Preliminary Engineering Report

Triangle Wastewater Treatment Improvements
North Carolina State University
2024

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Prepared For:

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Abstract

Rehabilitation and upgrades of the Triangle Wastewater Treatment Plant (TWWTP), owned and operated by Durham County, will improve the efficiency and longevity of the plant to effectively serve customers. Multiple assets are at the end of their life (EOL), or not operational. Additionally, the plant has received five permit violations for excess effluent BOD in recent years. Replacement of EOL assets will improve the consistency of TWWTP BOD removal. The team met with TWWTP staff and toured other local treatment plants to aid in prioritization of equipment rehabilitation and evaluation of replacements. The team found that the screens, compactors and conveyors, odor control system, grit chambers and classifier, filters, and UV system needed to be replaced or rehabilitated. An additional UV train is also needed for redundancy. To enhance BOD removal, an inline equalization basin will be utilized for improved consistency of flow and BOD loading, in combination with fine-bubble diffuse aeration in the 5-stage Biological Nutrient Removal. These upgrades will extend the life span of the plant and allow for consistent BOD removal to best serve the residents of Durham County while protecting the environment.

Summary of Project Team Effort

The members of the North Carolina Carolina State University team included Andie Toney, David Broud, Shannon Roock, Jacob Beeker, Lindsey Stillson, and Theodore Markham. Competing in the WEFTEC Student Design Competition are Andie Toney, David Broud, and Shannon Roock. The tasks for the completion of this project were divided among these six individuals although Jacob Beeker, Lindsey Stillson, and Theodore Markham are unable to participate in the WEFTEC SDC. This project served as the senior design project for our team, providing much of the work being done during the 2024 spring semester.

Theodore Markham took the lead on GPS-X modeling. He researched GPS-X tutorials and created the preliminary models of the TWWTP and continued to edit and iterate through variations. Theodore also conducted the staff interviews regarding the criticality assessment as well as developed the criticality assessment criteria. The BNR aeration calculations and placement was also Theodore's responsibility.

Lindsey Stillson served as the team's main contact to manufacturers. She also reached out to local treatment plants during the equipment vetting process.

Jacob Beeker worked primarily on equalization basing sizing, equipment, hydraulics, and aeration requirements. Jacob also contacted manufacturers and acquired cost estimates. He competed in the NC One Water Student Design Competition.

David Broud was responsible for researching and sourcing new UV disinfection units. This required conversations between manufacturers and plant staff. David also created the construction Gantt chart, and researched equipment for headworks replacements. He researched pretreatment permits and violations as well. David conducted hydraulic analyses to assess potential pumping requirements. He participated in the NC One Water Student Design Competition as well.

Shannon Roock took charge of permit information, and document organization and vetting. She conducted both flow and population projections and organized this data. Shannon also created the decision matrix and aided in choosing our design alternative. She participated in the NC One Water Competition as well.

Andie Toney specialized in AutoCAD rendering. She used existing plant documents to create drawings and schematics including the hydraulic profile. Andie developed the construction sequence and modeled it in AutoCAD. Andie also aided in GPS-X development and research of equipment replacements, including contact with manufacturers. She participated in the NC One Water Competition as well.

While each member of the team served individual roles, all members contributed to the writing of this report and conducted multiple site visits to TWWTP and other treatment facilities.

In addition to the students on this design team, two advisors, Dr. Francis de los Reyes and Dr. Michael Wang, contributed to the success of this project. Dr. de los Reyes and Dr. Wang provided essential guidance on how to perform a preliminary engineering report. They coordinated site visits and meetings with plant personnel. Both Dr. de los Reyes and Dr. Wang also offered crucial instruction on treatment processes which aided in the teams understanding of wastewater treatment. This report would not be possible without the mentorship of Dr. Wang and Dr. de los Reyes.

In consultations with plant staff, Mr. Wade Shaw, TWWTP Superintendent, offered much insight into the condition of the treatment plant and the needs of both personnel and the treatment process. Mr. Shaw's input in the conditions assessment aided the team's decision in equipment replacement and design recommendation. Mr. Jonathan Bulla, North Cary Water Reclamation Facility Manager, also offered insight into equipment options and pricing estimates. Mr. Bulla allowed the group to visit the North Cary plant multiples times as well to gain a better understanding of various wastewater treatment processes.

NC One Water facilitated this team's participation in the 2024 WEFTEC SDC. NC One Water selected this team to represent their organization and funded the travel, lodging, and dining of competing group members. This team is honored to represent NC One Water in the 2024 WEFTEC SDC.

Project Description
1. Statement of Design Problem

The objective of this report is to assess the condition of TWWTP and propose solutions to issues of aging infrastructure, lack of operation redundancy, and past permit violations. Included in this report are a condition assessment, design alternative comparison, proposed upgrades, and an opinion of probable engineering cost. The scope of this design is focused on improving secondary treatment to ensure effluent permit limits are met, however, our assessment does identify a significant need to address end-of-life equipment and additional redundancy. Figure 1.1 presents an overview of the TWWTP with current processes labeled.

Figure 1.1: *Aerial Image of Triangle Wastewater Treatment Plant, Google*

1.1 Introduction

The North Carolina State University team has been retained by Durham County to prepare a Preliminary Engineering Report (PER) to upgrade and improve the Triangle Wastewater Treatment Plant. The purpose of this report is to analyze upgrades to Triangle Wastewater Treatment Plant (TWWTP) located in Durham, NC. The report is intended to inform Durham County and the plant staff on how they can improve their plant to better serve their clients. TWWTP has received several Notice of Violations and Notices of Deficiencies for exceeding their National Pollutant Discharge Elimination System (NPDES) Biological Oxygen Demand (BOD) limits. Additionally, the last major upgrade to the plant was made in 2001. A lot of systems are currently past, or close to their useful end of life. This report analyzes three different solutions to help reduce BOD in the TWWTP effluent. New systems are proposed for those that need replacing. The project was tasked with a $30 million budget. The plant is rated for 12 million gallons per day and receives a majority industrial wastewater, which causes highly variable flow.

The report analyzes three different solutions to address the BOD NPDES violations. The solutions that were considered were building an in-line equalization basin (EQ basin), adding diffuse aeration to the two oxidation ditches that utilize brush aeration, and a combination of both solutions: an in-line equalization basin and diffuse aerators. The criteria for decision making are the solution's BOD removal efficiency, American Association of Cost Engineering (AACE) class 3 estimate, staff wishes, Envision rating, and anticipated plant maintenance. After careful consideration, both solutions used in conjunction result in the best outcome for the plant. The EQ basin will help unify the highly variable industrial flow, which will aid the nutrient removal system. The diffuse aeration will allow the plant to meet its dissolved oxygen demand in the summer, and when loads are high.

An analysis of the current plant systems revealed multiple systems that need to be replaced. Talking to plant staff and analyses of the systems' life spans provided information about what should be upgraded. The bar screens, compactors, odor system, grit chamber, classifier, filters, and UV system all need to be replaced. Product recommendations were made for each of these systems. The filter would be rehabilitated, saving money and time. A second UV train would be added for redundancy. The system replacements would ensure the plant runs effectively, which will help improve current BOD removal. The total cost of using both the EQ basin and diffuse aeration and all the replacements is approximately $27.7 million. This is notably under the budget provided of $30 million.

Due to the TWWTP's aging infrastructure and issues in adequate BOD removal, this report recommends the implementation of an EQ basin, diffuse aeration in the oxidation ditches, and replacement of all critical systems in the plant.

1.2 Regulations

1.2.1 Wastewater Discharge Regulation

TWWTP is obligated to receive permits to discharge wastewater in Northeast Creek pursuant to the North Carolina General Statute 143-215.1. In August of 2022, the North Carolina Department of Environmental Quality (NCDEQ) issued a permit to TWWTP with effluent limits and monitoring requirements found in Table 1.2.1. This permit is valid until April 30th, 2027. Of note are the average monthly flow and BOD limits. The plant is permitted for 12MGD average monthly flow and BOD limits of 5.0mg/L and 7.5mg/L, monthly and weekly averages, respectively, from April 1st to October 31st. From November 1st to March 31st the monthly and weekly effluent BOD limits are 10.0mg/L and 15.0mg/L, respectively.

Table 1.2.1: *NPDES Permit Limits issued by NCDEQ for TWWTP*

Parameter	**Effluent Limitations**			**Monitoring Requirements**		
	Monthly Av.	*Weekly Av.*	*Daily Max.*	*Measurement Frequency*	*Sample Type*	*Sample Location*
Flow	12.0 MGD			Continuous	Recording	Influent or Effluent
Monthly Flow	Monitor and Report			Monthly	ecorded or Calculated	Influent or Effluent
BOD_5 (20°C) (April 1 – Oct 31)	5.0 mg/L	7.5 mg/L		2/week	Composite	Influent & Effluent

BOD_5 (20°C) (Nov. 1 – Mar. 31)	10.0 mg/L	15.0 mg/L		2/week	Composite	Influent & Effluent
Total Suspended Solids (TSS)	30.0 mg/L	45.0 mg/L		2/week	Composite	Influent & Effluent
Ammonia (NH_3 as N) (April 1 – Oct 31)	1.0 mg/L	3.0 mg/L		2/week	Composite	Effluent
Ammonia (NH_3 as N) (Nov. 1 – Mar. 31)	1.8 mg/L	5.4 mg/L		2/week	Composite	Effluent
Fecal Coliform (geometric mean)	200/100 ml	400/100 ml		2/week	Grab	Effluent
Dissolved Oxygen (DO)	Daily average ≥ 6.0 mg/L			Daily	Grab	Effluent
Temperature, °C	Monitor and Report			Daily	Grab	Effluent
pH	veen 6.0 and 9.0 standard units			Daily	Grab	Effluent
Conductivity, µmhos/cm	Monitor and Report			Daily	Grab	Effluent
Total Residual Chlorine (TRC)			1.7 µg/L	Daily	Grab	Effluent
TKN, mg/L	Monitor and Report			Weekly	Composite	Effluent
NO_3-N + NO_2-N, mg/L	Monitor and Report			Weekly	Composite	Effluent
Total Nitrogen (TN), mg/L	Monitor and Report			Weekly	Composite	Effluent
TN Load	tor and Report (lb/mo) 111,207 lb/yr			Monthly	Calculated	Effluent
				Annually	Calculated	Effluent
Total Phosphorous. (TP) mg/L	Monitor and Report			Weekly	Composite	Effluent
TP Load	itor and Report (lb/mo) 8,432 lb/yr			Monthly	Calculated	Effluent
				Annually	Calculated	Effluent
Total Hardness ($CaCO_3$), mg/L	Monitor and Report			Quarterly	Composite	Effluent
Total Fluoride (as F), µg/L	Monitor and Report			Quarterly	Composite	Effluent
Chloride (as Cl), µg/L	Monitor and Report			Quarterly	Composite	Effluent
Nitrate-N (NO_3-N), mg/L	Monitor and Report			Quarterly	Composite	Effluent

1.2.2 Floodplain Construction Regulation

The Durham County Unified Development Ordinance Section 8.4 regulates construction or substantial improvement projects on properties existing in floodplains. This regulation outlines projects which must seek floodplain administrator approval, or additional permitting. Section 17.3 provides a definition of the term *Substantial Improvements* as “Any repair, reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50% of the market value of the structure before the "start of construction" of the improvement.” However, it continues by stating this rule does not apply in cases where “any project or improvement of a structure to correct existing violations of State or local health, sanitary, or safety code specifications which have been identified by the local code enforcement official and which are the minimum necessary to assure safe living conditions”. This guidance will be used to determine if our design will require additional permitting.

1.2.3 Pretreatment Regulations

The North Carolina Department of Environmental Quality issues pretreatment permits to industries who discharge to the TWWTP. These permits are specific to each plant and can carry violations. The list of violations was examined to determine if any industry permit violations overlapped with plant discharge violations. The time periods just before and during the plant violations were examined. There was one notable industrial violations that coincide with the TWWTP discharge permit violation in 2022. BioMASON was issued a violation for not sampling their effluent for the second half of 2022 (July-Dec.TWWTP plant discharge violations occurred in July, August, and September in 2022. The overlap of violations could be a reason the plant exceeded its effluent BOD limits. However, the source of the violations is inconclusive as there are likely other contributing factors.

1.3 Projections

The county of Durham anticipates growth in its population and demands in infrastructure. Currently, the Triangle Wastewater Treatment Plant is not expecting their capacity to require an increase from 12MGD. However, the influent source is expected to move away from industrial towards domestic based on conversations with the plant superintendent about residential development.

Historically, TWWTP has seen a 5% growth rate in their flow and treats 75% industrial wastewater. The plant superintendent does not anticipate any increase in industrial flow. Using this information, we can separate the residential flow from the industrial flow and perform a growth analysis on the residential flow. We can then perform a 20-year flow projection for the plant by adding the residential flow projection to the industrial flow. TWWTP would not exceed its 12 MGD capacity within 20 years (Appendix Figure B.1).

1.4 Available Information

1.4.1 Phase I & II Expansions

In 2000, McKim and Creed updated some aspects of the treatment plant. The Phase I Expansion drawings detail some of the changes made to the process at that time. The Phase II Expansion, also contracted through McKim and Creed, consists of a complete schematic of the, then proposed, and now current TWWTP operation. The Phase II document contains thorough drawings and details of operating equipment.

1.4.2.1 PER and Conditions Assessment

A Preliminary Engineering Report (PER) and Conditions Assessment was conducted in 2022 by CDM Smith. CDM Smith's report includes descriptions and areas of interest of mechanical processes at the Triangle Wastewater Treatment Plant. While some information is redacted, the report provides a basis of the effectiveness of plant operations. CDM Smith's PER was a condition assessment and did not recommend upgrades or changes to the facilities. The report provided by our team utilizes CDM Smith's assessments to aid in providing informed recommendations for plant improvements and replacements.

1.4.3 NOVs and NODs

TWWTP has received three Notice of Violation (NOV) letters and three Notice of Deficiency (NOD) letters from the North Carolina Department of Environmental Quality (NCDEQ) that this team has been provided. In September 2018, the weekly and monthly limits of BOD5 were exceeded resulting in a NOV. In July 2022, the weekly average limit of BOD5 was exceeded resulting in a NOD. In August 2022, both the weekly and month average limits of BOD5 were exceeded resulting in a NOV. In September 2022, the weekly average limit of BOD5 was exceeded resulting in a NOD. In March 2023, the treatment facility lost power for 65 minutes resulting in a NOV. In May 2023, the BOD5 weekly average limit was exceeded resulting in a NOD. Daily DMR Data is available dating back to May of 2019. Included in this data is influent flow, BOD, TSS, ammonia, effluent flow, TKN, NO2 & NO3, total nitrogen, phosphorus, pH, temperature, fecal coliform, dissolved oxygen, and toxicity. A partial example of the given data is shown in Appendix Table C.1.

1.5 Existing Processes and Equipment

1.5.1 Existing Primary Treatment

The existing preliminary treatment process for TWWTP consists of three parts: mechanical screening, influent pumping, and grit removal chamber. Influent wastewater flows through two screening channels each equipped with a ¼ inch mechanical bar screen. Screenings are discharged into an enclosed screw conveyor and transported to a screening washer/compactor (not currently installed). Following screening, wastewater flows by gravity into the influent pump station of two rectangular wet wells. Each pump station has two 200 horsepower (hp) submersible pumps and one 60 hp submersible pump. Each pump is equipped with variable frequency drives (VFDs) to control their respective operating speed based on maintaining a constant level of water in the wet well. Pumped flow is conveyed to a grit removal process consisting of two (one duty and one standby) vortex grit units and a single grit classifier. Grit removed from the vortex grit removal is transferred via airlift pump to the grit classifier which separates and dewaters the grit. Grit is discharged to a dumpster located at ground level. Wastewater flows by gravity into the secondary treatment train. Table D.1 located in the Appendix summarizes the specifications for the existing preliminary treatment systems and Appendix Figure H.1 provides a visualization of the headworks.

1.5.2 Existing Secondary Treatment

Wastewater flows by gravity from the preliminary treatment facilities into the secondary treatment system. The secondary treatment system consists of an influent/return activated sludge (RAS) distribution box, three biological nutrient removal (BNR) treatment trains, each rated at 4.0 MGD, with 5-stage Bardenpho process, four secondary clarifiers and a RAS/WAS submersible pump station. Methanol is injected at the secondary anoxic zones as an additional carbon source for enhanced denitrification. Sodium aluminate is added to the secondary clarifier distribution box to reduce effluent phosphorus concentrations.

The influent/RAS distribution box is designed to equally distribute the influent flow, recycle from solids process, and RAS among the BNR treatment trains through three outlet chambers which feed into the respective BNR treatment train via 30-inch ductile iron (DI) pipes. The three BNR treatment trains include a three-cell anaerobic selector for biological phosphorous removal followed by a two-cell primary anoxic zone for the removal of nitrate-nitrogen. Figure H.2 is a visualization of a treatment train shown in the Appendix. Each cell of anaerobic selector and primary anoxic zone has a 2.7 hp and 6.0 hp low-speed submersible mixer, respectively. Wastewater flows from the second cell primary anoxic zone into an oxidation ditch for nitrification and oxidation of carbonaceous biochemical oxygen demand (BOD). Each oxidation ditch is equipped with four 75 hp variable speed 9.0-meter brush aerators (herein referred to as rotors) and two 7.4 hp submersible velocity boosters. An automated dissolved oxygen (DO) control system operates the rotors based on an operator adjustable DO setpoint. The two velocity boosters operate continuously to maintain suspension of biological solids. A wall pump equipped with a VFD recycles nitrates to the first stage of primary anoxic zone. Mixed liquor suspended solids (MLSS) from the oxidation ditch flow over a 7.0-meter weir to a two-cell secondary anoxic zone for additional denitrification. Each cell of the secondary anoxic zone is equipped with a 6.0 hp submersible mixer. Effluent from the secondary anoxic zone passes over a 5.0-meter motor actuated weir to a reaeration zone. Four secondary clarifiers are used for solids separation and thickening of RAS and WAS. The rapid sludge removal clarifiers utilize equally spaced draw-off tubes for removal of settled solids. Appendix Figure H.3 represents a visualization of the secondary clarifiers. Solids are conveyed to a sludge well for removal by the RAS and WAS pumps. The existing RAS/WAS pump station consists of four RAS pumps and two WAS pumps. Appendix Table D.2 summarizes the specifications of the existing secondary treatment systems.

1.5.3 Tertiary Treatment

The existing tertiary treatment system consists of five traveling bridge filters and a one-channel horizontal ultraviolet (UV) disinfection system featuring post aeration prior to discharge. The five traveling bridge filters receive effluent from the four secondary clarifiers. Each filter includes a compartmental bottom, porous media plates, sand filter media, and a cleaning and backwash mechanism with interconnected automatic operating system. Two pumps operate to perform backwashing in the filter. The backwash for each filter is automatically initiated by either an adjustable timer or preset levels. A visualization of the filters is shown in Appendix Figure H.4. A Trojan UV 4000 system provides disinfection of the filtered effluent. From the UV disinfection, the effluent moves to a post aeration system featuring diffuse aerators. If needed, the system can be turned on to provide a boost in DO before the effluent travels via 54" DI pipe to discharge into the Northeast Creek. Appendix Table D.3 provides a summary of the design criteria for the existing tertiary treatment systems and the UV Disinfection/Post-Aeration can be visualized in Appendix Figure H.5.

1.2.4 Sludge Processing and Disposal

The existing residuals process and disposal facilities consist of two sludge holding tanks and three centrifuges for dewatering. The sludge holding tanks are equipped with jet aeration, a submersible mixer, and a floating decanter. WAS from the secondary clarifiers is pumped to the sludge holding tanks for thickening prior to the biosolids dewatering process by three centrifuges. Three progressive cavity WAS feed pumps deliver thickened sludge to the centrifuges. Cake pumps from each centrifuge deliver cake to one of two loading bays where dump trailers can be loaded. Three liquid polymer units are located within the dewatering area for polymer injection to the pipe to condition the biosolids to enhance dewatering in each centrifuge. Backwash, decant, and centrate from the filter and residual processing operation are discharged to an equalization tank. The contents are pumped to the headworks over a 12-hour period, increasing the nutrient loading to the BNR treatment trains. Table D.4 provides a summary of the design criteria for the existing processing and disposal systems in the Appendix.

1.3 Condition and Criticality Assessment

To determine the risk associated with the condition of the existing assets in TWWTP, a criticality assessment was conducted. Criticality is determined by multiplying an asset's probability of failure (POF) by the asset's consequence of failure (COF). POF and COF are rated on a scale of 1-5 (Table 15-1), and thus possible values for criticality range from 1-25. The criticality rating indicates the level of risk associated with the asset as it exists. Some assets, such as the blowers for diffused air, are highly critical to the BNR process but have a low probability of failure and thus the risk associated with the asset is low. Other assets, such as mixers, though more at risk of breaking down, have more redundancies and are quicker to replace and thus have a moderate criticality rating. Assets with a high criticality (20-25) are highly concerning and are recommended to be repaired, replaced, upgraded, or increase redundancy. This assessment helps the team identify the priorities regarding asset replacement, repair, and redundancy increases. Detailed criteria can be found Table 1.6.1 below.

To determine the POF and COF values for each asset, members of our team met with the plant superintendent and operators of TWWTP to review each asset and agree on a rating for both POF and COF based on a determined criteria found in Table 1.6.1 below. The useful life for each asset of the headworks, secondary treatment and tertiary treatment systems was confirmed and a criticality rating was determined. To identify the risk rating associated with each asset, we multiply the POF by the COF per equation below. Thus, risk is rated on a scale from 1-25. The results of this analysis can be seen below in Table 1.6.2.

$$Risk = POF * COF$$

Equation 1.6*: Criticality Assessment Risk Quantifier*

Table 1.6.1: *Probability and Consequence of Failure rating criteria.*

		Probability of Failure	Consequence of Failure
1	Very Low POF/COF	Asset is brand new or like new. Failure not anticipated within the foreseeable future.	No identifiable consequences. Less than $10,000 in repair costs. (use the appropriate monetary amount for your system. A smaller system will want to set a lower monetary threshold).
2	Low POF/COF	Asset is not brand new but shows no more than cosmetic signs of wear and tear. Asset failure is not anticipated in the near future. The asset receives regular maintenance.	$10,000 to $49,999 in repair costs. Short term disruption to traffic or business or operations (less than 4 hours). Bypassing (without violating permit) for less than 3 days.
3	Moderate POF/COF	Asset shows signs of wear but has not yet entered a potential failure state. Asset has the potential to be maintained at a level 3 for some period of time if the proper maintenance is completed and repairs are made. Asset may show light rust, some light wear and tear, or be nearing, but not at, physical capacity.	$50,000 to $99,999 in repair costs. Disruption to businesses. Disruption to traffic. Disruption to septic haulers. Disruption to staff or regular operations. Bypassing (without violating permit) for more than 3 days.
4	High POF/COF	Asset is in potential failure, but not functional failure mode. Functional failure not expected within the next year. Potential failure means the asset is showing signs of failure, such as cracks, root intrusions, vibration, noise, excessive rust, but is still delivering all or most of the required service. The potential failure issues will need to be addressed to prevent a functional failure.	$100,000 or more in costs related to repair. Damage to other assets and/or private property. Potential to negatively harm the environment; potential to cause impacts to endangered species. May make some minor news report.
5	Very High POF/COF	Already in functional failure mode (Mortality – already broken, collapsed; Level of Service - not doing what it's supposed to; Capacity – not sufficiently sized; Financial Inefficiency – costing too much to continue to use) or expected to be in functional failure mode within 1 year. A failure of one of the four types is imminent if the asset is not already in failure mode.	Health and safety of employees and/or public at risk. Exceedance of permit limits. Politically problematic/becomes a major news story.

Table 1.6.2*: Criticality Assessment*

Asset	Useful Life Remaining (Yrs)	Probability of Failure	Consequence of Failure	Criticality
Headworks				
Mechanical Screens (x2)	0	3- Moderate POF	3 - Moderate COF	9
Screenings Conveyor	0	1- Very Low POF	2 - Low COF	2
Washer/Compactor	0	2- Low POF	3 - Moderate COF	6

60 hp Pump (x2)	0	2- Low POF	1 - Very Low COF	2
200 hp Pump (x4)	0	2- Low POF	1 - Very Low COF	2
Vortex Grit (x2 - 1 redundant)	0	4- High POF	5 - Very High COF	20
Grit Classifier (1)	0	4- High POF	4 - High COF	16
Odor Control System	N/A			N/A
Secondary Treatment				
BNR TT 1—Blowers	N/A			N/A
BNR TT 1—Mixers*	21	4- High POF	3 - Moderate COF	12
BNR TT 1—Brush Aerators	24	1- Very Low POF	5 - Very High COF	5
BNR TT 1—Internal Recycle Pump	21	3- Moderate POF	4 - High COF	12
BNR TT 2—Blowers	21	1- Very Low POF	5 - Very High COF	5
BNR TT 2—Mixers*	21	4- High POF	3 - Moderate COF	12
BNR TT 2—Brush Aerators	N/A			N/A
BNR TT 2—Internal Recycle Pump	21	3- Moderate POF	4 - High COF	12
BNR TT 3—Blowers	N/A			N/A
BNR TT 3—Mixers*	0	4- High POF	3 - Moderate COF	12
BNR TT 3—Brush Aerators	24	1- Very Low POF	5 - Very High COF	5
BNR TT 3—Internal Recycle Pump	21	3- Moderate POF	4 - High COF	12
Secondary Aeration—Blowers	21	3- Moderate POF	4 - High COF	12
Clarifiers (x4 - 2 redundant)	0	1- Very Low POF	1 - Very Low COF	1
Clarifier Drive Mechanism	0	3- Moderate POF	3 - Moderate COF	9
WAS Pumps (2)	0	2- Low POF	2 - Low COF	4
RAS Pumps (4)	0	2- Low POF	2 - Low COF	4
Tertiary Treatment				
Bridge Filters (x5)	0	5 - Very High POF	5 - Very High COF	25
Backwash Pumps	0	3- Moderate POF	5 - Very High COF	15
Wash Water Pumps	0	4- High POF	5 - Very High COF	20
UV Disinfection	0	5 - Very High POF	5 - Very High COF	25

2. Alternatives Evaluation

2.1 Proposed Facilities

2.1.1 Screening and Compacting

The current screens the plant has in place are manufactured by Andritz. The brushes on these screens have required frequent repairs and replacements. An option to replace the current screens is a system such as JWC Bandscreen Monsters. These screens use pressurized water to clean the screens instead of a brush. This would eliminate the issues the plant has been having with broken brushes not cleaning screens effectively. With these screens, a new washer compactor would be installed with each screen, a model such as the JWC Screenings Washing. Each screen will discharge its waste to its respective compactor, where both compactors will discharge into the same dumpster.

2.1.2 Grit Removal

The plant has two 20 MGD grit chambers that have surpassed their end-of-life use. Both chambers will have to be upgraded. Since there are two, this will improve the maintenance of plant operations during the construction process. One chamber will be in use while one is on standby. The recommended grit chambers are Jones and Atwood Jeta Model 900 due to its compatibility in plant operations and space. Cost estimates for the replacement and upgrades for the grit removal were estimated by manufacturer Ovivo to be approximately $3.6 million for both new Jeta chambers if installed today. The grit classifier is also at its end-of-life use and needs to be replaced. Currently, the plant has one grit classifier which is a Jones and Atwood Model 450. Replacement with the same model classifier would reduce training demands and has known compatibility with plant operations. Replacement of the classifier with a new Jones and Atwood Mode 450 has been estimated by Ovivo to be $400,000.

2.1.3 Odor Removal

The plant currently does not have an in-service odor control system. A viable option for odor removal is the Biorem Odor system. The odor control system is composed of two vertical scrubbers with a recirculation pump, a biofiltair cell, and media irrigation. When touring other WWTP besides the TWWTP, this system stood out as an effective and efficient model. In a plant of comparable size, 12MGD, the purchase and installation of the Biorem Odor system was estimated to be $2M-$2.5M for present day. While odor removal does not directly impact BOD levels, it is vital to the working conditions of the plant and in reducing environmental impact.

2.1.4 Filtration

Filtration in TWWTP is nearing end-of-life and a concern of the plant Superintendent's as a potential source of BOD violations as any equipment failures from filtration would directly impact effluent quality. Replacing the filters is of critical importance due to these issues, which are reflected in Table 1.6.1. Ondeo Degremont, now called Suez, provided minimal replacement parts to TWWTP over the course of the life of the filter. This could have impacted filter operation over time. Suez estimates it can rehabilitate the filters for $1.5 million. This would include an onsite inspection to determine what would need to be replaced. The plant would be able to keep the footprint, electrical, and instrumentation. Maintaining the same footprint contributed greatly to the decision to rehabilitate the filters rather than installing a different system. Because the same structure would be used, the upgrade would be more sustainable and less expensive. Reusing the same electrical equipment and instrumentation also significantly reduces plant O&M cost. The improved filter should prevent accidental discharge of solids and maintain BOD levels.

2.1.5 UV Disinfection

UV disinfection is an integral part of ensuring effluent discharge complies with NPDES standards. The current UV system, a Trojan 4000, is a single train rated for a peak flow of 36 MGD. The main issues with this system are that the Trojan 4000 and replacement parts are no longer in production and the plant superintendent has expressed a desire to add a second train for redundancy. The necessity for replacement/upgrade is reflected in the criticality assessment in Table 1.6.1. After contacting Trojan, they recommended the TrojanUV Signa as a viable replacement for the current system as it requires no change to the channel size or shape and maintaining headloss through the channel. This system would be much easier to conduct maintenance on as its banks can be pulled straight out instead of needed to hinge and swing. A second UV system would be installed in a new channel for needed redundancy. The details of this channel can be seen Figure 2.1.1 below, and the construction sequence is established in Section 3.4.1.

2.1.6 Post Aeration

Treated effluent is aerated prior to discharge to boost DO levels. The existing aeration is via diffusors which require both electricity and air from blowers. Due to preferences of TWWTP superintendent and concerns regarding efficiency, the diffused aerators will be removed and replaced with step aeration. Step aeration requires only gravity to introduce DO, eliminating the air and electricity requirements. Because air is no longer needed, the existing blowers can be demolished to allow room for the second UV channel as mentioned in Section 2.1.5. A model of the step aeration design can be seen in Figure 2.1.1 and Figure 2.1.2. The sequence for construction is outlined in Section 3.4.1.

Because the TWWTP is located on a 100-year floodplain, the step aeration design features a weir at an elevation of 252’, which is above than the 100-year flood elevation of 251.75’ (Figure 2.1.2). In the event of a 100-year flood, the plant may experience loss of their step aeration usage but, the weir would prevent backflow into critical treatment processes.

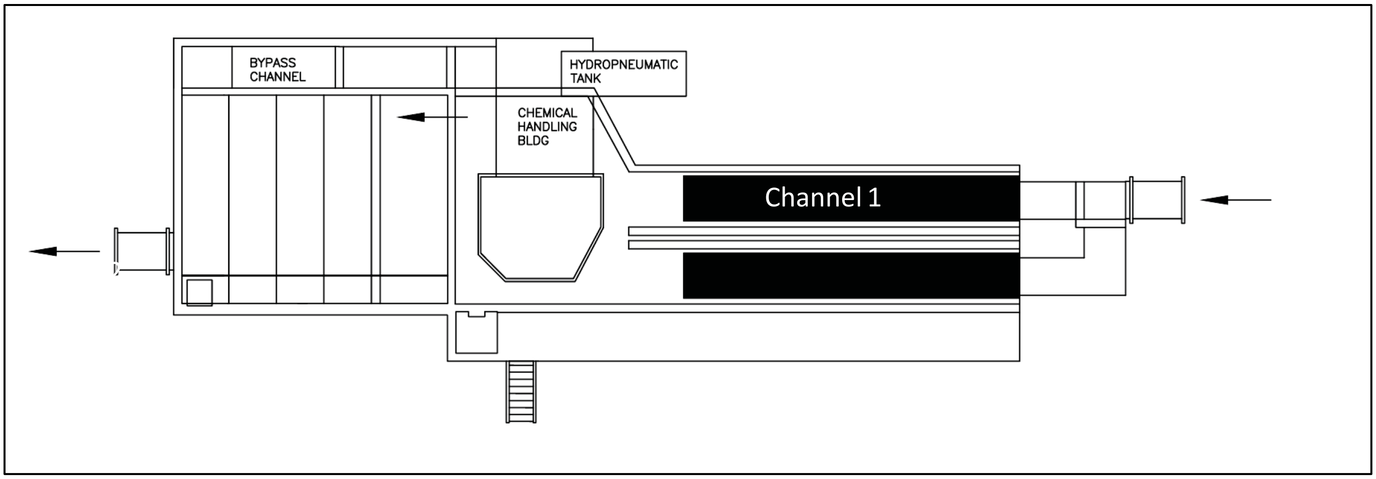


Figure 2.1.1: *Proposed UV Disinfection and Step Aeration Enhancement (Aerial View), rendered using AutoCAD*

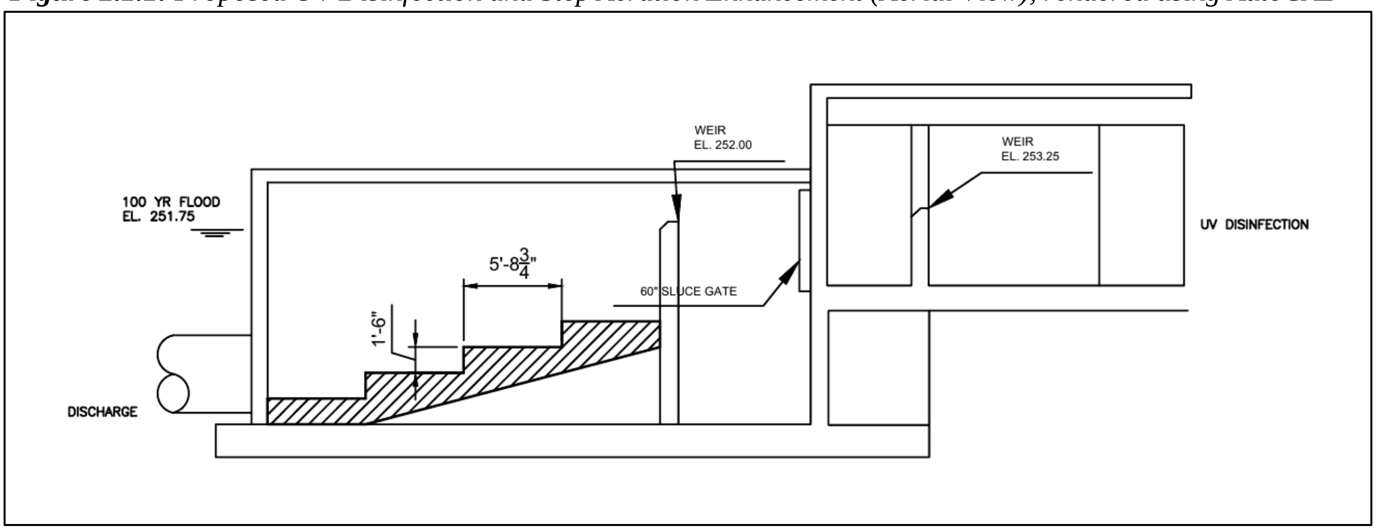


Figure 2.1.2: *Proposed Step Aeration Enhancement (Section View), rendered using AutoCAD*

2.2 Plant Hydraulic Profile

The proposed TWWTP hydraulic profile is shown in Figure 2.2.1. The hydraulic profile shows the ground elevation, and the HGL (also referred to as HWL) at each process unit in the plant. Figure 2.2.1 also notes the elevation of the 100-year flood mark. After the main bar screens, an influent pump brings water to the grit chambers. After the grit chambers, gravity carries the flow to the in-line EQ basin. The EQ basin effluent is pumped to the BNR flow distribution box. The pumping requirements were calculated using the Hazen-Williams equation to evaluate head loss. The flow then moves through the plant via gravity until it discharges into Northeast

Creek, at a HGL of 240 feet. There are additional pumps for the RAS and WAS lines.

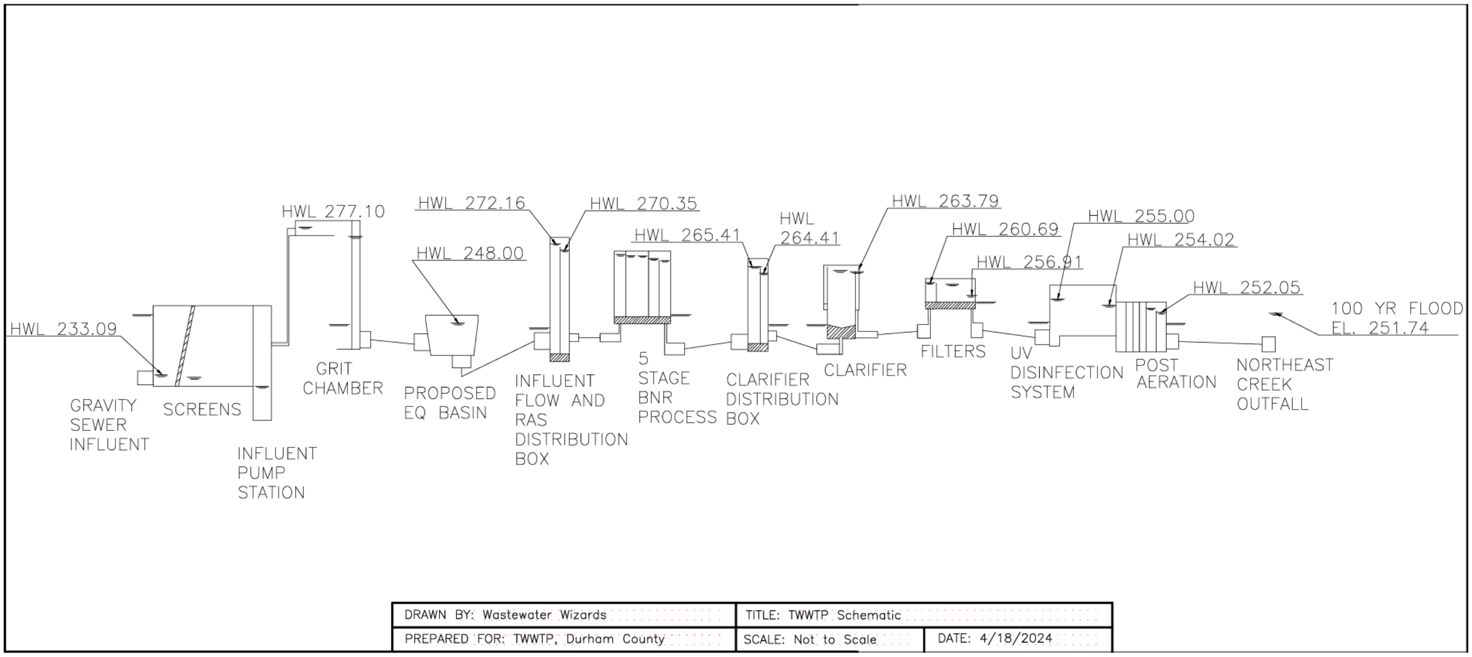


Figure 2.2.1: *TWWTP Hydraulic Schematic, rendered using AutoCAD*

2.3 Design Priorities

Priorities outlined by the plant operators include equalization of the flow to TWWTP, uniformity of treatment processes, and upgrades to the UV disinfection system. The team designed with these priorities in mind while considering the results of GPS-X modeling, cost estimations and evaluation of design alternatives. Alternatives were explored, such as finding more reliable equipment manufacturers and splitting the UV treatment train in two for increased redundancy.

2.4 Equalization Basin

2.4.1 Equalization Effects

To address concerns regarding irregular flow from industrial sources, an in-line flow equalization basin will be implemented as a part of the design. Equalization basins are typically located between secondary treatment processes and the headworks of the plant to minimize the amount of large influent solids, as well as reduce the amount of sludge and scum accumulating inside the tank. In-line flow equalization dampens influent flow and BOD spikes by having all influent flow pass through a mixed basin before being discharged to downstream treatment processes. The effect of this mechanism is illustrated in Figure 2.4.1 below.

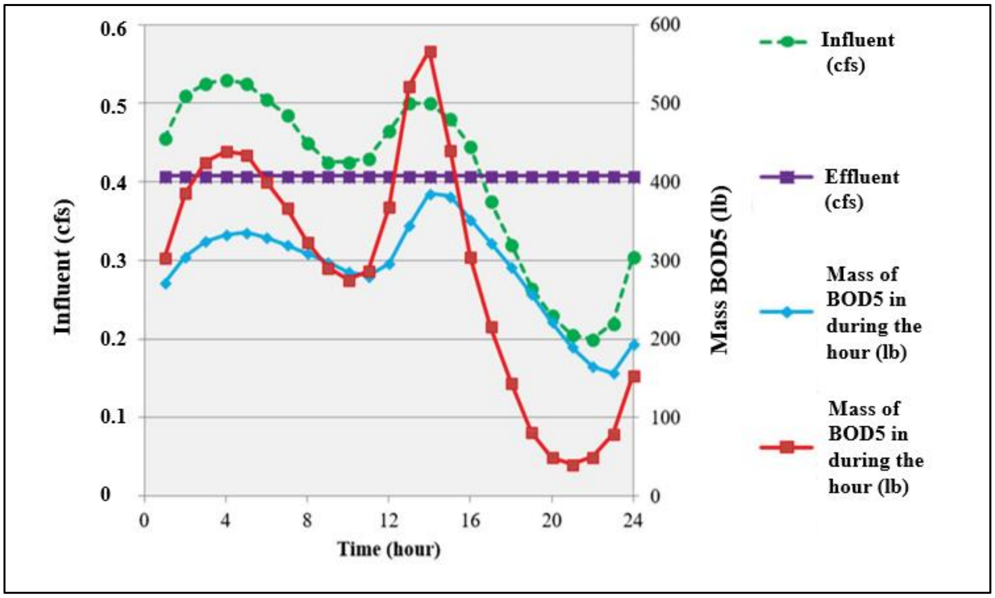


Figure 2.4.1: *Effects of Flow Equalization on BOD Loading*

In addition to leveling out the flow to the rest of the plant, the BOD loading is also evened out. The benefits of this are twofold: first, spikes in BOD loading are prevented, ensuring high influent BOD does not break through treatment and end up in effluent. Second, removing low points in the flow and BOD loading will ensure that BOD-dependent processes such as denitrification are not impacted by these troughs. This increase in consistency will also make it easier to implement future process upgrades, due to the reduced amount of uncertainty involved in sizing those processes.

2.4.2 Basin Selection

The decommissioned aeration basin located in the north of TWWTP would be the basin used for equalization. It has a capacity of roughly 3.5 MG, which is more than needed for current flows. However, flow can be modulated from the basin to ensure a certain fill level is always met. This option was chosen over construction of a new basin on the lagoon, which would be filled in. This choice is due to the large capital investment in brand new infrastructure, but also the uncertainty that would come from filling the lagoon. The composition of the lagoon bed is unknown, and the costs incurred from dredging out the lagoon to fill it in are likely far more than what is allocated for that portion of the project. As a result, it was found to be more cost-effective and less resource demanding to route flow over to the abandoned aeration basin and pump it back up to the BNR distribution box.

2.4.3 Basin Mixing and Blower Selection

A key part of using an equalization basin is the mixing of said basin. Not only does proper mixing keep sediments suspended so they don't build up on the bottom of the basin, but it also prevents odor buildup. Without mixing, sulfide gases such as hydrogen sulfide will be produced through anaerobic breakdown of BOD. To solve this, the basin would be mixed using an array of twelve air-powered mixers, such as the IXOM AP7000. Mixers such as these would sit on the bottom of the basin and release air upward to produce circulation in the basin, as illustrated in Figure 2.4.2. These air-powered mixers would also increase the dissolved oxygen levels of the influent, further inhibiting anaerobic processes. This mixing would alleviate odor issues, rendering a cover unnecessary.

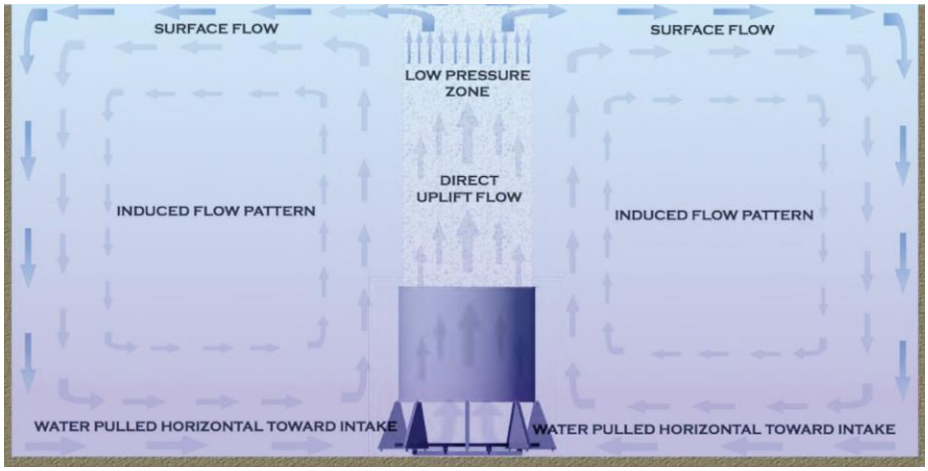


Figure 2.4.2: *Illustration of IXOM AP7000 Mixing Mechanism*

The array of 12 IXOM AP7000 air mixers would have their air supplied by a series of four blowers such as the Roots 36 URAI blowers, operating in a 3+1 configuration. At any point of operation, a maximum of three blowers would be on at once with one left on standby. These could be used in rotation to increase the amount of time needed between maintenance as well as reduce individual wear on each motor. Each blower would be powered by a 10 HP motor equipped with a VFD drive. At most times these blowers would be running at a fraction of their maximum capacity, since the power required to mix the basin is dependent on the fill depth of the basin. This turndown of the blowers would not only save power, but further reduce maintenance requirements.

2.4.4 Rehabilitation

The abandoned aeration basin will need rehabilitation before it can be utilized as an equalization basin. It has not been in use since it was decommissioned in 2001 and has likely suffered damage, visible or otherwise. Room in the budget has been allotted for the inspection and rehabilitation of the basin, as well as the decommissioning of the old mixing equipment in place. This equipment is neither in use nor powered, so it currently serves no purpose. The platforms in place will be rehabilitated for use if possible since they will likely help with basin maintenance. Lastly, the old effluent system will be removed, since the basin's effluent will be pumped out from the bottom of the basin.

2.4.5 Effluent Pumping

Finally, a submersible pump would be used to pump effluent to the BNR distribution box. From the elevation of the bottom of the basin to the box, accounting for friction and minor losses in the piping along the way, roughly 36 feet of head is needed to pump the water where it needs to go. This would be supplied by three submersible pumps, like Grundfos S2 80HP, located on the bottom of the basin, which will operate in a 2+1 configuration. This pump's flow would be modulated to ensure the basin maintains a minimum fill level of 4 feet and a maximum fill level of 14 feet. Effluent flow from the basin should average roughly 4-6 MGD during typical days.

2.4.6 BNR Aeration System Upgrades

The existing aeration system for the three BNR treatment trains is an inconsistent mixture of diffuse and surface aeration. Treatment trains 1 and 3 both utilize surface aeration equipped with VFDs. Both surface aeration systems have been replaced in recent years. In 2019, the existing rotor surface aerators were replaced with two 125 hp rotary lobe blowers and two fine bubble diffuse aeration grids were installed. The diffuse aeration grids were installed near the center of the oxidation ditch on both sides of the ditch. The placement of the aeration grid near internal recycle pump is concerning to plant operators because it has caused aerated wastewater to be recycled to the primary anoxic zone hindering nitrification.

Upgrades to the aeration system include the addition of one large aeration grid to the opposite oxidation ditch 1 and 3 to lower energy costs and increase efficiency of oxygen transfer. The diffusers in oxidation ditch 2 will also be replaced to maintain consistency throughout the process, which is something plant employees requested. The Standard Cubic Foot per Minute (SCFM) was calculated to be about 4,000 per TT. The estimate is using 9-inch 270AFD disc diffusers from a company called SSI, this or a similar piece of equipment could be used. Each diffuser can push 3 cubic feet per minute but is rated for 2 cfm. Thus, we expect to need 2,000 diffusers per treatment train. The calculations are further explored in Appendix D and placement is shown in Appendix Figure D.1. To meet the total air requirements for the new blowers. Four new 260 hp pd blowers would be installed with VFDs. The VFDs would help save power costs and wear on the blowers so they can operate when needed. Plant staff conveyed that the current standby generation capacity would be enough to meet the electrical demand of the blowers.

3. Design Solution

3.1 Recommendation Determination

3.1.1 Envision Analysis

In the process of evaluating the design alternatives, an Envision analysis was conducted on each of the design alternatives to evaluate areas where more sustainable decisions could be made, as well as analyse the sustainability and community impacts of the design. In the process of doing so, it was found that each of the design alternatives had roughly the same Envision rating. Due to the decision to not fill in the lagoon for construction of the equalization basin, environmental impacts were minimized across all alternatives. After conducting an Envision analysis on the final design of the plant, a rating of Envision Verified was achieved, with many points coming from the Natural World category due to the plant's increased efficiency and the impact that that prevents. The distribution of these points is illustrated in Figure 3.1.1. As a result of the Envision rating being the same between design alternatives, it is not a deciding factor between alternatives.

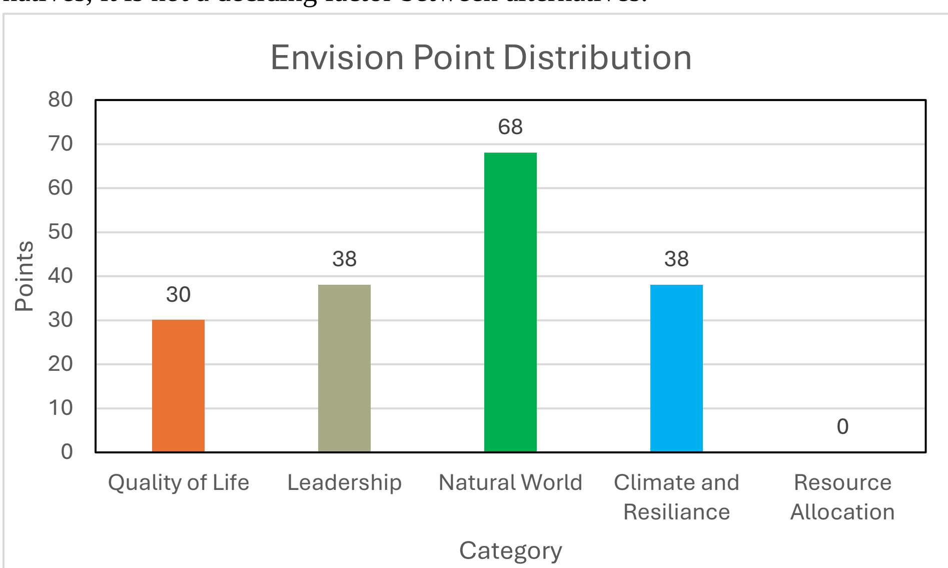


Figure 3.1.1: Envision Point Distribution

3.1.2 Decision Matrix

Alternatives were scored from 1-3 based on how each alternative ranks against the others in each category (with 3 being the most positive impact, and 1 being the least positive impact). Each category is weighted based on priority. BOD removal is the top priority, so it has a weight factor of 3. AACE cost lifecycle analysis and staff priorities have a weight factor of 2. Lastly, the Envision rating and maintenance have a weight factor of 1, because the construction will stay within the plant site and likely won't have much impact on its surroundings. The alternative with the highest score was chosen. The highest possible score is 30.

BOD removal efficiency is judged based on how well that design alternative removes BOD comparatively. The EQ basin received a score of 1 because the basin serves mainly to homogenize flow rather than perform nutrient removal. The diffuse aeration aids in removal of BOD but both uniformity of BOD loading provided by the EQ basin and diffuse aeration would offer the most efficient BOD removal, earning diffuse aeration a score of 2 and alternative with both diffuse air and EQ basin a score of 3. The cost ratings were assigned based on the most expensive alternative to least expensive. In descending order, utilizing both the EQ basin and the diffuse aeration, EQ basin only, and diffuse air only. Staff priorities were determined by discussions with staff including the plant superintendent, and maintenance staff. Considering their opinions regarding plant operations, the points were awarded as seen below in Table 3.1.1. The Envision rating points were uniform across all design alternatives. Each alternative was scored in Envision and all three received the same rating of Envision Verified. Finally, maintenance points were given according to the demands of each design alternative, utilizing both the EQ basin and the diffuse aeration requiring the most maintenance (a score of 1), and the diffuse air requiring the least maintenance, (a score of 3), leaving EQ basin with a score of 2.

The final scores are as follows: EQ basin only, a score of 16, diffuse aeration only, a score of 18, and both diffuse aeration and an EQ basin, a score of 20. As the design alternative utilizing both technologies scored the highest, this team chose to move forward with this design.

Table 3.1.1: *Decision Matrix*

	Weight Factor	EQ Basin	Diffuse Aeration	Both
BOD Removal Efficiency	3	1	2	3
AACE Class 3 Cost Opinion	2	2	3	1
Staff Priorities	2	2	1	3
ENVISION Rating	1	2	2	2
Maintenance	1	3	2	1
Final Scores:		16	18	20

3.2 Modeling

3.2.1 Modeling in GPS-X

A model was created using Hydromantis GPS-X software to simulate the treatment process at TWWTP to date (Appendix Figure E.1). Average daily flow, design flow and peak daily flow were simulated using this plant model to assess BOD, ammonia, and phosphorous removal efficiency. The model showed an inability for the current process to meet peak oxygen demands for BOD and ammonia removal at 12 MGD and above in accordance with permit limits. The results are shown in Appendix Figure E.2.

The model was updated to reflect the proposed upgrades including capacity for additional oxygen supply and the inclusion of the equalization basin. Identical simulations were run for average, design, and max daily flows. These simulations demonstrated the ability of our proposed upgrades to meet permit requirements. The results are shown in Appendix Figure E.3.

3.2.2 Modeling in AutoCAD

In addition to modeling in GPS-X, AutoCAD models have been rendered. Modeling in AutoCAD enables a better understanding of flow schematics, equipment operations, and aids in construction planning and sequencing. Models of the current headworks, BNR trains, secondary clarifiers, filtration, UV disinfection, and post aeration have been modeled in detail, as shown in Appendix Figures H.1-5. The entire plant schematic has been laid out for visualization of space for construction as seen in Appendix Figure H.6.

3.3 Cost Analysis

3.3.1 Cost Overview

This project was given a $30 million dollar budget, not including engineering fees. An opinion of probable construction cost (OPCC) was produced. Additionally, an AACE class 3 estimate for the alternatives was performed. The capital cost values were collected from quotes from manufacturers for equipment options. Tables 3.3.1 and 3.3.2 contain the percentages of capital cost per item and total overall cost respectively that were used to estimate the OPCC. The estimates for these cost percentages provided from Dr. Michael Wang of Hazen and Sawyer based on recent similar construction cost.

Table 3.3.1: *Capital Cost Percentages*

Cost Percentages	
Cost Item	**Percentage of Item Capital Cost**
Construction Cost	25
Electrical Equipment	15
Instrumentation and Controls	12

Table 3.3.2: *Total Cost Percentages*

Cost Percentages	
Cost Item	**Percentage of Total Cost**
General Conditions	25
Contractor Overhead and Profit	15
Bonds and Insurance	12
Contingency	30

3.3.1 Total Cost Analysis

Using the cost percentages above, a total cost analysis was conducted. Not every category includes all the capital cost percentages. The items that do not include these estimates already include those totals in the quote, or do not need electrical and instrumentation. If the quote was unclear for an item, it was assumed that all three of the capital cost percentages applied. Volumes and square footage for pricing were calculated from measurement estimations using AutoCAD. Appendix Table F.1 shows all the items that are being proposed. This chart includes all capital costs, construction costs, electrical, and instrument costs. Table 3.3.3 below shows the predicted cost of the project. This figure includes general conditions, overhead, bonds and insurance, and contingency. The cost of the project comes out to about $28 million. This is slightly under the $30 million budget.

Item	Amount
Materials and Subtotals	$17,811,000
General Conditions	$890,000
Contractors and Overhead	$2,672,000
Bonds	$890,000
Contingency	$5,343,000
Opinion of Probable Construction Cost (OPCC)	**$27,600,000**

Table 3.3.3: *OPCC for TWWTP rehabilitation and upgrades*

3.3.3 AACE-III 20 yr Analysis

A key metric for any new system is how the system will cost over the course of its life span. For this project, a class 3 AACE 20-year cost estimate was conducted. All the costs have been converted back into 2024 dollars using a 3% estimated inflation rate. Additionally, 80% efficiency was assumed for all pumps and blowers. The calculations were only done on the two different BOD reduction alternatives, being the equalization basin and then the diffuse aerators in the BNR. The analysis considered the power consumption of each of the blower and pumps in both the alternatives. It is assumed all the physical structures and equipment will not need to be replaced during this time. Any instruments and controls are assumed to be of minor energy use. The energy cost was derived from an average of plant energy consumption data which can be found in Appendix F. This came out to be an average cost of 0.0471 $/kWh.

The main cost for the equalization basin is the two 80 HP pumps and the three 10 HP blowers for the air mixer. Over 20 years, the life cycle cost for this alternative was $2.4 million. The main cost for the diffuse air system is the blowers that provide the air for the system. The life cycle cost for this alternative is $1.5 million. Table 3.3.4 shows the total cost of the parts of the proposed project that were requested. The total cost is just over $30 million.

Table 3.3.4: *Life Cycle Cost and Capital Cost (In Millions, 2024 Dollars)*

	Cost
Initial Cost	27.6
Life Cycle Cost	3.9
Total Cost	31.5

3.4 Construction

3.4.1 Sequence/MOPO

The construction sequence is based on priority of the proposed upgraded and new facilities as discussed in Section 1.3. The sequence is broken down into five phases, moving from the front of the plant to the end, (Appendix Figure G.1). By starting upgrades with the headworks, strain is taken off the secondary and tertiary treatment prior to renovations. The sequence was developed with maintenance of plant operations (MOPO) in mind, ensuring there is no disruption to the flow capacity the plant can treat.

Phase 1 – The Headworks Phase

Screens (2) would be replaced, one at a time, followed by each compactor. Each old screen is rated for 18 MGD as well as each new screen. Odor control (1) would be replaced. Flow is not impacted by the replacement. Grit chambers (2) and classifier (1) would be replaced, each grit chamber one at a time. Flow would not be impacted by classifier replacement. While installing the new grit chambers, connections for piping to the EQ basin would be installed. When the first grit chamber is taken offline, a junction gate would be installed. This would allow the flow to be directed to the new EQ basin, or the old path straight to the BNR. When the second grit chamber goes offline flow would go through the new grit chamber to the BNR. The second chamber would be connected to the pipe that was laid when the first chamber was taken offline. Flow would be able to continue to the BNR until the EQ basin is ready.

Phase 2 – The Equalization Basin Phase

The abandoned aeration basin would be emptied to allow for maintenance and rehabilitation to occur. The old aerators would be removed. The pumps and jet air mixers would also be installed at this time. Land would be cleared, and piping would be laid. Influent pipe from the grit chambers and effluent pipe to the BNR splitter box. To ensure flow is uninterrupted, temporary piping would be necessary. The effluent pipe would be fitted with a tee with the bottom orifice plugged and temporary piping connected at the perpendicular orifice. The temporary pipe would outfall over the BNR splitter box to be distributed. The flow would be moved from the old headworks effluent pipe to the EQ basin effluent and the plugged end of the tee would be connected to the old pipework. Flow can resume in the permanent effluent pipe and the temporary pipe can be demolished.

Phase 3 – The BNR Phase

Because the plant typically utilizes two of the three BNR trains, one can be taken offline at a time for upgrades. The train would have the brush aerators removed, and the new diffusers and blowers would be installed along with the necessary piping and equipment. In Train 2, the existing diffusers would be removed instead of the brush aerators.

Phase 4 – The Filter Phase

Similarly to the BNR, four of the five filtration trains are in operation at a time. The offline train would be excavated, and new media and backwash components would be installed. The trains would be replaced one by one until the rehabilitation is complete. For construction, the roof of the filtration building would be removed, then replaced when the filter installation is complete.

Phase 5 – The UV Disinfection and Post Aeration Phase

To ensure MOPO, this phase is broken down into a sub-sequence of four phases. After phase 5 is completed, the roads will be repaved. A visualization can be seen in Appendix Figure G.2.

I. The existing blowers would be removed, and the platform demolished.
   A flow splitter would be constructed, splitting the one influent flow into two.

II. A second channel (Channel 2) would be constructed, and the Trojan Signa installed. Temporary piping would be constructed from Channel 2 to the outfall location into Northeast Creek.

III. Flow would be diverted from the existing channel (Channel 1) to Channel 2. In the aeration basin, the diffusors would be removed, and the baffles demolished. The existing weir would be demolished, and a new weir would be built. Step aeration would be constructed and a connection for Channel 2 to the basin would be added. In Channel 1, the existing UV disinfection unit would be removed and replaced with the Trojan Signa.

IV. Flow would be diverted to Channel 1.

The temporary piping would be removed, and the permanent piping would be installed to connect Channel 2 to the aeration basin.

3.4.2 Construction Sequence Timeline

Using estimations based on current projects a construction Gantt chart was developed. The timeline is an approximate representation of how long the rehabilitation of the plant will take. If the county applies for funding, then the project could be delayed further. The construction timeline is broken down into three different phases. The first phase, pre-construction, will last approximately one year. This includes design, permitting, and bidding. The next phase is the construction phase and includes mobilization plus all the construction phases outlined in section 12. Some of the phases can be completed at the same time. The construction phase will last approximately two years. The final phase is the post construction phase. It includes the final touches like training and inspection. The final phase will last about half a year and can start before the construction phase ends. The total project is expected to take about 3.5 years and is visually represented in Figure 3.4.1.

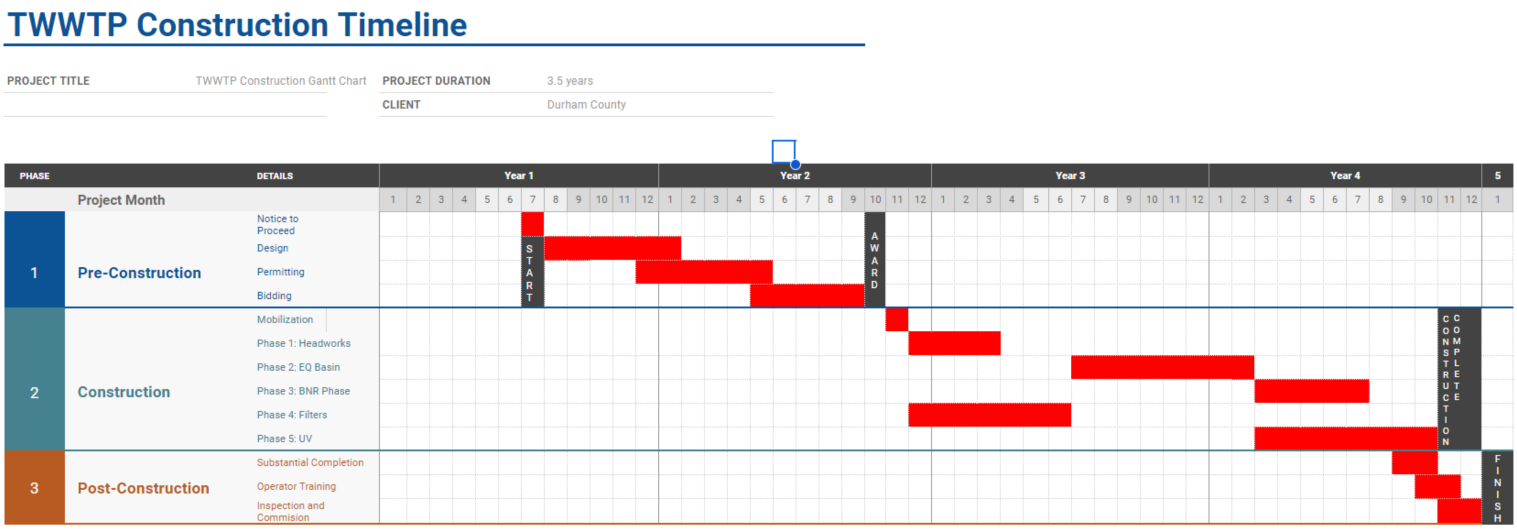


Figure 3.4.1: *TWWTP Construction Gantt Chart*

References

This report contains information from existing plant documents. These came from McKim and Creed, CDM Smith, Aquarius Technologies, and the North Carolina Department of Environmental Quality. The report also utilizes information from interviews and correspondence with manufacturers. These people are listed below:

TrojanUV- Bryan Wheeler, *EW2*
Screening- Austin Huskerson, *Heyward*
Filters- Greg Mahan, *Veolia*
Diffuse Air- Will Brower, *SSI*
Odor- Jonathan Bulla, North Cary Wastewater Treatment Plant
OPCC- Dr. Michael Wang, *Hazen and Sawyer*
Wade Shaw, Triangle Wastewater Treatment Plant

Design Resources included:

Design of Water Resource Recovery Facilities, 6th Edition, (2018). RSMeans green building cost data. (2010). Norwell, MA :RSMeans
Francis de los Reyes, Ph.D., BCEE
Michael Wang, Ph.D., PE, BCEE

Appendix

Appendix A: List of Acronyms

AACE: Association for the Advancement of Cost Engineering
AOR: Actual Oxygen Requirement
BNR: Biological Nutrient Removal
BOD: Biochemical Oxygen Demand
COF: Consequence of Failure
DIP: Ductile Iron Pipe
DMR: Discharge Monitoring Reports
DO: Dissolved Oxygen
EQ: Equalization
GPM: Gallons Per Minute
hp: Horsepower
MGD: Million Gallons Per Day
MLSS: Mixed Liquor Suspended Solids
NOD: Notice of Deficiency
NOV: Notice of Violation
NPDES: National Pollutant Discharge Elimination System
OPCC: Opinion of Probable Construction Cost
PER: Preliminary Engineering Report
POF: Probability of Failure
RAS: Return Activated Sludge
RPM: Revolutions Per Minute
SCFM: Standard Cubic Feet Per Minute
SOR: Standard Oxygen Requirement
TKN: Total Kjeldahl Nitrogen
TSS: Total Suspended Solids
TT: Treatment Train
TWWTP: Triangle Wastewater Treatment Plant
VFD: Variable Frequency Drive
WAS: Waste Activated Sludge

Appendix B: Flow Projections

B.1 Flow Projection Calculations

B.1.1 Residential Flows:

TWWTP is currently 25% residential flow, 75% industrial flow

Residential Flow in 2019: $5.10\ [MGD] \times 0.25 \left[\frac{residential\ flow}{total\ flow}\right] = 1.28[MGD]$

Residential flow in 2023: $6.16\ [MGD] \times 0.25 \left[\frac{residential\ flow}{total\ flow}\right] = 1.54[MGD]$

B.1.2 Growth Rate

Growth Rate (from 2019-2023): $r = \frac{\ln\left(\frac{F}{F_0}\right)}{t} = 4.6\%$

F = Current Flow (from year 2023) = 1.54[MGD]

F_0= Initial flow (from year 2019) = 1.28 [MGD]

r = Growth rate

t =time since 2019 (in years)

This means that historically, the TWWTP has ~ 5% growth rate

B.1.3 Flow Projection

$F = F_0 e^{rt} + c$

F = Projected Flow [MGD]

F_0= Initial residential flow (from year 2023) = 1.54 [MGD]

r = Growth rate (5%)

t = time since 2023 (in years)

c = constant industrial flow rate = $6.16[MGD] - 1.54[MGD] = 4.62[MGD]$

Table B.1: *Projected Flow Increase*

Year	Flow (MGD)
2019	5.10
2020	5.89
2021	5.91
2022	5.64
2023	6.16
2024	6.34
2025	6.43
2026	6.52
2027	6.62
2028	6.72
2029	6.83
2030	6.94
2031	7.06
2032	7.18
2033	7.32
2034	7.45
2035	7.60
2036	7.75
2037	7.91
2038	8.08
2039	8.26
2040	8.45
2041	8.64
2042	8.85
2043	9.06

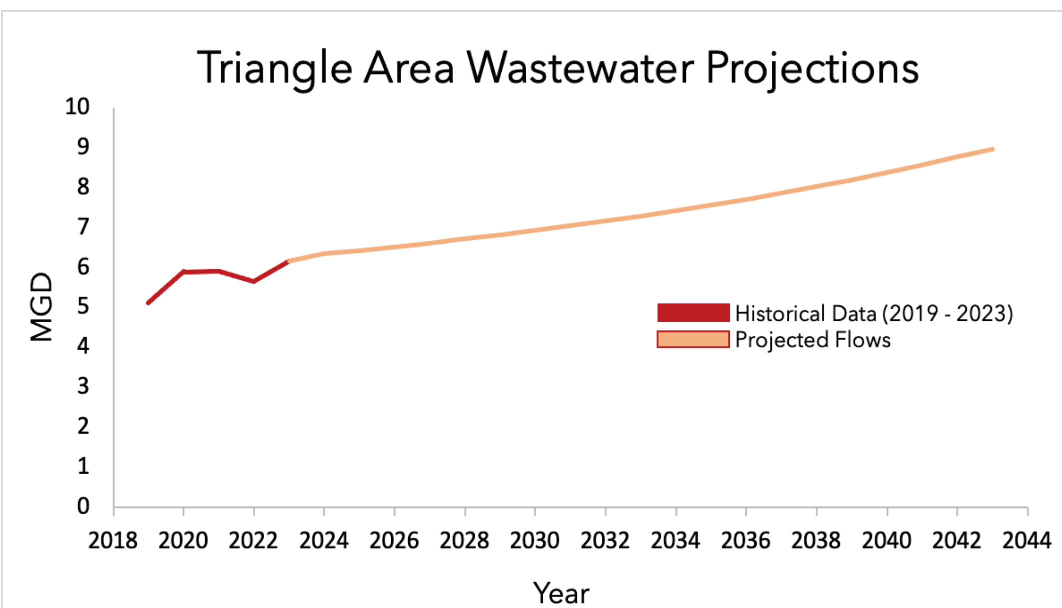


Figure B.1: *Wastewater Projection Trends*

Appendix C: DMR Data

Table C.1: *Example of given DMR data for May 2019*

DMR Data									
May-19									
Date	Influent Flow MGD	Influent BOD mg/l	Influent TSS mg/l	Influent Ammonia mg/l	Effluent Flow MGD	Effluent BOD mg/l	Effluent TSS mg/l	Effluent Ammonia mg/l	Effluent TKN mg/l
5/1/2019	10	195	344	25	4.77	<2.0	<2.5	<0.1	
5/2/2019	4.84				4.62				
5/3/2019	4.53				4.4				
5/4/2019	4.51				4.27				
5/5/2019	5.2				4.89				
5/6/2019	4.88	221	310	26	4.56	<2.0	<2.5	<0.1	
5/7/2019	4.8				4.25				
5/8/2019	4.86	229	400	28	3.97	<2.0	<2.5	<0.1	0.93
5/9/2019	4.65				3.93				
5/10/2019	4.66				3.78				
5/11/2019	4.47				3.85				
5/12/2019	4.63				3.76				
5/13/2019	6.05	195	276	21	4.41	<2.0	<2.5	0.4	
5/14/2019	5.36				4.06				0.9
5/15/2019	5.03	236	324	27	3.89	<2.0	<2.5	<0.1	
5/16/2019	4.69				3.78				
5/17/2019	4.64				3.88				
5/18/2019	3.98				3.6				
5/19/2019	4.29				3.68				
5/20/2019	4.7	189	280	29	3.89	<2.0	<2.5	<0.1	
5/21/2019	4.4				3.75				0.2
5/22/2019	4.63	342	404	32	3.69	<2.0	<2.5	<0.1	
5/23/2019	5.06				3.91				
5/24/2019	4.56				3.47				
5/25/2019	4.09				3.35				
5/26/2019	4.15				3.23				
5/27/2019	4.28	321	384	22	3.22	4.8	<2.5	<0.1	
5/28/2019	4.68				3.51				0.89
5/29/2019	4.72	193	292	26	3.46	<2.0	<2.5	<0.1	
5/30/2019	4.54				3.43				
5/31/2019	5.04				3.51				
Minimum	3.98	189	276	21	3.22	<2.0	<2.5	<0.1	0.2
Maximum	10	342	404	32	4.89	4.8	<2.5	0.4	0.93
Total	150.92	2,121.00	3,014.00	236	120.77	<4.8	<22.5	<0.4	2.92
Average	4.868	235.7	334.9	26.2	3.896	<0.5	<2.5	<0.0	0.73
Geo Mean	4.797	230.2	331.5	26	3.872	<1.2	<2.5	<0.9	0.62

Appendix D: Existing Treatment and Processes Specifications

Table D.1: *Existing Preliminary Treatment*

Screening Facilities	
Equipment	**Description**
Mechanical Screens	
No. Screens	2
Manufacturer	Andritz
Model No.	1500 ASC (Aqua-Screen)
Screen Type	Belt
Channel Width	4 ft – 11 in
Discharge Chute Height	31ft – 2 in
Screen Opening	0.25 in holes
Component Material	316 Stainless Steel
Screenings Conveyor	
No. Conveyors	1
Manufacturer	Jim Meyers & Sons
Type	Shafted Horizontal Screw Conveyer
Screenings Washer/Compactor[1]	
No. Washer/Compactors	1
Manufacturer	Andritz
Capacity	200 ft^3 /hr screenings, max. lump size 3 ½”
Discharge Chute Pipe Diameter	14”
Influent Pump Station	

No. Pumps	6 (2 – 60 hp, 4 – 200 hp)
Pump Type	Wetwell submersible
Manufacturer	Fairbanks
60 HP Pumps	
Model No.	D5731MV
Impeller Diameter	18.4-inch
Suction Flange Diameter	16-inch
Discharge Flange Diameter	16-inch
Pump Speed	900 RPM
Pump Capacity	8,300 gpm
Pump Rated Head (Feet)	63
Motor Voltage and Phase	460 V / 2 Phase
200 HP Pumps	
Model No.	D5434MV
Impeller Diameter	14.8-inch
Suction Flange Diameter	6-inch
Discharge Flange Dimeter	6-inch
Pump Speed	1,180 RPM
Pump Capacity	2,100 gpm
Pump Rated Head (feet)	67
Motor Voltage and Phase	460 V/3 Phase
Grit Removal	
Vortex Grit Removal	
No. Units	2(1 duty, 1 standby)
Manufacturer	Jones + Attwood
Model No.	Jeta Model 900
Peak Flow Rate	20 MGD (Each)
Grit Classifier	
No. units	1
Manufacturer	Jones + Attwood
Model No.	Model 450

1. Screenings washer/compactor is not currently installed.

Table D.2: *Existing Secondary Treatment*

BNR	
Equipment	**Description**
BNR Treatment Trains	
No. of Trains	3
Treatment Process	5-Stage Bardenpho
Manufacturer	Veolia/Kruger
Rated Capacity	4MGD (Each)
3-Cell Anaerobic Process	
No. Cells	3
Zone Dimensions	35' W x 15' L x 20.75' D
No. Submersible Mixers (Per Train)	3
Motor Horsepower	2.7 hp
2-Cell Primary Anoxic Process	
No. Cells	2
Zone Dimensions	35' W x 68' L x 20.75' D
No. Submersible Mixers (Per Train)	2
Motor Horsepower	6 hp
Oxidation Ditches	
No. Brush Aerators (Rotors) (Per Ditch)	4
Motor Horsepower	75 hp
No. Submersible Mixers (Per Ditch)	2
Motor Horsepower	7.4 hp
2-Cell Secondary Anoxic Process	
No. Cells	2
Zone Dimensions	35' W x 45' L x 20.75' D
No. Submersibles Mixers (per Train)	2
Motor Horsepower	6 hp
Secondary Clarifier	
No. Clarifiers	4
Manufacturer	Ovivo Enviroquip
Type	Rapid Sludge Removal – Suction Tube
Diameter	110 ft
Side Water Depth	16 ft
RAS/WAS Pump	
No. WAS Pumps	2

Type of Pumps	Screw submersible, centrifugal
Manufacturer	Heyward Gordon
Horsepower	10 hp
Suction Flange Diameter	6-inch
Discharge Flange Diameter	6-inch
Pump Capacity	350 gpm
Rated Head	49 ft
Motor Voltage and Phase	460 V /3 Phase
Drive	Variable Frequency
No. of RAS Pumps	4
Type of Pumps	Screw submersible, centrifugal
Manufacturer	Heyward Gordon
Horsepower	100 hp
Suction Flange Diameter	10-inch
Discharge Flange Diameter	10-inch
Pump Capacity	3,500 gpm
Rated Head	55 ft
Motor Voltage and Phase	460 V /3 Phase
Drive	Variable Frequency

Table D.3: *Existing Tertiary Treatment*

Traveling Bridge Filter	
Equipment	**Description**
Filters	
No. Filters	5
Type of Filter	Traveling Bridge, Automatic Backwash
Manufacturer	Ondeo Degremont Inc. (ODI)
Average Daily Flow (ADF)	12 MGD
Peak Hourly Flow (PHF)	30 MGD
Filter Bed Size (Each Filter)	16 ft x 87 ft
Effective Filter surface area (per Filter)	1,376 ft^2
Filtration Rate at ADF	2 gpm/ft^2 of cell area
Filtration Rate at PHF	5 gpm/ft^2 of cell area
TSS, max. Suspended Solids to Filter	20 mg/L
TSS, Effluent limit	5 mg/L
Backwash Pumps	
No. Backwash Pumps	5

Pump Capacity	20 gpm/ft^2 of cell area
Motor Horsepower	3 hp
Motor Voltage and Phase	480V / 3 Phase
Washwater Pumps	
No. Washwater Pumps	5
Pump Capacity	20 gpm/ft^2 of cell area
Motor Horsepower	3 hp
Motor Voltage and Phase	480 V / 3 Phase
UV Disinfection	
Manufacturer	TrojanUV
Model	4000
Configuration	Horizontal
Average Daily Flow (ADF)	12 MGD
Peak Hourly Flow (PHF)	36 MGD
UV Transmission (min)	60%
Max Mean Particle Size	30 microns
Influent E. Coli [1]	200,000 colonies/100ml
Effluent E. Coli [1]	200 colonies/100ml
No. Channels	1
Number of Modules	8 (4+4 in series)
No. of Lamps/Module	14
Total No. of Lamps	112
Length	29'-3"
Width 6'2"	6.04

1. 30-day geometric mean

Table D.4: *Existing Processing and Disposal Design*

Processing and Disposal	
Equipment	**Description**
WAS Feed Pumps	
No. Pumps	3
Type of Pump	Progressive Cavity
Manufacturer	Seepex
Motor Horsepower	15 hp
Pump Capacity	190 gpm
Rated Head	120 ft
Motor Voltage and Phase	460V / 3 Phase

Polymer System	
No. Units	3
Type of System	Liquid Metering
Manufacturer	Siemens PolyBlend
Water Capacity	10 gph
Polymer Capacity	1200 gph
Max. Working Pressure	100 psi
Centrifuges	
No. Centrifuges	3
Manufacturer	Alfa Laval
Type	ALDEC G2-70
Max. Solids Density	1.2 kg/dm3
Max. Bowl Speed	2900 rpm
Cake Pumps	
No. Pumps	3
Type of Pump	Progressive Cavity
Manufacturer	Seepex
Dry Solids Capacity	20-24%
Max. Working Pressure	200 psi
Motor Horsepower	20 hp
Motor Voltage and Phase	460V / 3 Phase
Lube Pumps	
No. Pumps	5
Type of Pumps	Progressive Cavity
Manufacturer	Seepex
Max. Working Pressure	250 psi
Motor Horsepower	0.5 hp
Motor Voltage and Phase	115V / 1 Phase

Appendix C: Equalization Basin Sizing

Time	Flow (MGD)	Flow per Time Period (MG)	Accumulation (MG)	Total Volume (MG)			
4/6/2024 8:58	3.303	0.0136	0.011	0.011		Outflow Rate	
4/6/2024 9:04	3.260	0.0135	-0.005	0.005		4.5	MGD
4/6/2024 9:09	3.475	0.0125	-0.004	0.002			
4/6/2024 9:15	3.346	0.0138	-0.005	-0.003			
4/6/2024 9:18	4.032	0.0084	-0.001	-0.004		Volume Needed	
4/6/2024 9:19	6.520	0.0033	0.001	-0.003		1.284	MG
4/6/2024 9:23	6.306	0.0163	0.005	0.002			
4/6/2024 9:28	6.391	0.0264	0.008	0.009			
4/6/2024 9:31	6.048	0.0094	0.002	0.012			
4/6/2024 9:37	5.920	0.0245	0.006	0.018			
4/6/2024 9:41	6.220	0.0192	0.005	0.023			
4/6/2024 9:46	6.177	0.0192	0.005	0.028			
4/6/2024 9:51	6.048	0.0218	0.006	0.034			
4/6/2024 9:57	6.692	0.0276	0.009	0.043			
4/6/2024 10:00	6.177	0.0159	0.004	0.047			
4/6/2024 10:04	6.434	0.0166	0.005	0.052			
4/6/2024 10:11	6.606	0.0307	0.010	0.062			
4/6/2024 10:11	6.606	0.0000	0.000	0.062			
4/6/2024 10:20	6.263	0.0388	0.011	0.073			
4/6/2024 10:27	3.432	0.0177	-0.006	0.067			
4/6/2024 10:30	5.662	0.0117	0.002	0.070			
4/6/2024 10:35	6.306	0.0196	0.006	0.075			
4/6/2024 10:41	5.877	0.0273	0.006	0.082			
4/6/2024 10:43	3.217	0.0034	-0.001	0.080			
4/6/2024 10:47	2.960	0.0076	-0.004	0.076			
4/6/2024 10:52	6.692	0.0242	0.008	0.084			
4/6/2024 10:58	5.147	0.0239	0.003	0.087			
4/6/2024 11:00	10.381	0.0108	0.006	0.094			
4/6/2024 11:04	6.563	0.0169	0.005	0.099			

Figure C.1: *Total Volumetric Flow for 4/6/2024*

Time	Flow (MGD)	Flow per Time Period (MG)	Accumulation (MG)	Total Volume (MG)			
4/7/2024 8:57	3.264	0.0252	0.022	0.022		Outflow Rate	
4/7/2024 9:08	9.233	0.0714	0.037	0.059		4.5	MGD
4/7/2024 9:13	3.178	0.0099	-0.004	0.055			
4/7/2024 9:17	3.049	0.0094	-0.004	0.050			
4/7/2024 9:22	4.724	0.0147	0.001	0.051		Volume Needed	
4/7/2024 9:26	11.166	0.0345	0.021	0.071		1.319	MG
4/7/2024 9:29	3.049	0.0063	-0.003	0.068			
4/7/2024 9:36	2.920	0.0136	-0.007	0.061			
4/7/2024 9:46	3.264	0.0219	-0.008	0.053			
4/7/2024 9:51	6.399	0.0231	0.007	0.060			
4/7/2024 9:57	6.012	0.0279	0.007	0.067			
4/7/2024 10:02	3.049	0.0094	-0.004	0.062			
4/7/2024 10:09	6.528	0.0304	0.009	0.072			
4/7/2024 10:12	6.270	0.0129	0.004	0.075			
4/7/2024 10:15	6.656	0.0172	0.006	0.081			
4/7/2024 10:22	6.270	0.0291	0.008	0.089			
4/7/2024 10:29	6.699	0.0346	0.011	0.100			
4/7/2024 10:33	6.442	0.0166	0.005	0.105			
4/7/2024 10:41	6.613	0.0375	0.012	0.117			
4/7/2024 10:46	6.399	0.0198	0.006	0.123			
4/7/2024 10:52	6.699	0.0276	0.009	0.132			
4/7/2024 10:58	6.270	0.0292	0.008	0.141			
4/7/2024 11:05	6.399	0.0297	0.009	0.149			
4/7/2024 11:10	3.779	0.0136	-0.003	0.147			
4/7/2024 11:14	3.178	0.0082	-0.003	0.143			
4/7/2024 11:20	6.313	0.0261	0.007	0.151			
4/7/2024 11:30	6.528	0.0437	0.014	0.164			
4/7/2024 11:36	6.399	0.0264	0.008	0.172			
4/7/2024 11:38	10.779	0.0166	0.010	0.182			

Figure C.2: *Total Volumetric Flow for 4/7/2024*

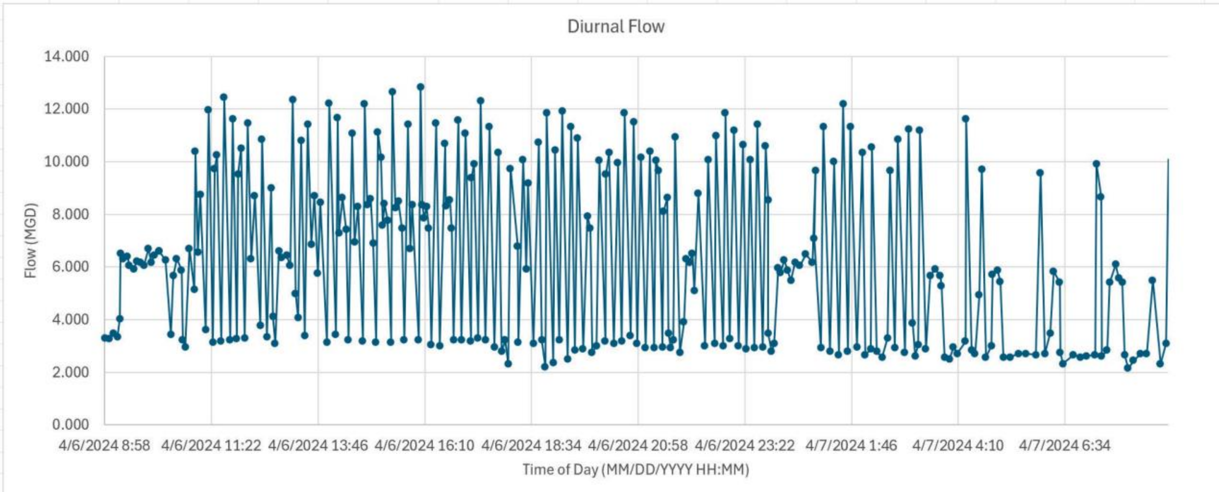


Figure C.3: *Diurnal Flow Pattern for 4/6/24 to 4/7/24*

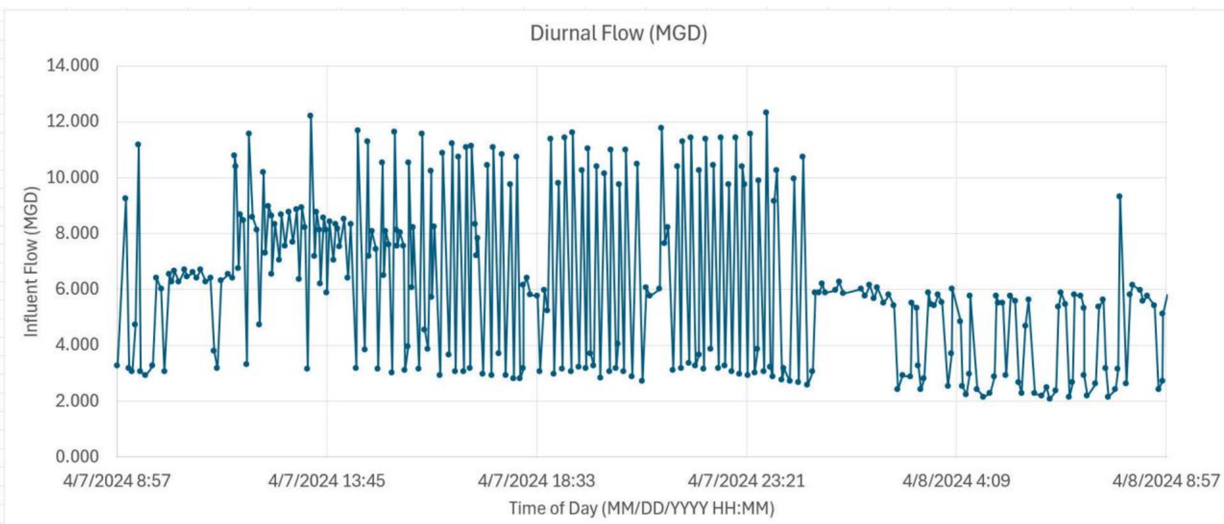


Figure C.4: *Diurnal Flow Pattern for 4/7/24 to 4/8/24*

Appendix D: BNR Oxygen Demand

D.1 Influent Loading

To identify the aeration needs for the all three trains of the BNR system, the BOD-5 and NH3-N average, design, and peak loadings need to be calculated. Average daily flow was determined based on given DMR data for the years 2019-2023. Design flow and peak day design flow were evaluated to identify maximum likely oxygen requirements. An additional flow of 5% was assumed from recycle. The values for BOD and NH3-N are averages of the maximum monthly influent concentrations to ensure system resilience.

Daily BOD_5 mass loading at average daily flow (Q = 7.91 MGD):

$$BOD_5 = 285 \frac{mg}{L} \cdot \frac{8.34 lb}{mg \cdot MG} = 20{,}800 \frac{lb}{day}$$

Ammonia average day mass loading:

$$NH_3 - N = 28 \frac{mg}{L} * 8.31 MGD * 8.34 \frac{lb}{(mg \cdot MG)} = 1{,}900 \frac{lb\ O_2}{day}$$

A summary of the calculated loadings is given in Table F.1.

Table D.1: *Influent at average, design, and peak daily flow.*

	Av. Daily Flow	Design Flow (Q)	Peak day (2*Q)
Flow	8.31 MGD	12.6 MGD	16.8 MGD
BOD5 concentration	285 mg/L	285 mg/L	285 mg/L
BOD5 mass loading	20,800 lb/day	30,000 lb/day	40,000 lb/day
NH3-N concentration	28 mg/L	28 mg/L	28 mg/L
NH3-N mass loading	1,900 lb/day	3000 lb/day	4,000 lb/day

Oxygen requirements for BOD and ammonia removal are 1.2 lb O_2 and 4.6 lb O_2 respectively. The ratio of AOR to SOR is typically 0.3-0.5 a value of 0.4 was used.

Actual oxygen requirement for BOD removal on average day:

$$AOR\ BOD = 20{,}800 \frac{lb}{day} * \frac{1\ day}{24\ hr} * \frac{1.2\ lb\ O_2}{1\ lb\ BOD} = 1040 \frac{lb\ O_2}{hr}$$

Actual oxygen requirement for ammonia removal on average day:

$$AOR\ NH3{-}N = 1{,}900 \frac{lb}{day} * \frac{1\ day}{24\ hr} * \frac{4.6\ lb\ O_2}{1\ lb\ NH3{-}N} = 370 \frac{lb\ O_2}{hr}$$

Standard oxygen requirement:

$$SOR = AOR * 1.6$$

Table D.2: *AOR and SOR at average, design, and peak daily flow.*

	Av. Daily Flow	Design Flow	Peak Day
AOR, lb O_2/hr	1,400	2,000	2,700
SOR, lb O_2/hr	2,300	3,300	4,400

To determine the airflow required from the blowers to meet the SOR, the SCFM must be calculated. The standard oxygen transfer efficiency for fine bubble diffuse aeration is 2.0-3.3%. The lower value of 2.0% and the typical water height of 17ft were used for this estimation.

The SCFM was estimated using the equation:

$$SCFM = \frac{SOR}{h * SOTE} * \frac{1\ lb\ air}{0.21\ lb\ O2} * \frac{12.076\ ft^3}{1\ lb\ air} * \frac{60\ min}{1\ hr}$$

A loading per diffuser of 0.5 – 2.5 SCFM is expected. Currently, treatment train 2 has 1440 diffusers installed giving it a maximum capacity of ~3,600 SCFM. Designing for peak day, we expect a design requirement of ~4,000 SCFM per TT. Thus, we expect to need 2,000 diffusers per treatment train.

Table D.3 *SCFM at average, design, and peak daily flow.*

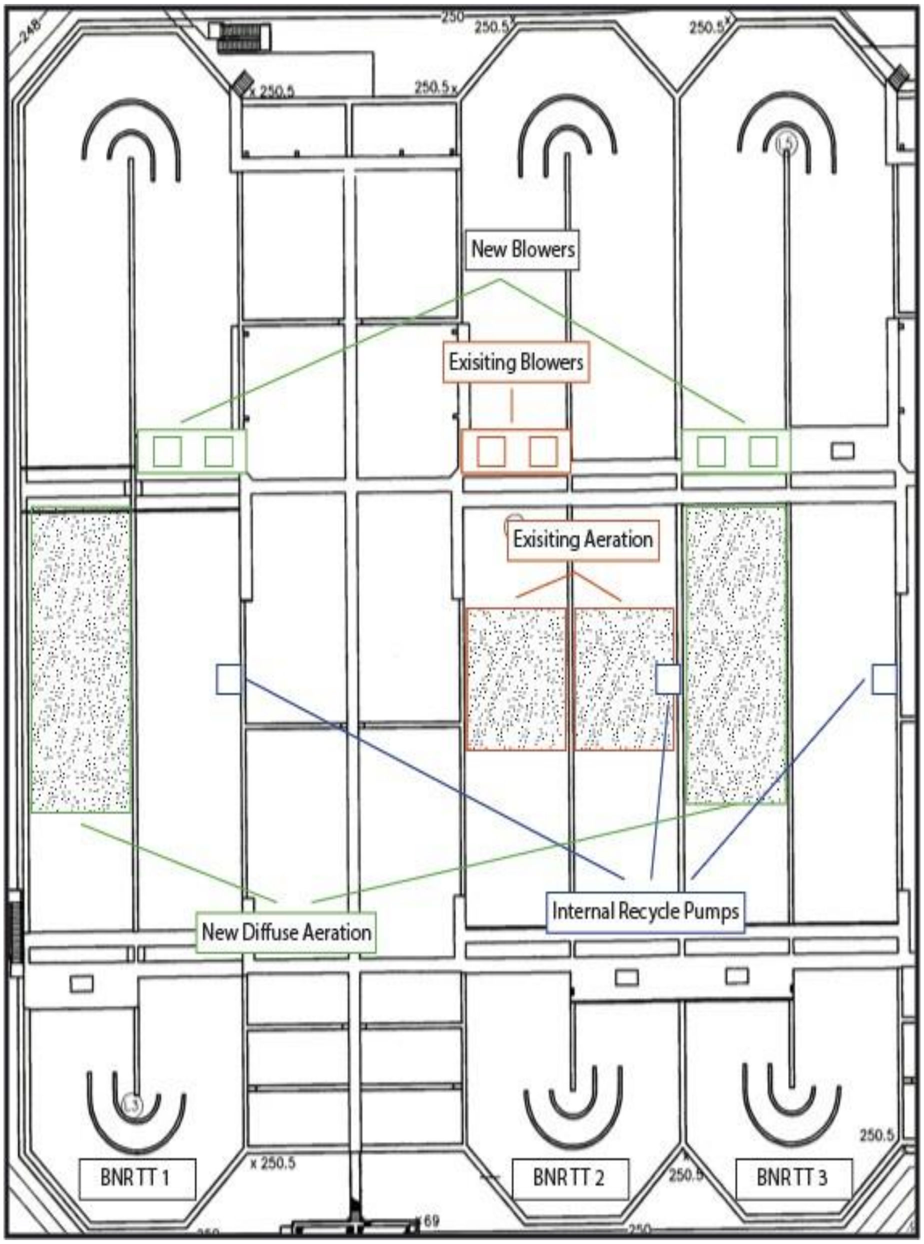
	Av. Daily Flow	Design Flow	Peak Day
Standard CFM ft^3/min	6,000	8,800	11,800
SCFM per TT (3 TT)	2,000	3,000	4,000
Req'd # Diffusers / TT (2 SCFM each)	1,000	1,500	2,000
Loading per diffuser (2000/TT)	1.0 SCFM	1.5 SCFM	2.0 SCFM

Currently, two 125 hp rotary lobe blowers rated for 1,500 SCFM each are installed to supply air to the 1,440 diffuse aerator pipes.

Table D.4*: Blower Comparison-PD*

	hp	kWh	SCFM
Installed Blowers (x2)	125 (ea.)	185	3,000
New PD Blowers (x4)	250 (ea.)	745	8,000
Total	1,250	930	12,000

Figure D.1*: Proposed BNR Aeration and Blower Placement*



Appendix E: GPS-X

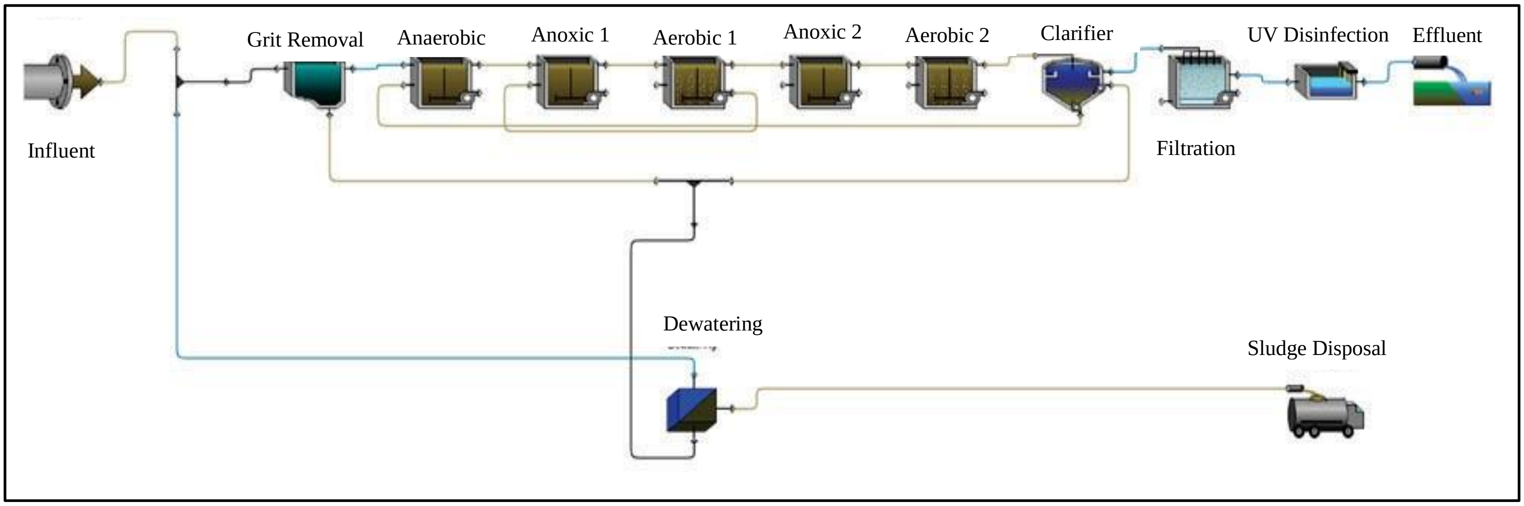


Figure E.1: *Current Process GPS-X Model*

Av. Flow			Design Flow			Max Daily Flow		
		46			46			46
Flow	MGD(US)	7.693	Flow	m3/d	44510	Flow	m3/d	59350
TSS	mg/L	0.01568	TSS	mg/L	0.1353	TSS	mg/L	0.191
VSS	mg/L	1.038e-05	VSS	mg/L	1.038e-05	VSS	mg/L	1.038e-05
cBOD5	mg/L	2.404	cBOD5	mg/L	13.62	cBOD5	mg/L	19.29
COD	mg/L	28.45	COD	mg/L	44.1	COD	mg/L	52.01
Ammonia N	mgN/L	0.8979	Ammonia N	mgN/L	10.28	Ammonia N	mgN/L	28.01
Nitrite N	mgN/L	0.6412	Nitrite N	mgN/L	0.6673	Nitrite N	mgN/L	0.001818
Nitrate N	mgN/L	2.446e-05	Nitrate N	mgN/L	1.188e-06	Nitrate N	mgN/L	1.001e-06
TKN	mgN/L	2.506	TKN	mgN/L	11.95	TKN	mgN/L	29.85
TN	mgN/L	3.171	TN	mgN/L	12.65	TN	mgN/L	29.86
Soluble PO4-P	mgP/L	0.3337	Soluble PO4-P	mgP/L	7.117	Soluble PO4-P	mgP/L	7.005
TP	mgP/L	0.5854	TP	mgP/L	7.388	TP	mgP/L	7.282
Total Alkalinity	mgCaCO3/L	51.97	Total Alkalinity	mgCaCO3/L	75.86	Total Alkalinity	mgCaCO3/L	81.28
pH	-	7.0	pH	-	7.0	pH	-	7.0
DO	mgO2/L	8.0	DO	mgO2/L	8.0	DO	mgO2/L	8.521

Figure E.2: *Current Process GPS-X Model Results*

Av. Flow			Design Flow			Max Daily Flow		
		46			46			46
Flow	m3/d	28820	Flow	m3/d	44060	Flow	m3/d	58750
TSS	mg/L	0.007232	TSS	mg/L	0.002755	TSS	mg/L	0.003419
VSS	mg/L	1.038e-05	VSS	mg/L	1.038e-05	VSS	mg/L	1.038e-05
cBOD5	mg/L	3.217	cBOD5	mg/L	3.76	cBOD5	mg/L	4.269
COD	mg/L	29.59	COD	mg/L	30.34	COD	mg/L	31.05
Ammonia N	mgN/L	0.3302	Ammonia N	mgN/L	0.7316	Ammonia N	mgN/L	1.64
Nitrite N	mgN/L	0.3309	Nitrite N	mgN/L	0.4923	Nitrite N	mgN/L	0.6477
Nitrate N	mgN/L	2.626e-06	Nitrate N	mgN/L	0.0061	Nitrate N	mgN/L	0.01436
TKN	mgN/L	2.441	TKN	mgN/L	2.896	TKN	mgN/L	3.844
TN	mgN/L	2.801	TN	mgN/L	3.416	TN	mgN/L	4.529
Soluble PO4-P	mgP/L	0.05469	Soluble PO4-P	mgP/L	0.06094	Soluble PO4-P	mgP/L	0.0677
TP	mgP/L	0.3058	TP	mgP/L	0.312	TP	mgP/L	0.3388
Total Alkalinity	mgCaCO3/L	28.71	Total Alkalinity	mgCaCO3/L	11.05	Total Alkalinity	mgCaCO3/L	13.76
pH	-	7.0	pH	-	7.0	pH	-	7.0
DO	mgO2/L	8.0	DO	mgO2/L	9.692	DO	mgO2/L	9.659

Figure E.3: *Upgraded Process GPS-X Model Result*

Appendix F: Cost and Power Analysis

F.1 Capital Cost

Table F.1: *Overview of Capital and Construction Cost*

Item	Capital ice Per Unit	Units Needed	l Capital Cost	struction Cost	Electric Equipment	Instrument and Control	TOTAL
Trojan UV SIGNA	$873,400	2	$1,746,800	$436,700	-	-	$2,183,500
NR Diffuse Air (per train)	$150,000	3	$450,000	$112,500	$67,500	$54,000	$684,000
Blowers	$100,000	4	$400,000	$100,000	$60,000	$48,000	$608,000
UV Channel Expansion (yd3)	$1,200	46	$55,200	$13,800	-	-	$69,000
UV Slab Expansion (yd3)	$800	50.5	$40,400	$10,100	-	-	$50,500
UV Temporary Piping (ft)	$1,000	300	$300,000	$75,000	-	-	$375,000
UV Step Aeration	$800	1156.4	$925,120	$231,280	-	-	$1,156,400
UV Platform Expansion (ft3)	$15	682	$10,230	$2,557	-	-	$12,787
EQ Mixer	$12,000	12	$144,000	$36,000	$21,600	$17,280	$218,880
EQ Air System	$12,00	4	$48,000	$12,000	$7,200	$5,760	$72,960
EQ Pumps	$200,000	1	$200,000	$50,000	$30,000	$24,000	$304,000
EQ Piping (ft)	$1,000	1600	$1,600,000	$400,000	-	-	$2,000,000
EQ Rehab Estimate	$50,000	1	$50,000	-	$7,500	$6,000	$63,500
Screens and Compactors	$400,000	2	$800,000	$500,000	-	-	$1,300,000
Grit	$4,000,000	1	$4,000,000	-	-	-	$4,000,000
Odor	$2,500,000	1	$2,500,000	-	-	-	$2,500,000
Roadway (sqr ft)	$22.50	15000	$337,500	-	-	-	$337,500
Filters	$1,500,000	1	$1,500,000	$375,000	-	-	$1,875,000

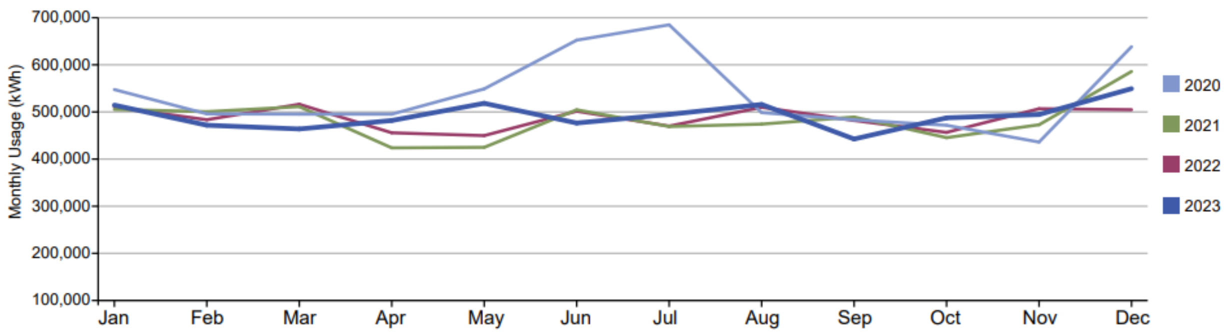
F.2 Power Cost

The total power usage and costs for 2023 are in the figures below. 2023 cost data was divided by the consumption data was used to get an average cost of 0.0471 $/kWh.

Building Monthly Electric Usage Report

TWWTP

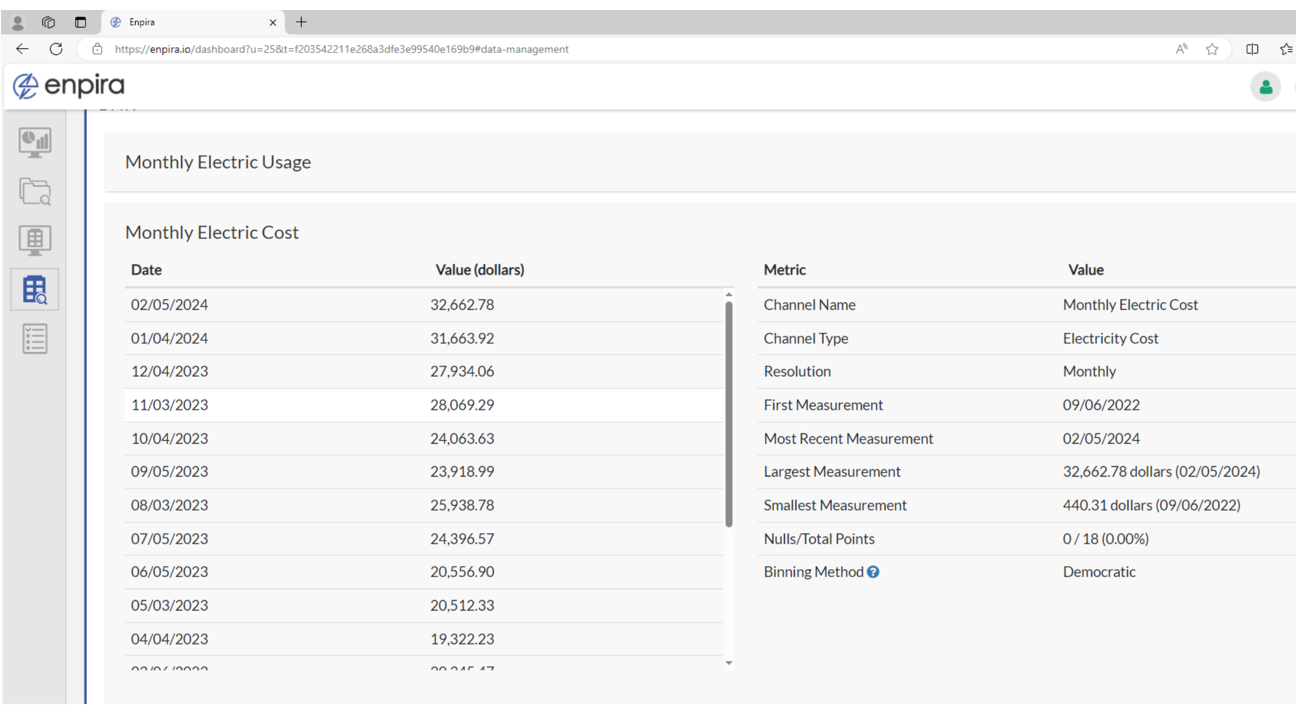
5926 NC Highway 55, Durham NC



Monthly Usage (kWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020	547,504	495,940	495,306	495,269	548,932	652,292	684,846	498,566	483,263	471,678	436,089	638,388
2021	505,384	500,545	511,215	423,815	424,872	504,569	469,038	474,185	489,188	445,452	472,790	585,833
2022	510,315	483,465	516,329	455,763	449,781	501,538	469,968	509,878	481,877	456,587	506,819	504,817
2023	514,531	471,847	463,897	481,819	518,364	476,489	494,759	515,903	442,564	487,467	494,568	549,357

Figure F.1: *Electric Usage Report Provided by Durham County*



Date	Value (dollars)
02/05/2024	32,662.78
01/04/2024	31,663.92
12/04/2023	27,934.06
11/03/2023	28,069.29
10/04/2023	24,063.63
09/05/2023	23,918.99
08/03/2023	25,938.78
07/05/2023	24,396.57
06/05/2023	20,556.90
05/03/2023	20,512.33
04/04/2023	19,322.23

Metric	Value
Channel Name	Monthly Electric Cost
Channel Type	Electricity Cost
Resolution	Monthly
First Measurement	09/06/2022
Most Recent Measurement	02/05/2024
Largest Measurement	32,662.78 dollars (02/05/2024)
Smallest Measurement	440.31 dollars (09/06/2022)
Nulls/Total Points	0 / 18 (0.00%)
Binning Method	Democratic

Figure F.2: *Monthly Electric Bill for November 2023*

Table F.2: *Electric Cost Breakdown by $/kWh*

Usage (kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2023	514,531	471,847	463,897	481,819	518,364	476,759	494,759	515,903	442,564	487,467	494,568	549,357
Cost ($)												
2023	-	-	-	-	$19,332.23	$20,512.33	$20,556.90	$24,396.57	$25,938.78	$23,918.99	$24,063.63	$28,069.29
Monthly $/kWh					$ 0.04	$ 0.04	$ 0.04	$ 0.05	$ 0.06	$ 0.05	$ 0.05	$ 0.05
Avg Cost ($/kWh)	$ 0.05											

Table F.3: *AACE 20-yr Life-Cycle Cost Analysis*

Diffuse Air		
Total Blower Output	8000	SCFM
Total Blower Power Usage	745	kWh
Avg SCFM Demand	2000	SCFM
Blower Power Usage	186.25	kWh
Efficiency	80	%
Run Time	24	h/d
	365	d/yr
Total:	8760	h/yr
Power Consumption:	2039437.5	kWh/yr
Power Cost	0.0471	$/kWh
Power Cost for Blowers	$ 96,057.51	$/yr
Estimated Inflation Rate	3%	
Year	Cost in 2024 Dollars	
1	$ 97,978.66	
2	$ 99,938.23	
3	$ 101,936.99	
4	$ 103,975.73	
5	$ 106,055.25	
6	$ 108,176.35	
7	$ 110,339.88	
8	$ 112,546.68	
9	$ 114,797.61	
10	$ 117,093.56	
11	$ 119,435.44	
12	$ 121,824.14	
13	$ 124,260.63	
14	$ 126,745.84	
15	$ 129,280.76	
16	$ 131,866.37	
17	$ 134,503.70	

18	$ 137,193.77
19	$ 139,937.65
20	$ 142,736.40
Total:	$ 2,380,623.65

Equalization Basin

Mixer Blower (ea)	10	HP
Mixer Blower (ea)	7.457121551	kW
Total	22.37136465	kW
Pumps (ea)	80	HP
Pumps (ea)	59.65697241	kW
Total	119.3139448	kW
Efficiency	80	%
Run Time	24	h/d
	365	d/yr
Total:	8760	h/yr
Power Consumption:	1306488	kWh/yr
	0.0471	$/kWh
Power Cost		
Total Cost	$ 61,535.57	
Estimated Inflation Rate	3%	

Year	**Cost in 2024 Dollars**
1	$ 62,766.28
2	$ 64,021.61
3	$ 65,302.04
4	$ 66,608.08
5	$ 67,940.24
6	$ 69,299.05
7	$ 70,685.03
8	$ 72,098.73
9	$ 73,540.70
10	$ 75,011.52
11	$ 76,511.75
12	$ 78,041.98
13	$ 79,602.82
14	$ 81,194.88
15	$ 82,818.78
16	$ 84,475.15
17	$ 86,164.65
18	$ 87,887.95
19	$ 89,645.71
20	$ 91,438.62
Total:	$ 1,525,055.56

Appendix G: Construction Sequence

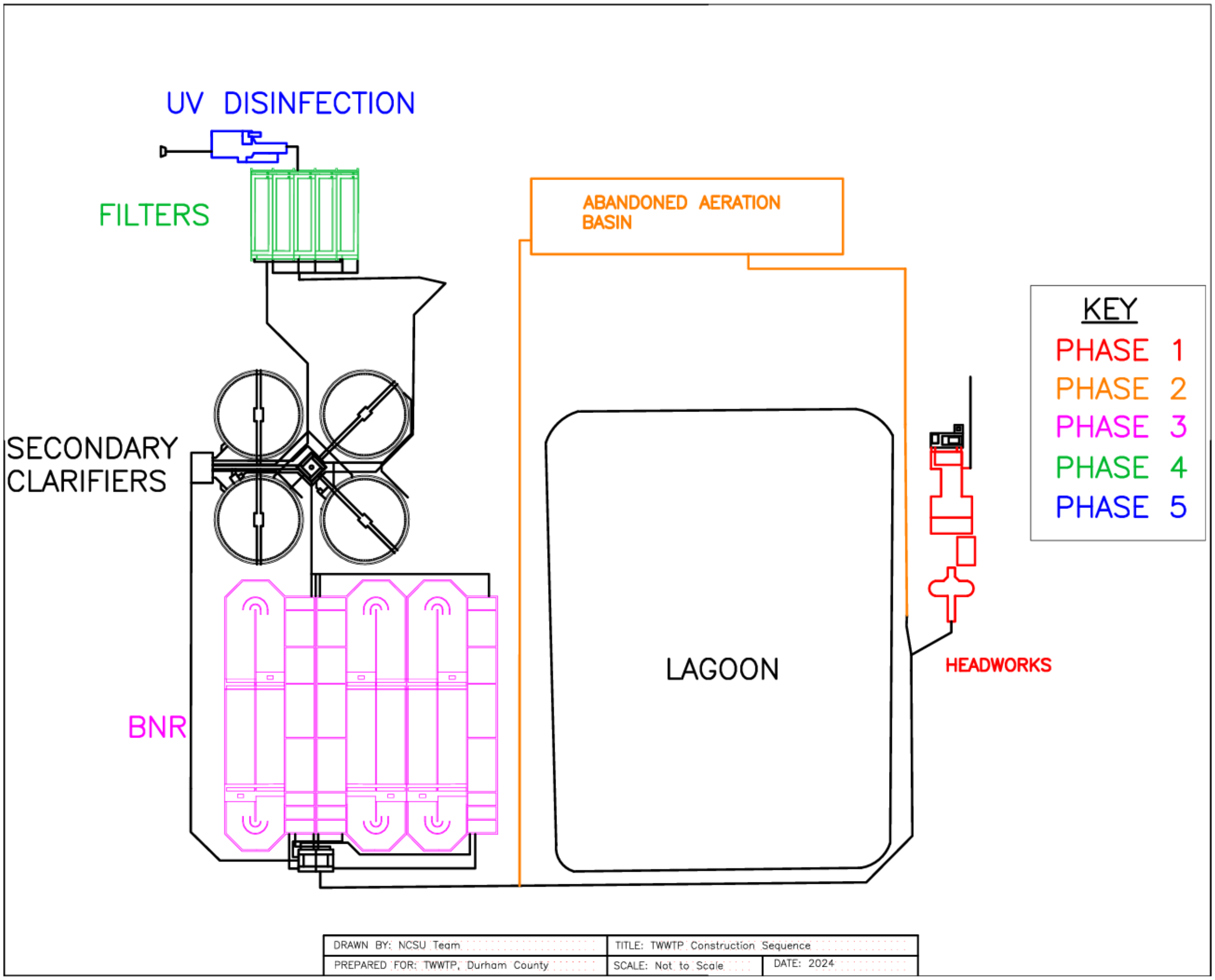


Figure G.1: *Construction Sequence Visualization, rendered in AutoCAD*

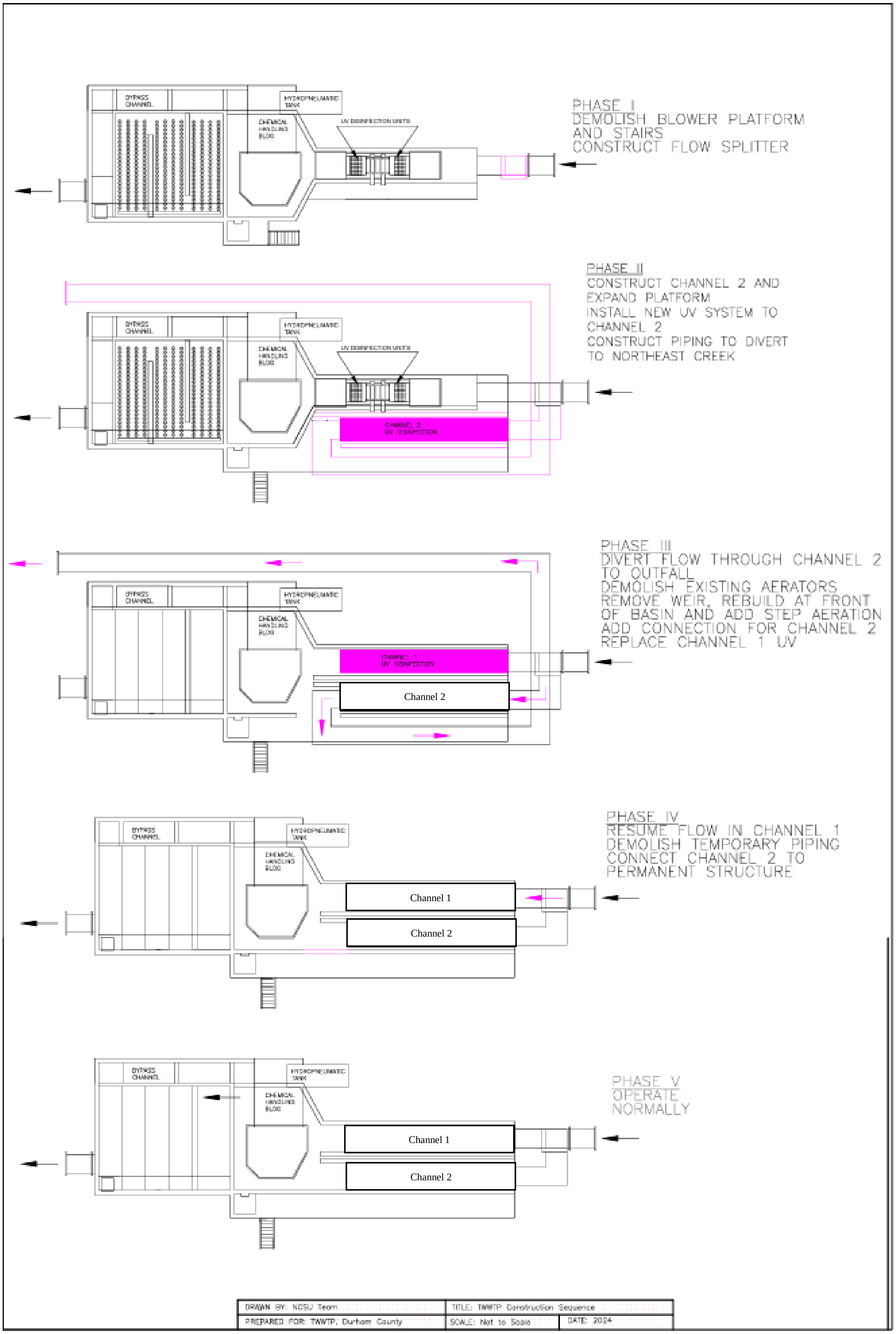


Figure G.2: *Construction Sequence Phase V (Changes shown in magenta), rendered using AutoCAD*

Appendix H: AutoCAD

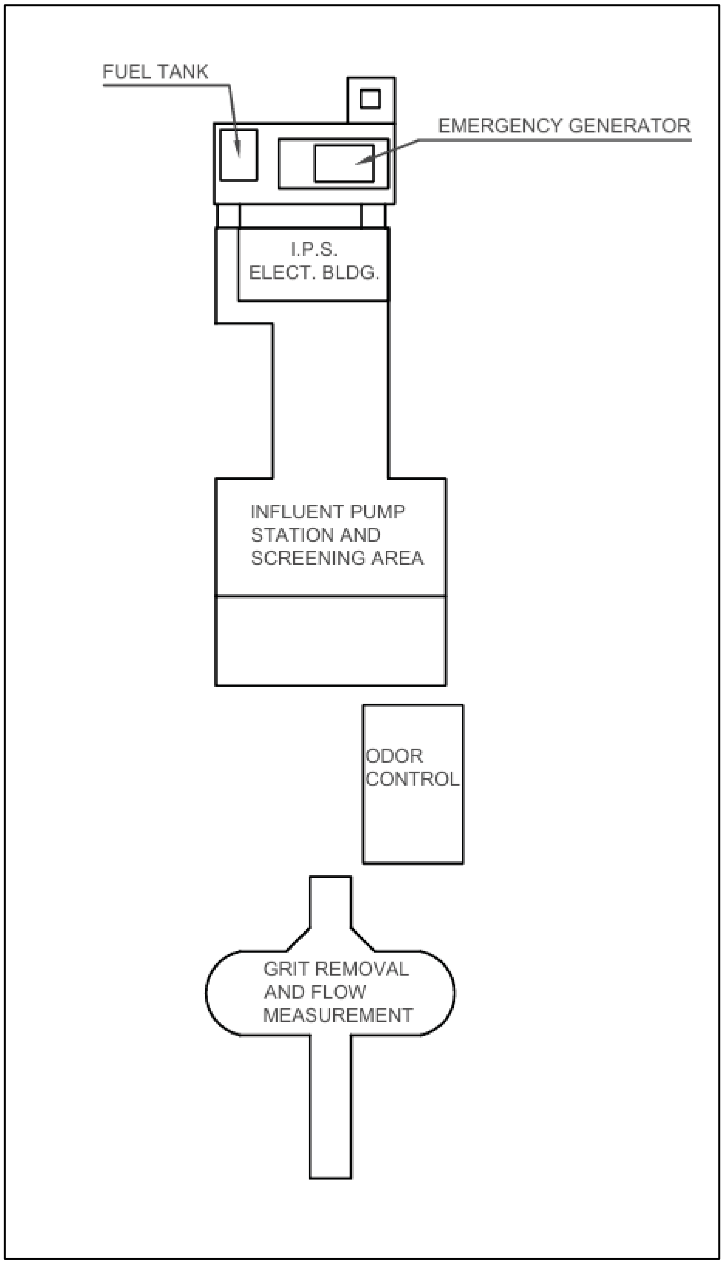


Figure H.1: *Headworks modeled with AutoCAD*

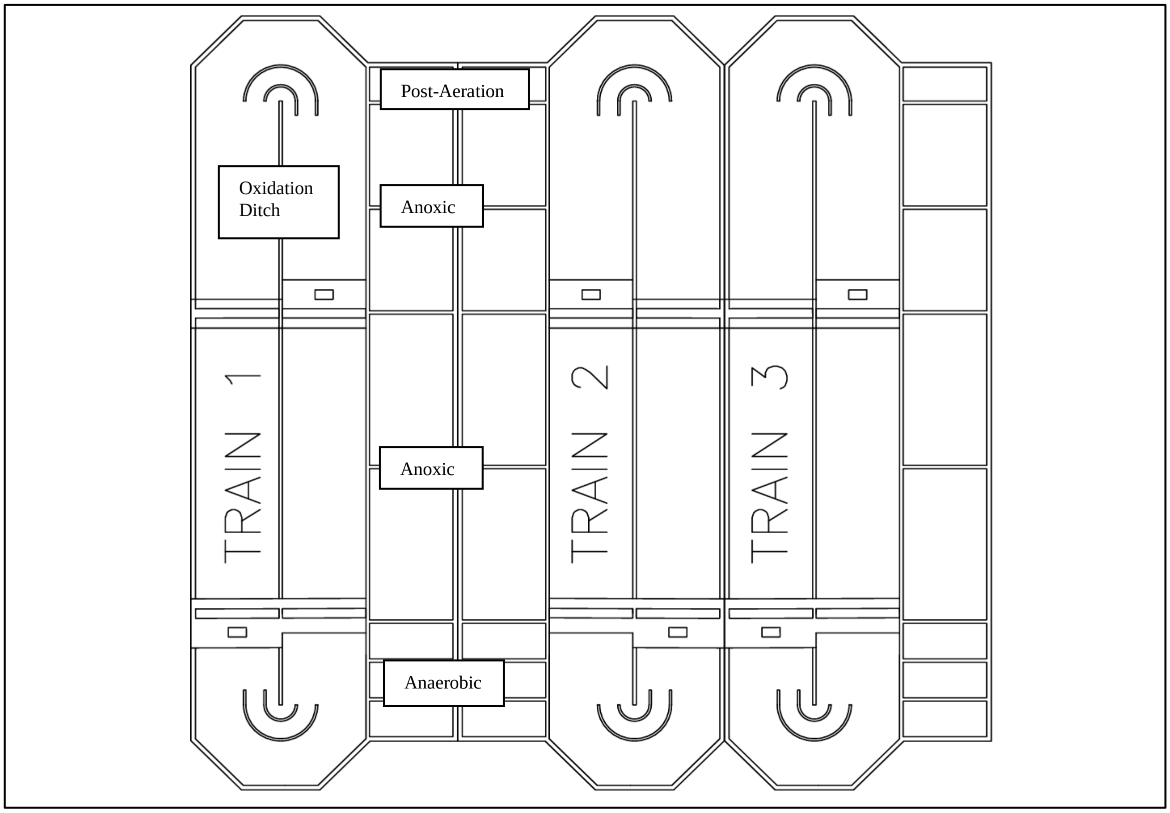


Figure H.2: *BNR modeled with AutoCAD*

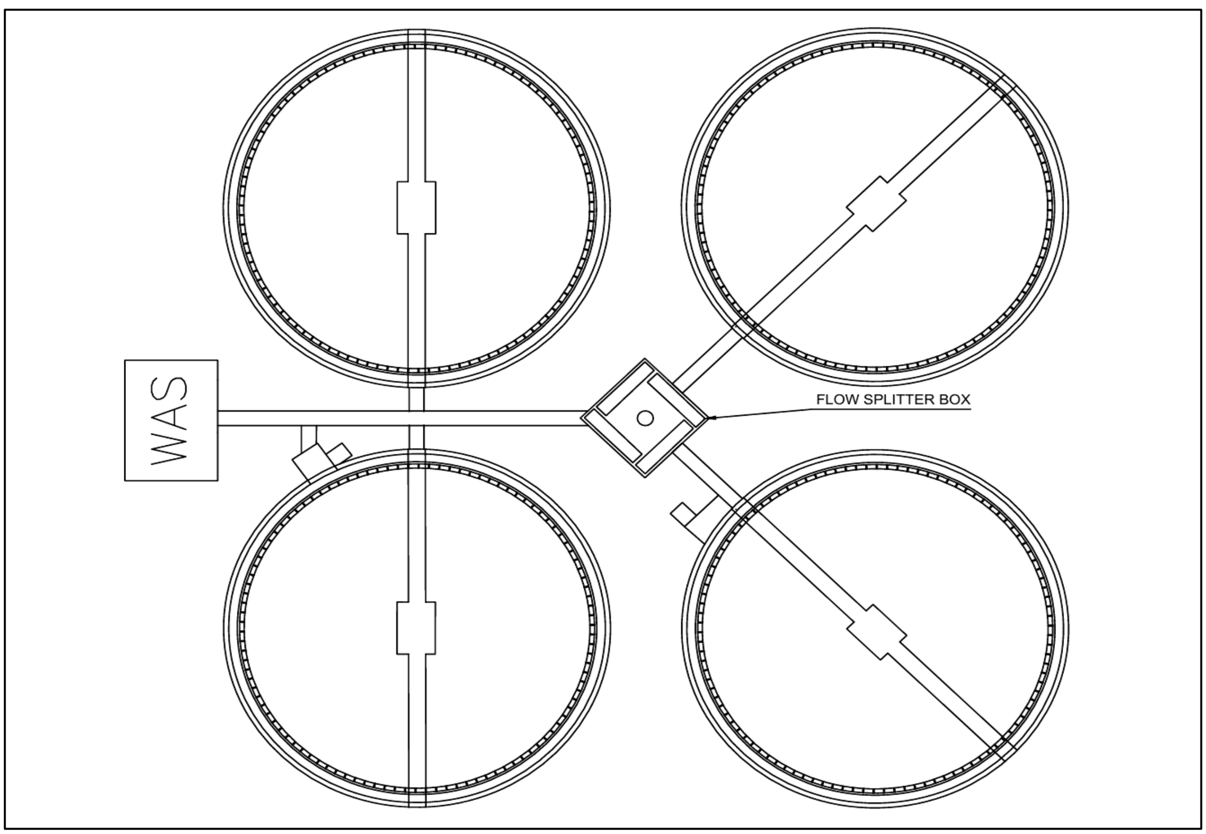


Figure H.3: *Secondary Clarifiers modeled with AutoCAD*

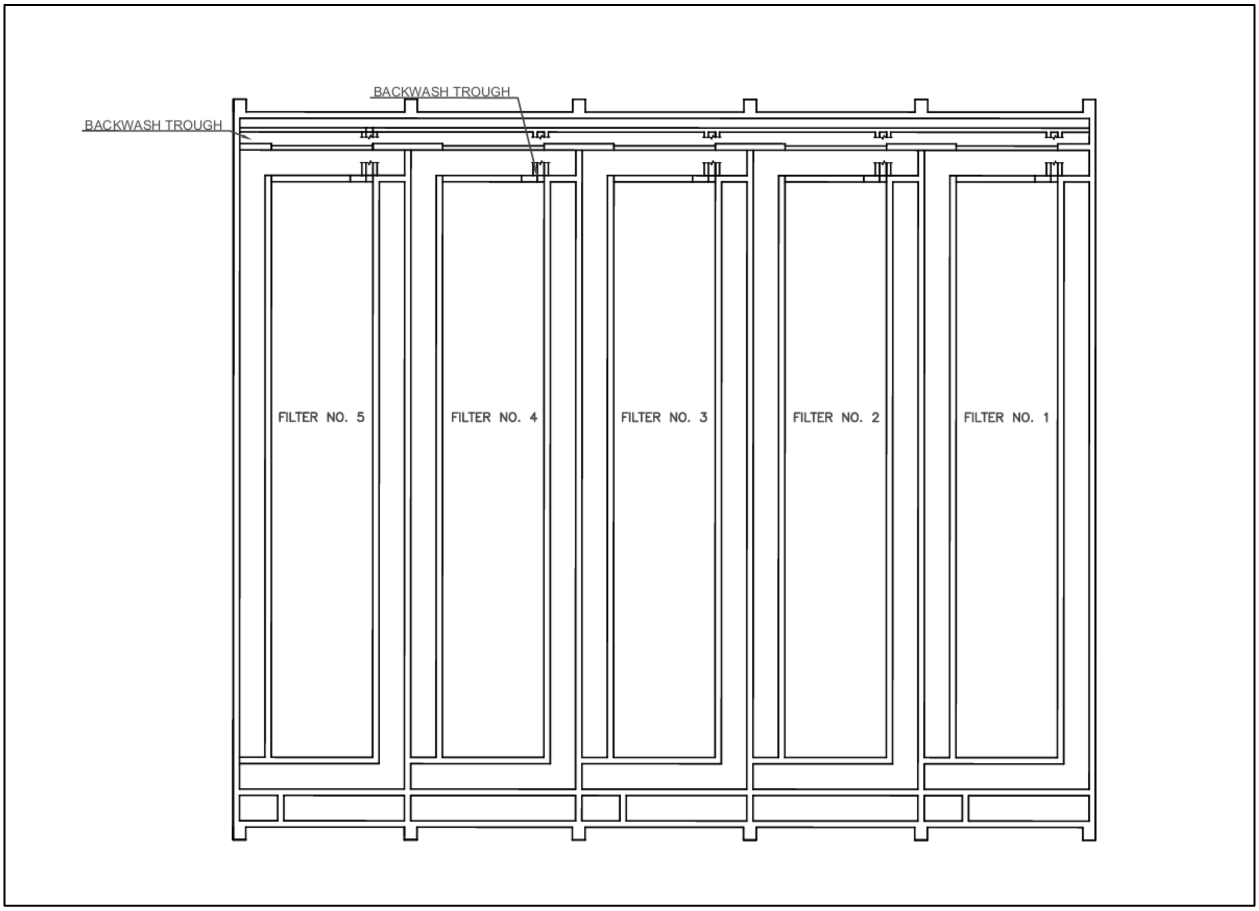


Figure H.4: *Filtration modeled with AutoCAD*

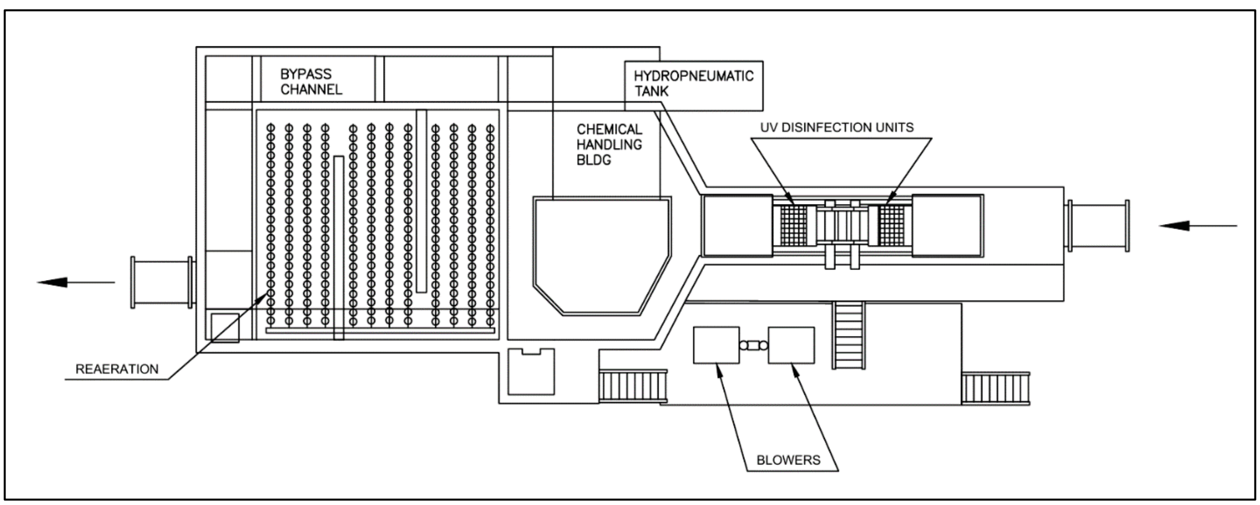


Figure H.5: *Existing UV Disinfection and Post Aeration modeled with AutoCAD*

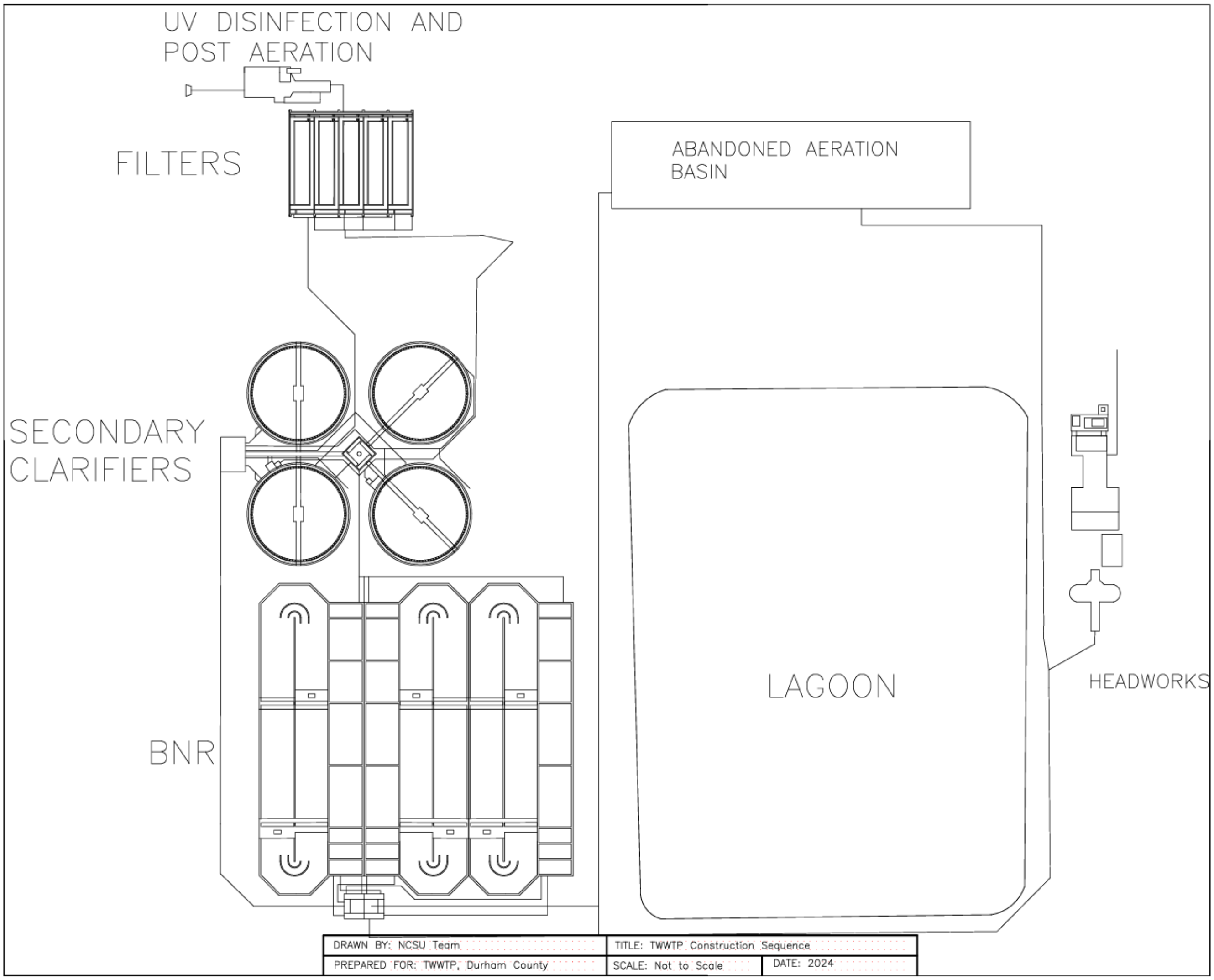


Figure H.6: *TWWTP Schematic modeled with AutoCAD*