1.5 Team Member Roles

The team consists of five team members, listed below along with their roles and responsibilities.

- Jocelyn Ramriez is the Senior Engineer of the team. Her main responsibilities include verifying and editing any submittals as well as ensuring quality of design.
- Wes Levin is the Project Manager of the team. His main responsibilities include managing the team when it comes to progress of schedule, submission of deliverables, management of team meetings, and implementing a cohesive strategy for the design of this retrofit.
- Jacob Mitten's role in the team is as a Lead Designer. His responsibilities mainly consist of organizing and directing the team to overall designs of the refitting and integrating all of the designs made into a cohesive whole.
- Shiqing Cai is the team's Project Engineer. She will respond to manage the work for the project and review the work being done.
- Khalid Abushousha is the CAD Designer. He is responsible for studying and creating AutoCAD drawings. In addition he will also be the lead website designer.

2.0 Technical Sections

2.1 Site Visit

2.1.1 Influent Quality

The influent comes from the Rural Road and Kyrene Road diversion structures. The historical influent quality was provided by a spreadsheet from the KWRF. Table 2-1 has a yearly average influent flow rate, BOD, COD, and TSS in 2009 and 2010, measured after the combination of the pipelines running under the roads Rural and Kyrene. In 2009, the influent data was measured at the Kyrene influent lift station four or five times per month. In 2010, the influent data was measured from January to June at the Kyrene influent lift station four or five times per month. The yearly influent conditions in Table 2-1 are the average of the whole year's data in 2009 and the half year's data in 2010. In 2025, the City of Tempe projects 3.0 MGD average daily flow in the KWRF.

Table 2-1: Influent Conditions from Kyrene Influent Lift Station in 2009 and 2010

KWRF Flow and Loading Summary				
Year	**Flow Rate (MGD)**	**BOD (mg/L)**	**COD (mg/L)**	**TSS (mg/L)**
2009	3.70	318.40	696.50	294.42
2010	3.33	373.38	813.00	377.69

The provided data included influent properties measured at two influent lines from Kyrene Road and Rural Road obtained in May 2019. The biological data in Table 2-2 is the average of several days data from the spreadsheet. The biological data has physical, chemical, and biological properties for influent from Kyrene and Rural Roads. The diurnal data in Table 2-2 was generated by collecting samples every hour for 24 hours. These diurnal data results from Kyrene Road were collected on May 3rd, 13th, 14th, and 16th, 2019; the data from Rural Road were collected on May 3rd, 4th, 5th, 13th, 14th, and 15th, 2019. This data provided insight into the influent water quality from two influents, which can be used to design the detailed treatment processes in the KWRF.

Table 2-2: Influent Properties from Two Influent Lines in 2019

	TSS (mg/L)	COD (mg/L)	Phosphorus Total (As P) (mg/L)	Total Nitrogen (mg/L)	Nitrogen Ammonia (mg/L)	Nitrogen Ammonia (As N) (mg/L)
Biological Data						
Kyrene	269.33	665.64	4.87	26.13	25.56	20.57
Rural	371.67	246.42	5.08	37.01	44.00	36.33
Diurnal Data						
Kyrene	335.25	793.37	17.82	26.4	12.84	22.41
Rural	282.32	461.42	10.40	31.86	35.44	29.04

2.1.2 Layout of KWRF

Evaluation of existing conditions showed the major processes of the facility consisted of coarse and fine screening, grit removal, aeration biological nutrient removal (BNR), membrane filtration, and Ultra-Violet (UV) disinfection. Appendix A-3: Existing Layout Photo shows the existing layout of the KWRF.

2.1.3 Existing Conditions

The KWRF was taken offline in 2010, as a result the influent was allocated to the WWTP on 91st Ave. In order to bring it back as a class A+ reuse treatment facility, repairs or the introduction of innovative technologies will be required [1]. The goal is to reduce the capacity of the facility from 9MGD to 3MGD. There is limited space to accomplish this and there needs to be design considerations to account for the City of Tempe's goal to use 100% renewable energy by the year 2030 and to be carbon neutral by the year 2050.

In addition to these criteria, there are also current issues that need to be dealt with. Currently, there is no solid treatment onsite. Instead, the grit and sludge are returned into the water that is sent to 91st Avenue WWTP. There are also high levels of hydrogen sulfide in the sewer system. Manholes have had up to 1000 ppm of hydrogen sulfide which can cause instantaneous death [1]. The facility also lacks redundancy and relies heavily on pumps rather than gravity systems. There is one system of odor control that runs through the entire facility. Since the plant is located in an urban location, it would be advised to add additional measures. The plant can be reopened with an entirely new infrastructure or reuse some of the existing infrastructure but it would require some repair work which can be costly.

2.1.4 Existing Hydraulic Analysis

Listed below is the KWRF Hydraulic Profile based on the existing conditions. Excepting the two final assumptions listed at the end, the information is based on the Phase 1 Design Report created by the city of Tempe [1].

- Influent Peak Flow: 14.4 MGD
- Peak Equalization Foreword Flow: 11.7 MGD
- Maximum Recycle Wastewater Flow Capacity: 45 MGD
- Maximum Process Flow: 56.7 MGD
- Assuming One Aeration Basin is offline

- Assuming One Membrane Basin is offline

The data shown is the assumed capacity of KWRF as existing, based on the 2002 Design Report implemented in 2006; there are no more documented changes between then and the closure in 2010. As a note, recycle wastewater flow refers to the plant's current capacity to reuse effluent and put it through the influent again, such as in the case of the aeration basins. The maximum process flow is the peak capacity considered with a full equalization basin.

2.2 Effluent Requirements

In 2002, the existing effluent quality in the KWRF was governed by the Arizona Department of Environmental Quality (ADEQ) Aquifer Protection Permit (APP), and National Pollutant Discharge Elimination System (NPDES) Permit. Table 2-3 contains the KWRF's effluent quality design criteria, found in the Class A+ reclaimed water effluent permit granted to KWRF. Upon the reopening of the kWRF, the goal of the City of Tempe is to continue producing Class A+ effluent. The Class A+ effluent standards are published in the Arizona Administrative Code Title 18 by the Department of Environmental Quality, Water Quality Division. The turbidity should be measured after the filtration process and immediately before the disinfection process in the WWTP. After disinfection treatment and before discharge to a water distribution system, for the last seven daily reclaimed water samples, the water should not have detectable fecal coliform organisms in four of the seven taken samples [2]. The standard level for fecal coliform organisms is the maximum concentration in a single sample [2]. The total nitrogen is tested as the 5-sample geometric mean concentration [2]. The Class A+ reclaimed water can't be used in any type of direct reuse [2].

Table 2-3: Effluent Quality Design Criteria [1]

Parameter	Min.	Monthly Average	Daily Max.
pH	6.5	N/A	9.0
BOD5	N/A	30.0 mg/L	N/A
Total Nitrogen	N/A	8.0 mg/L	N/A
Ammonia (as N)	N/A	N/A	8.3 mg/L
Settleable Solids	N/A	1.0 mg/L	2.0 mg/L
Suspended Solids	N/A	30.0 mg/L	N/A
Fecal Coliform	N/A	Non-detectable in 4 of 7 samples	23 FCU/100 mL in single sample
Turbidity	N/A	Less than 2.0 NTU	5.0 NTU

2.3 Biosolids Regulations

ADEQ Provides permits for the treatment of biosolids for land application according to the Arizona Pollutant Discharge Elimination System program which is in compliance with the Arizona Revised Statutes, Title 49, Chapter 2, Article 3.1 and the Arizona Administrative Code, Title 18, Chapter 9, Articles 9 and 10, and the Clean Water Act [3]. Permitting should happen at least 120 days before the start of the operation. There are initial costs depending on the level of the permit. The facility must provide a detailed description of the onsite management such as location, volume, biosolids storage whether that be on or off-site, and types of pathogens and contaminants present. After obtaining the adequate permit the facility must continue to monitor the biosolids' conditions. The biosolids must meet Class A or Class B Pathogen reduction requirements [3]. Further discussion of requirements can be found in section 2.7.5.

2.4 Criteria and Scoring

Different criteria with different weights were used to determine the optimal recommendations of technologies used in the preliminary, primary, secondary, and advanced treatments. A fifth matrix was developed to select biosolids handling. The criterion was based on the stated client's desires and weighted according to their priority. There are five criteria: feasibility of construction, the lifecycle cost, the frequency and cost of operations and maintenance (O&M), the environmental and social impacts, and the removal efficiency of the contaminant. The reason to consider feasibility is due to the small and compact area available at KWRF. Life Cycle Costs and O&M were criteria due to the general constraint of budget limits and an attempt to limit maintenance. O&M was also considered, along with environmental and social impacts due to a desire on the part of the city of Tempe to reduce energy consumption in the municipal sector. Finally, contaminant removal efficiency was considered due to the necessity of achieving Class A+ effluent and the need for effective processes. Table 2-4 contains the criteria, weight value, and justification for the weight of each criteria. It is important to note that the weights of each criterion change slightly for each treatment decision making process, since one treatment may look at one criterion as stronger than another due to the nature of the treatment process.

Table 2-4: Criteria Weights

Criteria	Weight (%)	Reasoning
Lifecycle Costs	**5-10%**	Least important as KWRF is already an additional cost, and so it seems that cost is the least prioritized desire of Tempe.
Feasibility	**5-25%**	Generally least important as the majority of technology is not too cumbersome to be disqualified.
O&M	**10-20%**	Of moderate weight as large energy consumption in operations may interfere with Tempe's renewable energy goal.
Environmental/ Social Impacts	**20-30%**	High weight so as to help prioritize the carbon neutral and renewable energy goal that Tempe has set.
Contaminant Removal Efficiency	**30-50%**	High weight since one of the requirements is to provide an effluent of Class A+ quality.

In order to properly rate each alternative against the existing technologies, the existing technologies were used as a baseline. Table 2-5 has the detailed parameters applied in each criterion. Under feasibility a smaller area would result in a higher score. Under Operation and Maintenance a lower operational cost and a higher lifespan would constitute a higher score. Operation and Maintenance also took into consideration staffing. This was rated using the values 1-3. The higher the score the better. In other words, a 3 would mean the alternative required less maintenance hours, 2 moderate maintenance hours, and 1 high maintenance hours. Similarly under Environmental and Social Impacts by-products were rated using the 1-3 scale in which the higher value was better, meaning 3 had low/no by-products, 2 had moderate, and 1 had a large amount. Power was also considered under impacts. High kW-hr/year would lower the score. Finally, contaminant removal such as total nitrogen, BOD, Coliform, and particle removal were also analyzed. Removal rates were put into the matrix as removal percentages. Overall, a higher total score demonstrated its favorability.

Table 2-5: Criteria Parameters

Criteria	Parameters
Feasibility	Area (m^2)
O&M	Operational Cost ($/year)
	Life Span (year)
	Staffing
Environmental/Social Impacts	Power (kW-hr/year)
	By-Products
Lifecycle Costs	Capital Cost ($)
Contaminant Removal Efficiency	Removal Rate(s) (%)

The decision matrix regarding the biosolids handling process has changed weights to the criteria as well due to its unique characteristics. Here, contaminant removal efficiency was weighted heavily because of the importance for KWRF to treat its own sludge. The process of sending the sludge to a second WWTP at 91st avenue resulted in lethal amounts of hydrogen sulfide accumulating in the pipes. The client also expressed a desire for a biosolids handling facility.

2.5 Design Alternatives

2.5.1 Preliminary Treatment

The preliminary treatment is composed of three different stations: the influent pump station, the screening station, and the grit removal chamber. Three alternatives are proposed in addition to the existing.

Existing: The influent pump station has three variable frequency drive (VFD) submersible pumps in a wet well. The screening section consists of 2 coarse screens (self-cleaning) and 2 fine screens (rotary drum). The grit chamber was a Pista 360-degree vortex grit chamber with a 7 MGD capacity. Pista 360-degree vortex grit chamber reduces grit of 150 micron by 95%. At the time of operation, all grit and debris captured was pumped down to the 91st avenue WWTP [1]. An issue arose in which much of the grit remained in the pipeline, producing a lethal amount of hydrogen sulfide.

Alternative 1: The influent pump station is reduced to two VFD submersible pumps. Each pump is designed to be able to handle the total average flow (3 MGD) by itself. No fine screens were in the screening section, only two self cleaning RakeFlex coarse screens. The debris that is captured will be pumped into the pipeline to 91st avenue as the plant was functioning prior to closing. The grit chamber was a Mectan V vortex grit chamber with a 7.2 MGD capacity. Mectan V grit vortex chamber removes grit of 150 microns by 75% [4].

Alternative 2: The influent pump station was reduced to two VFD turbine pumps. The pump motors are designed to be dry-well to improve ease of access for maintenance. Each pump is designed to be able to pump the average flow (3 MGD) by itself. The pumps are to be housed in the control facility near the influent pump station. The screening section is identical to alternative 1 where it consists of 2 self-cleaning RakeFlex coarse screens [5]. The debris is to be collected and sent to a hopper, where upon a regular schedule the debris shall be removed to a designated landfill. The grit chamber was designed to be a Pista 360-degree vortex grit chamber of a capacity of 7 MGD so that it is capable of peak flows. The removal efficiency of the equipment is 95% of grit of 150 microns [6].

Alternative 3: This design has an influent pump station identical to that of alternative 1 in which there are two VFD submersible pumps. In the screening section, replacing the coarse screens is a designed single grinder. The TaskMaster Titan TM14052 is capable of 6.9 MGD. 2 Fine screens are downstream of the grinder. The fine screens are SHP Series Pressure Screens. Afterwards, an aerobic grit chamber follows. Aerobic grit chambers are capable of 75% removal of 150 micron grit [7].

Assessment: Table 2-6 is the summary of the decision matrix for the assessment of the alternative technologies. The detailed scoring and calculating of the scores may be found in Appendix B-1. It should be noted that higher values in the total score is preferable. As can be seen in Appendix B-1, with the exception of two inputs, the values are calculated quantities. The method of calculation is described in the recommendations. The two inputs for subjective judgement are staffing level and by-products. The higher the value the more preferable it is (i.e. a 3 means low staffing required for staffing level and no/low by-products produced for by-products).

Table 2-6: Preliminary Treatment Decision Matrix

Preliminary Treatment Decision Matrix									
Criteria	**Weight**	Existing		Alt 1		Alt 2		Alt 3	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	10%	4.7	0.5	4.7	0.5	4.7	0.5	5.0	0.5
O&M	20%	2.9	0.6	4.6	0.9	5.0	1.0	4.1	0.8
Env/social Impacts	30%	1.4	0.4	4.2	1.3	5.0	1.5	3.4	1.0
Lifecycle Costs	10%	1.2	0.1	3.9	0.4	3.2	0.3	5.0	0.5
Cont. Removal Efficiency	30%	5.0	1.5	4.0	1.2	4.5	1.4	4.3	1.3
Total Score			**3.1**		**4.3**	**Best Tech**	**4.6**		**4.2**

Alternative 2 was decided to be the optimal design as it recieved the highest score among all the designs. The existing design received the worst rating of all the alternatives overall due to the excessive amount of by-products produced with a fine screen. The overall reason that alternative 2 was chosen was due to its removing the most contaminants, excluding the existing, and having a lower O&M need due to the more efficient screens and easier to repair dry well turbine pumps.

2.5.2 Primary Treatment

The primary treatment consists of the flow equalization station with the addition of a possible primary treatment, which the current site does not employ.

Existing: The primary treatment in KWRF is minimal. After the wastewater is discharged through the final stage of the preliminary treatment, it is sent to a 1.5 MG capacity equalization (EQ) basin with a surface area of 1275.9 m^2. Within the EQ basin are two EQ blowers that aerate the wastewater. No solids removal treatment is presumed to occur. Four pumps are used to send the water to the secondary treatment [1].

Alternative 1 - Rectangular Clarifier: After the preliminary treatment, the wastewater will be fed to a reduced 0.5 MG EQ basin. This was the original size of the basin before the upgrade when the average intake was 4 MGD in 1998 [1]. With a height of 5 meters, the surface area of the EQ basin is 425 m^2. The air blower will be kept to 2, but at a reduced rate. The water will go into 2 rectangular sedimentation basins with high rate settling modules which are each 50.5 m^2. Two tanks were stacked to reduce area.

Alternative 2 - Ballasted Clarifier: Alternative 2 will also require a downsized EQ basin of 0.5 MG, but instead of rectangular basins, there is one ballasted enhanced clarifier. The influent would be fed with alum in line with pipes designed to bend to induce proper mixture. Afterwards, approximately 180 lb/day of sand (conservatively estimated) is introduced into the ballast tank. After settling occurs in the clarifier basin, where an average of 90% of TSS and 80% of BOD, the effluent is pumped to the secondary treatment system [8].

Alternative 3 - Reduced EQ Basin: Similarly to Alternatives 1 and 2, the effluent from the preliminary treatment will be fed into a reduced 0.5 MG EQ basin. However, this alternative will not include any additional primary treatment. The reduction of the EQ basin is the only change.

Assessment: Table 2-7 is the summary decision matrix for the assessment of the alternative technologies. In Appendix B-2, a detailed decision matrix for the primary treatment.

Table 2-7: Primary Treatment Decision Matrix

Primary Treatment Decision Matrix										
Criteria	**Wt**	Existing		Alt. 1 Rect. Clarifier		Alt. 2 Microsand Clarifier		Alt. 3 Reduced EQ Basin	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	10%	1.7	0.2	3.9	0.4	4.8	0.5	5.0	0.5
O&M	20%	4.4	0.9	3.2	0.6	3.3	0.7	5.0	1.0
Env/social Impacts	30%	4.0	0.8	4.7	0.9	2.1	0.4	5.0	1.0
Lifecycle Costs	10%	2.5	0.3	0.5	0.1	3.4	0.3	5.0	0.5
Cont. Removal Efficiency	30%	0.0	0.0	2.9	1.2	5.0	2.0	0.0	0.0
Total Score			**2.1**		**3.2**	**Best Tech**	**3.9**		**3.0**

The best solution for the primary treatment is alternative 2, which is a downsized EQ basin and one ballasted enhanced clarifier. Alternative 2 ultimately did better due to its ability to remove a higher amount of contaminants which was one of the higher weighted criterion. The Existing technology did the worst since there is no primary treatment happening. For that same reason, alternative 3 did not score high either, however it did better than the existing since it did offer a smaller footprint and lower costs.

2.5.3 Secondary Treatment

Secondary treatment is the section of the treatment process in which all organics and nutrients are removed. The following are the alternative designs being considered.

Existing: The existing technologies include the biomembrane basin and aeration basin. The technology has a lifespan of 8 years for municipal wastewater applications. The operating cost is $239,000 per year, the energy consumption is at least $632,000 per year. The existing cost per year is $589,000. The six basins are 180-feet long and 21-feet wide with a side water depth of 15-feet in the anoxic zone and 14-feet in the aerobic zone. Therefore, with this technology, it has been easy and able enough to clean the wastewater [1].

Alternative 1 - Microalgae System: Alternative 1 is a microalgae treatment system. This system requires large amounts of land for the algae cultivation to develop multiple subsystems in a system, approximately 200,000 m^2. The method would contribute to 2449 kW-h/d but put back to 7256 kW-h/d hence yielding positive gain and algae cultivation [9]. The algae provides the oxygen necessary to perform the aerobic bacterial process and the bacteria decomposes the complex organic matter into simpler compounds. There is a risk of heavy metals in water if the incoming flow rate is high in industrial wastewater. The contaminant removal efficiencies are 83.3% of nitrate and 92% of phosphorus. In addition there is a possibility of the collection of excess biogas and heavy metal risk [9].

Alternative 2 - Anammox Reactor: Anammox removes the nitrogen pollution from wastewater with a high concentration of nitrate. The process of Anammox is done in two phases.The first phase is aeration phase, ammonia oxidizing bacteria will convert 50% of the ammonia into nitrite. In the second phase, mixing phase, the Anammox will use the newly formed nitrite and the remaining ammonia and convert them to nitrogen gas. The proposed Anammox reactor volume is 70 m^3. To keep the sludge perfectly mixed with the Partial Denitrification (DN) sequence batch reactor (SBR) a cantilever agitator is installed and operated at 150 rpm [10]. In order to prevent the growth of phototrophic organisms anammox, the upflow anaerobic sludge blanket (UASB) is covered completely with black sponge. After the completion of the process it produced sludge and CO_2 in a cost effective way. The O&M cost is $671,600 per year. The capital cost is $22,710,400 after the process of 95% contamination in the form of nitrogen was omitted. The Anammox process is widely applied in wastewater treatment plants in Europe. In the United States, Anammox reactors are supplied by Paques, EssDe Gmbh, World Water Works, Degremont, Veolia (Kruger). Anammox reactor is considered innovative treatment technology, but is beginning to be used more and more not only in Europe but in the US as well [10].

Alternative 3 - Biomembrane Reactor: The third alternative is the bioreactor technology. This combines the aeration basin with biomembrane into a single process. The volume of the application would come to a total 4900 m^3 to make it functional even at higher concentrations. The power is 5400 kW-h/d, it can operate at a low energy level of biomass which results in low value of the carbon substrate which would also reduce the production of the sludge resulting in less odor. The total cost for this method was calculated to be $2.4 million. Contaminant removal efficiency for BOD, total nitrogen, and turbidity were determined to all be 99% [7].

Assessment: Below, Table 2-8 is the summary decision matrix for the assessment of the alternative technologies. Appendix B-3 contains the detailed decision matrix

Table 2-8: Secondary Treatment Decision Matrix

Secondary Treatment Decision Matrix									
Criteria	**Wt**	Existing		Alt. 1 Microalgae System		Alt. 2 Anammox Reactor		Alt. 3 Biomembrane Reactor	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	10%	2.1	0.5	0.0	0.0	5.0	1.3	4.3	1.1
O&M	20%	2.2	0.4	3.0	0.6	5.0	1.0	2.3	0.5
Env/social Impacts	30%	5.0	1.0	1.7	0.3	0.9	0.2	1.7	0.3
Lifecycle Costs	10%	5.0	0.3	0.2	0.0	0.6	0.0	0.6	0.0
Cont. Removal Efficiency	30%	4.6	1.4	4.2	1.3	4.6	1.4	5.0	1.5
Total Score			**3.6**		**2.2**	**Best Tech**	**3.8**		**3.4**

The preferred option is alternative 2, the Anammox Reactor. The Anammox reactor was optimal in terms of feasibility and O&M because it took up the least amount of space, and also because the cost of operation is the lowest. Although it was one of the most expensive technologies to implement, it scored well in the other aspects and was overall the best solution that was considered.

In the subjective judgment of staffing as can be seen in Appendix B-3, alternative 2, the Anammox reactor, and alternative 1, the microalgae system, are given 2 because, while requiring a staff to maintain it, are not needed for frequently extensive repairs. The existing biomembrane filters and alternative 3, the biomembrane reactor, received a 1 due to the frequency of the biomembranes being fouled and needing repairs.

For the scoring of by-products, the main consideration was volume of sludge. The biomembrane filters as existing handled the least amount of sludge, with the microalgae, alternative 1, and the biomembrane reactor, alternative 3, produced a moderate amount of sludge. The technology that produced the most sludge was alternative 2, the Anammox reactor, and so received a score of 1.

2.5.4 Advanced Wastewater Treatment

The existing technology and three alternatives were analyzed for advanced wastewater treatment. The existing advanced wastewater treatment consists of the UV Disinfection Facility.

Existing: The existing technology at KWRF is a UV Disinfection Facility that disinfects filtered effluent coming from the pressurized effluent pumps. Currently, this disinfection system is capable of meeting Class A+ Reclaimed Water Quality Standards, providing an absence in four out of seven daily fecal coliform effluent samples, and not exceeding a single sample maximum of 23 Colony Forming Units (CFU) per 100 mL of effluent. It is designed to operate efficiently against an average daily flow of 9 MGD and an equalized peak hourly flow of 11.7 MGD. The current system operates with assumed use of Trojan- Chamber ASSY 72AL75A Low Pressure/ High Intensity closed vessel at a UV transmittance of 70% and dosage of 80000 $\mu W\text{-}s/cm^2$ [11]. This system uses 7 UV reactor trains with each train possessing an actuated isolation valve upstream and a manual isolation valve downstream. Each train also possesses UV intensity monitors, automatic mechanical wiper systems, and a manually initiated chemical cleaning system which uses phosphoric acid and citric acid for cleaning [1].

Alternative 1 - Reverse Osmosis: For alternative 1, Reverse Osmosis (RO) was analyzed. A system utilizing a 40" long and 35 square meter system was chosen. When constituents are needed to be removed from water, the water is pumped against the surface of a semipermeable membrane and a waste stream and product stream is created. Use of a RO system requires, on average, 61,320 kW-h/yr and is extremely expensive at a capital cost of close to $10 million a year. This system would take place of the membranes while being able to remove 97% of TSS and 95% of organic matter [7]. The high removal efficiency is undermined by a susceptibility to biological degradation and chlorine concentrations above 1mg/L and a requirement for high levels of pre/post treatment in order to avoid damage to the system [7].

Alternative 2 - VigorOx Wastewater Technology (WWT) II with UV Radiation: The existing technology of UV Disinfection is followed after the addition of VigorOx WWTII is introduced. Effluent from the UV treatment is pumped by the effluent pumps and mixed with the VigorOx solution (mixture of 15% Peracetic Acid and 23% Hydrogen Peroxide) [12][13]. This solution requires 18 m^2 of area for two large chemical storage tanks and adequate piping systems for distributing the chemical into the flow. This solution mixes with the permeate and effectively reduces fecal and E. coli coliforms by 80-90% after 15 minutes and total inactivation of fecal coliform and E. coli after 25 minutes [12]. The addition of this chemical before the UV trains allows a higher efficiency in the UV disinfection process and requires a 33% decrease in power consumption for the UV trains. VigorOX breaks down into oxygen, water, and vinegar and produces no chlorine disinfection by-products. Overall, the two systems combined together allow for maximum efficiency in microbial removal [13][14].

Alternative 3 - Chlorine: For the third alternative, the use of chlorine to disinfect the permeate that comes from the membrane basin. After the secondary treatment in the membrane filters, the addition of chlorine is introduced to the flow. This addition requires an area of 212 m^2 used for chemical storage as well as distribution into flow. The use of chlorine produces chlorine disinfectant by-products which have to be considered before the treated water is released. For this purpose, sodium thiosulfate would have to be added to the effluent to meet the permit requirements. The nature of chlorine is extremely toxic and corrosive when stored in large quantities for treatment use which requires high levels of storage containment and precautionary measures. The use of this system results in 99% CFU removal and 95% particulate removal which meets Class A+ effluent standards and once in use, requires low maintenance and management [15].

Assessment: Table 2-9 is the decision matrix for the assessment of the alternative technologies. Appendix B-4 contains the detailed decision matrix.

Table 2-9: Advanced Treatment Decision Matrix

Advanced Treatment Decision Matrix									
Criteria	**Wt**	Existing		Alt. 1 Reverse Osmosis		Alt. 2 VigorOX WWTII + UV		Alt. 3 Chlorine	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	10%	3.3	0.3	4.4	0.4	5.0	0.5	0.7	0.1
O&M	20%	5.0	1.0	2.8	0.6	4.3	0.9	3.5	0.7
Env/social Impacts	30%	3.9	1.2	2.6	0.8	4.0	1.2	5.0	1.5
Lifecycle Costs	10%	5.0	0.5	0.1	0.0	2.4	0.2	0.8	0.1
Cont. Removal Efficiency	30%	3.0	0.9	5.0	1.5	4.5	1.4	4.2	1.3
Total Score			**3.9**		**3.3**	**Best Tech**	**4.2**		**3.6**

The chosen technology was alternate 2, which was a combination of VigorOX WWTII Wastewater Chemical Disinfectant followed by treatment through an array of UV reactor trains. The reasoning behind this decision is that the existing technology UV reactor trains currently meet the Class A+ Effluent and reuse standard and the addition of the VigorOX WWTII chemical treatment would allow the effluent water to be used in not just reclaimed water and groundwater discharge practices, but in potable reuse as well. This makes further upgrades easier to adapt to, if the city wishes to transition to potable reuse. With the KWRF lowering its average flow rate from 9 MGD to 3 MGD, the decision to lower the amount of UV reactor trains from 7 to 4 trains while maintaining the same wattage per train was chosen. The lowering of the amount of UV trains and addition of VigorOX allows for a synergistic effect where the combination results in an exceeded performance compared to using one method or the other. This combination allows for the reduction of UV capital costs, UV power usage, and UV/VigorOX operational and maintenance expenses. This combination also allows for outdated UV systems to be able to meet permit requirements without the need for redesign or replacement and achieve new regulatory standards when it comes to new age and low target microorganisms.

2.5.5 Biosolids Handling

With the expressed desire by the client for a renovated system of handling biosolids produced from the treatment processes, several variations were considered.

Existing: It was the practice of the KWRF prior to its shutdown to dispose of all of its biosolids and grit accumulated during the stages of treatment by sending it to the WWTP located at 91st ave [1]. It was reported that due to the large amount of BOD present in the biosolids and the low slope grade of the piping leading to 91st ave, extremely high levels of hydrogen sulfide accumulated.

Alternative 1 - Bio-Fix: The first alternative proposed is to implement a Bio-Fix system, an in-house alkaline stabilization process that is assembled and manufactured by Synagro [16]. It was determined that due to the relatively small amount of dry sludge produced by the KWRF (approx. 164 kg/hr) a thickening process was unnecessary. Furthermore, the Bio-Fix stabilization process produces treated sludge matching class A. A small facility was determined to be adequate for the needs of KWRF.

Alternative 2 - Centrysis Thickener & Centrifuge: The second alternative looks at a combination of the Centrisys Sludge Thickener THK Series and Centrisys Dewatering Centrifuge CS Series. The THK Sludge Thickener includes a centrifuge of 3,000 Gs, a rotary drum thickener that is fully enclosed, and a dissolved air flotation (DAFT) via air injection.

Alternative 3 - Gravity Belt & Anaerobic Digester: The third alternative consists of gravity belt thickener, anaerobic digester stabilizer, and chemical conditioning. Gravity belt thickener flocculates sludge by using polymers. The sludge is thickened on the belt and the released water is sent out through the gravity belt. Anaerobic digester is a solids stabilization process, which converts the biosolids, such as microbiological cells, to a stable end product. The polymer is selected for chemical conditioning, which destabilizes sludge particles first by dehydration and charge neutralization, then adheres small particles by agglomeration. Anaerobic digestion also reduces the mass of the biosolids.

Alternative 4 - Thermal Hydrolysis Process Reactor: The fourth alternative consists of implementing a Thermal Hydrolysis Process (THP) Reactor that is manufactured and installed by Lystek. This process is able to treat biosolids and organics by combining them with a 45% liquid alkali solution and steam injection to create a hydrolyzed product which can be used in three different ways. The first is a biofertilizer which meets Class A biosolids criteria, second is a digester optimization method where biogas production is increased by 40% and volatile solids is reduced by 25%, and the third option is to use the by-product as an alternate fuel source which would eliminate the use of costly chemicals such as methanol and glycerol. The drawbacks to this alternative are the massive electrical and heat requirements of 60 kw-h per dry ton and 1,100,00 BTU per dry ton in order to operate efficiently. Another drawback is that the unit that would be deemed appropriate for KWRF has an area footprint of close to 130 m^2.

Assessment: Table 2-10 is the decision matrix that was employed to determine the optimal sludge handling process. As mentioned before, a higher score correlated to higher favorability. Staffing is still based on values 1-3 with 3 being little staffing needed. Moreover, a value system was given to the quality of sludge produced, 3 was for Class A, 2 was for Class B, 1 was for Class C, and 0 was for no class assigned. For detailed analysis refer to Appendix B-5

Table 2-10: Biosolids Handling Decision Matrix

Biosolid Handling Decision Matrix											
Criteria	**Wt**	Existing		Alt 1 - Bio-Fix		Alt 2 - Centrysis Thickener & Centrifuge		Alt 3 - Gravity Belt Thickener & Anaerobic Digester		Alt 4 - Thermal Hydrolysis Process Reactor	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	10%	5.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
O&M	20%	4.4	0.4	3.3	0.3	3.1	0.3	2.9	0.3	5.0	0.5
Env/social Impacts	30%	5.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lifecycle Costs	10%	5.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cont. Removal Efficiency	30%	0.0	0.0	5.0	2.5	3.8	1.9	3.8	1.9	2.5	1.3
Total Score			**2.4**	**Best**	**2.8**		**2.2**		**2.2**		**1.8**

As demonstrated above, alternative 1, the bio-fix alkaline stabilization process, was deemed to be the preferred option. It may be commented that in most criteria the Existing, that is no sludge handling process, was deemed to be the best. However, since the client showed a desire for a biosolids handling process, the quality of sludge produced was weighted highly. Consequently, the inability of the existing process to produce quality sludge made it fail. Profit that can be made from the selling of class A biosolids can be found in section 2.11.3: Phase 2: Addition of Biosolids Handling Construction.

2.7 Design Recommendations

2.7.1 Preliminary Treatment

As the assessment in Table 2-6: Preliminary Treatment Decision Matrix shows, the treatment process labeled alternative 2 was deemed optimal. It is then recommended that the three current VFD submersible pumps be replaced with 2 Dry-Well pumps. The pumps are recommended to be Robocco turbine pumps series 14JHE. Pump details may be found in Table 2-11. Refer to Appendix C-1 for the System Curve of the influent pump station and Appendix C-2 for the calculation values and assumptions used for the system curve. Appendix C-3 contains the pump curve overlayed with the system curve.

Table 2-11: Influent Pump Details

Pump No.	Flow (MGD)	Head (ft)	Speed (rpm)	Efficiency
1	1.5	60	900	84%
2	1.5	60	900	84%

The flow from the pumps is to be pumped to an open flow channel in the screening room with a width of 0.75 m and a total depth of 0.9 m. The channel is given a length of 3.5m upstream of the screens to normalize flow. There are two channels each designed to accept the maximum flow of 6 MGD. These design choices were made to satisfy the Great Lakes Upper Mississippi River Board (GLUMRB) requirements, which though not necessary were used to ensure quality of design [7]. In each channel is a Dueperon RakeFlex, tear dropped shape. Appendix C-4 contains the manufacturer information. Appendix C-5 contains a schematic drawing of the placement of the coarse screens with the channel in the screening room.

Finally, the flow from the coarse screens is sent to the Pista 360-degree 7.0 MGD vortex grit chamber. Here 95% of a grit diameter of 100 microns or larger is removed. Appendix C-6 contains the manufacturer information.

In determining the removal of grit/biosolids, a particle size distribution (PSD) curve of wastewater, constructed by Fides Izdori *et al.,* was assumed as the characteristic of the raw influent as no specific data concerning the PSD of the Kyrene wastewater is known [17]. The PSD curve may be seen Appendix C-7. At the removal rate capabilities of the Pista 360-degree Vortex Grit Chamber and with 45% of the TSS being of a diameter of 100 microns or more, the resulting grit removal is 1.8 tons per day. The calculations supporting this finding may be found in the table of Appendix C-8.

2.7.2 Primary Treatment

In Table 2-7, the Primary Treatment Decision Matrix, the treatment process labeled alternative 2 scored the highest. This alternative includes a reduced equalization basin and the addition of ballasted flocculation.

The flow equalization basin is to be located downstream of the headworks. The reduced flow equalization basin will require three new pumps to compensate for the change in flow since pumps are designed to run near their point of highest efficiency. Two of the three pumps will be running while the other is on standby. Below Table 2-12 contains the pump details for flow equalization basin pumps. Refer to Appendix D-1 for the system curve of the flow equalization pumps and Appendix D-2 for the calculation values and assumptions used for the system curve. Appendix D-3 contains the pump curve.

Table 2-12:Flow Equalization Pump Details

Pump No.	Flow (MGD)	Head (ft)	RPM	Efficiency
1	1	68.9	1770	83.4%
2	1	68.9	1770	83.4%
3	1	68.9	1770	83.4%

Since the plant relies on UV disinfection which provides no removal of particulates, it is important that there is a strong particulate removal prior to disinfection process. The addition of a primary treatment process should drive operational costs down. The ACTIFLO®Pack is technology which uses ballasted flocculation to treat the water in a physical and chemical way [8]. It combies coagulation, flocculation, and clarification into one small footprint technology. For further details on the ACTIFLO®Pack refer to Appendix D-4 which contains manufacture information.

Additional operation recommendations include using a lower mixer speed of 80-85% of the maximum and the blades should be positioned a full diameter from the floor, as well as using a grain size of 130-150 µm to optimize operations.

2.7.3 Secondary Treatment

In Table 2-8: Secondary Treatment Decision Matrix, the alternative 2: Anammox Reactor received the highest score and was deemed optimal. Three VFD turbine pumps series 12JMO from Robocco Pumps in the recycle pump station replace the three existing pumps. Table 2-13 has the detailed pump information. Appendix E-1 is the system curve of the recycle pump station, Appendix E-2 has all the calculation values, and Appendix E-3 includes the pump curve.

Table 2-13: Recycle Pump Details

Pump No.	Flow (MGD)	Head (ft)	Speed (rpm)	Efficiency
1	1	22	1470	81.9%
2	1	22	1470	81.9%
3	1	22	1470	81.9%

The anammox reactor chosen specs can be found in Appendix E-4. The bacteria chosen for anammox reactor is anammox bacteria. The microorganism concentration in the aeration tank is assumed to be 2460 mg/L. The half-saturation constant (Ks) is 0.1 mg/L [18]. The maximum growth rate constant (µM) is 0.33 d^{-1} [19]. The decay rate of microorganisms is 0.00385 d^{-1} [19]. The fraction of MLVSS/MLSS is 0.7 [1]. Yield coefficient is 0.11 g BOD/g VSS [20]. The primary settling percentage of BOD removal is 35%, which is computed in the primary treatment. Table 2-14 contains the designed parameters for anammox reactor. The equations listed in Appendix E-5 are used for the design calculations of anammox reactor. Calculation values and equations are in Appendix E-5. The optimum temperature and pH for the growth of the bacteria are 30-40 Degrees C and 6.7 - 8.3 [21].

The anammox bacteria is a slow growing bacteria and are sensitive to temperature and pH. Therefore, a pH control program needs to be set for monitoring the pH and the dissolved oxygen inside the reactor. Also, the bacteria should be kept inside the reactor. The anammox reactor is a closed tank. A micro-screen is installed at the top of the anammox reactor, which is used to separate the anammox granules from the other waste bacteria. The majority of anammox bacteria will not leave the anammox reactor, so the secondary disinfection process is not necessary.

Table 2-14: Anammox Reactor Parameters

Anammox Reactor Parameters	
Hydraulic Retention Time (hr)	0.6
Wet Sludge Produced (kg/day)	36.9
Volume (m^3)	266
Dimension (LxWxH) (ft)	24x24x17
Required Air (kg/day)	11146

2.7.4 Advanced Treatment

In Table 2-9: Advanced Treatment Decision Matrix, the treatment which scored the highest was alternative 2, which is a combination of VigorOX WWTII Wastewater Chemical Disinfectant followed by treatment through an array of UV reactor trains. The cleaning and electrical methods of the UV system will stay the same, while the addition of VigorOX will provide a secondary service of reducing scale build up and algae presence in and before the UV lamps. The pumps are recommended to be Robocco turbine pumps series 14JMO. Table 2-15 contains the pump details for permeate pumps. Appendix F-1 shows the permeate pump system curve, Appendix F-2 shows the permeate pump system curve calculations, and Appendix F-3 shows the permeate pump curve graph.

Table 2-15: Permeate Pump Details

Pump No.	**Flow (MGD)**	**Head (ft)**	**Speed (rpm)**	**Efficiency**
1	1	361	1770	85%
2	1	361	1770	85%
3	1	361	1770	85%

Effluent pumps are recommended to the three current VFD submersible pumps. The pumps are recommended to be Robocco turbine pumps series 14JMO. Pump details may be found in Table 2-15. Refer to Appendix F-4 for the system curve of the effluent pump station and Appendix F-5 for the calculation values and assumptions used for the system curve. Appendix F-6 contains the pump curve overlayed with the system curve.

Table 2-16: Effluent Pump Details

Pump No.	**Flow (MGD)**	**Head (ft)**	**Speed (rpm)**	**Efficiency**
1	1	175	1770	84%
2	1	175	1770	84%
3	1	175	1770	84%

The flow from the permeate pumps starts by getting mixed with the VigorOX chemical flow where it then flows to the UV reactors by entering any of the 7 12” diameter inlet butterfly valves. While the water is mixed with the VigorOX solution, the effluent moves through the UV trains then exits via a 12” diameter outlet butterfly valve where it is then pumped out to the reclaimed water structure via a 24” diameter [1].

The treated effluent is then distributed to either the Ken McDonald Golf Course, used for cooling water at Salt River Projects Kyrene Generating Station, or made available for groundwater recharge [1]. Table 2-17 below highlights the parameters surrounding the chemical technology of VigorOX WWTII.

Table 2-17: VigorOX WWTII Details

VigorOX WWTII	
Parameter	**Result**
Chemical Makeup	15% Peracetic Acid (PAA) 23% Hydrogen Peroxide
EPA and NCPED Approved	Requirement Met
Levels of Disinfection Byproducts (DBP)	None
pH Range	4.1-8.9 ±
E. Coli Inactivation %	100%
PAA Amount Required to Meet Permit	2 mg PAA/L
Area (m^2)	17.21
Dimensions (m)	3.5m x 1.5m x 2m (LxWxH)
Amount of VigorOX WWTII per Day	23 GPD
Amount of Chemical Usage for a Chlorine System per Day	235 GPD

UV is a proven tactic in wastewater treatment but is limited by high particulate matter and effluent that possesses low UV quality transmittance [11]. VigorOX is seen as an innovative technology that specializes in disinfecting microbial presence via radical-type reactions, which hydrogen peroxide, chlorine, and UV either cannot do or cannot perform without extreme by-product setbacks. The weaknesses of VigorOX have shown that it is not as effective versus water with high oxidant demands and microbial types that need high dose concentrations to be eliminated [12]. The weaknesses of both UV and VigorOX are counteracted by the others respective strengths and results in a higher level of efficiency for a lower level of energy costs between the two systems [13]. Appendix F-7 shows the VigorOX WWTII brochure and various studies associated with the use of the chemical. Shown below is Table 2-18 which shows the details of the current UV system vs the proposed UV system.

Table 2-18: Current UV Details Vs. Proposed UV Details

	Current UV System	**Proposed UV System**
# of Reactor Trains	7	4
Type	Mercury Arc Lamps	Mercury Arc Lamps
Average Designed Flow (MGD)	9	3
Dosage (μW-s/cm^2)	80000	80000
UV Transmittance	70%	70%
Effluent Quality	Class A+	Class A+
Germicidal Wavelength (nm)	253.7	253.7
Chemical Cleaning System	Citric Acid	Citric Acid and VigorOX
Area (m^2)	208.7	120
Power	68kW	39kW
Dimensions	7.9m x 8.1m x 3.96m	4.5m x 4.6m x 3.96m

Throughout this process, 100% of microbial life is removed. The only by-products that are produced from the use of VigorOX is H_2O, O_2, and vinegar. Using a recommended dose of 2mg PAA/L paired with the UV system has proven to be able to eradicate microbial levels to meet permit regulations for Class A+

effluent and reuse applications. The synergistic effect of both processes is seen at this stage where the combination takes advantage of each disinfection capability that the two technologies offer while also counterbalancing their limitations [14]. VigorOX has shown to reduce microbial presence to a higher extent compared to chlorine or bleach and VigorOX requires a shorter contact time with lower use rates and no chlorinated by-products. Throughout KWRF, chemical usage is seen as a huge operational cost for plants so the introduction of VigorOX has proven to reduce disinfection chemical use by 90%, is 30% cheaper than chlorination/dechlorination chemicals, has been used to replace chemical agents responsible for clearing buildup and algae, and reduces the amount of sodium hypochlorite needed to stabilize the solution because the effluent remained below a pH of 8 [13][14].

Additional changes to the system include the conversion of the downstream isolation valves from manual operation modes to actuated operation modes, automated transmittance measuring devices, and an automated chemical cleaning system that utilizes VigorOX regularly and citric acid/phosphoric acid periodically as needed based on flows and effluent makeup [1].

2.7.5 Biosolids Handling

As previously demonstrated in Table 2-10, the alkaline stabilization process in the form of Synagro's Bio-Fix. The design and operational requirements for the bio-fix system is based on Mark Girovich's *Biosolids Treatment and Management: Process for Beneficial Use* [22]. The two main criteria needed for an alkaline stabilization process to produce Class A sludge is that the pH is maintained at 12 or higher and that the temperature be maintained at 70°C or higher for 30 minutes [16]. This demands two resources: lime (CaO) and power to maintain the temperature. Calculations based on standard bio-fix facilities from Biosolids Treatment and Management: Process for Beneficial Use are in Appendix H-5. Table 2-19 contains the parameters of the Bio-fix system.

Table 2-19: Bio-Fix Parameters

Bio-Fix Parameters	
Dry Ton Produced (ton/day)	4.35
Wet Sludge Produced (ton/day)	23.28
Power (kW-hr/yr)	49,579.16
Area (ft^2)	350
Dimensions (LxWxH) (ft)	29x12x17
Required CaO (ton/day)	6.53

2.8 Treatment Efficiency Analysis

The purpose of this section is to demonstrate that the recommended operations, if used as proposed, are sufficient to produce an effluent of class A+, which is in accordance with the client's wishes. Table 2-20 summarizes the effluent results. Refer to Appendix G for calculations of the final effluent water after going through the entire reclamation facility. Most settleable solids are removed during the preliminary treatment, while the remaining are fully removed in the primary treatment. VigorOX technology paired with UV is used for disinfection which allows for most pathogens to be removed and adherence to the Non-detectable in 4 of 7 samples of Fecal Coliform standards for A+ effluent.

Table 2-20: Final Effluent Results

Parameter	Effluent Results
BOD5	8.40 mg/L
Total Nitrogen	0.46 mg/L
Ammonia (as N)	1.90 mg/L
Settleable Solids	1.0 mg/L
Suspended Solids	14.81 mg/L
Fecal Coliform	Non-detectable in 4 of 7 samples
Turbidity	Less than 2.0 NTU

2.9 Projected Costs

The cost of the recommendation considers both the capital cost and the cost of operations and maintenance. Capital costs only consider the capital of the equipment needed. O&M costs include the cost of power, according to the City of Tempe Industrial Rate ($0.061/kW-hr), the staffing needed, and other maintenance costs, such as replacements, that are found necessary to maintain operations [23]. Table 2-21 contains a summary of the capital cost and O&M cost, both currently as of this writing and the projected cost in 2025 when KWRF is planned to reopen, which was calculated using a 2% inflation rate. Refer to Appendices H-1 through H-7 for the detailed costs calculations for the preliminary treatment, primary treatment, secondary treatment, advanced treatment, biosolids handling, construction costs, and solar electricity costs. Note that construction costs do not include the addition of solar panels since the capital costs of solar electricity already accounted for installation.

Table 2-21: Summary of Capital and O&M Costs

Proposed Recommendation Costs				
Process	**Year 2020 (Present)**		**Year 2025**	
	Capital Cost ($)	**O&M ($/yr)**	**Capital Cost ($)**	**O&M ($/yr)**
Preliminary	$7,054	$100,196	$7,788	$110,624
Primary	$1,511,581	$390,477	$1,668,908	$431,118
Secondary	$1,311,781	$483,988	$1,448,312	$534,362
Advanced Treatment	$379,000	$135,386	$418,447	$149,477
Biosolids Handling	$1,500,000	$272,024	$1,656,121	$300,337
Construction Costs	$12,697,200	N/A	$14,018,735	N/A
Solar Electricity	$599,200	$14,800	$661,565	$16,340
Total	**$18,005,816**	**$1,396,870**	**$19,879,876**	**$1,542,257**

2.10 Staffing Levels

Staffing levels were determined based on two reasons: first, the total hours estimated to operate and maintain the recommended plans, and second, any specialized positions, such as machinists or managers. Based upon the recommendations of the New England Interstate Pollution Control Commision's manual for staff estimation, a total amount of hours were estimated for the processes [24]. Table 2-22 contains the total annual hours needed and the staff based on specialized positions and hours needed based on a typical work week including vacation and sick days. Appendix I-1 contains the manual's form that was used to estimate the staff levels. Appendix I-2 contains all the activity from whence the total hours were derived.

Table 2-22: Estimated Staffing Levels

Staffing Estimations	
Estimated Annual Hours of O&M	5039.25
Estimated Required Staff	4
Specialized Staff Members	4
Total Estimated Staff	8

2.11 Phases of Construction

2.11.2 Phase 1: Reconstruction of Wastewater Treatment Facility

The first phase of this project will be the demolition of old and unneeded systems followed by the construction of new facilities and parts. Any reusable systems will be saved for resale. This phase will require a collaboration of teamwork from multiple parties over the course of the project with strict deadlines involved. Emphasis will be focused on reviews and confirmations of newly installed products, approval from engineering consultants on services, inspections of all old and new systems, constructed list of suppliers for services and parts, actual construction of improvements and demolition of old systems, pre-startup evaluations and procedures, and training of staff for all necessary features. Refer to Appendix H-6 for detailed analysis of Phase 1 of construction.

2.11.3 Phase 2: Addition of Biosolids Handling Construction

The next phase of the project involves the utilization of biosolids and the handling of them. Once the first phase of the project is complete and the plant has proven to run efficiently with its new upgrades, steps will be made to incorporate the removal of biosolids and use them for profit. Refer to Appendix H-6 got a detailed analysis of construction cost which include workforce and cost associated with the installation of biosolid technologies. The waste biosolids can be recycled for other uses since the state of Arizona permits biosolids management for land application and surface disposal. The plant can apply for a Biosolids Land Application Registration, which is for applying biosolids to land. A permit, named Arizona Pollutant Discharge Elimination System Biosolids General Permit, is issued by ADEQ for the land application of biosolids. The biosolids products from landfill or surface disposal sites can be used for composting operations as long as the biosolids are of Grade A. The composted biosolids can be sold to agricultural, landscaping, nurserby and homeowner markets. The selling price ranges from $5 to $10 per cubic yard or $10 to $20 per ton [25]. As a result this plant could produce a profit of $127,525 per year from biosolids. Refer to Appendix H-5 for detailed analysis of biosolids production and profit.

2.11.4 Phase 3: Addition of Solar Panels

In order to incorporate green energy, solar panels can be installed on the site. Solar covered parking can be added to the two already existing parking lots and solar panels can be installed above the administrative building. The annual power savings are approximately $132,400. This investment has a payback cost in about 7.1 years. Refer to Appendix H-7 for a detailed cost analysis of solar panel installation.

3.0 Impacts Analysis

Below are the preliminary impacts researched. Further analysis is yet to be conducted.

3.1 Social Impacts

The design, construction, and operation of the project will impact the Tempe community socially. The negative social impacts come from odor pollution, noise pollution, and chemicals. KWRF has had a history of not disposing of their biosolids and just pumping them back into the effluent that they sent over to the WWTP on 91st Avenue [9]. The biosolids removed from wastewater in the preliminary, primary, and secondary processes have their own distinctive odor, which cause odor pollution on the site and neighboring industries. Further, as it is recommended to implement a biosolids treatment process, a stigma will be attached to the local area of biosolids. Beyond this slight social impression, the physical features will not be greatly affected as the odor will be controlled and the only change would be the more continuous presence of trucks to transport the treated biosolids. In the KWRF, there are three pump stations, influent pump station, recycle pump station, and effluent pump station. These pumps will cause noise pollution during the operation of the plant. In order to treat the wastewater, some chemicals are added into the wastewater. The presence of the chemicals, such as VirgOX and Alum, can create a stigma to the area as an industrialized area. As the area is already fairly industrialized, the effect will be small and only increase rather than create this social impression.

Along with the negative, there are also positive social impacts the retrofit is expected to have. The retrofitting and reopening of the KWRF will reduce pressure on the 91st Avenue Wastewater Treatment Plant. The reclaimed water plan to irrigate at the golf course can increase recreation for the communities in Tempe. Also, the reclaimed water from the KWRF, which is used for irrigation, can save the city and the community on water costs. The reopening of the KWRF creates jobs and increases the economic revenue in Tempe. The A+ reclaimed water keeps pollutants away from the citizens, allows people to be able to live in ever-growing cities, and allows for the development of more housing.

3.2 Environmental Impacts

Negative environmental impacts can be expected to result from the reopening of the KWRF. The consumption of energy in a WWTP, even when equipped with some renewable energy sources and energy efficient technology, is always of a large scale. Thus, the demand for power must rely on electricity that is derived from the consumption of fossil fuels because the plant is not equipped to be run solely by renewable energy sources. Thus, in the retrofitting and operation of KWRF, consumption and depletion of fossil fuels must be accounted for among its negative impacts. Likewise, this reliance on fossil fuels will increase carbon emissions, a greenhouse gas causing global warming. Moreover, with the new need of transportation for treated biosolids increases fossil fuel consumption and carbon emissions in its own right.

The new technology used in the treatment process can reduce the biosolids and the energy usage. For instance, the anammox process is greener than an aerobic chamber as it reduces the need of follow-up processes, thus reducing power consumption and land use as a whole. The reclaimed water will be used to recharge groundwater, which has a positive environmental impact. The reopened KWRF is able to take the effluent water quality to a higher standards A+, which is more environmentally-friendly reclaimed water. Another positive impact will be the distribution of class A+ biosolids for land application. This will allow resources to be recycled and lessen the impact of golf course construction on the extraction of soil. This is significant as golf courses are common and many in the greater Phoenix area.

3.3 Economic Impacts

A negative impact to be considered is that this project proposed is a multi-million dollar expenditure. While there are some positive aspects of this to be considered, the negative one is that due to the global pandemic of COVID-19, there may be new and highly prioritized programs needed. This is an immediate impact whose effect will be felt less as the years go by, but construction and economic effects will potentially be delayed in the span of two years. Most likely, as a result, the government will have to spend money as a response. Proposing the retrofit on KWRF may strain the government's financial status, and thus pose a risk to its stability. Another negative may be that those dependent on KWRF for effluent, such as the Ken McDonald Golf Course, may have since the 2010 shutdown grown to an equilibrium of receiving their needs from elsewhere. Reopening the KWRF may shake this equilibrium and disrupt the local economy in this aspect.

However, along with the negatives, there are many positives. The first is that this multi-million dollar project may stimulate the construction and wastewater technology industries, which may be a well needed one due to the struggling economy left behind by the COVID-19 pandemic. An obvious positive is that this will provide regular employment to 8 additional positions (see Section 2.10 Staffing for justification). Finally, another positive impact is that with the production of treated biosolids, trucks and transportation will become necessary. This will lead to an economic gain for the transportation industry and perhaps more jobs created in that sector.

4.0 Summary of Work

4.1: Scope Modifications

Due to the new information given by the competition requirements published by AZ Waters, it was decided to more properly capture the aims presented in the project problem statement that several sub-tasks were modified. First, the creation of a decision matrix made for the purposes of deciding upon general technologies for the design was added to the requirements of Task 2.1: Site Research. The decision for this was based on the fact that the primary question the decision matrices were supposed to answer is whether to maintain a certain technology in the Kyrene Wastewater Plant or to decide upon another type of technology to use. Thus, this generalized research concerning the desirable direction of the project was best fitted into the task of site research. While expanding the time needed for this task, it does not change the critical path, as no new tasks were needed.

The next change was a shortening of the duration of sub-task 3.1.2: Population Estimation. The justification for this is that the rigor needed for this task dropped as the population dropped in importance in the project. The problem statement requires a certain flow rate, thus it is outside the purview of the project to determine the flow rate necessary based on the population in the area. Moreover, AZ Waters published data concerning population statistics from the past, in the present, and estimation for the future. Thus, if any justifications require considerations of population estimations, the calculations have already been supplied. Once again, this does not fundamentally alter the Gantt Chart as the critical path remains the same.

The final change was the correction of critical paths. The misunderstanding of critical paths results in the wrong identification in the original Gantt Chart. The correct critical paths are shown in the final Gantt Chart. The major tasks become critical paths and their progresses determine the shortest time possible to complete this project.

4.2: Schedule Modifications

The Gantt chart has been modified as described above in accordance with the new scope. The original Gantt chart as laid out in the proposal may be seen in Appendix J-1: Original Gantt Chart. The updated Gantt Chart may be seen in Appendix J-2: Final Gantt Chart.

Briefly describing the changes, they are as follows. Task 3.1.2: Population Estimation had its duration shortened by approximately a week to acknowledge the less rigorous nature of the examination. The date of the site visit was moved from January 27th to January 25th in order to correctly reflect the date of the tour. The competition submittal sub-tasks of 6.4.1: Project Plan and 6.4.2: Final Report and Competition Entry were put in at the appropriate dates. The sub-task 6.2.6: AZ Water Presentation was added to 6.2: Presentations with the appropriate date. Finally, the date of sub-task 6.1.1: 30% Report was moved to the appropriate date of February 11th from February 13th. 90% Report was moved to the appropriate date of April 16th.

Due to the emergence, spread, and severity of COVID-19, the AZ Water competition and deliverable dates were moved. The report was submitted on April 19th and the presentation was submitted on April 26th instead of on April 8th and April 15th. The presentation was given virtually on April 28th instead of in person during the econference which would have taken place April 15th.

5.0 Design Hours Summary

Table 5-1 contains the proposed hours the team would require to complete the project. The table is divided by the main tasks and by role. The roles are senior engineer, project engineer, engineer in training, administrative assistant, and intern.

Table 5-1: Summary of Proposal Hours

Task	SENG	ENG	EIT	AA	Intern	Task Total
1.0 Research Preparation	2	2	12	7	32	55
2.0 Site Assessment	5	8	18	3	8	42
3.0 Treatment Design	16	190	97	17	52	372
4.0 Cost/Economics	6	12	12	9	5	44
5.0 Project Impacts	4	8	32	0	0	44
6.0 Project Deliverables	16	150	82	27	27	302
7.0 Project Management	14	41	21	21	0	97
TOTAL	**63**	**411**	**274**	**84**	**124**	**956**

Table 5-2 contains the actual hours used by the team to complete this project. Like Table 4-1 the table is divided by the main tasks and by the same roles. Originally it was estimated that the engineering design would require 956 hours, however the actual design took 1012 hour. This difference was due to having to change the approach of the project from looking at each existing technology station separately to grouping stations into treatments; preliminary, primary, secondary, and advanced. In addition to this, the team had to adapt their approach due to the COVID-19 outbreak. Another difference was that the team originally thought the entire team would have the opportunity to visit the site, however upon client's request only 3 were able to do so.

Table 5-2: Summary of Hours

Task	SENG	ENG	EIT	AA	Intern	Task Total
1.0 Research Preparation	1	58	6	2	5	72
2.0 Site Assessment	0	34	8	0	9	51
3.0 Treatment Design	2	118	78	36	57	291
4.0 Cost/Economics	1	22	59	16	17	115
5.0 Project Impacts	0	12	26	8	17	63
6.0 Project Deliverables	44	66	59	50	65	284
7.0 Project Management	6	19	106	18	11	160
TOTAL	**54**	**329**	**342**	**130**	**181**	**1036**

Table 5-3 uses information from Tables 5-1 and 5-2 to calculate estimated and actual personnel costs. In addition to personnel costs the table also contains both the estimated and actual travel and supplies costs. Due to COVID-19 certain expenses were not used such as conference travel cost since the conference was postponed and 3D printing costs since facilities were closed. The cost of engineering design was estimated to be $113,590. The actual engineering design actual cost ended up being $94,715. The difference happened as mentioned before because of the change in approach of the decisions matrices, this required more hours but the roles who handled the problems changed as well. As a result the personnel costs were lower despite the increase in hours.

Due to the COVID-19 outbreak other modifications were also necessary. The team was unable to use their 3D printing cost due to the closure in facilities Travel costs were also lower since the conference has been postponed.

Table 5-3: Cost to Date vs. Estimation

1.0 Personnel	Classification	Hours	Rate $/hr	Cost
	Senior Engineer	54	195	$10,530
	Engineer	329	120	$39,480
	EIT	342	100	$34,200
	Admin. Assist	130	50	$6,500
	Intern	181	20	$3,620
			Actual Personnel Sub-total	**$94,330**
			Estimated Personnel Sub-total	**$112,325**
2.0 Travel	**Classification**	**Items**	**Rates**	**Cost**
	Site Visit	288 mi max	$0.58 / mi	$167
		Van Fee	$43 / day	$43
	Conference	310 mi	$0.58 / mi	$0
		Van Fee	$43 / day	$0
		2 Rooms 2 Nights	$ 133/room/ night	$0
			Actual Travel Sub-total	**$210**
			Estimated Travel Sub-total	**$1,040**
3.0 Supplies	**Classification**	**Items**	**Rate $/mi**	**Cost**
	3D Printing	1kg	$0.05 / g	$0
	Memberships	5 people	$35 / person	$175
			Actual Supplies Subtotal	**$175**
			Estimated Supplies Subtotal	**$225**
			Actual Total	**$94,715**
			Estimated Total	**$113,590**

6.0 Conclusion

6.1 Final Results

The recommended solution was tailored so as to produce class A+ effluent upon a downsized average influent flow of 3 MGD. The recommended plan can be seen in layout in Appendix A-4. The infrastructure was downsized to accommodate the decreased flow. New sets of pumps at the influent point, effluent point, and between treatment processes are recommended so that the pumps could pump the average 3 MGD flow and the peak 6 MGD flow. Redundancy for reliability was taken into consideration to allow maintenance. Furthermore, it was recommended that two Duperon FlexRake mechanical screens be used in place of the existing coarse and fine screen. However, it is recommended to maintain the existing 7 MGD Pista 360-degree vortex grit chamber.

Following this, it is proposed that the concrete flow EQ Basin be reduced in size to 0.5 MG and to reduce the flow by half of the two aeration blowers in the basin so that it can accomodate the reduced flow. A ballasted upflow clarifier by ACTIFLO® is recommended to be placed prior to the EQ basin. The ballasted clarifier is proposed to utilize both alum and microsand to assist in its function.

The proposed secondary treatment is to employ DEMON®Anammox ANaerobic AMMonium OXidation. This is to replace both the aeration basins and the biomembrane basins. This is possible as Anammox replaces conventional nitrification/denitrification (N/DN) with partial nitrification and anammox bacterial reaction (PN/A).

The UV light system is to be reduced from seven tracks to four tracks to accommodate the reduced flow. Furthermore, to achieve class A+ effluent, it is recommended to add the chemical VigorOX WWTII before the effluent goes through the UV system.

Finally, it is recommended that the KWRF adopt a bio-fix operations facility by Synagro. This adoption will require further chemical treatment and purchasing of CaO to keep the facility operating to standard. Furthermore, as this produces Class A wet sludge, it is recommended that KWRF hire the services of a transportation company so that the sludge may be stored and dealt with in terms of final destination off-site. This recommendation is based on the need to treat biosolids on-site, as sending it to further treatment to other WWTPs has proved problematic, as explained above.

6.2 Objectives Met

Based on the original set objects the team was able to use the site's historic wastewater flow rates and loading characteristic data in order to design a WWTF that produces Grade A+ effluent for reuse. The recommendation included both conventional and innovative emerging technologies all of which were sized for the reduced incoming flow of 3MGD.

In addition to the effluent requirements, the team added biosolids handling for potential use in order to create revenue to the facility. Energy and chemical efficiency was also looked at by the addition of small footprint technologies as well as the addition of solar panels.

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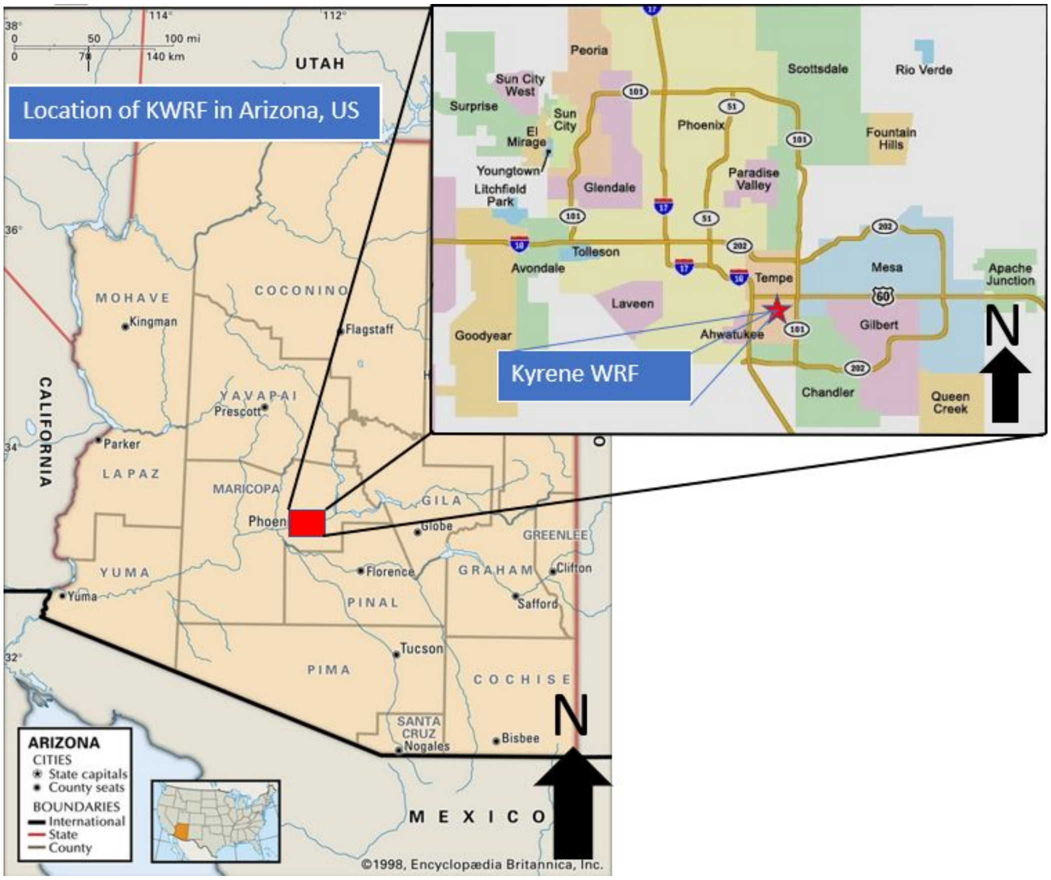
[29] Map showing location of Kyrene Wastewater Reclamation Facility, Tempe, AZ. *Google Earth Pro,* earth.google.com/web/

7.0 Appendices

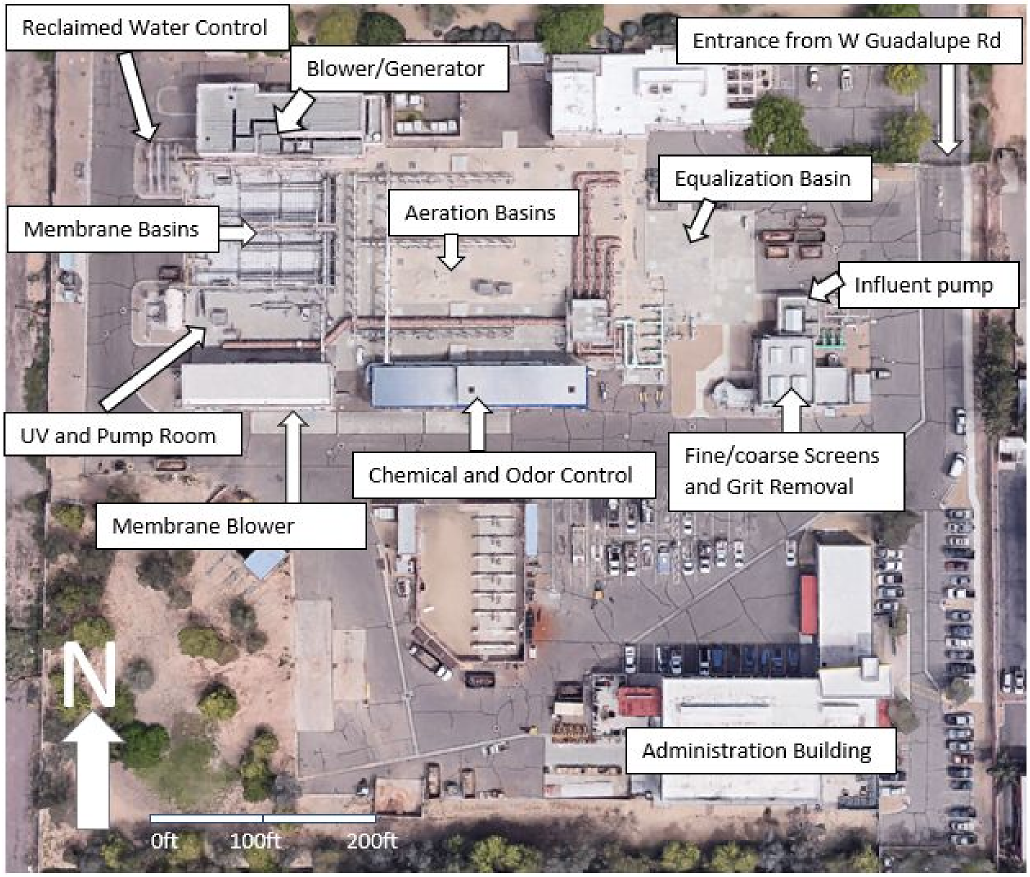
Appendix A: General Project Information

Appendix A-1: Map of KWRF Location [27] [28]

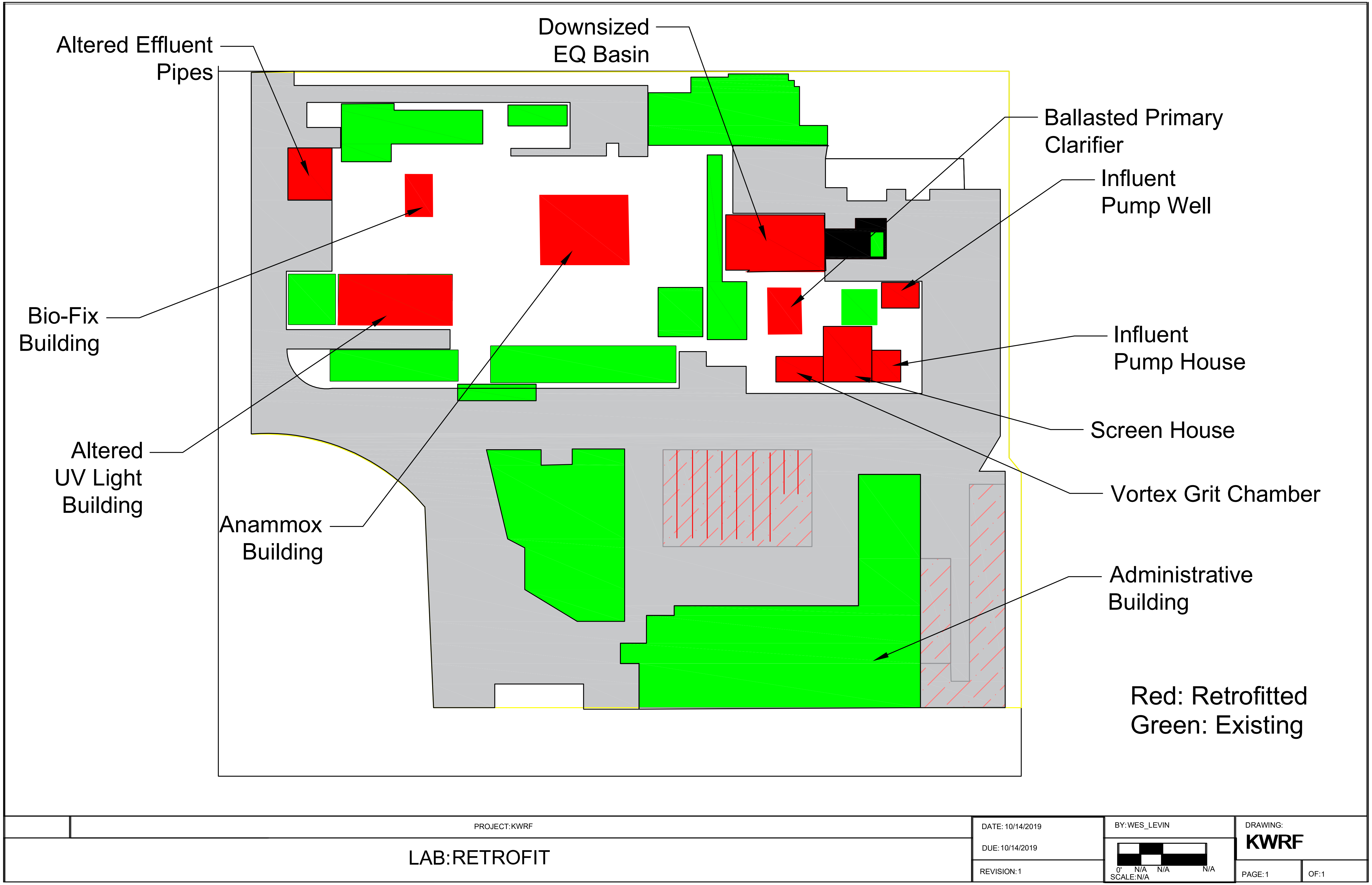


Appendix A-2: Layout of KWRF Existing

Appendix A-3: Existing Layout Photo [29]



Appendix A-4: Layout of KWRF Retrofit



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Appendix B: Detailed Decision Matrices

Appendix B-1: Detailed Preliminary Treatment Decision Matrix

Preliminary Treatment Decision Matrix										
Criteria		**Wt**	Existing - 3 VFD submersible pumps, 2 coarse screens, 2 fine screens, Pista 360 Grit Chamber		Alt 1 - 2 VFD submersible pumps, 2 coarse screens, no fine screens, Mectan V Grit Chamber		Alt 2 - 2 VFD turbine pumps (dry well), 2 coarse screens, no fine screen, Pista 360 Grit Chamber		Alt 3 - 2 VFD submersible pumps (wet well), 1 grinder, Aerobic Grit Chamber	
			Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	Area (m^2)	10%	265.5		265.5		265.5		250.0	
	Final Score		**4.7**	**0.5**	**4.7**	**0.5**	**4.7**	**0.5**	**5.0**	**0.5**
O&M	Operational Cost ($/yr)	20%	1,012,326		89,896		85,968		96,000	
	Life Span (yr)		25.0		25.0		25.0		22.5	
	Staffing		2.0		2.5		3.0		2.0	
	Final Score		**2.9**	**0.6**	**4.6**	**0.9**	**5.0**	**1.0**	**4.1**	**0.8**
Environmental/ Social Impacts	Power (kW-hr/yr)	30%	16,595,510		1,087,834		1,023,436		1,356,000	
	By-Products		1.0		1.5		2.0		1.3	
	Final Score		**1.4**	**0.4**	**4.2**	**1.3**	**5.0**	**1.5**	**3.4**	**1.0**
Lifecycle Costs	Capital Cost ($)	10%	26,921,200		8,230,300		1,0230,300		6,500,000	
	Final Score		**1.2**	**0.1**	**3.9**	**0.4**	**3.2**	**0.3**	**5.0**	**0.5**
Contaminant Removal Efficiency	Debris Rem. (%)	30%	100%		80%		80%		95%	
	Grit Rem. (%)		95%		75%		95%		75%	
	Final Score		**5.0**	**1.5**	**4.0**	**1.2**	**4.5**	**1.4**	**4.3**	**1.3**
Total Score				**3.1**		**4.3**	**Best Tech**	**4.6**		**4.2**

Appendix B-2: Detailed Primary Treatment Decision Matrix

Primary Treatment Decision Matrix										
Criteria		**Wt**	Existing - EQ Basin		Alt. 1 - Rect. Clarifier		Alt 2 - Microsand Clarifier		Alt. 3 - Reduced EQ Basin	
			Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	Area (m^2)	10%	1,275.9		538.8		445.3		425.2	
	Final Score		**1.7**	**0.2**	**3.9**	**0.4**	**4.8**	**0.5**	**5.0**	**0.5**
O&M	Operational Cost ($/yr)	20%	100,000		104,000		149,548		100,000	
	Life Span (yr)		20.0		19.0		30.0		30.0	
	Staffing		3.0		1.0		1.0		3.0	
	Final Score		**4.4**	**0.9**	**3.2**	**0.6**	**3.3**	**0.7**	**5.0**	**1.0**
Environmental/ Social Impacts	Power (kW-hr/yr)	20%	1,143,180		431,060		16,848,465		381,060	
	By-Products		3.0		2.0		2.0		2.0	
	Final Score		**4.0**	**0.8**	**4.7**	**0.9**	**2.1**	**0.4**	**5.0**	**1.0**
Lifecycle Costs	Capital Cost ($)	10%	441,000		2,113,000		323,252		220,500	
	Final Score		**2.5**	**0.3**	**0.5**	**0.1**	**3.4**	**0.3**	**5.0**	**0.5**
Contaminant Removal Efficiency	Particle Rem. (%)	40%	0%		75%		90%		0%	
	BOD Rem. (%)		0%		27%		80%		0%	
	Final Score		**0.0**	**0.0**	**2.9**	**1.2**	**5.0**	**2.0**	**0.0**	**0.0**
Total Score				**2.1**		**3.2**	**Best Tech**	**3.9**		**3.0**

Appendix B-3: Detailed Secondary Treatment Decision Matrix

Secondary Treatment Decision Matrix										
Criteria		**Wt**	Existing - Aeration Basins & Biomembrane Filter		Alt. 1 - Microalgae System		Alt. 2 - Anammox Reactor		Alt. 3 - Biomembrane Reactor	
			Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	Area (m^2)	25%	2,065.7		200,000.0		874.0		1020.0	
	Final Score		**2.1**	**0.5**	**0.0**	**0.0**	**5.0**	**1.3**	**4.3**	**1.1**
O&M	Operational Cost ($/yr)	20%	2,396,012.0		8,861,600.0		671600.0		1939477.5	
	Life Span (yr)		8.0		11.0		15.0		8.0	
	Staffing		1.0		2.0		2.0		1.0	
	Final Score		**2.2**	**0.4**	**3.0**	**0.6**	**5.0**	**1.0**	**2.3**	**0.5**
Environmental/ Social Impacts	Power (kW-hr/yr)	20%	57,396.1		1,755,756.8		1,359,105.0		1,972,350.0	
	By-Products		3.0		2.0		1.0		2.0	
	Final Score		**5.0**	**1.0**	**1.7**	**0.3**	**0.9**	**0.2**	**1.7**	**0.3**
Lifecycle Costs	Capital Cost ($)	5%	2,780,012.0		89,000,000.0		22,710,400.0		24,352,484.7	
	Final Score		**5.0**	**0.3**	**0.2**	**0.0**	**0.6**	**0.0**	**0.6**	**0.0**
Contaminant Removal Efficiency	BOD Rem. (%)	30%	85%		83%		85%		99%	
	Total N (%)		97%		82%		95%		99%	
	Final Score		**4.6**	**1.4**	**4.2**	**1.3**	**4.5**	**1.4**	**5.0**	**1.5**
Total Score				**3.6**		**2.2**	**Best Tech**	**3.8**		**3.4**

Appendix B-4: Detailed Advanced Treatment Decision Matrix

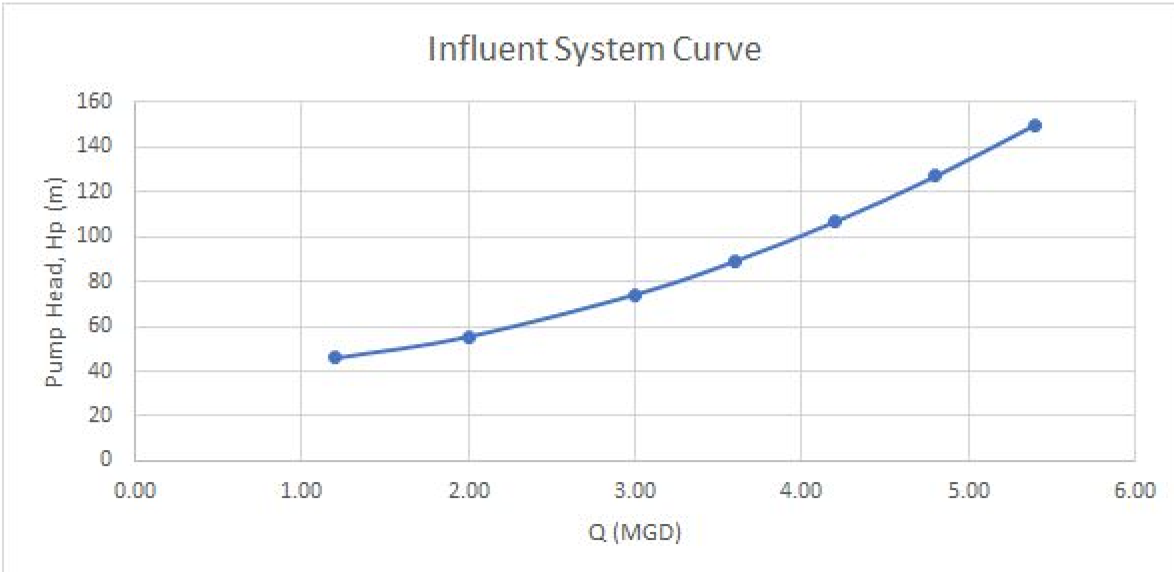
Advanced Treatment Decision Matrix										
Criteria		**Wt**	Existing - UV Lights		Alt - Reverse Osmosis		Alt 2 - VigorOX WWTII & UV Lights		Alt 3 - Chlorine	
			Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	Area (m^2)	10%	45.0		34.4		30.0		212.4	
	Final Score		**3.3**	**0.3**	**4.4**	**0.4**	**5.0**	**0.5**	**0.7**	**0.1**
O&M	Operational Cost ($/yr)	20%	19,190		120,000		280,000		85,600	
	Life Span (yr)		10.0		13.0		25.0		20.0	
	Staffing		3.0		2.0		3.0		2.0	
	Final Score		**5.0**	**1.0**	**2.8**	**0.6**	**4.3**	**0.9**	**3.5**	**0.7**
Environmental/ Social Impacts	Power (kW-hr/yr)	30%	27,027		61320		15,000		1,096	
	By-Products		3.0		2.0		3.0		1.0	
	Final Score		**3.9**	**1.2**	**2.6**	**0.8**	**4.0**	**1.2**	**5.0**	**1.5**
Lifecycle Costs	Capital Cost ($)	10%	244,000		10,000,000		515,000		1,497,333	
	Final Score		**5.0**	**0.5**	**0.1**	**0.0**	**2.4**	**0.2**	**0.8**	**0.1**
Contaminant Removal Efficiency	Coliform Rem. (%)	30%	98%		97%		100%		99%	
	Particle Rem. (%)		20%		95%		75%		65%	
	Final Score		**3.0**	**0.9**	**5.0**	**1.5**	**4.5**	**1.4**	**4.2**	**1.3**
Total Score				**3.9**		**3.3**	**Best Tech**	**4.2**		**3.6**

Appendix B-5: Detailed Biosolids Handling Decision Matrix

Biosolids Handling Decision Matrix												
Criteria		**Wt**	Existing		Alt. 1- Bio-Fix		Alt. 2 - Centrylis Thickener & Centrifuge		Alt. 3 - Gravity Belt & Anaerobic Digestor		Alt. 4 - Thermal Hydrolysis Process Reactor	
			Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Feasibility	Area (m^2)	5%	0.0		32.5		125.0		200.0		400.0	
	Final Score		**5.0**	**0.25**	**0.0**	**0.00**	**0.0**	**0.00**	**0.0**	**0.00**	**0.0**	**0.00**
O&M	Operational Cost ($/yr)	10%	0.0		271,896		488,354		453,809		475000	
	Life Span (yr)		0.0		25.0		15.0		20.0		30.0	
	Staffing		3.0		2.0		3.0		2.0		4.0	
	Final Score		**4.4**	**0.4**	**3.3**	**0.3**	**3.1**	**0.3**	**2.9**	**0.3**	**5.0**	**0.5**
Environmental/ Social Impacts	Power (kW-hr/yr)	25%	0.0		49,579		75432		69,788		65000	
	Wet Sludge (ton/day)		0		23.2		12.2		10.4		14.0	
	Final Score		**5.0**	**1.3**	**0.5**	**0.1**	**0.9**	**0.2**	**1.1**	**0.3**	**0.8**	**0.2**
Lifecycle Costs	Capital Cost ($)	10%	0.0		1,500,000		3,457,600		4,074,000		3,000,000	
	Final Score		**5.0**	**0.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Contaminant Removal Efficiency	Class of Biosolids	50%	0.0		3.00		2.00		3.00		2.00	
	Final Score		**0.0**	**0.0**	**5.0**	**2.5**	**3.8**	**1.9**	**3.8**	**1.9**	**2.5**	**1.3**
Total Score				**2.44**	**Best Tech**	**2.96**		**2.42**		**2.44**		**1.96**

Appendix C: Preliminary Treatment

Appendix C-1: System Curve of Influent Pump Station

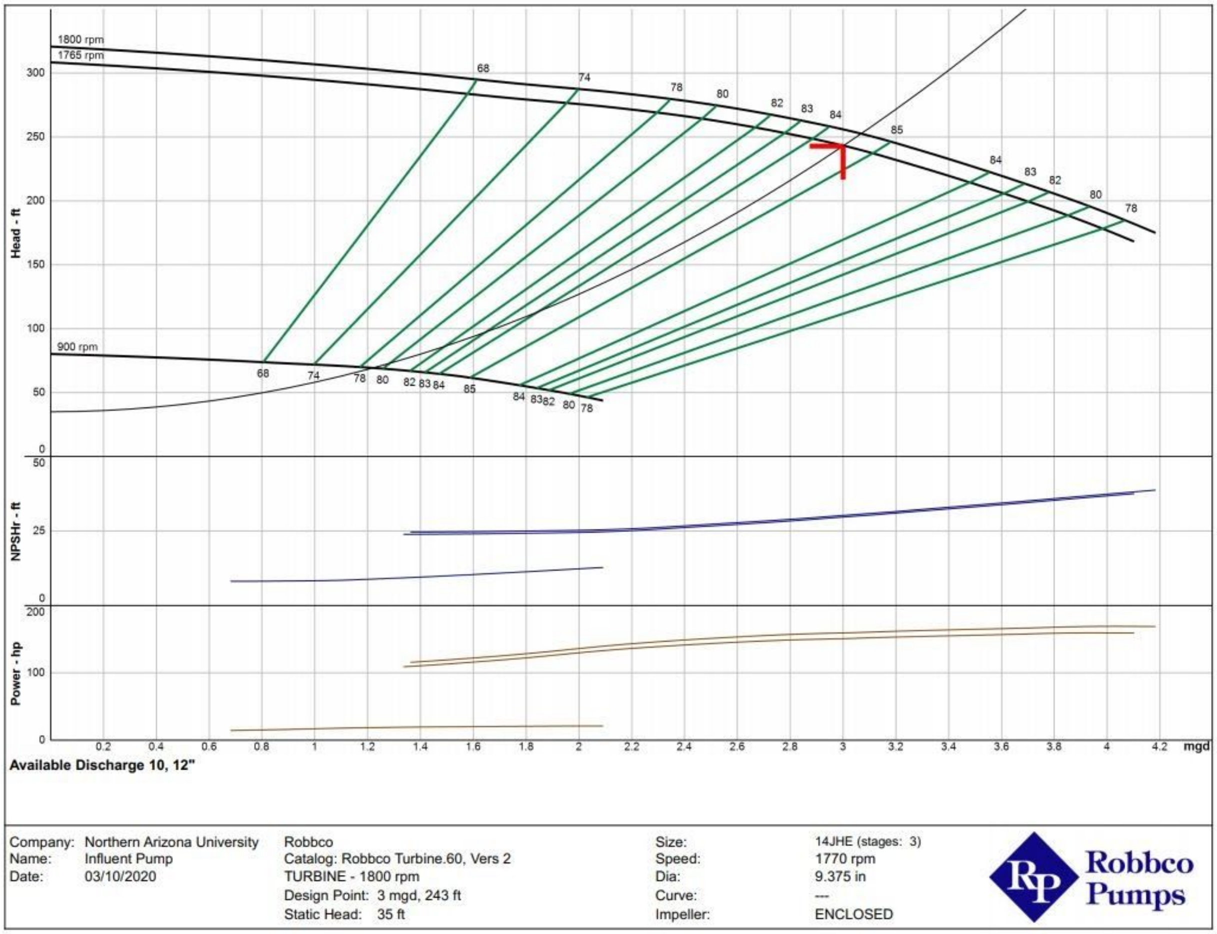


Appendix C-2: System Curve Calculations

System Curve Values							
v (m/s)	**Re**	**f**	**Major hL**	**Minor hL**	**Hp (m)**	**Q (m^3/s)**	**Q (MGD)**
0.6	1.33E+04	0.0287	0.0193904	5.403348	45.822738	0.053	1.2
1	2.21E+04	0.0252	0.0472611	15.0093	55.456561	0.088	2
1.5	3.32E+04	0.0228	0.0964159	33.770925	74.267341	0.131	3
1.8	3.98E+04	0.0219	0.1330617	48.630132	89.163194	0.158	3.6
2.1	4.65E+04	0.0211	0.1748428	66.191013	106.76586	0.184	4.2
2.4	5.31E+04	0.0205	0.2216149	86.453568	127.07518	0.21	4.8
2.7	5.98E+04	0.02	0.2732582	109.4178	150.09106	0.237	5.4

Pipe Information	
Material	PVC
e (m)	0.0000015
Diameter (m)	0.33
Total Length (m)	12.3
Number of Joints, Nj	2
Types of Joints	Gasket Bell
Number of Bends, Nb	2
Type of Bend	90˚

Appendix C-3: Influent Pump Curve



Appendix C-4: Coarse Screen Information [5]

Duperon ADAPTIVE TECHNOLOGY™

The Duperon® FlexRake®

Duperon®
PRELIMINARY LIQUIDS/SOLIDS SEPARATION TECHNOLOGIES

The Duperon® FlexRake®

Only three basic components:

1. A powerful drive head
2. A durable raking device
3. A rugged bar screen

Duperon® simplicity of design solves many headaches associated with preliminary liquids/solids separation

ENGINEERED FOR DURABLE, RELIABLE OPERATION

The achievement of mechanical simplicity requires the design of one part doing more. The simplicity of the Duperon® FlexRake® is possible through the multi-functioning action of one part: the FlexLink™. This innovative design allows the link to function as a frame, lower sprocket, and connection point for scrapers, and be driven by a single sprocket. The rugged bar screen has a frame which guides the chain and relocates it in the screen. Bottom line: simplicity works when it achieves a simple cleaning mechanism with trouble-free longevity.

The design of the Duperon® FlexRake® solves many of the headaches associated with liquids/solids separation equipment: complex gear mechanisms and controls; high maintenance components subject to regular lubrication, wear or fouling; confined space entries; reversal of mass in systems that must travel in one direction and then auto-reverse; carryover; shutdown due to unexpected debris volumes or conditions; inability to remove accumulation at the bottom of the channel...

How the Duperon® FlexRake® works...

1.  The FlexLink™ articulates to a 90 degree angle, closing on the drive pin. Once closed, the sprocket drives the link system forward.

2.  As it leaves the drive sprocket, the FlexLink™ locks into a solid bar, forming its own frame. (It works similarly to a knee or elbow.)

3.  As the FlexLink™ chain and attached scrapers reach the bottom of the screen, the FlexLink™ forms its own rotating framework.

4.  Once the links turn to travel slowly up the screen, they are engineered to allow clearance around the pin and water lubrication, allowing stainless on stainless movement without gouging or wear.

5.  Industry-exclusive Thru-Bar™ technology features scrapers designed to clean 3 sides of the bar, as well as horizontal cross members.

6.  Multiple scrapers placed every 21 inches continuously rake the bar screen. With screen head-loss minimized, some sites report a 3x greater capture rate than with their previous machines.

DEBRIS ACCUMULATION ELIMINATED

The Duperon® FlexRake® wastewater product line offers industry-exclusive Thru-Bar™ Technology with a scraper designed to clean 3 sides of the bar – as well as cross support members – so debris simply cannot accumulate. Assembly/disassembly is simple… just 4 bolts, from the deck. This Duperon® technology leaves nothing to chance.

ELIMINATES FOULING POINTS

The Duperon® FlexLink™ system is an innovative solution to complex gear sprocket mechanisms - simple 90 degree articulation drives the unit. No tight clearances to bind or jam; no close tolerances to foul due to corrosion or wear.

UNHAMPERED BY LARGE DEBRIS

As the Duperon® FlexRake® flexes and pivots around large debris, rigid side fabrications are angled to guide the scrapers to return engagement. This simple method for positive location, along with the scraper's lateral containment by that same rigid frame, ensures the continuous engagement of each successive scraper.

- ENERGY EFFICIENT
- LONG PRODUCT LIFE

REDUCES HEADLOSS, IMPROVES CAPTURE

Multiple scrapers on the screen operating at a speed of 0.5 rpm discharge debris once per minute. The slow operating speed provides long product life. Multiple scrapers minimize debris accumulation, resulting in reduced headloss and slot velocity, as well as greater capture rates.

KEEPS YOU IN CONTROL

Start it up… let it run. In their simplest form, controls are designed for continuous operation. Duperon offers pre-engineered packages that range from basic (continuous operation) to complex (level control with complete SCADA integration).

ELIMINATES ALL SPROCKET-RELATED PROBLEMS

The exclusive flex/pivot action of the Duperon® FlexRake® allows all types of debris to be removed, all at the same screen – regardless of coarse or fine screen openings. With the rugged durability of Duperon equipment, prescreening is no longer a necessity. The design of the Duperon® FlexRake® eliminates the need for a lower sprocket and the common problems that come with it. No lower sprocket means no drive shaft, drive sprockets, or bearings requiring in-channel lubrications. No tracks, gaskets, seals or other close tolerances prone to wear due to grit. Most importantly: NO confined space entries.

STRONGEST IN THE INDUSTRY

THE DUPERON® SOLUTION TO
- LOWER SPROCKETS
- BEARINGS
- SHAFTS
- LUBRICATION POINTS
- CONFINED SPACE ENTRIES
- TRACKS...

THE DUPERON® LINK SYSTEM: The Duperon® FlexLink™ design utilizes a stainless steel cast link system to create its own in-channel rigid framework and scraper connection point. With a 33,000 lb yield and 60,000 lb break point, it forms a chain that is stronger and more hard-wearing than any other in the industry. That's strength where it's needed most!

VIRTUALLY INDESTRUCTIBLE

State-of-the-art materials such as UHMW and stainless steel are used for all wetted parts, eliminating corrosion in the harsh wastewater environment. Such materials ensure the highest duty of performance, designed such that the pressures and velocities exerted by the equipment and environment will assure a long life cycle.

Cyclo® BBB

MAINTENANCE AT FIVE-YEAR INTERVALS

This powerful drive lifts up to 1,000 lbs. The Duperon use of premium efficiency Sumitomo Cyclo gear motors eliminates abrasive sliding contact. Unique rolling contact, low operating speeds and the grease-filled non-vented gearbox allow for five-year maintenance schedules.

FIVE-YEAR WARRANTY

With more than 25 years in the industry and over 1000 machines worldwide… Duperon has the experience to assure excellence with the industry's first Five-Year Warranty. Duperon® technology leaves nothing to chance… we guarantee it.

Duperon ADAPTIVE TECHNOLOGY™ Your Path to the Future℠

EASIER TO INSTALL

The Duperon® FlexRake® ships fully assembled to sites without space or handling constraints, creating installation as simple as pick, place, anchor, wire and run.

When site constraints such as limited access doors, multiple floors, and handling constraints exist, the Duperon® FlexRake® ships fully factory-tested to be disassembled on site. The Duperon simplicity of design makes re-assembly easy, with sites often accomplishing re-assembly and installation in one day – sometimes using an on-site maintenance crew.

LESS MAINTENANCE

Maintenance Schedule	
Daily	None
Monthly	None
Semi-Annually	Check drive and bearing for any apparent leakage or damage. Lubricate bearing.
Annually	Check drive and bearing for any apparent leakage or damage. Verify unit condition.
5 year	Change grease in gearbox.

NOTE: Maintenance is reduced by the simple design of the Duperon® FlexLink™, which is engineered for water lubrication. Slow operating speeds of 0.5 rpm allow for lubrication of the gear motor to occur every 5 years or 20,000 hours.

SIGNIFICANTLY LOWER COST OF OWNERSHIP

Maintenance Schedule and Estimated Labor Hours				
		1 year	5 year	20 years
Daily	None	0.0	0.0	0.0
Monthly	None	0.0	0.0	0.0
Semi-Annually	Visual inspection/lubrication of bearing and seals.	0.5	2.5	10.0
Annually	Visual inspection for general mechanical condition.	0.5	2.5	10.0
	Check grease in gearbox.	0.5	2.5	10.0
	Visual inspection of snap rings.	2.0	10.0	40.0
	Total Labor Hours	3.5	17.5	70.0

1. Lifting units with use of spreader bar
2. Placing unit at installation angle
3. Use of lifting brackets (for units >4500 lbs.)

LOW PROFILE MEANS REDUCED CONSTRUCTION COSTS

The tougher functionality of the Duperon® FlexRake®, proven through repeated grease attacks and high I & I, was just one benefit of the equipment's installation in Phoenix, Arizona. During plant upgrades, the low profile of the Duperon® FlexRake® saved over $1M in construction costs when compared to previous equipment.

UNINTERRUPTED BY GREASE AND GRIT ATTACK

In 2004, the City of Monroe, Michigan participated in a "cleaning project" initiated for the purpose of raising awareness of the grease problem within commercial business concerns such as car washes (wax) and restaurants (grease). Prior to the project, influent sewer lines were chemically treated to break down the accumulation of grease, wax and similar solids in successive stages. As was typical, one Duperon® FlexRake® in the City's 6 foot channel was in operation for the project.

Unexpectedly, grease, wax and other solids hit the plant nearly at once, creating a "grease attack" at the headworks. This "attack" overwhelmed the conveyor, but the Duperon® FlexRake® continued as normal, removing several inches of grease and debris with each pass at the screen. The Duperon® FlexRake® maintained headworks operations: when the crew returned the following morning, they found plant processes continuing uninterrupted.

"Ingenious...screenings are 50% drier than what I was seeing before..."
-Michigan installation

1. City of Monroe grease attack
2. Stones/grit easily lifted
3. Duperon® FlexRake® flexing around a barrel

PROVEN STANDARD OF EXCELLENCE

In 2006, Duperon® was the first to offer a Five-Year Warranty in wastewater–the industry's toughest standard for equipment excellence.

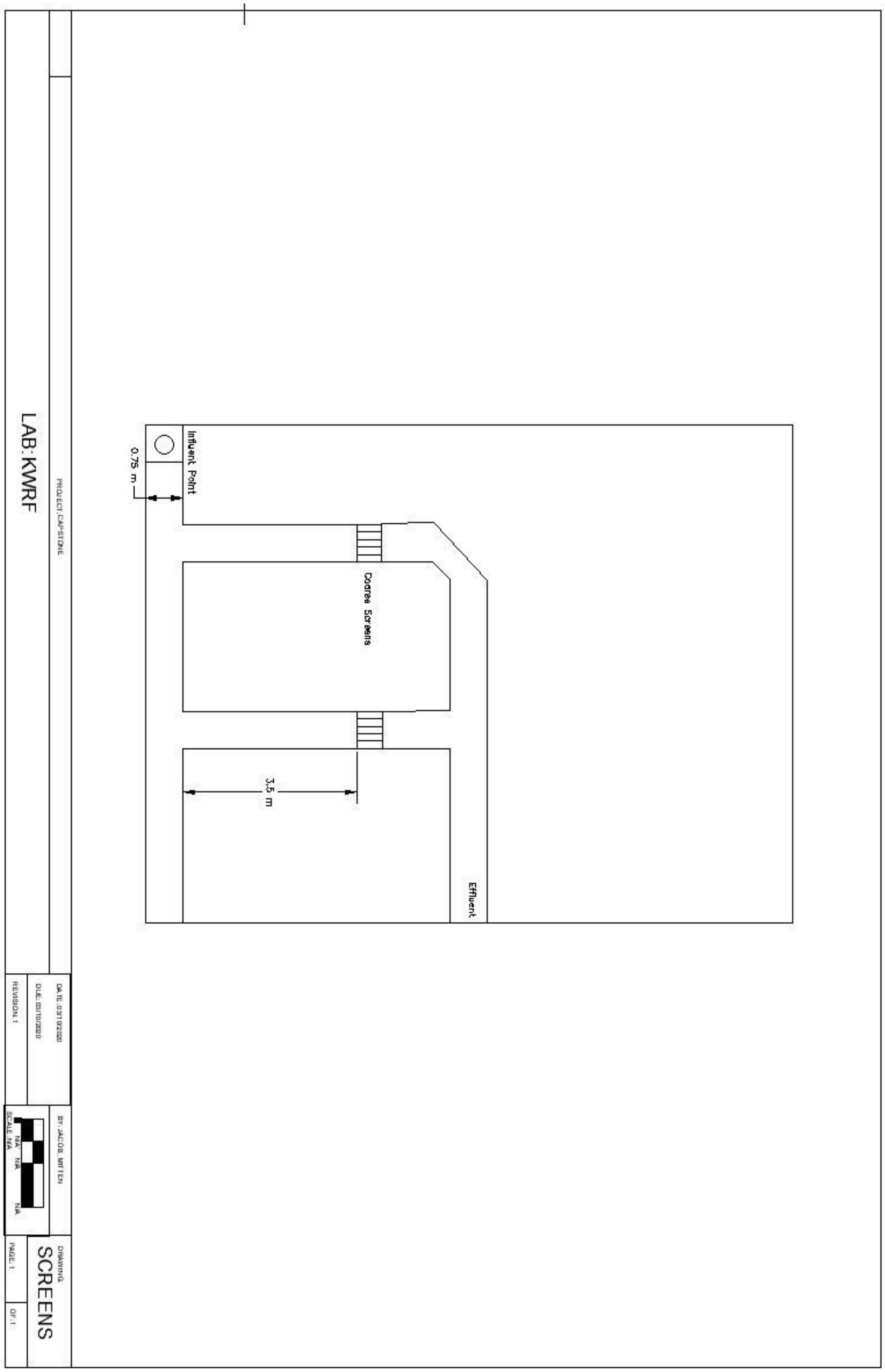
New Mexico

2/3 reduction in disposal volume!
-Pennsylvania installation

DUPERON® SYSTEM OPTIMIZES SAVINGS

An installation in Pennsylvania has reported satisfaction exceeding expectations. Historically, the Authority had disposed of one 3 cubic yard dumpster each week. The dumpster contained extremely wet organic screening waste. The combined installation of a Duperon® FlexRake® and a Duperon® Washer Compactor has reduced this disposal to one 2 cubic yard dumpster every two weeks. With no standing water, there has been significant reduction of weight, thereby reducing trucking and disposal costs. Odor has been considerably reduced, and the dryness of the compacted screenings has improved appearance on disposal. The combined efforts of the Duperon® FlexRake® and the Duperon® Washer Compactor have also had a very favorable impact on maintenance processes downstream.

Appendix C-5: Coarse Screen Drawing



Appendix C-6: Vortex Grit Chamber [6]

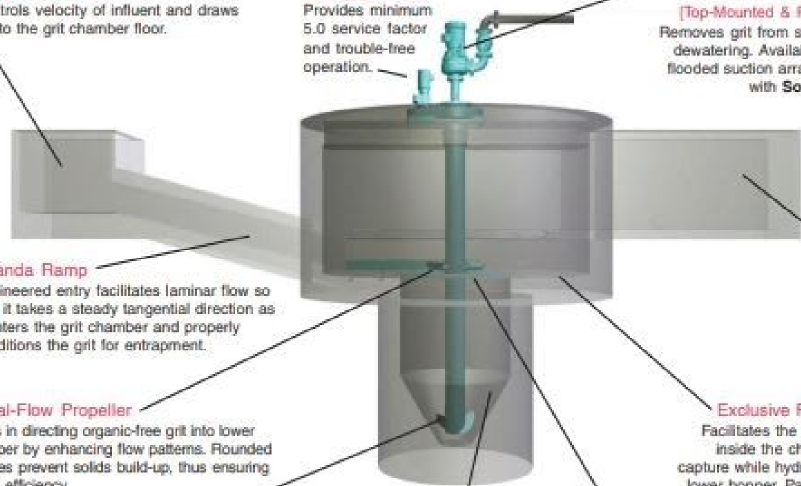
PISTA GRIT REMOVAL SYSTEM ***360° Grit Chamber Features and Benefits*** **B2**

Model A

Inlet Channel
Controls velocity of influent and draws grit to the grit chamber floor.

Bull Gear Drive
Provides minimum 5.0 service factor and trouble-free operation.

PISTA® Turbo Grit Pump
[Top-Mounted & Remote-Mounted Options]
Removes grit from storage hopper to washing dewatering. Available in vacuum-primed and flooded suction arrangements. Now available with **SonicStart™** prime sensing.



Coanda Ramp
Engineered entry facilitates laminar flow so that it takes a steady tangential direction as it enters the grit chamber and properly conditions the grit for entrapment.

Outlet Channel
S&L can assist with design information for optimal performance.

Axial-Flow Propeller
Aids in directing organic-free grit into lower hopper by enhancing flow patterns. Rounded edges prevent solids build-up, thus ensuring high efficiency.

Exclusive Flat-Bottom Basin Floor
Facilitates the forced vortex flow pattern inside the chamber. Minimizes organic capture while hydraulically directing grit into lower hopper. Patented, 360-degree in-line design.

PISTA® Grit Fluidizer
Patented blade exclusive to S&L design. Loosens collected grit, preventing compacting.

Storage Hopper
Stores removed grit prior to dewatering.

Hopper Cover Plate
Stationary and recessed, it removes for quick access to storage hopper.

PISTA GRIT REMOVAL SYSTEM ***Grit Removal, Handling & Dewatering System Flow Scheme***

[1] ***PISTA® Grit Chamber*** — Influent enters flat-floor grit chamber hydraulically guided by coanda ramp, internal baffles and central, low-speed propeller. Forced vortex drives grit particles to center chamber floor and into lower grit hopper while organics and flow continue to plant.

[2] ***PISTA® Turbo Grit Pump*** — Top-mounted or remote mounted unit pumps collected grit slurry (kept fluid by the **PISTA®** Grit Fluidizer) to the **PISTA®**'s second-stage grit washing and dewatering system while also providing proper head.

[3] ***PISTA® Grit Concentrator*** — Specifically engineered for the **PISTA®** system, this abrasion-resistant Ni-Hard unit washes and separates grit further. It positions on the grit discharge line.

[4] ***PISTA® Grit Screw Conveyor*** — Grit from the concentrator deposits into the parallel (lamella) plate section of the S&L dewatering screw conveyor, which aids in retaining finer grit and reducing the stream's turbulence and overflow rate.

[5] ***Dewatered Grit Discharges*** from the top of the inclined screw conveyor into a container for disposal.

[6] ***The Flow and any Residual Organics are Returned*** to the inlet channel prior to the grit chamber, typically 93% of flow and 95% of organics.

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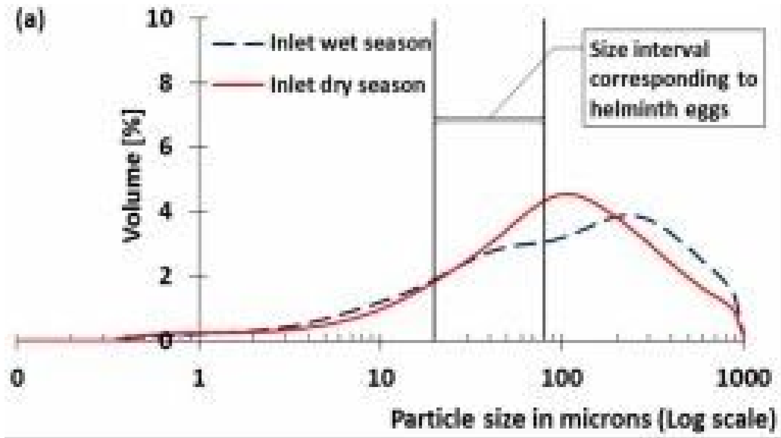
Appendix C-7: Influent PSD Curve [17]

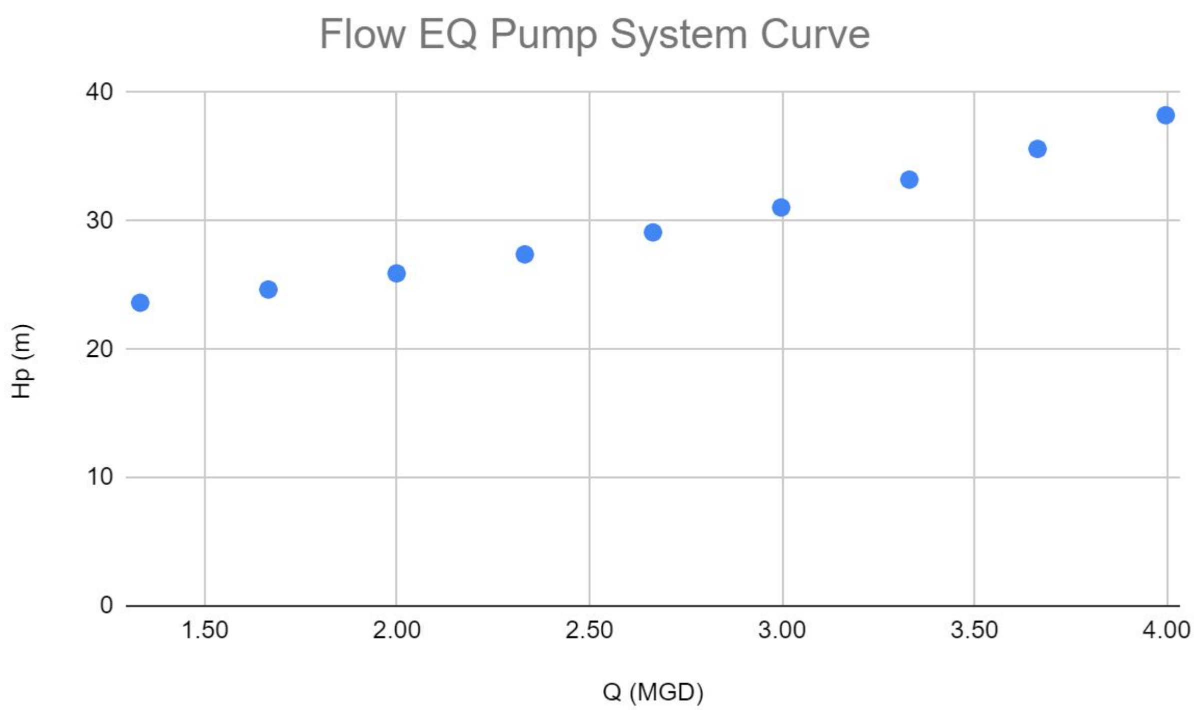


Appendix C-8: Grit Removal Production

Vortex Grit Grit Collection	
Removal Efficiency of 100 microns and greater	95%
Percentage of TSS of 100 microns or higher	45%
TSS Influent (mg/L)	336.06
Influent (MGD)	3
TSS Removed (kg/d)	1631.5
TSS Removed (ton/day)	1.8

Appendix D: Primary Treatment

Appendix D-1: Flow Equalization System Curve of Pump Station

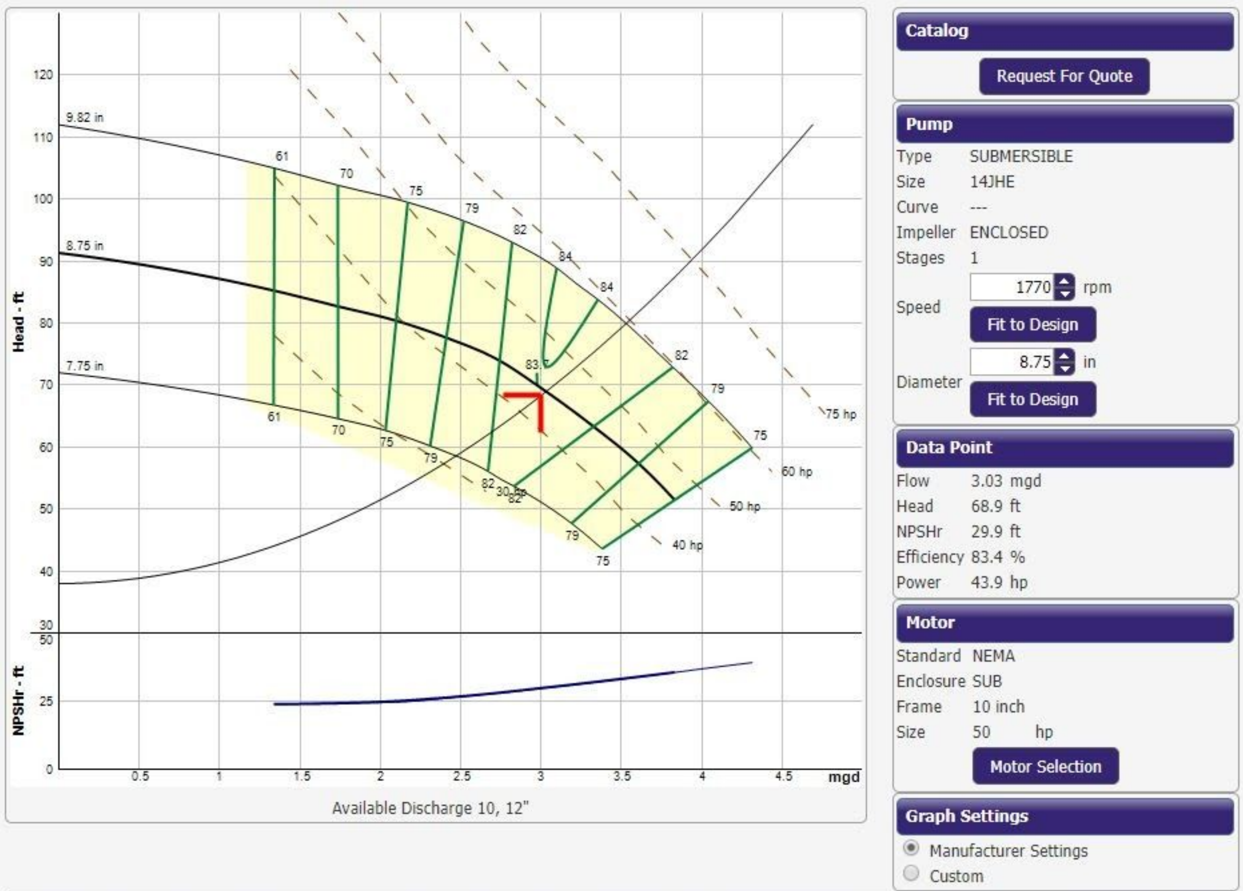


Appendix D-2: Flow Equalization System Curve Calculations

System Curve Values							
v (m/s)	**Re**	**f**	**Major hL**	**Minor hL**	**Hp (m)**	**Q (m^3/s)**	**Q (MGD)**
0.2	8.08E+03	0.0329	0.002012120814	1.82466	13.40667212	0.058	1.33
0.25	1.01E+04	0.0309	0.002954188955	2.85103125	14.43398544	0.073	1.67
0.3	1.21E+04	0.0294	0.004048748245	4.105485	15.68953375	0.088	2.00
0.35	1.41E+04	0.0282	0.005290054799	5.58802125	17.1733113	0.102	2.33
0.4	1.62E+04	0.0273	0.006673503412	7.29864	18.8853135	0.117	2.66
0.45	1.82E+04	0.0265	0.008195277734	9.23734125	20.82553653	0.131	3.00
0.5	2.02E+04	0.0258	0.009852137005	11.404125	22.99397714	0.146	3.33
0.55	2.22E+04	0.0252	0.01164127707	13.79899125	25.39063253	0.161	3.66
0.6	2.42E+04	0.0246	0.01356023514	16.42194	28.01550024	0.175	4.00

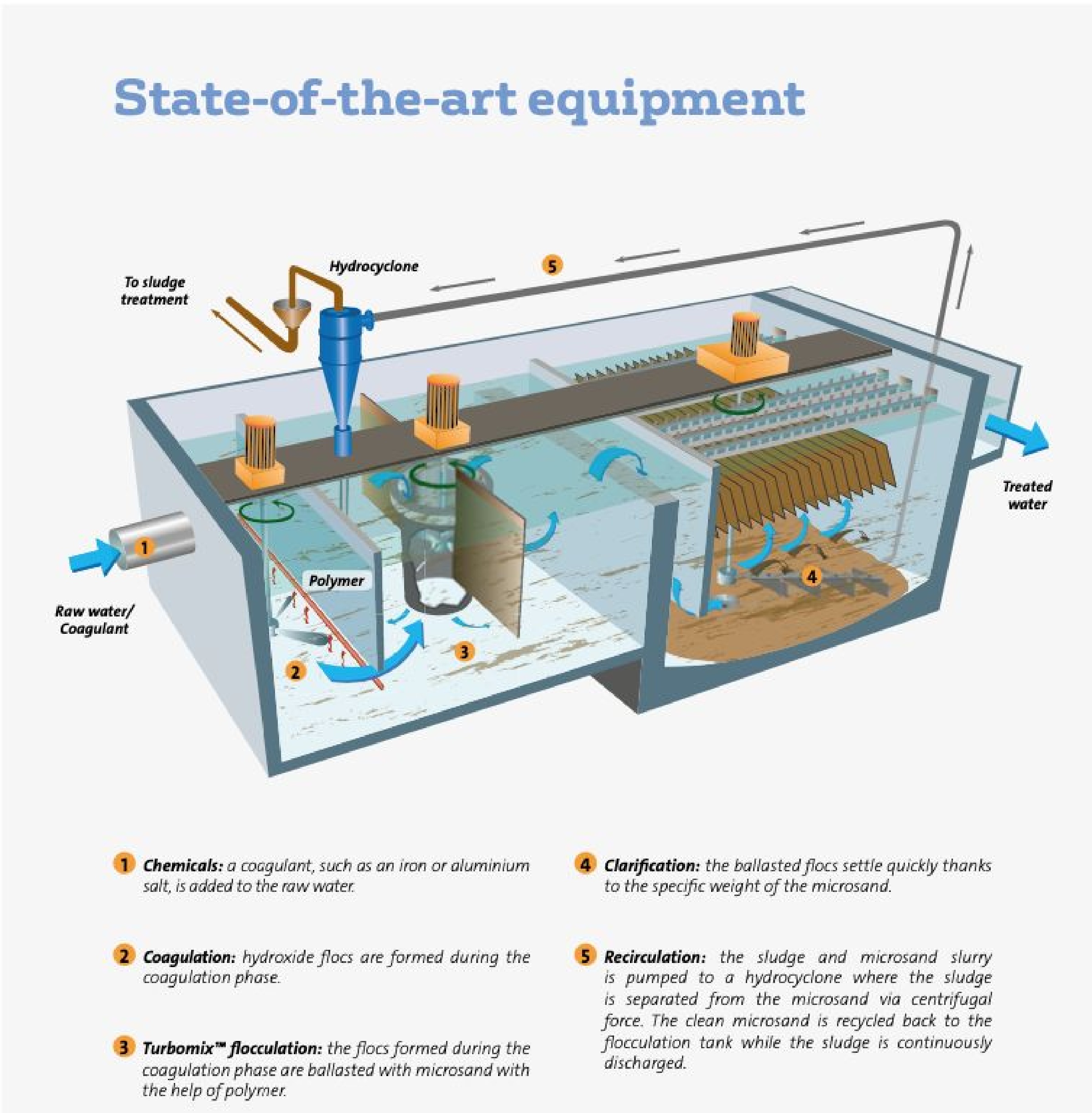
Pipe Information	
Material	PVC
e (m)	0.0000015
Sector Length (m)	6
Diameter (m)	0.61
Total Length (m)	18.3
# of Joints	3
Types of Joints	Regular 90-d flanged
# of Bends	1
Type of bend	90-d

Appendix D-3: Flow Equalization Pump Curve



Data Point	Speed (rpm)	Flow (mgd)	Head (ft)	NPSHr (ft)	Efficiency (%)	Power (hp)	Min Flow (mgd)
Primary	1770	3.03	68.9	29.9	83.4	43.9	---

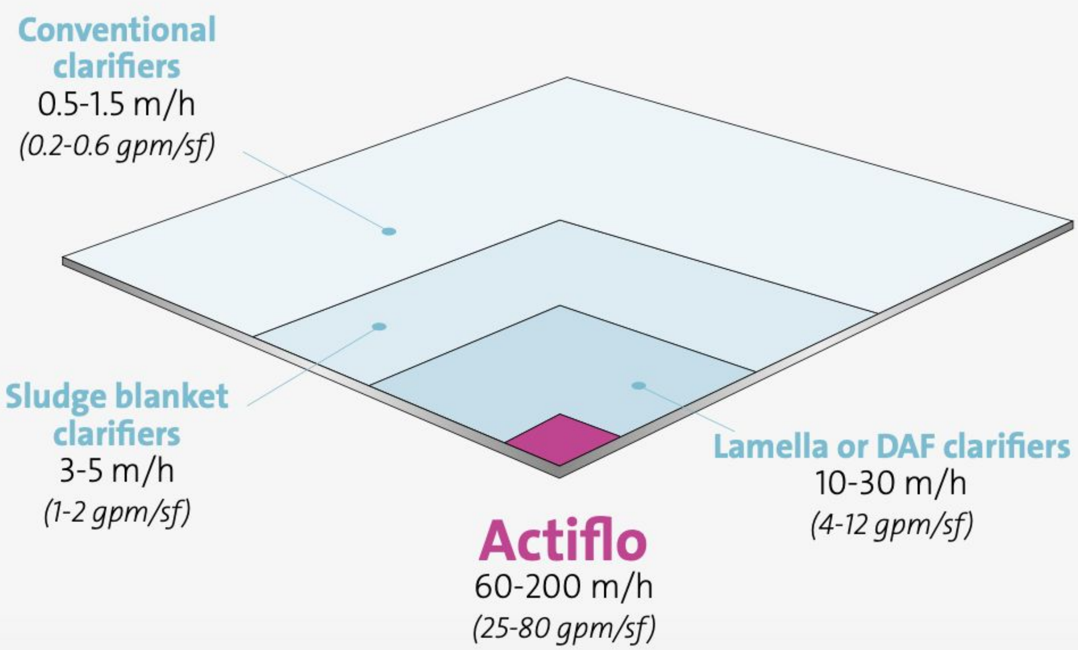
Appendix D-4: Ballasted Flocculation Unit [26]



Compact and ultra-rapid

Actiflo is characterized by:

- Very high settling rates:
  - > Drinking water: 60-80 m/h *(25-35 gpm/sf)*
  - > Municipal wastewater and stormwater: 60-150 m/h *(25-60 gpm/sf)*
  - > Industrial process water and wastewater: 60-200 m/h *(25-80 gpm/sf)*
- Increased compactness: Actiflo is the ideal response where there are space restrictions for rehabilitating existing installations or building new ones. Its footprint is 4 to 8 times smaller than lamella or dissolved air flotation (DAF) clarifiers and up to 50 times smaller than conventional clarification systems.
- Very short residence times resulting in great reactivity and user-friendly operation.



Associated services

Our after-sales services and local technical support teams offer preventive and corrective maintenance programs that guarantee the effective commissioning and long-term operation of the installation.

For even greater performance and safety, Actiflo Pack can be offered with the Hydrex™ range of additives, coagulants and polymers and with Actisand™ micro-sand developed by Veolia.

ACTIFLO® PACK
Standardized high-performance clarification units

Ideal for treating all types of drinking water, process water, sewage and reuse applications, Actiflo Pack standardized units are designed to be **extremely compact.**

Actiflo Pack units offer an economical solution, **with minimal requirements for civil engineering and very short delivery and commissioning times.**

The Actiflo Pack range

The operating characteristics of Actiflo Pack are identical to those of Actiflo – coagulation/flocculation and ballasted sedimentation – giving it the advantages **of fast, high-performance treatment and great operational flexibility.**

The Actiflo Pack range offers a wide choice of configurations with unit treatment capacity **of 2 to 2,500 m^3/hour** depending on the application.

The systems are supplied with **all equipment and accessories,** from process reagent preparation to instrumentation and supervision tools.

The Actiflo Pack range is also available as **a mobile unit for emergency solutions** requiring temporary water treatment in the event of an unplanned downtime or to cover occasional additional water needs. Loaded onto trailers or in containers, they are available in a range of flow rates up to 350 m^3/h. They can be started very quickly to guarantee continuity of production for clients.

ACTIFLO® PACK

Advantages

- Performance: constant production of high-quality water
- Flexible operation: possibility of fast and frequent stops and starts
- Very compact with small footprint: between 2 m^2 and 55 m^2 per unit
- Economical solution, pre-fabricated in our workshops
- Choice of construction materials
- Delivery on a chassis with very short lead times

Applications

The standardized Actiflo Pack unit covers all municipal and industrial water treatment applications (drinking water, sewage, process water, reuse).

A varied range

- Actiflo Pack Mini: up to 15 m^3/h
- Actiflo Pack: up to 2,500 m^3/h

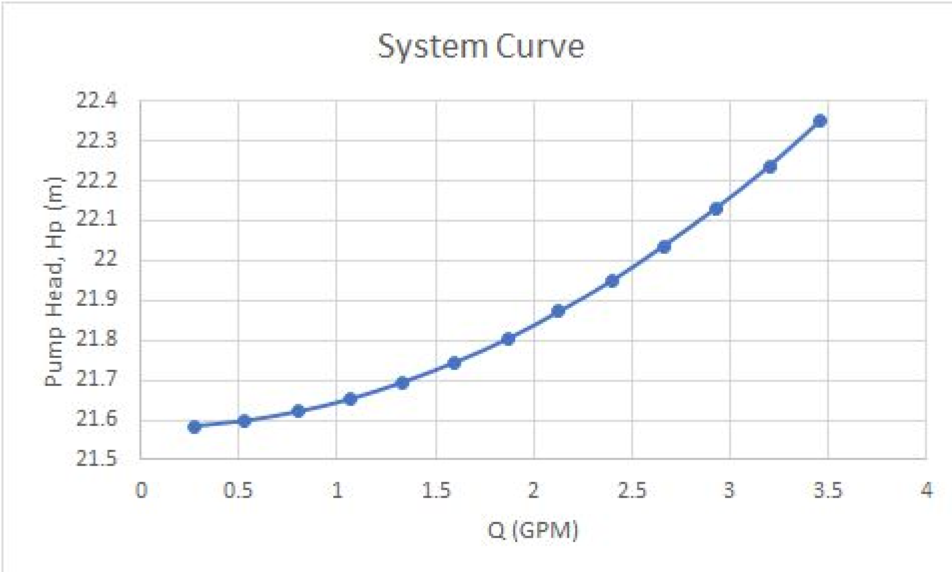
Actiflo Pack is the ideal response to situations that require a low-cost solution with fast set-up.

- Exceptional treatment performance regardless of field of application.
- Operational flexibility
- Optimization of installed equipment at lower operating costs.
- Lower reagent consumption: up to 50% savings compared to conventional processes.
- Lower civil engineering costs thanks to process compactness.
- Easy-to-use process: simply operation demanding little attention from operators.

Operating procedure	Conventional clarifier	Conventional clarifier with reagents	ACTIFLO®
Chemicals	NO	YES	YES
Microsand location	Inactive at bottom of tanks	Inactive at bottom of tanks	In suspension
Scrapers and pumps	Operate intermittently	Operate intermittently	Operate continuously
Suspended solids removal	>50%	>90%	>90%

Appendix E: Secondary Wastewater Treatment

Appendix E-1: System Curve of Influent Pump Station

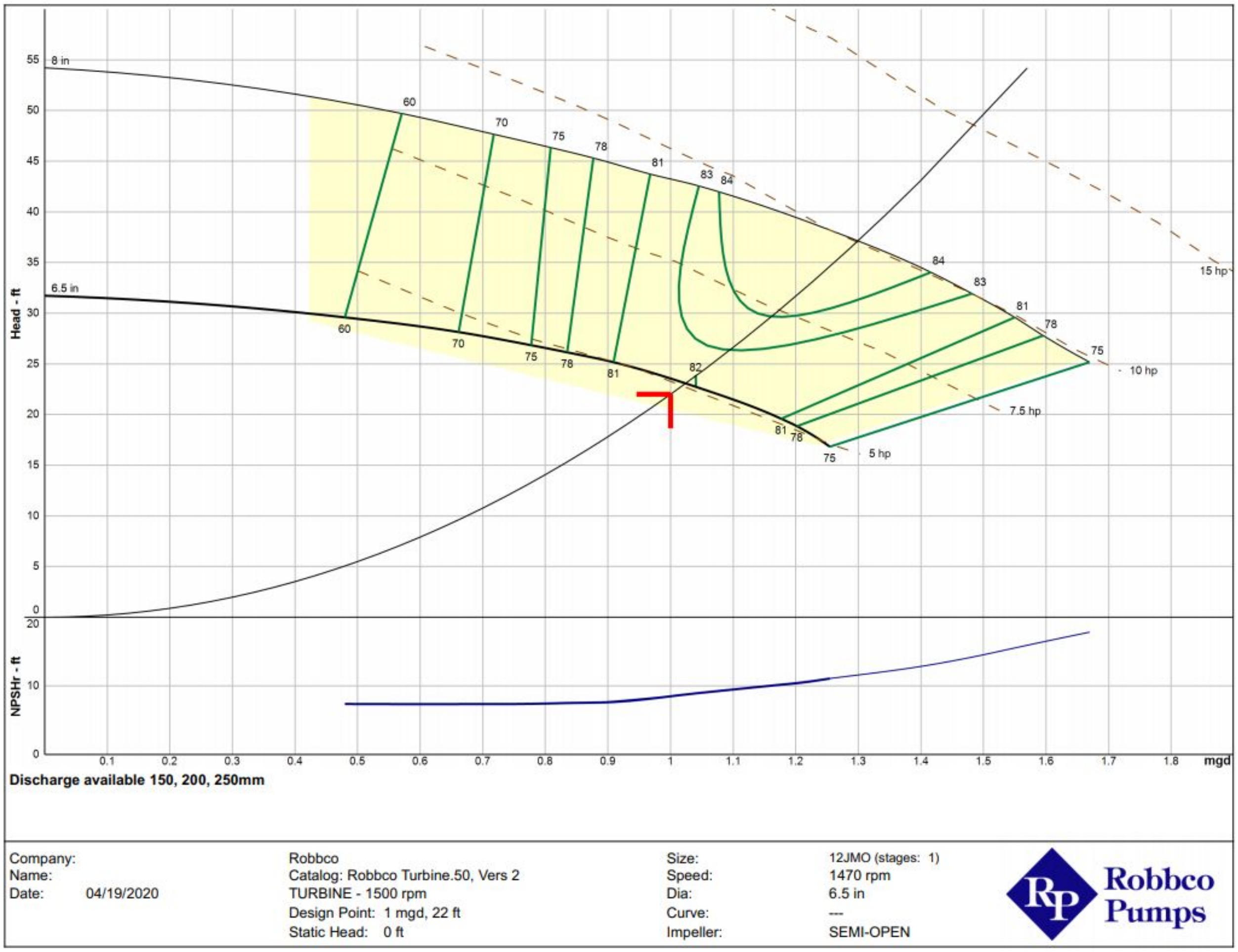


Appendix E-2: Recycle Pump System Curve Calculations

System Curve Values							
v (m/s)	**Re**	**f**	**Major hL**	**Minor hL**	**Hp (ft)**	**Q (m^3/s)**	**Q (MGD)**
0.01	8.08E+02	0.0724	0.0000023	0.0046	21.585	0.012	0.27
0.02	1.62E+03	0.0552	0.0000070	0.0182	21.598	0.023	0.53
0.03	2.42E+03	0.0478	0.0000137	0.0411	21.621	0.035	0.80
0.04	3.23E+03	0.0434	0.0000221	0.0730	21.653	0.047	1.07
0.05	4.04E+03	0.0404	0.0000322	0.1140	21.694	0.058	1.33
0.06	4.85E+03	0.0382	0.0000438	0.1642	21.744	0.070	1.60
0.07	5.66E+03	0.0365	0.0000569	0.2235	21.804	0.082	1.87
0.08	6.46E+03	0.0351	0.0000715	0.2919	21.872	0.093	2.13
0.09	7.27E+03	0.0339	0.0000874	0.3695	21.950	0.105	2.40
0.1	8.08E+03	0.0329	0.0001047	0.4562	22.036	0.117	2.66
0.11	8.89E+03	0.0320	0.0001234	0.5520	22.132	0.128	2.93
0.12	9.70E+03	0.0312	0.0001433	0.6569	22.237	0.140	3.20
0.13	1.05E+04	0.0306	0.0001645	0.7709	22.351	0.152	3.46

Pipe Information	
Material	PVC
e (m)	0.0000015
Sector Length (m)	6
Diameter (m)	1.22
Total Length (m)	7.62
# of Joints	3
Types of Joints	Regular 90-d flanged
# of Bends	1
Type of Bend	90˚
Minor Head Loss	
Coefficient of Entrance	1
Coefficient of Exit	1
Join Coefficient	1
Bend Coefficient	0.3
Total Minor Coefficient	9.30

Appendix E-3: Recycle Pump Curve



Appendix E-4: Anammox Reactor [10]

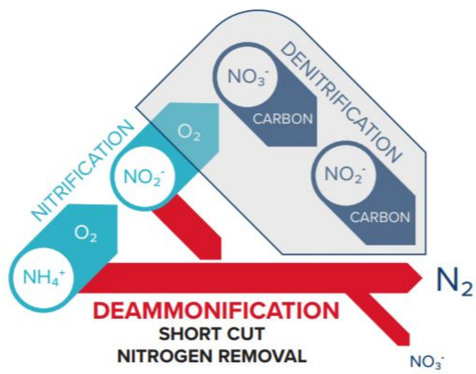
DEMON®

DEMON® Anammox treatment provides for cost effective total nitrogen removal via deammonification. Operating in either continuous or SBR modes, the system utilizes granular anaerobic ammonium oxidizing bacteria (anammox) for reduction of high strength ammonia using a fraction of the energy required by conventional means and zero carbon source. Waste streams generated from dewatered anaerobically digested municipal sludge or waste to energy facilities and- leachate from landfills are perfect applications for the World Water Works' DEMON technology and solves the problem of returning high concentrations of ammonia to the plant influent.

The true key to the success of the technology is the patented advanced biological process controls and the physical separation used to facilitate the growth and retention of the anammox bacteria.

Benefits

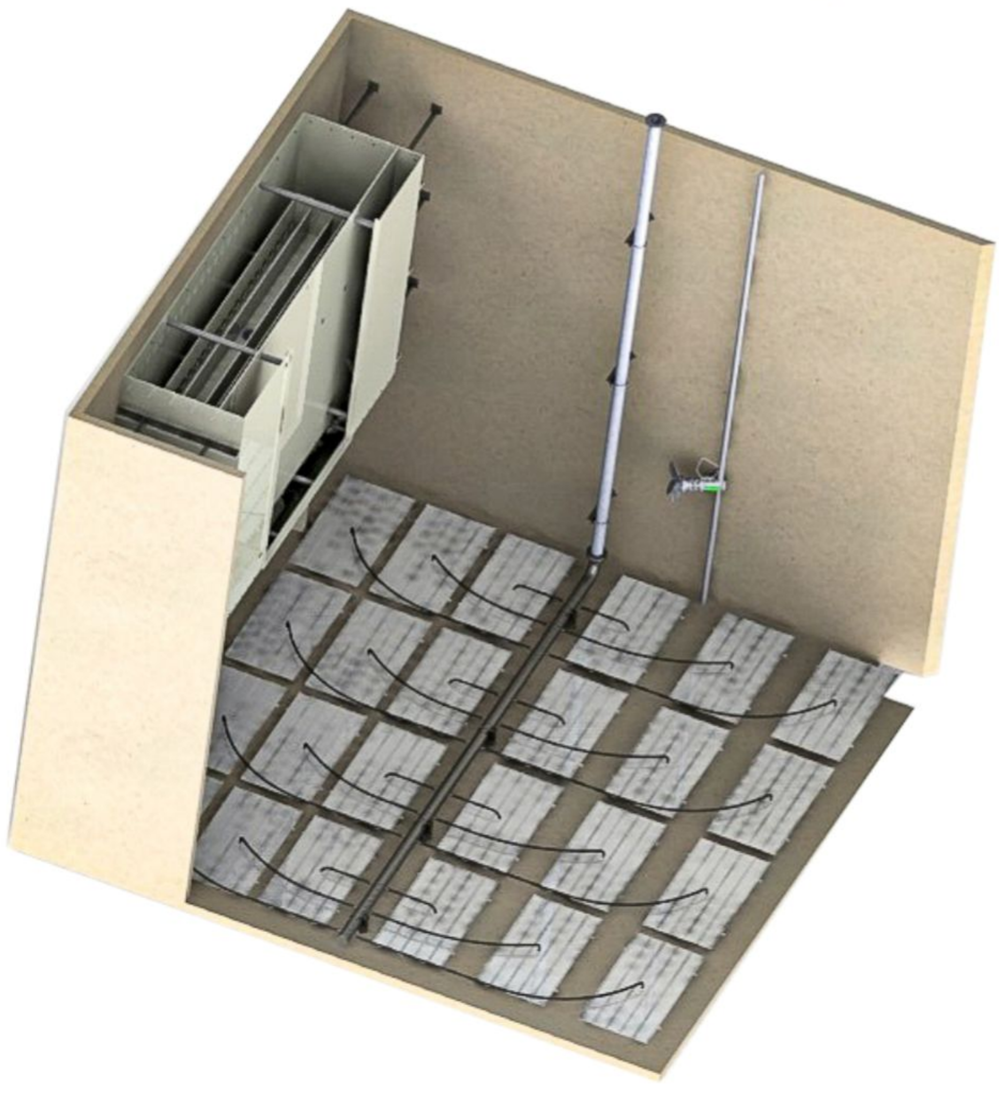
- Lowest cost Total Nitrogen removal process
- > 60% Less energy consumption
- 90% Less sludge production
- CO2 Fixation = Zero carbon footprint
- Simple and flexible operation
- Quick startup with available seed sludge
- Retrofit of existing tanks
- No supplemental alkalinity / carbon required

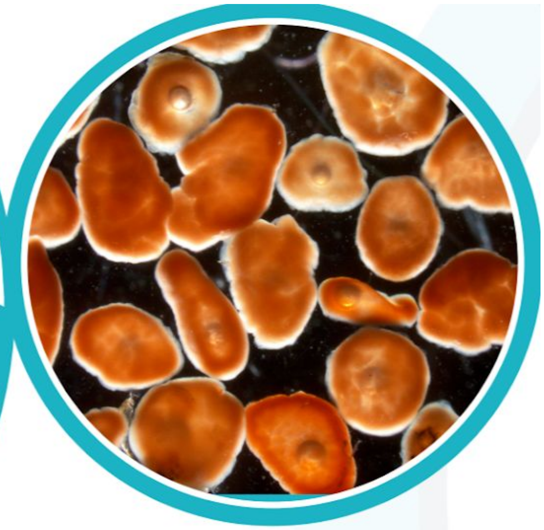


Unlike the traditional nitrification-denitrification method for removing nitrogen, which requires large amounts of energy (1.8-2.7 KW-hr/lb. nitrogen removed), alkalinity and external carbon addition, the DEMON process uses ammonia oxidizing bacteria (AOB) and annamox to efficiently and reliably remove ammonia from wastewater. The system operates under intermittent aeration with typical operational dissolved oxygen levels range from 0.3-0.5 mg/L. The system is completely automated which provides great system resilience and minimizes operator oversight.

Partial nitritation/deammonification represents a shortcut of the traditional process of nitrogen removal. The two-step process includes the partial nitritation of ammonia and the subsequent anaerobic oxidation of the residual ammonia and nitrite to nitrogen gas by annamox bacteria. This process is a greenhouse gas sequestrian and a truly sustainable improvement over traditional ammonia removal processes.

Deammonification represents the most cost effective upgrade a facility can take when looking at reducing the recycled nitrogen loads from their anaerobic digestors.





Appendix E-5: Secondary Aeration Basin Design Values and Equations

Q: Flow rate (m^3/d)

S_0: Secondary influent BOD_5 (mg/L)

X'_e: Secondary effluent TSS (mg/L)

S: Secondary Allowable Effluent BOD_5 (mg/L)

Ks: Half velocity constant (mg/L)

μM: Maximum growth rate constant (d^{-1})

kd: Decay rate of microorganism (d^{-1})

θ_c: Mean cell residence time (days)

θ_{c-min}: Critical mean cell residence time (days)

HRT: Hydraulic retention time (hours)

X: microorganism (MLVSS) concentration in the aeration tank (mg/L)

Y: Yield coefficient

V: Volume of aeration Tank (m^3)

Q_r: Return flow flow rate (m^3/d)

X': MLSS concentration (mg/L)

X'_r: Return sludge concentration (mg/L)

Q_w: Flow rate of liquid containing microorganisms to be wasted (m^3/d)

Y_{obs}: Observed yield coefficient

P_x: Net waste activated sludge produced in terms of MLVSS (kg/d)

P'_x: Net waste activated sludge produced in terms of MLSS (kg/d)

$$S_0 = \text{WWTP Influent } BOD_5 \times \frac{1 - \text{Primary Settling \% BOD Removal}}{100}$$

$$S = \text{Secondary Effluent } BOD_5 - X'_e \cdot (BOD_5 \text{ of TSS})$$

$$\theta_c = \frac{K_s + S}{(S \cdot \mu m - S \cdot kd - K_s \cdot kd)}$$

$$\theta_{c-min} = \frac{1}{(\mu m - kd)}$$

$$HRT = \frac{\theta_c \cdot Y (S_0 - S)}{X \cdot (1 + kd \cdot \theta_c)} \times \frac{24\,hrs}{1\,day}$$

$$V = Q \cdot HRT \times \frac{1\,day}{24\,hrs}$$

$$Q_r = \frac{Q \cdot (\%\ \text{Return flow})}{100}$$

$$X(MLSS) = \frac{X}{\left(\frac{MLVSS}{MLSS}\right)}$$

$$X'_r = \frac{X' \cdot [Q + Q_r - \frac{V}{\theta_c}]}{Q_r}$$

$$Q_w = \frac{V \cdot X'}{\theta_c \cdot X'_r}$$

$$Y_{obs} = \frac{Y}{1 + kd\,\theta_c}$$

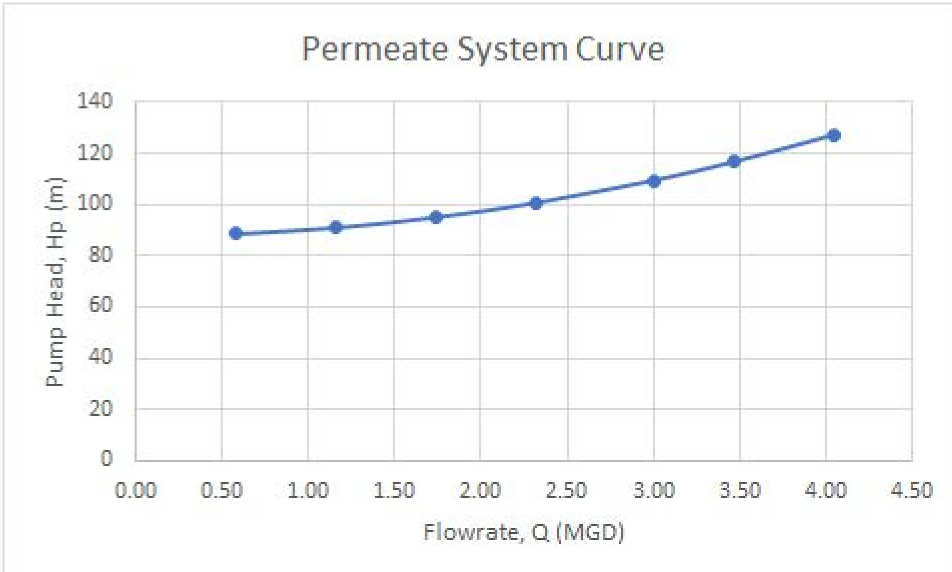
$$P_x = Y_{obs}\, Q (S_0 - S)\, (10^{-3}\ kg/g)$$

$$P'_x = \frac{P_x}{\left(\frac{MLVSS}{MLSS}\right)}$$

$$\text{MLSS in Effluent} = P'_x - (Q - Q_w) X'_e$$

Appendix F: Advanced Wastewater Treatment

Appendix F-1: System Curve of Permeate Pump

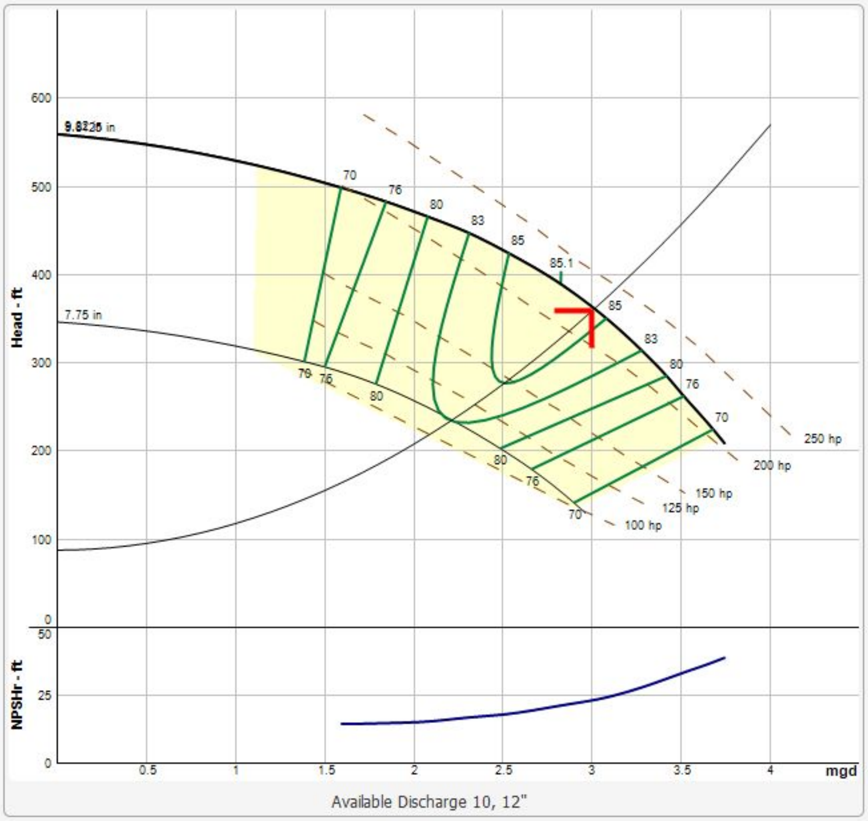


Appendix F-2: Permeate Pump System Curve Calculations

System Curve							
v (m/s)	Re	f	Major hL	Minor hL	Hp (m)	Q (m3/s)	Q (MGD)
0.5	8412.748	0.034104	0.100121	0.73575	88.61587	0.025349	0.5786
1	16825.5	0.029153	0.342348	2.943	91.06535	0.050697	1.1571
1.5	25238.25	0.026977	0.712798	6.62175	95.11455	0.076046	1.7357
2	33650.99	0.025699	1.207127	11.772	100.7591	0.101394	2.3143
2.59261	43621.95	0.024711	1.950478	19.78175	109.5122	0.131438	3.0000
3	50476.49	0.024218	2.559521	26.487	116.8265	0.152091	3.4714
3.5	58889.24	0.023742	3.415416	36.05175	127.2472	0.17744	4.0500

Pipe Information	
Material	Ductile Iron
e (m)	0.00026
Diameter (m)	0.254065
Area (m2)	0.050697
Total Length (m)	58.5366
Number of Joints	0
Types of Joints	NA
Number of Bends	2
Types of Bends	90 degree bend

Appendix F-3: Permeate Pump Curve



Catalog

Request For Quote

Pump

Type TURBINE
Size 14JMO
Curve ---
Impeller SEMI-OPEN
Stages 5
Speed 1770 rpm
Fit to Design
Diameter 9.8125 in
Fit to Design

Data Point

Flow 3.01 mgd
Head 361 ft
NPSHr 23.5 ft
Efficiency 85 %
Power 224 hp

Motor

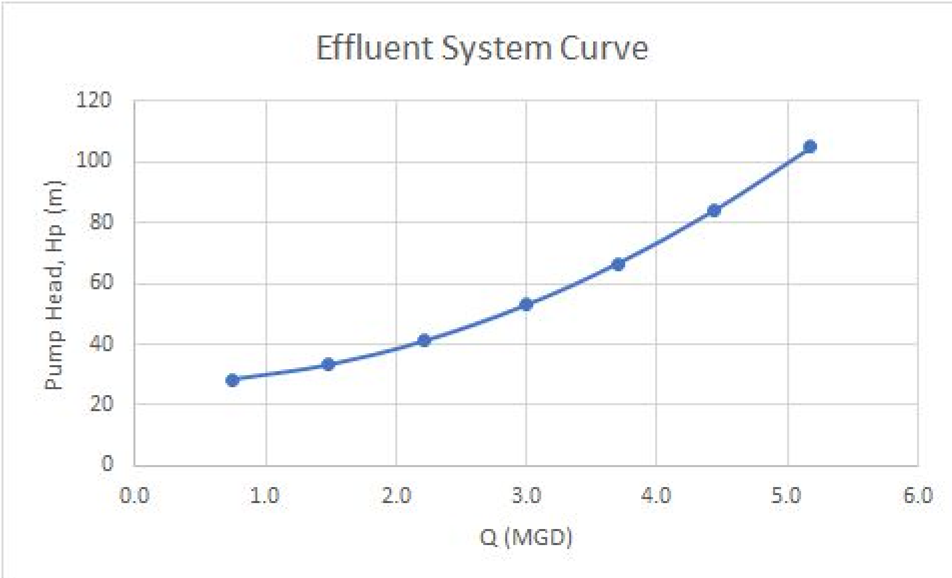
Standard NEMA
Enclosure WP1
Frame 447
Size 250 hp
Motor Selection

Graph Settings

◉ Manufacturer Settings
○ Custom

Data Point	Speed (rpm)	Flow (mgd)	Head (ft)	NPSHr (ft)	Efficiency (%)	Power (hp)	Min Flow (mgd)
Primary	1770	3.01	361	23.5	85	224	---

Appendix F-4: System Curve of Effluent Pump

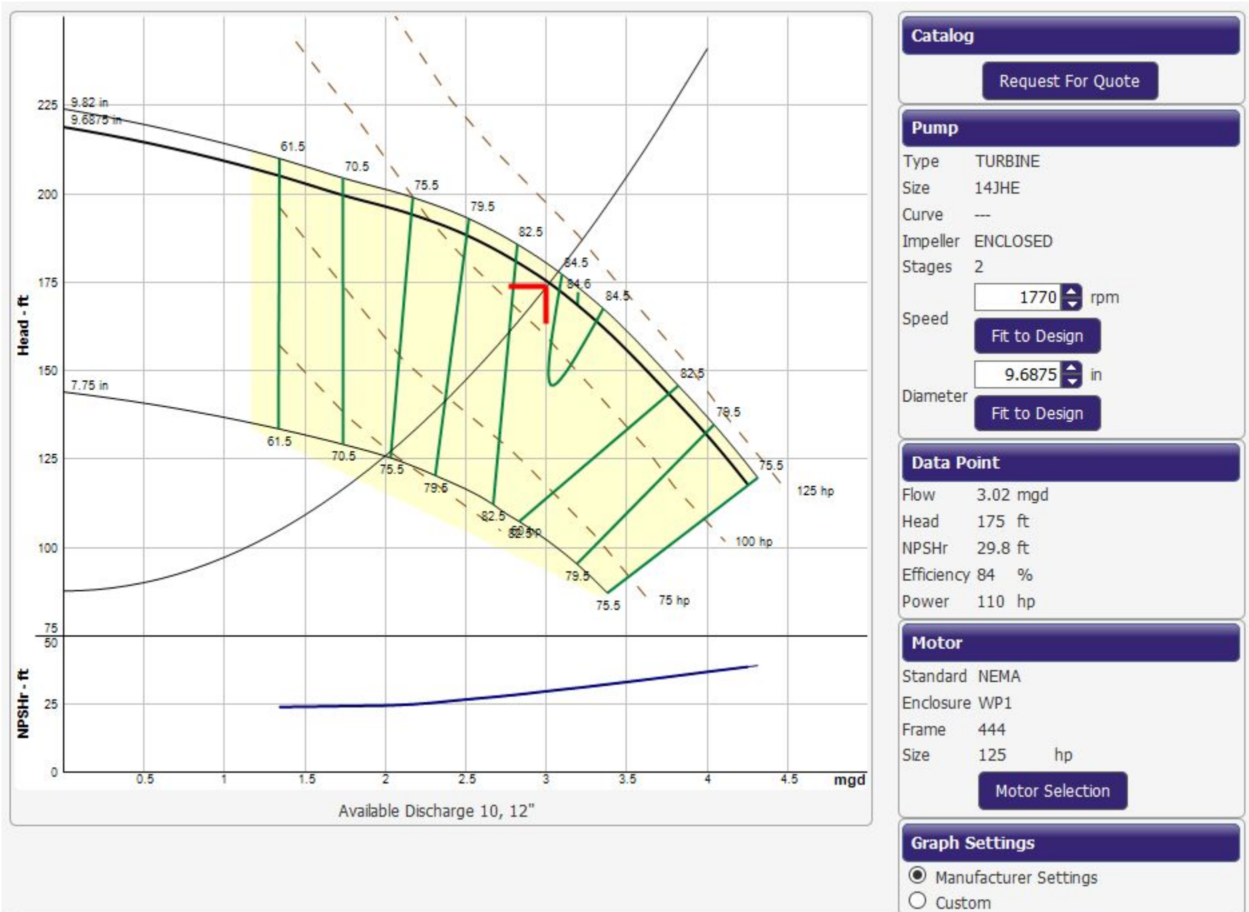


Appendix F-5: Effluent System Curve Calculations

System Curve							
v (m/s)	Re	f	Major hL	Minor hL	Hp (m)	Q (m3/s)	Q (MGD)
0.3	8130	0.033817	0.006548	1.58922	28.35797	0.038935	0.7400
0.6	16260	0.028589	0.022144	6.35688	33.14122	0.07787	1.4800
0.9	24390	0.02624	0.045731	14.30298	41.11091	0.116806	2.2199
1.21625	32960.38	0.024773	0.078848	26.12084482	52.96189	0.15785	3.0000
1.5	40650	0.023876	0.115585	39.7305	66.60829	0.194676	3.6999
1.8	48780	0.023172	0.161533	57.21192	84.13565	0.233611	4.4399
2.1	56910	0.022628	0.214702	77.87178	104.8487	0.272546	5.1798

Pipe Information	
Material	Ductile Iron
e (m)	0.00026
Diameter (m)	0.4065
Area (m2)	0.129784
Total Length (m)	17.16
Number of Joints	1
Types of Joints	16"x16"x16"x16" Cross
Number of Bends	2
Types of Bends	90 Degree Elbow and 45 Degree Dip Bend

Appendix F-6: Effluent Pump Curve



Data Point	Speed (rpm)	Flow (mgd)	Head (ft)	NPSHr (ft)	Efficiency (%)	Power (hp)	Min Flow (mgd)
Primary	1770	3.02	175	29.8	84	110	---

Appendix F-7: Advanced Wastewater Treatment Information

VigorOx® WWT II Performance Evaluation

Client

The Global Peroxygens Division of FMC Corporation (FMC) operates seven plants around the world that produce hydrogen peroxide, persulfates, and peracetic acid (PAA) based products.

Opportunity Areas

Among FMC's newest products is VigorOx® WWT II, a proprietary mixture containing 15% PAA that is registered with the USEPA for use in wastewater disinfection. PAA is an attractive, active ingredient because it breaks down into acetic acid (vinegar) and water in the environment and has no known toxic or carcinogenic byproducts of disinfection.

Previous evaluations of VigorOx® WWT II conducted by the company demonstrated superior reductions in bacterial count at lower use rates and shorter contact times than gaseous chlorine or bleach[1]. Further demonstration of the disinfection performance of VigorOx® WWT II at an operating wastewater treatment plant was desired to support broader acceptance by both the regulatory community and treatment plants across New York State.

Objectives

FMC requested that NYSP2I's Green Technology Accelerator Center evaluate the performance of VigorOx® WWT II at the Potsdam Wastewater Treatment Plant in Potsdam, NY. Because the plant utilized ultraviolet (UV) disinfection, this study location allowed synergies between PAA and UV to be explored. It was anticipated that the use of VigorOx® WWT II would improve the operation of the UV system, for example, by reducing the rate of lamp fouling.

Work Performed

NYSP2I's evaluation was conducted in collaboration with Clarkson University. The VigorOx® WWT II delivery system was retrofitted to the plant's existing disinfection chamber. Reduction of indicator bacteria were measured during full-scale testing at target doses of both PAA and PAA with UV disinfection. A laboratory study was also used to explore the combined effects of UV-PAA treatment.

Results

- During full-scale testing, the VigorOx® WWT II technology exceeded New York State disinfection requirements as permitted for the Potsdam Wastewater Treatment Plant.
- Laboratory analysis demonstrated that the addition of 1.0 mg/L PAA could reduce the UV dose required by as much as 50%.

The Value Proposition for VigorOx WWT II

VigorOx WWT II is an effective alternative for wastewater disinfection. But why choose this as the disinfection solution for a wastewater treatment plant? The following are some of the key drivers in choosing VigorOx WWT II:

1. Ease of Use

VigorOx WWT II is a highly soluble, low freezing point, stabilized concentrated solution that can easily be retrofitted into existing chlorine infrastructure. Easy to install tankage, pumps, piping and probe technology require low investment costs to the incorporation of peracetic acid at a given facility.

2. Low Toxic Impact on the Environment

VigorOx WWT II generates no chlorinated disinfection by-products, such as trihalomethanes (THMs) or cyanides. Coupled with its rapid breakdown to the begin products of vinegar and water, VigorOx WWT II has a very low impact on the environment with low aquatic toxicity.

3. Low Demand

Compared to other oxidative disinfectants, VigorOx WWT II has a relatively low oxidant demand from organics and suspended solids within the wastewater stream. This often leads to lower effective dosages needed. Furthermore, the dosing of peracetic acid needed will not depend on the amount of ammonia present, making it a perfect fit for wastewaters with varying ammonia levels, which may affect the performance of chlorination processes.

4. Increase Disinfection Capacity.

VigorOx WWT II can be coupled with UV systems to increase disinfection capacity for UV systems that are currently constrained and cannot meet disinfection requirements. The combination of peracetic acid and UV leads to a synergistic increase in inactivation of target bacteria, thereby reducing the power consumption of the UV system.

Conclusion

VigorOx WWT II has been demonstrated to provide cost effective disinfection as compared to chlorination systems, often requiring lower dosages and shorter contact times. Peracetic acid does not generate toxic disinfection by-products, resulting in a lower impact profile on the environment. It can be implemented with on-line probe monitoring and can be controlled at the plant level for several factors, including residual, flow pacing and incoming water quality.

Future *Disinfection Digests* will take a look at these attributes of VigorOx WWT II and the factors governing its effective use to disinfect target micro-organisms.

IMPACT ON UV POWER REQUIREMENTS

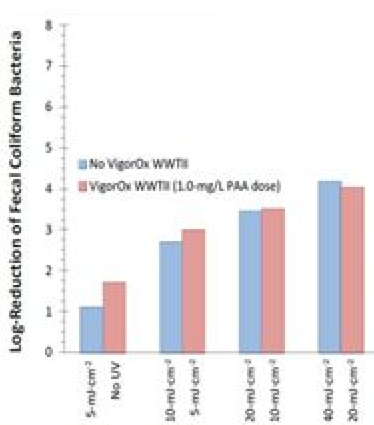


Figure 1 Reduction in Fecal Coliforms for PA + UV and UV Only Disinfection (ref 9)

One of the potential benefits of utilizing PAA in conjunction with UV is the ability to use less power for the UV disinfection to achieve equivalent microbial reduction performance with UV alone. This was demonstrated in a study by the New York Pollution State Prevention Institute[9], utilizing a bench scale collimated beam apparatus. The study was run with wastewater and the samples were enumerated for fecal coliforms and *Enterococci*. PAA was added to the wastewater prior to UV radiation. Figure 1 shows the results from this study for fecal coliforms. As seen in the fecal, the addition of 1 mg PAA / L resulted in the ability to reduce the UV power requirements by 50% to achieve equivalent coliform log reduction. Similar results were seen for *Enterococci* at UV doses of 10 mJ/cm^2, but not a significant at 20 and 40 mJ/cm^2. Similar results were seen by Martin[8] who reported that for fecal coliforms, a UV fluence of 40 mJ/cm^2 gave approximately the same 4 log inactivation as did 2 mg PAA / L + 20 mJ/cm^2.

Appendix G: Final Effluent Analysis

Final Analysis		
Initial Data		
Table 1: Influent Data		
Parameter	**Units**	**Value**
g	m/s2	9.81
T	˙C	20
γ	N/m3	9790
ν	m2/s	1.51E-05
μ	s/m2	1.82E-05
Flow Rate, Q	m3/d	11356.2354
Influent BOD	mg/L	373.38
Influent COD	mg/L	813
Influent TSS	mg/L	377.69
Influent TN	mg/L	30.35
Influent Ammonium (as N)	mg/L	27.0875
Influent P	mg/L	9.5425
ACTIFLO PACK % BOD Removal	%	85
ACTIFLO PACK % COD Removal	%	63
ACTIFLO PACK % TSS Removal	%	93
ACTIFLO PACK % TN Removal	%	90
ACTIFLO PACK % P Removal	%	95
ACTIFLO PACK % Ammonium Removal	%	30
DEMON Anammox % Alkalinity Removal	%	73
DEMON Anammox % BOD Removal	%	85
DEMON Anammox % COD Removal	%	95
DEMON Anammox % TSS Removal	%	44
DEMON Anammox % TN Removal	%	85
DEMON Anammox % Ammonium Removal	%	90

Final Analysis		
Water Treatment		
Table 2: Effluent Results		
Parameter	**Units**	**Value**
Preliminary Treatment Design		
RakeFlex coarse screens		
Pista 360 vortex grit chamber		
Primary Treatment Design		
Concrete Flow EQ Basin		
Ballasted Clarifer		
BOD	mg/L	56.01
TSS	mg/L	26.44
COD	mg/L	300.81
TN	mg/L	3.04
Ammonium	mg/L	18.96
P	mg/L	0.48
Secondary Treatment Design		
Ammanox Reactor		
BOD	mg/L	8.40
TSS	mg/L	14.81
COD	mg/L	15.04
TN	mg/L	0.46
Ammonium	mg/L	1.90
Advanced Treatment Design		
VigorOxx		
UV		

Appendix H: Cost Estimation Calculations

Appendix H-1: Preliminary Treatment Cost Estimate

Preliminary Treatment Cost	
Capital Cost	
Pump Cost ($/pump)	$1,527.00
Number of Pumps	2
Total Pump Cost ($)	$3,054.00
Screen Cost ($/screen)	$2,000.00
Number of Screens	2
Total Screen Cost ($)	$4,000.00
Vortex Grit Chamber	0
Number Installed	0
Total GC Cost	0
Total Capital Cost ($)	$7,054.00
Operations and Maintenance Cost	
Power Rate ($/kW-hr)	0.061
Pump Rate (kW/pump)	89.5
Pump Power (kW)	179
Screen Rate (kW/screen)	0.373
Screen Power (kW)	0.746
Pisa 360 Power (kW)	2.98
Total Power (kW-hr/yr)	1,601,776.12
Power Cost ($/yr)	$97,708.34
Pump Maintenance ($/yr)	$125.00
Screen Maintenance ($/yr)	$81.25
GC Maintenance ($/yr)	$2,281.25
Maintenance Cost ($/yr)	**$2,487.50**
Operational Cost ($/yr)	**$100,195.84**

Appendix H-2: Primary Treatment Cost Estimate

Primary Treatment Cost	
Capital Cost	
Pump Cost ($/pump)	$1,527
Number of Pumps	3
Total Pump Cost ($)	$4,581
ACTIFLO®PACK ($)	$1,007,000
Number of units	1
Total Cost ($)	$1,007,000
EQ BAsin ($)	$500,000
Total Capital Cost ($)	**$1,511,581**
Operations and Maintenance Cost	
Power Rate ($/kW-hr)	$0.061
Pump Rate (kW/pump)	48.02307
Pump Power (kW)	144.06921
ACTIFLO®Pack Power (kW)	400
Total Power (kW-hr/yr)	4769310.695
Power Cost ($/yr)	$290,927
Sand/Polymer ($/MG)	$90.85
Sand/Polymer ($/yr)	$99,548
Pump Maintenance ($/yr)	$125
ACTIFLO®Pack Maintenance ($/yr)	$700
Maintenance Cost ($/yr)	**$825**
Operational Cost ($/yr)	**$390,476**

Appendix H-3: Secondary Treatment Cost Estimate

Secondary Treatment Cost	
Capital Cost	
Pump Cost ($/pump)	$1,527
Number of Pumps	3
Total Pump Cost ($)	$4,581
Number of reactor	1
Total Anammox Reactor Cost ($)	$1,307,200
Total Capital Cost ($)	$1,311,781
Operations and Maintenance Cost	
Power Rate ($/kW-hr)	$0.061
Pump Rate (kW/pump)	11.2
Pump Power (kW)	33.6
Demon Anammox Reactor Power(kW-hr/Ib)	2.25
Anammox Reactor Power(kW)	70.41523924
Total Power (kW-hr/yr)	911416.3
Power Cost ($/yr)	$55,596
Chemical Feed ($/yr)	$1,084
Oxygen Needs ($/yr)	$426,000
Pump Maintenance ($/yr)	$125
Demon Anammox Reactor Maintenance ($/yr)	$1,182
Maintenance Cost ($/yr)	$1,307
Operational Cost ($/yr)	$483,988

Appendix H-4: Advanced Treatment Cost Estimate

Advanced Treatment Cost	
Capital Cost	
Lamp Cost ($/pump)	$575
Number of Lamps	4
Total Pump Cost ($)	$2,300
Number of reactor	1
VigorOX WWTII + UV System Cost	$275,500
Total Capital Cost ($)	$277,800
Operations and Maintenance Cost	
Power Rate ($/kW-hr)	$0.061
UV Pump Rate (kW/Lamp)	18.5
UV Lamp Power (kW)	74.0
VigorOX WWTII Power (kW)	28.68
Total Power (kW-hr/yr)	900092.9
Power Cost ($/yr)	$54,906
Chemical Feed ($/yr)	$76,500.0
Pump and Lamp Maintenance ($/yr)	$3980
Operation and Maintenance Cost ($/yr)	$135,385.67

Appendix H-5: Biosolids Cost Estimate

Typical Bio-Fix Constants	
Wet sludge/ Dry sludge	5.35
CaO ton/dry ton	1.5
Power (kW/medium tank)	65
Med. Building Size	70'x20'x17'
Med. Building Area (SQ. FT)	1400
Med. dry ton capacity (dt/hr)	2
CaO + Transportation Cost ($/dt)	$169.20
City of Tempe Constants	
Power Rate ($/kW-hr)	0.061
KWRF Sludge Information	
Preliminary Sludge (ton/hr)	0.0745833
Primary Sludge (ton/hr)	0.09625
Secondary Sludge (ton/hr)	0.01
Total Dry Sludge (ton/hr)	0.18
Calculated Values	
Wet Sludge (ton/day)	23.28
Needed Unit : Medium Unit	0.091
Power (kW)	5.89
Power (kW-hr/yr)	51610.42
Power Cost ($/yr)	$3,148
CaO+Transportation ($/yr)	$268,876
Operational Cost ($/yr)	**$272,024**
CaO Needed (ton/day)	6.53
Estimated Values	
Area (SQ. FT)	350
Dimensions (LxWxH) (ft)	29x12x17
Capital Cost ($)	**$1,500,000**
Wet Sludge (ton/yr)	8501.687568
Selling ($/ton)	$15.00
Biosolids Profit ($/year)	**$127,525.31**

Appendix H-6: Construction Cost Estimate

Estimated Phase 1 Construction	
Labor Costs	
Amount of Laborers	10
Work (hours/week)	40
Rate of Pay ($/hr)	$35
Amount of 5hr work weeks/year	44
Number of years	1.5
Total Labor Cost ($)	**$$924,000**
Construction Equipment Costs	
Rental Equipment ($)	$8,580,000
Contractor Equipment ($)	$840,000
Total Equip Cost	**$9,420,000**
Estimated Phase 2 Construction	
Labor Costs	
Amount of Laborers	7
Work (hours/week)	40
Rate of Pay ($/hr)	$40
Amount of 5hr work weeks/year	44
Number of years	0.25
Total Labor Cost	**$123,200.00**
Construction Equipment Costs	
Rental Equipment ($)	$1,650,000
Contractor Equipment ($)	$580,000
Total Equip Cost	**$2,230,000**
Total Construction Cost	**$12,697,200**

Appendix H-7: Solar Electricity Cost Estimator

Location	Panel Manufacture	Area (ft^2)	Power (kW)	Capital and Construction Cost	Capital Cost	Life Span (yr)	Annual Savings
Parking Lot	**Axitec**	16200	250	$327,600	$8,250	25	$70,000
Admin Building	**Trina**	14440	250	$271,600	$6,550	25	$62,395
Total		**16200**	**500**	**$599,200**	**$14,800**	**25**	**$132,395**

Appendix I: Staffing Estimation

Appendix I-1: Staffing Estimation Form [22]

NEIWPCC

THE NORTHEAST GUIDE FOR ESTIMATING STAFFING AT PUBLICLY AND PRIVATELY OWNED WASTEWATER TREATMENT PLANTS (24/7 Plant)

Plant Name: Kyrene Reclamation Facility

Design Flow: 3 MGD **Actual Flow:** N/A

FINAL ESTIMATES	
Chart #	**Annual Hours**
1 – Basic and Advanced Operations and Processes	2007.5
2 – Maintenance	894.25
3 – Laboratory Operations	1726.5
4 – Biosolids/Sludge Handling	91.25
5 – Yardwork	320
Estimated Operation and Maintenance Hours	5039.25
Estimated Operation and Maintenance Staff	4
Estimated Additional Staff from Chart 7	4
Total Staffing Estimate	8

• Divide the total of Annual Hours by 1500 hours per year to get the Estimated Operation and Maintenance Staff needed to operate the plant. This assumes 5-day work week; 29 days of vacation, sick leave, holidays; and 6.5 hours per day of productive work.

Note: The estimate from Charts 1-5 will not be the final amount of staff necessary to run the facility. Please review Chart 7 for additional staffing needs.

Chart 6 – Automation/SCADA (List all "yes" answers from Chart 6.)

Automated Meter Reading, Billing System, Computerized Facility Management System, E-mail, Integrated Purchasing and Inventory, Laboratory Information Management

Chart 7 – Considerations for Additional Plant Staffing (List all "yes" answers from Chart 7.) Attach supporting information to justify additional staffing needs from Chart 7.

Managment Responsibility, Inspections, Producing Class A+ Biosolid, On-Site Machinist

Appendix I-2: Staffing Projection Estimates

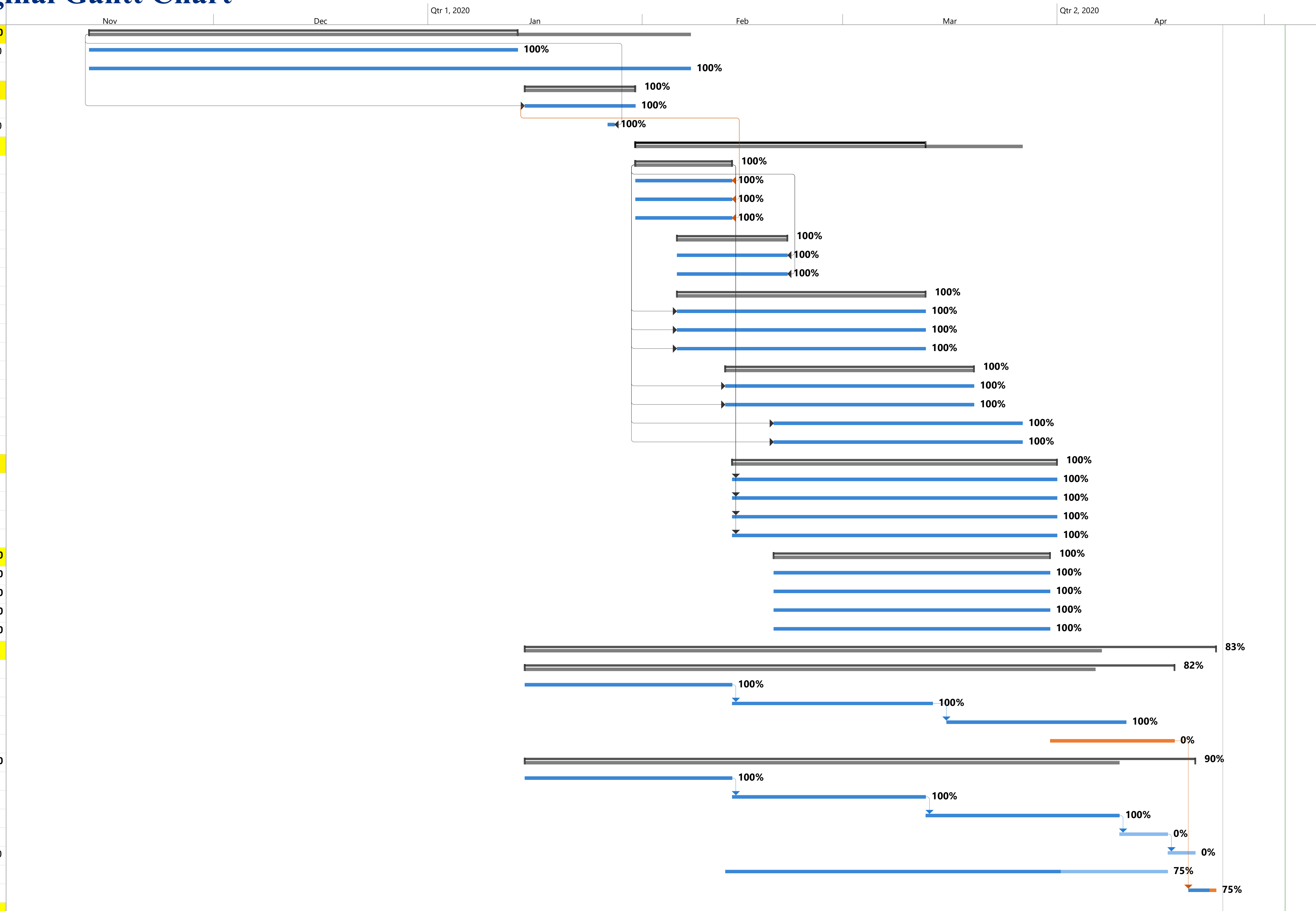
Estimated Basic Operations Hours		Laboratory Hours	
Process	Total Hours per Year	Test	Total Hours per Year
Preliminary Treatment	365	pH	91.25
Primary Clarifier	182.5	Turbidity	91.25
Anammox	1095	Fecal Coliform	730
UV Light	182.5	Total Nitrogen	730
VigorOx	182.5	Metals (n. 13)	78
Bio-Fix	91.25	Organics (n. 23)	5.75
Total	**2098.75**	**Total**	**1726.25**

Maintenance Hours		Yardwork	
Activity	Total Hours per Year	Activity	Total Hours per Year
Screens (Mechanically Cleaned)	182.5	Janitorial	100
Vortex Grit Chamber	91.25	Snow Removal	0
Alum/Ballast Addition	36.5	Mowing	0
Ballasted Clarifier	182.5	Vehicle Maintenance	100
Aeration Blower	146	Facility Painting	60
Anammox	73	Rust Removal	60
UV Radiation	146	**Total**	**320**
VigorOX Addition	36.5		
Total	**894.25**		

Appendix J: Gantt Charts

Appendix J-1: Original Gantt Chart

ID	Task Name	Start	Finish
1	**Task 1: Research Preparation**	**Wed 11/13/1**	**Mon 1/13/20**
2	Task 1.1: Application Process	Wed 11/13/1	Mon 1/13/20
3	Task 1.2: Treatment Research	Wed 11/13/1	Fri 2/7/20
4	**Task 2: Site Assessment**	**Wed 1/15/20**	**Thu 1/30/20**
5	Task 2.1: Site Research	Wed 1/15/20	Thu 1/30/20
6	Task 2.2: Site Visit	Mon 1/27/20	Mon 1/27/20
7	**Task 3: Treatment Design**	**Fri 1/31/20**	**Thu 3/12/20**
8	**Task 3.1: Plant Requirement**	**Fri 1/31/20**	**Thu 2/13/20**
9	Task 3.1.1: Source Water Quality	Fri 1/31/20	Thu 2/13/20
10	Task 3.1.2: Population Esimation	Fri 1/31/20	Thu 2/13/20
11	Task 3.1.3: Codes and Effluent Limit	Fri 1/31/20	Thu 2/13/20
12	**Task 3.2: Preliminary Treatment**	**Thu 2/6/20**	**Fri 2/21/20**
13	Task 3.2.1: Screen Design	Thu 2/6/20	Fri 2/21/20
14	Task 3.2.2: Grit Chamber Design	Thu 2/6/20	Fri 2/21/20
15	**Task 3.3: Primary Treatment**	**Thu 2/6/20**	**Thu 3/12/20**
16	Task 3.3.1: Sedimentation Basin Des	Thu 2/6/20	Thu 3/12/20
17	Task 3.3.2: Coagulation and Floccula	Thu 2/6/20	Thu 3/12/20
18	Task 3.3.3 Primary Sludge Handling	Thu 2/6/20	Thu 3/12/20
19	**Task 3.4: Secondary Treatment**	**Thu 2/13/20**	**Thu 3/19/20**
20	Task 3.4.1: OM and BOD Removal	Thu 2/13/20	Thu 3/19/20
21	Task 3.4.2: Disinfection	Thu 2/13/20	Thu 3/19/20
22	**Task 3.5: Tertiary Treatment**	**Thu 2/20/20**	**Thu 3/26/20**
23	**Task 3.6: Sludge/Biosolids Manageme**	**Thu 2/20/20**	**Thu 3/26/20**
24	**Task 4: Cost/Economics**	**Fri 2/14/20**	**Tue 3/31/20**
25	**Task 4.1: Construction Costs**	**Fri 2/14/20**	**Tue 3/31/20**
26	**Task 4.2: Maintenance Cost**	**Fri 2/14/20**	**Tue 3/31/20**
27	**Task 4.3: Operation Cost**	**Fri 2/14/20**	**Tue 3/31/20**
28	**Task 4.4: Design Cost**	**Fri 2/14/20**	**Tue 3/31/20**
29	**Task 5: Project Impacts**	**Thu 2/20/20**	**Mon 3/30/20**
30	**Task 5.1: Social Impacts**	**Thu 2/20/20**	**Mon 3/30/20**
31	**Task 5.2: Economic Impacts**	**Thu 2/20/20**	**Mon 3/30/20**
32	**Task 5.3: Regulatory Impacts**	**Thu 2/20/20**	**Mon 3/30/20**
33	**Task 5.4: Environmental Impacts**	**Thu 2/20/20**	**Mon 3/30/20**
34	**Task 6: Project Deliverables**	**Wed 1/15/20**	**Thu 4/23/20**
35	**Task 6.1: Project Reports**	**Wed 1/15/20**	**Fri 4/17/20**
36	Task 6.1.1: 30% Progress Report	Wed 1/15/20	Thu 2/13/20
37	Task 6.1.2: 60% Progress Report	Fri 2/14/20	Fri 3/13/20
38	Task 6.1.3: 90% Progress Report	Mon 3/16/20	Fri 4/10/20
39	Task 6.1.4: Final Report	Tue 3/31/20	Fri 4/17/20
40	**Task 6.2: Presentations**	**Wed 1/15/20**	**Mon 4/20/20**
41	Task 6.2.1: 30% Presentation	Wed 1/15/20	Thu 2/13/20
42	Task 6.2.2: 60% Presentation	Fri 2/14/20	Thu 3/12/20
43	Task 6.2.3: 90% Presentation	Fri 3/13/20	Thu 4/9/20
44	Task 6.2.4: Final Presentation	Fri 4/10/20	Thu 4/16/20
45	Task 6.2.5: U-Grad Presentation	Fri 4/17/20	Mon 4/20/20
46	**Task 6.3: Website and Submittal**	**Thu 2/13/20**	**Thu 4/16/20**
47	**Task 6.4: Competition Submittal**	**Mon 4/20/20**	**Thu 4/23/20**
48	**Task 7: Project Management**	Mon 1/13/20	Fri 4/24/20



Appendix J-2: Final Gantt Chart

ID	Task Name	Start	Finish
1	**Task 1: Research Preparation**	**Wed 11/13/1**	**Mon 1/13/20**
2	Task 1.1: Application Process	Wed 11/13/1	Mon 1/13/20
3	Task 1.2: Treatment Research	Wed 11/13/1	Fri 2/7/20
4	**Task 2: Site Assessment**	**Wed 1/15/2(**	**Thu 1/30/20**
5	Task 2.1: Site Research	Wed 1/15/2(	Thu 1/30/20
6	Task 2.2: Site Visit	Mon 1/27/2(	Mon 1/27/20
7	**Task 3: Treatment Design**	**Fri 1/31/20**	**Thu 3/12/20**
8	**Task 3.1: Plant Requirement**	**Fri 1/31/20**	**Thu 2/13/20**
9	Task 3.1.1: Source Water Quality	Fri 1/31/20	Thu 2/13/20
10	Task 3.1.2: Population Esimation	Fri 1/31/20	Thu 2/13/20
11	Task 3.1.3: Codes and Effluent Limits	Fri 1/31/20	Thu 2/13/20
12	**Task 3.2: Preliminary Treatment**	**Thu 2/6/20**	**Fri 2/21/20**
13	Task 3.2.1: Screen Design	Thu 2/6/20	Fri 2/21/20
14	Task 3.2.2: Grit Chamber Design	Thu 2/6/20	Fri 2/21/20
15	**Task 3.3: Primary Treatment**	**Thu 2/6/20**	**Thu 3/12/20**
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17	Task 3.3.2: Coagulation and Floccula	Thu 2/6/20	Thu 3/12/20
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19	**Task 3.4: Secondary Treatment**	**Thu 2/13/20**	**Thu 3/19/20**
20	Task 3.4.1: OM and BOD Removal	Thu 2/13/20	Thu 3/19/20
21	Task 3.4.2: Disinfection	Thu 2/13/20	Thu 3/19/20
22	**Task 3.5: Tertiary Treatment**	**Thu 2/20/20**	**Thu 3/26/20**
23	**Task 3.6: Sludge/Biosolids Manageme**	**Thu 2/20/20**	**Thu 3/26/20**
24	**Task 4: Cost/Economics**	**Fri 2/14/20**	**Tue 3/31/20**
25	**Task 4.1: Construction Costs**	**Fri 2/14/20**	**Tue 3/31/20**
26	**Task 4.2: Maintenance Cost**	**Fri 2/14/20**	**Tue 3/31/20**
27	**Task 4.3: Operation Cost**	**Fri 2/14/20**	**Tue 3/31/20**
28	**Task 4.4: Design Cost**	**Fri 2/14/20**	**Tue 3/31/20**
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