Water Environment Federation

STUDENT WASTEWATER DESIGN COMPETITION

Greenfield Water Reclamation Facility

CIVIL ENVIRONMENTAL
ENGINEERING
FINAL REPORT
2018

NICHOLAS BABCOCK
RYAN WINTER
JED WARD
MAXWELL WARD

NORTHERN ARIZONA UNIVERSITY

LETTER OF TRANSMITTAL

Water Environmental Federation Student Design Competition Team
Nicholas Babcock, Maxwell Ward, Jed Ward, Ryan Winter
Northern Arizona University

April 16, 2018

AZ Water Association Judging Panel
2018 Regional Competition

Dear AZ Water Association Judging Panel,

The Northern Arizona University student design competition team is pleased to submit this final plan for the expansion of Greenfield Water Reclamation Facility as part of the Water Environment Federation student design competition. This final design report includes a project description, summary of the project team, analysis of the existing treatment facility, discussion of the design solution, and all necessary supporting documentation. The expansion is expected to take 36 months to construct with a cost of approximately $152.46 million.

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Acknowledgments

The Northern Arizona University Water Environment Federation student wastewater design competition team would like to express our gratitude to the following individuals whose guidance and feedback allowed us to complete this design report:

Catherine Vanyo, PE. – Professional Advisor
Engineer at Brown & Caldwell

Terry Baxter, PhD, PE – Faculty Advisor
Professor of Environmental Engineering at Northern Arizona University

Paul Gremillion, PhD, PE
Civil and Environmental Engineering Department Chair at Northern Arizona University

Dianne McDonnell, PhD, PE
Assistant Professor of Civil and Environmental Engineering at Northern Arizona University

Sandra Schuler, M.Sc
Huber Technologies Inc. Mechanical Treatment – Team Leader

List of Abbreviations

ADEQ - Arizona Department of Environmental Quality
BOD - Biological Oxygen Demand
COD - Chemical Oxygen Demand
DO - Dissolved Oxygen
GPD - Gallons per Day
GPM - Gallons per Minute
GWRF - Greenfield Water Reclamation Facility
HP - Horsepower
HRT - Hydraulic Retention Time
MGD - Million gallons per day
MLE - Modified Ludzack-Ettinger Process
O&M - Operations and Maintenance
SEWRP - Southeast Water Reclamation Plant
TKN - Total Kjeldahl Nitrogen
TSS - Total Suspended Solids
UV - Ultraviolet
VSS - Volatile Suspended Solids
WEF - Water Environment Federation

STUDENT DESIGN COMPETITION REGISTRATION FORM

Number of students on team: 4

Name of University: Northern Arizona University
Address: S. San Francisco St.
City: Flagstaff
State: Arizona Zip: 86011
Phone: (928) 523-9011
Fax: N/A

Name of Student Contact: Jed Ward
Email: jw678@nau.edu
Address: 1906 N. Main St. #2
City: Flagstaff
State: Arizona Zip: 86001
Phone: (928) 951-4655
Fax: N/A

Name of Faculty Advisor: Dianne McDonnell
Email: dianne.mcdonnell@nau.edu
Address: 2112 S. Huffer Ln Office 259
City: Flagstaff
State: Arizona Zip: 86001
Phone: (928) 523-0737
Fax: N/A

STUDENT DESIGN COMPETITION ENTRY FORM

Title of Presentation: Norther Arizona University 2018 WEF Student Wastewater Design Competition

Names and Emails of Presenters:

1.	Nicholas Babcock	nwb5@nau.edu
2.	Jed Ward	jw678@nau.edu
3.	Maxwell Ward	mdw273@nau.edu
4.	Ryan Winter	rjw234@nau.edu

Special requests or equipment needed for the presentation:

Abstract

The Greenfield Water Reclamation Facility (GWRF) operates at a capacity of 16MGD producing A+ reclaimed water and Class B biosolids. The purpose of this project is to increase treatment capacity at the facility to 30MGD, with a peak design flow of 60MGD while maintaining reclaimed water and biosolid product quality. This plant serves the Town of Gilbert, City of Mesa, and Town of Queen Creek and is jointly owned by these three entities. It is operated by the City of Mesa.

The enclosed report includes background information on GWRF, modeling of the wastewater characteristics, hydraulics of the plant units, identification of alternatives, design criteria, analysis of the economics, feasibility, efficiency improvements, social impacts, operations and maintenance of proposed alternatives, selection of proposed improvements, implementation, construction, and future recommendations.

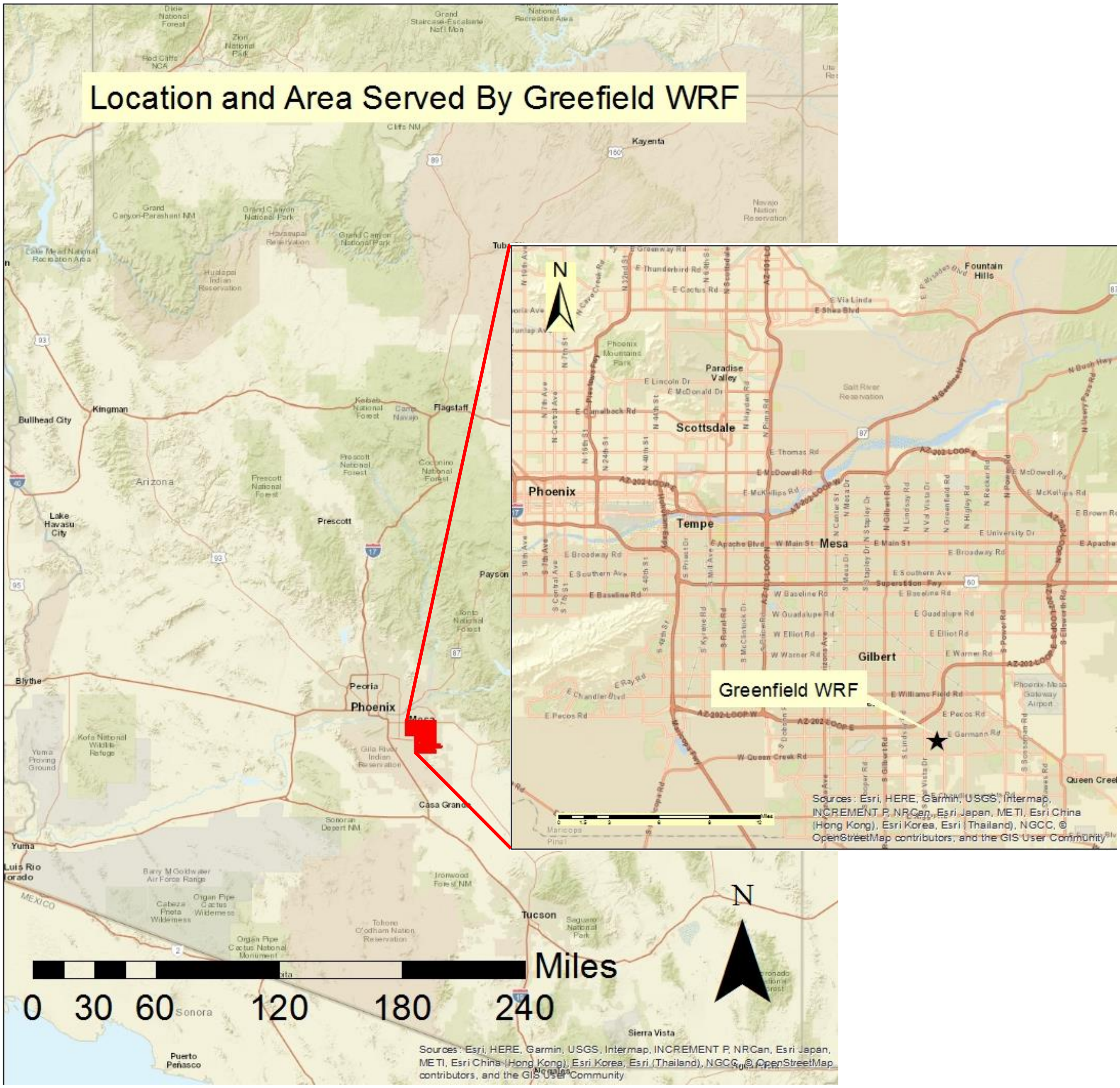
The final design will include:

- WesTech vortex grit removal system
- One circular primary sedimentation basin
- Two MLE aeration basins
- Three circular secondary clarifiers
- Six Kruger cloth-media disk filters
- Two UV channels with WEDECO lamps
- Two Westfalia thickening centrifuges
- One anaerobic digester
- Cambi thermal hydrolysis
- One Westfalia dewatering centrifuge

The total cost of the proposed design improvements will be approximately $152.46 million and will take approximately 36 months to complete construction.

1.0 Project Description

The Greenfield Water Reclamation Facility (GWRF), shown in Figure 1 and Figure 2, currently serving the Town of Gilbert, City of Mesa, and Town of Queen Creek, requires an expansion of treatment capacity due to an increase in influent flow. Currently this plant is rated to treat an average 16 million gallons per day (MGD) and produces Class A+ reclaimed water and Class B biosolids. The Town of Gilbert, City of Mesa, and Town of Queen Creek need to increase the capacity to 30 MGD while considering a peaking factor of two to provide a maximum capacity of 60MGD. GWRF will continue to accept an additional 8 MGD of sludge from the Southeast Water Reclamation Plant (SEWRP), while still producing Class A+ reclaimed water and Class B biosolids for reuse (See Appendix H).



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community

Figure 1: Location of Greenfield Water Reclamation Facility

Figure 2: Aerial Photograph of Greenfield Water Reclamation Facility

The objectives of this project:

1. Analyze the historic wastewater characteristics as well as existing treatment process,
2. Identify and evaluate processes and technologies to improve and upgrade the plant to a capacity of 30 MGD (with a peak flow of 60MGD), and
3. Prepare an implementation plan for the recommended process area expansion and new technologies without disrupting current plant operations.

1.1 Team Member Roles

To ensure the project is completed effectively and in a timely manner each team member was assigned specific roles. However, the team collaborated on all aspects of the project to check each other's work for quality control and ensure a shared understanding of project components. Therefore, each team member will be held accountable for each aspect of the project regardless of whether it is their main role.

Jed Ward:

As an environmental engineer, Jed worked mainly on analyzing wastewater characteristics at the influent, effluent, and throughout each process unit with Maxwell. This analysis was also applied to model each process unit to determine the sizing feasibility for the new or improved units that will need to be added. Jed took on the role of project manager by maintaining the schedule and keeping the team on track as well as contacting vendors to inquire about new products.

Maxwell Ward:

As an environmental engineer, Maxwell worked mainly on analyzing wastewater characteristics at the influent, effluent, and throughout each unit with Jed. This analysis was also applied to model each unit to determine sizing feasibility for the new or improved units that will need to be added. Maxwell took on the role of data analysis and focused mainly on process and computer work as well as contacting vendors to inquire about new products.

Ryan Winter:

As a civil engineer, Ryan worked alongside Nicholas to complete the hydraulic, expansion, and construction analyses. This includes creating hydraulic diagrams, determining adequate flows, drafting a new site plan, and creating a construction schedule. Ryan mainly focused on the hydraulic analysis and optimization as well as contacting vendors to inquire about new products.

Nicholas Babcock:

As a civil engineer, Nicholas worked alongside Ryan to complete the hydraulic, expansion, and construction analyses. This includes creating hydraulic diagrams, determining adequate flows, drafting a new site plan, and creating a construction schedule. Nicholas mainly focused on the expansion and construction analysis as well as contacting vendors to inquire about new products.

2.0 Background Information

To gain a better understanding the existing conditions, treatment processes were analyzed to understand the plant hydraulics, treatment methods, capacity, and identify expansion requirements. By understanding the existing facility layout (See Appendix C), the team determined locations for new process units required to meet the design flow needs and identify opportunities to implement new treatment technologies. In the interest of narrowing the scope the team has decided not to perform analysis on the expansion of the existing odor control system or pumps.

2.1 Analysis of Existing Wastewater Treatment Plant

This analysis includes an overview of the important characteristics of each unit including capacity, number of units operating and on standby, and dimensions (See Appendix H). A summary of the liquid stream treatment methods used at the GWRF is provided in Table 1 below.

Table 1: Existing Liquid Stream Units

INFLUENT SCREENING		
Manufacturer/Type	Duperon Flex Rake	
# Influent Channels	Operation	2
	Bypass	2
	Total	4
Capacity	Total (MGD)	64
GRIT REMOVAL SYSTEM		
Manufacturer/Type	WesTech Induced Vortex Grit Removal Unit	
# Units	Operation	1
	Standby	1
	Total	2
Capacity	Rated (MGD)	16
	Total (MGD)	32
Diameter (ft)		18
PRIMARY SEDIMENTATION BASINS		
Manufacturer/Type	Circular, Hopper Bottom, Center Feed, Spiral Scrapper	
# Units	Operation	1
	Standby	1
	Total	2
Capacity	Average day (MGD)	16
	Maximum Day (MGD)	32
AERATION BASINS		
Manufacturer/Type	MLE Process, with Coarse Bubble Diffusers	
# Units	Operation	2
	Standby	0
Capacity	Operating (MGD)	32
SECONDARY CLARIFIERS		
Manufacturer/Type	Circular, Center feed	
# Units	Operation	3
	Standby	1
	Total	4
Capacity	Operating (MGD)	32
TERTIARY FILTRATION		
Manufacturer/Type	USF/Kruger, Model HSF-3110	
# Filter Cells	Operation	5
	Standby	1
	Total	6
Capacity	Total (MGD)	32
DISINFECTION		
Manufacturer/Type	Concrete channel with Wedeco TAK55 system	
# Units		2
Capacity	Annual Average (MGD)	16
	Peak Hourly (MGD)	48

A summary of the solids treatment methods used at the GWRF are summarized in Table 2 below.

Table 2: Existing Solids Stream Units

BLENDED SLUDGE TANKS		
# Units		2
Capacity		Buildout
SLUDGE THICKENEING		
Manufacturer/Type	Westfalia Centrifuge horizontal, solid bowl	
# Units	Operation	2
	Standby	1
Loading Rates (@ Max Month)	Hydraulic (GPM)	300
	Solids (lbs/hour)	1500
THICKENED SLUDGE TANKS		
# Units		1
Capacity		Buildout
SLUDGE DIGESTION		
Manufacturer/Type	Egg-shaped, steel	
# Units	Operating	2
Unit Size/ Capacity (Nominal)	MG	1.2
DIGESTED SLUDGE STORAGE		
# Units		1
Capacity		Buildout
SLUDGE DEWATERING		
Manufacturer/Type	Westfalia Centrifuge horizontal, solid bowl	
# Units	Operating	1
	Standby	1
Max Month Loading Rates	Hydraulic (GPM)	150
	Solids (lbs/hr)	2,500
DEWATERED CAKE STORAGE		
# Units		2
Capacity		Buildout

2.1.1 Hydraulic Analysis

In order to determine which process units require a capacity increase, the existing treatment units were modeled hydraulically. This model was created in Microsoft Excel using existing data provided by the GWRF Phase II design report, and the GWRF O&M manuals. The new peak flow of 60MGD was modeled to identify the units requiring expansion based on standard design parameters. The units that were modeled were bar screens, grit removal, primary clarifiers, aeration basins, secondary clarifiers, tertiary filters, UV disinfection, sludge thickening, anaerobic digesters, and sludge dewatering. See Appendix A for complete hydraulic model and methodology.

2.1.2 Wastewater Analysis

Accurate estimates of the future wastewater characteristics are essential to a properly designed wastewater reclamation plant. This was achieved with Excel using pivot tables to predict the change of BOD, COD, TSS, and TKN, as flow increased. In Appendix B a full analysis of wastewater characteristics is displayed along with figures. This allowed for the estimation of wastewater characteristics at the design flow of 30 MGD. This data represents the increase in waste concentration that results from new development having more efficient bathroom fixtures. The concentrations described below in Table 3 were used as the influent parameters during design.

Table 3: Projected Wastewater Characteristics with increased Flow

Flow (MGD)	TKN (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)
15	55.9	384.3	822.7	298.2
25	64.2	431.1	909.7	319.7
30	67.1	447.8	940.8	327.4
45	73.6	484.9	1009.8	344.6
60	78.3	511.2	1058.8	356.7

3.0 Discussion of Design Solution

3.1 Determination of Design Criteria

For each step of the treatment process various alternatives will be analyzed in decision matrices. The threshold criteria include that proposed alternatives must meet the required capacity, fit within the area of the plant, and be readily available. There are five criteria that will be analyzed in the decision matrices including life cycle cost, feasibility/constructability, efficiency improvements, social impacts, and operations & maintenance (O&M).

Each of these criteria is assigned a weight based on their criticality to the success of the project. Life cycle cost is typically considered to be the most critical aspect of a project and is given a weight of 6. Feasibility/constructability received a weight of 5 and was determined to be the second most critical aspect because each alternative should be feasible and easily constructible. Efficiency improvements was weighted at 4 because while this is not as essential to the success of the project as life cycle cost or feasibility/constructability the team wishes to improve the efficiency of the treatment processes. Social impact was weighted at a 3 because GWRF already has positive social impacts and while no negative impacts should be expected it should be considered. The lowest weighted criterion was O&M at 2 since O&M costs are already built into life cycle cost. The purpose of this criteria is to ensure that the GWRF operators are safe and satisfied with the new technology.

Each alternative will be rated on a scale of one to five with one barely meeting the criteria, five exceeding the criteria, and three meeting the criteria. The rating from each criterion will then be multiplied by the weight and then summed to achieve a score out of 100.

3.2 Identification of Alternatives

The first step in the design is to identify alternatives that can be used to upgrade the plant from 16 MGD to 30 MGD. A peaking factor of two will be applied to accommodate peak flows so each alternative must be able to handle a peak flow of 60 MGD. The decision matrices will typically include adding redundant units and other viable alternatives that meet threshold criteria. Additional research was done to find new and innovative technologies. Since some of the existing units already met the new design flow Table 4 below summarizes the units that require expansion and those that do not.

Table 4: Expansion Required

EXPANSION REQUIRED	EXPANSION NOT REQUIRED
Liquids Stream	
Grit Removal System	Influent Screening
Primary Sedimentation Basins	
Aeration Basins	
Secondary Clarifiers	
Tertiary Filtration	
Disinfection	
Solids Stream	
Sludge Thickening	Blended Sludge Storage Tanks
Sludge Digestion	Thickened Sludge Storage Tanks
Sludge Dewatering	Digested Sludge Storage Tanks
	Dewatered Cake Storage

3.3 Analysis to Determine Unit Expansion

To determine the treatment performance of GWRF and verify it meets Arizona Department of Environmental Quality (ADEQ) Class A+ effluent standards the plant was modeled in Excel. The approach to this model was to perform a material balance on each of the treatment units and follow the removal of constituents throughout the plant. The model tracked the removal of BOD, COD, TSS, and TKN for each of the units at GWRF. The model is fed the initial concentrations and the amount removed by each unit was calculated. The exiting concentrations were then fed into the next treatment unit. This process was repeated for the liquids and solids treatment streams of GWRF. The complete model that was used to determine hydraulic capacity and unit treatment can be seen in Appendix A.

3.4 Opportunities for Unit Improvements

The existing GWRF units are considered to be the industry standard, therefore adding redundant units will be considered for every unit that requires expansion. However, through conversations with staff as well as industry research, we found opportunities to improve certain processes including the grit chambers, primary sedimentation basins, secondary clarifiers, tertiary filtration, disinfection, sludge thickening, digestion, and sludge dewatering. Alternative units that will be analyzed against the existing processes include:

1. WesTech aerated grit chamber
2. Rectangular primary sedimentation basin
3. Huber Primary Drum Screens (Appendix F)
4. Rectangular secondary clarifiers
5. Dual media filters
6. Chlorine disinfection
7. Gravity belt thickeners
8. Rotating drum thickeners
9. Cambi Thermal Hydrolysis prior to digestion
10. Belt press dewatering

These design alternatives were considered because the majority are commonly implemented in wastewater treatment. However, the Huber primary drum screens and Cambi Thermal Hydrolysis are relatively new technologies that were discovered through research. Both of these new technologies were considered because they are known to potentially provide benefits when compared to the existing treatment units.

3.5 Economic Analysis

The economic analysis includes the costs of design, construction, and O&M to determine the life cycle cost. Life cycle cost will be the basis to score the alternatives for the expansion of GWRF. Each life cycle cost was created using vendors quotes, design reports from other projects, and manufacturers websites. A typical design life 30 years was used to give a present worth cost for Phoenix, AZ. See Appendix E for complete economic analysis.

Table 5: Economic Analysis Rating Criteria

Economic Analysis Rating Criteria	
Score	Criteria
1	Significant increase in redundant units life cycle cost (over 20% increase)
2	Minor increase in redundant units life cycle cost (between 0% and 20% increase)
3	Redundant units life cycle cost
4	Minor decrease in redundant units life cycle cost (between 0% and 20% decrease)
5	Significant decrease in redundant units life cycle cost (over 20% decrease)

Table 6: Economic Analysis Ratings

GRIT REMOVAL		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant WesTech mechanically-induced vortex grit removal system	3	Adding a redundant WesTech mechanically-induced vortex grit removal system was rated at a three because it has a life cycle cost of approximately $1.37 million.
Option 2: Add one WesTech aerated grit chamber	1	Adding one WesTech aerated grit chamber was rated at a two because it has a life cycle cost of approximately $3.16 million.
PRIMARY SEDIMENTATION BASIN		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant primary sedimentation basin	3	Adding one redundant primary sedimentation basin was rated at a three because it has a life cycle cost of approximately $4.19 million.
Option 2: Add one rectangular sedimentation basin	2	Adding one rectangular sedimentation basin was rated at a two because it has a life cycle cost of approximately $4.39 million.
Option 3: Replace with Huber primary drum screens	1	Replacing the existing system with Huber primary drum screens was rated at a one because it has a life cycle cost of approximately $7.57 million.
AERATION BASIN		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant MLE aeration basins	3	Adding two redundant MLE aeration basins was rated at a three because it has a life cycle cost of approximately $45.68 million.

SECONDARY CLARIFIERS

Alternatives	Rating	Reason for Given Rating
Option 1: Add three redundant secondary clarifiers	3	Adding three redundant secondary clarifiers was rated at a three because it has a life cycle cost of approximately $11.36 million.
Option 2: Add three rectangular clarifiers	4	Adding three rectangular clarifiers was rated at a four because it has a life cycle cost of approximately $10.27 million.

TERTIARY FILTERS

Alternatives	Rating	Reason for Given Rating
Option 1: Add six redundant Kruger cloth-media disk filters	3	Adding six redundant Kruger cloth-media disk filters was rated at a three because it has a life cycle cost of approximately $11.6 million.
Option 2: Add additional dual media filters	1	Adding additional dual media filters was rated at a one because it has a life cycle cost of approximately $15.39 million.

DISINFECTION

Alternatives	Rating	Reason for Given Rating
Option 1: Add two redundant UV channels with WEDECO lamps	3	Adding two redundant UV channels with WEDECO lamps was rated at a three because it has a life cycle cost of approximately $27.94 million.
Option 2: Replace with chlorine contact	5	Replacing the UV disinfection with chlorine contact was rated at a five because it has a life cycle cost of approximately $21.91 million.

THICKENING CENTRIFUGES

Alternatives	Rating	Reason for Given Rating
Option 1: Add two redundant Westfalia centrifuges	3	Adding two redundant Westfalia centrifuges was rated at a three because it has a life cycle cost of approximately $4.53 million.
Option 2: Add two Komline-Sanderson gravity belt thickeners	4	Adding two Komline-Sanderson gravity belt thickeners was rated at a four because it has a life cycle cost of approximately $3.88 million.
Option 3: Add two Parkson rotating drum thickeners	5	Adding two Parkson rotating drum thickeners was rated at a five because it has a life cycle cost of approximately $2.17 million.

EGG-SHAPED DIGESTERS

Alternatives	Rating	Reason for Given Rating
Option 1: Add two redundant anaerobic digesters	3	Adding two redundant anaerobic digester was rated at a three because it has a life cycle cost of approximately $34.36 million.
Option 2: Add Cambi Thermal Hydrolysis prior to digestion and one redundant digester	2	Adding Cambi Thermal Hydrolysis prior to digestion and one redundant digester was rated at a two because it has a life cycle cost of approximately $39.29 million.

DEWATERING CENTIFUGES		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant Westfalia solid bowl dewatering centrifuge	3	Adding one redundant Westfalia solid bowl dewatering centrifuge was rated at a three because it has a life cycle cost of approximately $6.50 million.
Option 2: Add one FRC belt press dewatering system	2	Adding one FRC belt press dewatering system was rated at a two because it has a life cycle cost of approximately $5.87 million.

3.6 Feasibility Analysis

This feasibility analysis is based upon the potential space savings of the alternatives, compatibility of the new units with existing infrastructure, and compatibility with units for future expansion phases.

Table 7: Feasibility Analysis Rating Criteria

Feasibility Analysis Rating Criteria	
Score	Criteria
1	Not feasible
2	Feasible with minor modifications
3	No modifications to existing
4	Improves on existing features
5	Improves on existing features and future expansion

Table 8: Feasibility Analysis Ratings

GRIT REMOVAL		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant WesTech mechanically-induced vortex grit removal system	5	Adding one redundant WesTech mechanically-induced vortex grit removal system was rated at a five because it is easily compatible with the current system and allows for simple future expansion.
Option 2: Add one WesTech aerated grit chamber	2	The addition of a WesTech aerated grit chamber was rated at a two because the aerated grit chambers would not be easily compatible with the existing grit removal system.
PRIMARY SEDIMENTATION BASIN		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant primary sedimentation basin	4	Adding one redundant primary sedimentation basin was rated at a four because it will be easily compatible with the existing basins and future expansion will not be an issue.
Option 2: Add one rectangular sedimentation basin	3	The addition of a rectangular sedimentation basins was rated at a three because rectangular basins require approximately 21% less space however rectangular basins are not compatible with the existing basins. [10]
Option 3: Replace with Huber primary drum screens	5	Replacing the existing two primary sedimentation basins with Huber primary drum screens was rated at a five because they require approximately 90% less space.

AERATION BASIN		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant MLE aeration basins	5	Adding two additional redundant MLE aeration basins was rated at a five because adding redundant basins is the only feasible option and there is space for future expansion.
SECONDARY CLARIFIERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add three redundant secondary clarifiers	5	Adding three redundant secondary clarifiers was rated at a five because they would be easily compatible with the existing clarifiers and allow for simple future expansion.
Option 2: Add three rectangular clarifiers	3	The addition of three rectangular clarifiers was rated at a three because they do save space however they would not be compatible with the existing circular clarifiers.
TERTIARY FILTERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add six redundant Kruger cloth-media disk filters	5	Adding six redundant Kruger cloth-media disk filter units was rated at a five because the redundant units would be easily compatible and allow for future expansion.
Option 2: Add additional dual media filters	2	The addition of a mixed-media filter system was rated at a two because it is not compatible with the existing system and has a larger footprint.
DISINFECTION		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant UV channels with WEDECO lamps	5	Adding two redundant UV channels with WEDECO lamps was rated at a five because the additional units are easily compatible and would allow for simple future expansion.
Option 2: Replace with chlorine contact	2	Replacing the existing UV disinfection system with chlorine contact was rated at a two because this would require implementing chlorine contact basins and demolishing the existing UV system which would be difficult for further expansion.
THICKENING CENTRIFUGES		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant Westfalia centrifuges	5	Adding two redundant Westfalia centrifuges was rated at a five because the additional units would be compatible and would allow for future expansion.
Option 2: Add two Komline-Sanderson gravity belt thickeners	2	The addition of Komline-Sanderson gravity belt thickeners was rated at a two because the gravity belt thickeners would create a different percentage of solids than the centrifuges.
Option 3: Add two Parkson rotating drum thickeners	2	The addition of Parkson rotating drum thickeners was rated at a two because the rotating drum thickeners are not easily compatible with the centrifuges and would therefore require modification.

EGG-SHAPED DIGESTERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant anaerobic digesters	5	Adding two redundant anaerobic digesters was rated as a five because it would be easily compatible and would allow for future expansion.
Option 2: Add Cambi Thermal Hydrolysis prior to digestion and one redundant digester	5	Adding a Cambi Thermal Hydrolysis unit prior to digestion and one redundant digester was rated at a five because thermal hydrolysis is a separate unit that is compatible with the current units and allows for future expansion.
DEWATERING CENTIFUGES		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant Westfalia solid bowl dewatering centrifuge	5	Adding one redundant Westfalia solid bowl dewatering centrifuge was rated at a five because they are easily compatible with the existing units and future expansion.
Option 2: Add one FRC belt press dewatering system	2	The addition of an FRC belt press dewatering system was rated at a two because switching to the belt press dewatering system would create a different percentage of solids than the centrifuges.

3.7 Efficiency Improvements Analysis

This analysis is based upon various measurements of efficiency that are applicable to each unit and how they compare with the existing treatment efficiency.

Table 9: Efficiency Improvements Analysis Rating Criteria

Efficiency Improvement Analysis Rating Criteria	
Score	Criteria
1	Major decrease in efficiency (less than 20% efficient)
2	Minor decrease in efficiency (between 20% and 0% less efficient)
3	No change to efficiency
4	Minor increase in efficiency (between 0% and 20% increased efficiency)
5	Major increase in efficiency (greater than 20% increased efficiency)

Table 10: Efficiency Improvements Analysis Ratings

GRIT REMOVAL		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant WesTech mechanically-induced vortex grit removal system	3	Adding one additional WesTech mechanically-induced vortex grit removal system was rated at a three because there would be no increase or decrease in efficiency.
Option 2: Add one WesTech aerated grit chamber	2	The addition of a WesTech aerated grit chamber was rated at a two because the aeration process uses more energy and is therefore less efficient.

<table>
<tr><th colspan="3">PRIMARY SEDIMENTATION BASIN</th></tr>
<tr><th>Alternatives</th><th>Rating</th><th>Reason for Given Rating</th></tr>
<tr><td>Option 1: Add one redundant primary sedimentation basin</td><td>3</td><td>Adding one redundant primary sedimentation basin was rated at a three because there would be no increase or decrease in efficiency.</td></tr>
<tr><td>Option 2: Add one rectangular sedimentation basin</td><td>2</td><td>Adding a rectangular sedimentation basin was rated at a two because while rectangular and circular configurations are similar in efficiency in theory. Rectangular basins suffer from short circuiting which considerably reduces efficiency.</td></tr>
<tr><td>Option 3: Replace with Huber primary drum screens</td><td>5</td><td>Huber primary drum screens were rated at a five because they are more efficient in constituent removal, have a much lower HRT, and increases efficiency by 30-40% in the aeration basins.</td></tr>
<tr><th colspan="3">AERATION BASIN</th></tr>
<tr><th>Alternatives</th><th>Rating</th><th>Reason for Given Rating</th></tr>
<tr><td>Option 1: Add two redundant MLE aeration basins</td><td>3</td><td>Adding two redundant MLE aeration basins was rated at a three because there will be no increase or decrease in efficiency.</td></tr>
<tr><th colspan="3">SECONDARY CLARIFIERS</th></tr>
<tr><th>Alternatives</th><th>Rating</th><th>Reason for Given Rating</th></tr>
<tr><td>Option 1: Add three redundant secondary clarifiers</td><td>3</td><td>Adding three redundant secondary clarifiers was rated at a three because there will be no increase or decrease in efficiency.</td></tr>
<tr><td>Option 2: Add three rectangular clarifiers</td><td>2</td><td>Adding rectangular clarifiers was rated at a two because while rectangular and circular configurations are similar in efficiency in theory, rectangular basins suffer from short circuiting which considerably reduces efficiency.</td></tr>
<tr><th colspan="3">TERTIARY FILTERS</th></tr>
<tr><th>Alternatives</th><th>Rating</th><th>Reason for Given Rating</th></tr>
<tr><td>Option 1: Add six redundant Kruger cloth-media disk filters</td><td>3</td><td>Adding six redundant Kruger cloth-media disk filter units was rated at a three because there will be no increase or decrease in efficiency.</td></tr>
<tr><td>Option 2: Add additional dual media filters</td><td>3</td><td>Adding dual media filters was rated at a three because the difference in filtration efficiency between dual media and the cloth-media is negligible.</td></tr>
<tr><th colspan="3">DISINFECTION</th></tr>
<tr><th>Alternatives</th><th>Rating</th><th>Reason for Given Rating</th></tr>
<tr><td>Option 1: Add two redundant UV channels with WEDECO lamps</td><td>3</td><td>Adding two redundant UV channels with WEDECO lamps was rated at a three because there would be no increase or decrease in efficiency.</td></tr>
<tr><td>Option 2: Replace with chlorine contact</td><td>3</td><td>Using chlorine disinfection was rated at a three because the chlorine disinfection system would be designed to create the same efficiency as UV disinfection.</td></tr>
</table>

THICKENING CENTRIFUGES		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant Westfalia centrifuges	3	Adding two redundant Westfalia centrifuges was rated at a three because there will be no increase or decrease in efficiency.
Option 2: Add two Komline-Sanderson gravity belt thickeners	3	Adding gravity belt thickeners was rated at a three because the efficiency of the gravity belt thickeners compared to the existing centrifuges is negligible.
Option 3: Add two Parkson rotating drum thickeners	3	Adding rotating drum thickeners was rated at a three because the efficiency of the rotating drum thickeners compared to the existing centrifuges is negligible.
EGG-SHAPED DIGESTERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant anaerobic digesters	3	Adding two more redundant anaerobic digesters was rated as a three because there will be no increase or decrease in efficiency.
Option 2: Add Cambi Thermal Hydrolysis prior to digestion and one redundant digester	5	Implementing thermal hydrolysis and one redundant digester was rated at a five because thermal hydrolysis increases volatile solids destruction in the digesters making them considerably more efficient.
DEWATERING CENTIFUGES		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant Westfalia solid bowl dewatering centrifuge	3	Adding one redundant Westfalia solid bowl dewatering centrifuge was rated at a three because there will be no increase or decrease in efficiency.
Option 2: Add one FRC belt press dewatering system	2	Adding one additional FRC belt press dewatering system was rated at a two because the efficiency of the belt filter press is approximately 5-10% less than the existing centrifuge.

3.8 Social Impacts Analysis

This social impacts analysis will include an analysis for units that have a social impact whereas units that are given a three were determined to have no social impact.

Table 11: Social Impacts Analysis Rating Criteria

Social Impacts Analysis Rating Criteria	
Score	Criteria
1	Major negative social impact
2	Minor negative social impact
3	No social impact
4	Minor positive social impact
5	Major positive social impact

Table 12: Social Impacts Analysis Ratings

GRIT REMOVAL		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant WesTech mechanically-induced vortex grit removal system	3	No social impact.
Option 2: Add one WesTech aerated grit chamber	3	No social impact.
PRIMARY SEDIMENTATION BASIN		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant primary sedimentation basin	3	No social impact.
Option 2: Add one rectangular sedimentation basin	3	No social impact.
Option 3: Replace with Huber primary drum screens	4	The Huber primary drum screens were rated at a four because they increase plant efficiency, decreasing energy use and moving toward a “greener” community.
AERATION BASIN		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant MLE aeration basins	3	No social impact.
SECONDARY CLARIFIERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add three redundant secondary clarifiers	3	No social impact.
Option 2: Add three rectangular clarifiers	3	No social impact.
TERTIARY FILTERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add six redundant Kruger cloth-media disk filters	3	No social impact.
Option 2: Add additional dual media filters	3	No social impact.
DISINFECTION		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant UV channels with WEDECO lamps	3	No social impact.
Option 2: Replace with chlorine contact	2	Chlorine disinfection was rated at a two because it has potential for trihalomethane residuals along with the idea that the public does not like dangerous chemicals in our water.

THICKENING CENTRIFUGES		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant Westfalia centrifuges	3	No social impact.
Option 2: Add two Komline-Sanderson gravity belt thickeners	3	No social impact.
Option 3: Add two Parkson rotating drum thickeners	3	No social impact.
EGG-SHAPED DIGESTERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant anaerobic digesters	3	No social impact.
Option 2: Add Cambi Thermal Hydrolysis prior to digestion and one redundant digester	4	Adding thermal hydrolysis and one redundant digester was rated at a four because thermal hydrolysis will produce Class A biosolids along with less residual leaving the plant and save room in landfills.
DEWATERING CENTIFUGES		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant Westfalia solid bowl dewatering centrifuge	3	No social impact.
Option 2: Add one FRC belt press dewatering system	3	No social impact.

3.9 Operations and Maintenance Analysis

Table 13: Operations and Maintenance Analysis Rating Criteria

Operations and Maintenance Analysis Rating Criteria	
Score	Criteria
1	Major decrease in safety and operations and maintenance
2	Minor decrease in safety and operations and maintenance
3	Negligible impact to operations and maintenance
4	Minor increase in safety and operations and maintenance
5	Major increase in safety and operations and maintenance

Table 14: Operations and Maintenance Analysis Ratings

GRIT REMOVAL		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant WesTech mechanically-induced vortex grit removal system	3	Adding one additional WesTech mechanically-induced vortex grit removal system was rated at a three because there would be no increase or decrease in safety or O&M.
Option 2: Add one WesTech aerated grit chamber	2	The addition of a WesTech aerated grit chamber was rated at a two because additional O&M training would be required due to the aerated grit chambers new set of risks and increased maintenance.
PRIMARY SEDIMENTATION BASIN		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant primary sedimentation basin	3	Adding one redundant primary sedimentation basin was rated at a three because there would be no increase or decrease in safety or O&M procedures.
Option 2: Add one rectangular sedimentation basin	2	Addition of a rectangular sedimentation basin was rated at a two because rectangular sedimentation basins are known to have more loading issues resulting in more O&M.
Option 3: Replace with Huber primary drum screens	2	Replacing the existing two primary sedimentation basins with Huber primary drum screens was rated at a two because screens are a new technology which will require additional O&M training.
AERATION BASIN		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant MLE aeration basins	3	Adding two redundant MLE aeration basins was rated at a three because there would be no increase or decrease in safety or O&M processes.
SECONDARY CLARIFIERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add three redundant secondary clarifiers	3	Adding three redundant center feed secondary clarifiers was rated at a three because there would be no increase or decrease in safety or O&M processes.
Option 2: Add three rectangular clarifiers	2	Addition of rectangular clarifiers was rated at a two because rectangular clarifiers are known to have more loading issues resulting in more O&M.
TERTIARY FILTERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add six redundant Kruger cloth-media disk filters	3	Adding six redundant Kruger cloth-media disk filter units was rated at a three because there would be no increase or decrease in safety or O&M procedures.
Option 2: Add additional dual media filters	2	Addition of dual media filters was rated a two because it is a new technology that would require new safety measures and O&M.

DISINFECTION		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant UV channels with WEDECO lamps	3	Adding two redundant UV channels with WEDECO lamps was rated at a three because there would be no increase or decrease in safety or O&M processes.
Option 2: Replace with chlorine contact	1	Replacing the existing UV disinfection system with chlorine contact was rated at a one because chlorine is a hazardous chemical and would require special considerations.
THICKENING CENTRIFUGES		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant Westfalia centrifuges	3	Adding two redundant Westfalia thickening centrifuges was rated at a three because there would be no impact on safety and O&M.
Option 2: Add two Komline-Sanderson gravity belt thickeners	2	Addition of Komline-Sanderson gravity belt thickeners was rated at a two because it is a new technology that would require additional O&M.
Option 3: Add two Parkson rotating drum thickeners	2	Addition of Parkson rotating drum thickeners was rated at a two because it is a new technology that would require additional O&M.
EGG-SHAPED DIGESTERS		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add two redundant anaerobic digester	3	Adding two redundant anaerobic digesters was rated as a three because there would be no increase or decrease in safety or O&M.
Option 2: Add Cambi Thermal Hydrolysis prior to digestion and one redundant digester	2	Adding a Cambi Thermal Hydrolysis unit prior to digestion and one redundant digester was rated at a two because thermal hydrolysis is a new unit and will require additional O&M training.
DEWATERING CENTIFUGES		
Alternatives	**Rating**	**Reason for Given Rating**
Option 1: Add one redundant Westfalia solid bowl dewatering centrifuge	3	Adding one redundant Westfalia solid bowl dewatering centrifuge was rated at a three because there would be no increase or decrease in safety or O&M.
Option 2: Add one FRC belt press dewatering system	2	Addition of an FRC belt press dewatering system was rated at a two because this new unit will require additional O&M training.

4.0 Selection of Proposed Improvements

Based on the research and analysis of GWRF's existing treatment processes and units that required expansion the team has decided upon improvements for the facility. The result of the analyses were input into decision matrices that were utilized to determine the best alternatives (See Appendix D). The highest scoring alternatives recommended to meet expansion needs are summarized below:

Table 15: Proposed Improvements

Quantity	Units
1	Redundant WesTech mechanically-induced vortex grit removal system
1	Redundant primary sedimentation basin
2	Redundant MLE aeration basins
3	Redundant secondary clarifiers
6	Redundant Kruger cloth-media disk filters
2	Redundant UV channels with WEDECO lamps
2	Redundant Westfalia centrifuges
1	Redundant Anaerobic digester
1	Cambi Thermal Hydrolysis prior to digestion
1	Redundant Westfalia solid bowl dewatering centrifuge

The life cycle cost of adding each of these alternatives over 30 years has been determined below to find a total expansion cost of approximately $152.46 Million. It should be noted that this cost is only taking into account the added units and not the cost of operating the entire plant. This cost estimate also excludes odor control, pumps, piping, monitoring equipment, rehabilitation of existing units, and other miscellaneous costs. As a result of these assumptions the actual cost for the Town of Gilbert, City of Mesa, and Town of Queen Creek will likely be 20-25% higher. See Appendix E for full cost estimate.

Table 16: Life Cycle Cost of Expansion

Expansion Units	Estimated Life Cycle Cost
One WesTech mechanically-induced vortex grit removal system	$1.37 Million
One redundant primary sedimentation basin	$4.19 Million
Two redundant MLE aeration basins	$45.68 Million
Three redundant secondary clarifiers	$11.36 Million
Six redundant Kruger cloth-media disk filters	$11.60 Million
Two redundant UV channels with WEDECO lamps	$27.94 Million
Two redundant Westfalia centrifuges	$4.53 Million
One redundant anaerobic digester	$12.28 Million
Cambi Thermal Hydrolysis prior to digestion	$27.01 Million
One redundant Westfalia solid bowl dewatering centrifuge	$6.50 Million
Total Cost of Project	**$152.46 Million**

4.1 Implementation and Construction

This expansion will include the construction of one WesTech mechanically-induced vortex grit removal system, a redundant primary sedimentation basin, two MLE aeration basins, three secondary clarifiers, six Kruger cloth-media disk filters, two UV channels with WEDECO lamps, two Westfalia thickening centrifuges, one anaerobic digester, Cambi Thermal Hydrolysis, and one Westfalia solid bowl dewatering centrifuge.

The construction schedule was based off of typical construction schedules for wastewater treatment facilities. The expected construction duration for this expansion is approximately 36 months. A full construction schedule can be seen in Appendix G. For the expansion site layout refer to Appendix C.

5.0 Recommendations

This plant was designed and constructed in 2003, therefore the majority of the systems are the industry standard for efficiency and cost saving mechanisms. The UV disinfection process is more labor intensive than chlorine systems. Since the plant started with UV, it was determined to be more feasible to continue using UV rather than replacing them with a chlorine contact basin. However, chlorine contact may be a feasible option for future expansions. One major change is the addition of thermal hydrolysis. Current plant operations create Class B biosolids, implementing thermal hydrolysis would produce Class A biosolids. Heating the solids during the hydrolysis process destroys the pathogens before they enter the digester to meet Class A standards. Class A biosolids have more potential for reuse and income. The high construction cost of thermal hydrolysis if partially offset due to the income from selling sludge as a fertilizer and requiring less digesters. At a 30 MGD flow, GWRF would need to spend approximately $500,000 annually to dispose of sludge but by utilizing thermal hydrolysis the solids can be sold.

Looking towards future expansions additional innovations may become more viable as influent flow increases. The addition of primary screens in the final phase of this project will increase gas output from the digesters and make cogeneration more feasible. Cogeneration can be achieved by capturing biogas and utilizing gas generators to move the plant toward net zero energy use. Gas scrubbing will be used to remove sulfides and carbon dioxide to prepare the biogas for cleaner combustion in the generators. Cogeneration will require an initial higher capital cost, however it will significantly decrease the energy costs due to more sustainable energy consumption.

In the future, GWRF may become a viable candidate for direct potable reuse. This will become an increasingly important innovation in dry climates such as the southwest. This expansion continues to produce Class A+ effluent allowing the effluent to be distributed to a water treatment plant. As legislation regarding direct potable reuse continues to be developed the effluent leaving GWRF may become a revenue source as an influent into a drinking water plant. It will become the responsibility of engineers to inform the public of the advantages of direct potable reuse to sway the public opinion and improve legislation. As direct potable reuse become more accepted GWRF will become a model for a more sustainable future.

6.0 References

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7.0 Appendix A: GWRF Excel Model

Table 17: GWRF Excel Model Inputs

Influent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	327	mg/L
COD	941	mg/L
TSS	448	mg/L
TKN	67	mg/L
Contributing Solids	8	MGD
Contributing Solids	8,000,000	GPD

Bar Screens

The first unit in the treatment process is the bar screens. It was assumed that the treatment in the bar screens is negligible and none of the constituents were removed. The GWRF currently has two bar screens in operation. The two screens sit in identical channels that are 4.5ft wide, 8ft deep and have a maximum flow depth of 6ft. [1] The maximum velocity that is allowed through the channels is 5ft/sec. [1] To determine if an additional screen is required, the velocity was calculated by dividing the new design flow by the cross-sectional area of the channel. The equation used can be seen below in Equation 1. It was found that expansion was not required for the bar screens.

Equation 1: Channel Velocity [2]

$$V = \frac{Q}{A}$$

Where:
V= Channel Velocity (ft/sec)
Q= Flow in (ft^3/sec)
A= Cross sectional area (ft^2)

Table 18: Bar Screen Model

Influent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	327	mg/L
COD	941	mg/L
TSS	448	mg/L
TKN	67	mg/L
Bar Screen Criteria		
Width	4.5	ft
Depth	8	ft
Max Water Depth	6	ft
Flow Area	27	ft^2

Unit Conversions		
hrs to day	24	
hrs to min	60	
min to sec	60	
gal to ft^3	0.133681	
Design Max Velocity	**5**	**ft/s**
One Screen	3	ft/s
Two Screen	2	ft/s
Effluent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	327	mg/L
COD	941	mg/L
TSS	448	mg/L
TKN	67	mg/L

Grit Removal

The second unit modeled was grit removal. It was assumed that the treatment in the grit removal is negligible and none of the constituents were removed, due to the inert nature of the grit. There are two grit removal units at the GWRF with one in use and the other on standby. [1] Each of these units are rated for 32 MGD. The capacities were compared to the design flow, to determine if the units met the design criteria. An additional unit will be added to the grit removal section of the plant.

Table 19: Grit Removal Model

Influent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	327	mg/L
COD	941	mg/L
TSS	448	mg/L
TKN	67	mg/L
Max Rated Flow	**60**	**MGD**
1 Unit	32	MGD
2 Unit	64	MGD
3 Unit	96	MGD
Effluent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	327	mg/L
COD	941	mg/L
TSS	448	mg/L
TKN	67	mg/L

Primary Clarifiers

There are two circular primary sedimentation basins that are in use at the GWRF. The sedimentation basins have a diameter of 140ft and a sidewall depth of 14.5ft, each with a volume of 1,875,000 gallons. [1] In order for the primary sedimentation basins to function as designed, they must have a hydraulic retention time (HRT) of between 2-3 hours. [2] To determine the HRT, the total volume of the sedimentation basins is divided by the design flow. The equation used can be seen below in Equation 2.

Equation 2: Hydraulic Retention Time [2]

$$HRT = \frac{V}{Q}$$

Where:
HRT= Hydraulic Retention Time (hrs)
V= Volume (gal)
Q= Design Flow (gal/hr)

It was found that one identical sedimentation basin was needed to handle the increase in flow. With the additional sedimentation basin, the HRT would be in an acceptable range of 2-3 hours. [2] It was assumed that if the HRT fell in the design HRT range, 40% of BOD, 40% of COD, 60% of TSS, and 10% of TKN would be removed. [2] The effluent concentration was determined by multiplying the initial concentration by the removal efficiency. The mass removed was found by subtracting the effluent concertation from the initial concentration, using Equation 3 below.

Equation 3: Mass Removed [2]

$$\frac{mg}{L} removed = (\frac{mg}{L} influent - \frac{mg}{L} Effulent)$$

Once the mass removed was found the sludge flow rate leaving the primary sedimentation basins was calculated. The mass rate of TSS leaving was calculated by multiplying the TSS removed by the flowrate, which can be seen in Equation 4 below.

Equation 4: Mass Rate [3]

$$\dot{m_{Sludge}} = (\tfrac{mg}{L}\ removed \times Q)$$

Where:
m= Mass rate (lb/day)
Q= flowrate (gal/day)

The mass rate was then adjusted for the percent solids that are assumed to be produced in the sedimentation basins by dividing the mass rate by the decimal percent solids being produced. Lastly, the mass rate was then converted into flowrate using the specific gravity of the sludge as shown below in Equation 5.

Equation 5: Sludge Flow Rate [3]

$$Q_{Sludge} = \frac{\dot{m}}{G}$$

Where:
G= Specific gravity (kg/L)

Table 20: Primary Clarifier Model

Influent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	327	mg/L
COD	941	mg/L
TSS	448	mg/L
TKN	67	mg/L
Basin Dimensions		
Diameter	140	ft
Side Water Depth	14.5	ft
Center Depth	19.8	ft
Floor Slope	-0.076	ft/ft
Free Board	3.5	ft
Volume	1,875,000	Gal
Surface Area	15,400	ft^2
Weir Type	Single	
Weir Length	414.7	ft
% solids Produced	0.03	
Unit Conversions		
hrs to days	24	
L to gal	3.785	
mg to lb	453,592	
Specific Gravity (kg/L)	1.03	
lb to kg	0.454	
gallon to lb	8.36	
Design HRT	**2-3**	**Hours**
HRT 1 Unit	0.75	Hours
HRT 2 Units	1.5	Hours
HRT 3 Units	2.25	Hours
Percent Removal For Design HRT	**%**	**mg/L Removed**
BOD	40	130.8
COD	40	376.4
TSS	60	268.8
TKN	10	6.7
Sludge Production		**Units**
Dry mass rate	134,580	lb/day
Wet mass rate @ 3% solids	4,486,005	lb/day
Sludge Flow Rate	536,603	GPD
	372.6	GPM

Effluent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	196.2	mg/L
COD	564.6	mg/L
TSS	179.2	mg/L
TKN	60.3	mg/L

Aeration Basin

The GWRF currently has two aeration basins with dimensions of 240ft by 297ft and a total volume of 10.63 million gallons. [1] Aeration basins need to have a HRT of 10.2 hours in order to provide adequate treatment. [1] To determine the HRT for each basin, Equation 2 was used. It was calculated that a set of aeration basins would need to be added to handle the design flow. BOD and COD removal were based on the solids retention time (SRT), the yield of volatile suspended solids per BOD, HRT, and the decay coefficient. The effluent concentration of BOD and COD were calculated using Equation 6 below.

Equation 6: Effluent Substrate concentration [4]

$$S = S_0 - \frac{X(\theta(1 + k_d\theta_{c)}}{\theta_c Y}$$

Where:
S=Effluent Substrate Concentration (mg/L)
$S_{0=}$ Influent Substrate Concentration (mg/L)
X= MLVSS concentration (mg/L)
Θ= HRT
Θ_c= SRT
k_d= Decay Coefficient (1/day)
Y= Yield (gVSS/gBOD)

The removal of TKN was determined assuming that there is 3% of nitrifying bacteria in the system. [4] This is used to find the amount of VSS in the system that can perform nitrification and denitrification. The utilization rate of the nitrogen were calculated using the SRT, decay coefficient, and yield using Equation 7 below.

Equation 7: Nitrogen Utilization Rate [4]

$$U = \left(\frac{1}{\theta_c} + k_d\right)\left(\frac{1}{Y}\right)$$

Where:
U= Nitrogen Utilization Rate (1/day)
Θ= HRT
Θ_c= SRT
k_d= Decay Coefficient (1/day)
Y= Yield (gVSS/gBOD)

The effluent TKN concentration was determined using Equation 8 below.

Equation 8: Effluent Nitrogen Concentration [4]

$$N_0 - (U \times \theta \times X_n) = N$$

N_0=Influent TKN Concentration (mg/L)
U= Nitrogen Utilization Rate (1/day)
Θ= HRT
N= Effluent TKN Concentration (mg/L)

Next, the observed yield of TSS per BOD was calculated to find the mass of sludge wasted from the activated sludge system. This was done using Equation 9 below.

Equation 9: Observed Yield [4]

$$Y_{obs} = \frac{Y}{1 + k_d \times \theta_c}$$

Where:
Y_{obs}= Observed Yield of TSS per BOD

Lastly, the mass of sludge wasted in the activated sludge system was calculated to find the sludge flowrate going to the solids treatment stream. This was found using Equation 10 below.

Equation 10: Mass Rate of Sludge Wasted [4]

$$P_x = Y_{obs} \times Q \times BOD\ removed$$

Where:
P_x= Mass Rate of Sludge Wasted

Table 21: Aeration Basin Model

Influent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	196.2	mg/L
COD	564.6	mg/L
TSS	179.2	mg/L
TKN	60.3	mg/L
Basin Criteria		
Length	240.3	ft
Width	297.2	ft
Volume	10.6	MG
Volume	10,620,000	gal
Side Water Depth	24	ft
Working Volume	12,821,128	gal
MLVSS %	80	
MLSS Conc (X')	2,100	mg/L
HRT	10.2	hrs
HRT	0.425	days
SRT (θ_c)	9.72	days

Design HRT	**8-10**	**Hours**			
HRT 2 Unit	5	Hours			
HRT 4 Units	10	Hours			
HRT 6 Units	15	Hours			
Treatment Parameters		**BOD**	**COD**	**TKN**	**TSS**
X		1,680	1,680	1,680	
k_d	1/day	0.04	0.12	0.15	
Y	mg VSS/mg BOD_5	0.6	0.3	0.1	
% Nitrifying				0.03	
Xn				50.4	
U	1/day			2.53	
N_{out}				6.13	
TSS Production	multiplier				4
Unit Conversions					
gal to ft^3	7.48				
hrs to day	24				
gal to m^3	264.17				
Sludge Wasted					
(Y_{obs})	0.432	kg/kg BOD_5			
Px	16,684	kg/day of VSS			
Effluent Parameters					
Flow	60	MGD			
Flow	60,000,000	GPD			
BOD	26.17	mg/L			
COD	34.14	mg/L			
TSS	2,100	mg/L			
TKN	6.13	mg/L			

Secondary Clarifiers

There are four circular secondary clarifiers in use at the GWRF. The clarifiers have a diameter of 120ft and a sidewall depth of 15ft, each with a volume of 1,270,000 gallons. [1] In order for secondary clarifiers to function as designed they must have a HRT between 3-4 hours. [5] Equation 2 was used to calculate the HRT by dividing the total volume of the clarifiers by the design flow. For secondary clarifiers, it was found that with three additional identical clarifiers the HRT would be at an acceptable range of 3-4 hours. [2] It was assumed that if the HRT fell in the design, 40% of BOD, 40% of COD, 96% of TSS, and 25% of TKN would be removed. [1] These efficiencies were estimated from the mass balance performance of the Phase II Expansion. [1] The effluent concentration was found by multiplying the initial concentration by the removal efficiency using Equation 4.

Table 22: Secondary Clarifier Model

Influent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	26.2	mg/L
COD	34.1	mg/L
TSS	2,100	mg/L
TKN	6.13	mg/L
Basin Dimensions		
Diameter	120	ft
Side Water Depth	15	ft
Free Board	2.5	ft
Volume	1,270,000	Gal
Surface Area	11,300	ft^2
Weir Type	Single Inboard	
Weir Length	377	ft
% solids Produced	0.06	
Unit Conversions		
hrs to days	24	
L to gal	3.785	
mg to lb	453,592	
Specific Gravity (kg/L)	1.03	
lb to kg	0.453592	
Design HRT	**3-4**	**Hours**
HRT 4 Unit	2.0	Hours
HRT 5 Units	2.5	Hours
HRT 6 Units	3.0	Hours
HRT 7 Units	3.6	Hours
Percent Removal For Design HRT	**%**	**mg/L Removed**
BOD	40	10.5
COD	40	13.7
TSS	98	2,058
TKN	25	1.53
Sludge Production		**Units**
Mass Wasted	16684	kg/day
Ratio of solids of Sludge	0.51	%
Flow in gallons	839124.5	GPD
	0.84	GPD
Effluent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	15.7	mg/L
COD	20.5	mg/L
TSS	42	mg/L
TKN	4.6	mg/L

Tertiary Filters

The GWRF uses cloth media type tertiary filters. There are 6 filter cells in use with 12 modules per cell and each cell has 645.6ft^2 of filter area. [1] The design hydraulic loading rate for these filters is 5.7GPM/ft^2. Equation 3 was used to calculate the hydraulic loading rate.

Equation 3: Hydraulic Loading Rate [2]

$$Hydrallic\ Loading = \frac{Q}{A}$$

Where:
Q= Design Flow (GPM)
A= Total Filter Area (ft^2)

The tertiary disc filters were modeled based on hydraulic loading. The main design assumption made was that the plant has sufficient treatment based on hydraulic loading. This was then adapted to the higher design flow with the expansion. The plant has a hydraulic loading rate of 0.57 m^3/m^2*min which falls in the range of 0.25-0.83 m^3/m^2*min [6].

Equation 12: Hydraulic Loading Rate of Disc Filters

$$Hydrolic\ Loading\left(\frac{m^3}{m^2 * min}\right) = Flow(m^3/min)/Area\ of\ Filter(m^2)$$

Table 23: Tertiary Filter Model

Influent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	15.7	mg/L
COD	20.5	mg/L
TSS	42	mg/L
TKN	4.6	mg/L
Filter Cell Criteria		
Modules Per Cell	12	
Effective Filtration Area (Cell)	645.6	ft^2
Overall Filter Depth	11.5	ft
Design Hydraulic Loading Rate	5.7	GPM/ft^3
Unit Conversions		
hrs to days	24	
hrs to min	60	
Design Hydraulic Loading		
HL 6 Units	10.8	GPM/ft^2
HL 12 Units	5.4	GPM/ft^3
Percent Removal	**%**	
BOD	30	
COD	30	
TSS	90	
TKN	15	

Effluent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	10.99	mg/L
COD	14.34	mg/L
TSS	4.20	mg/L
TKN	3.91	mg/L

Disinfection

There are two UV disinfection channels in use at the GRWF. These channels are 11.8ft wide, 3.61ft deep, and 57ft long, with a water depth of 3.54ft. [1] In order to provide adequate disinfection the velocity in the channel must be between 0.05-.4 m/s. [2] Equation 1 was used to calculate the channel velocity. UV disinfection occurs in multiple channels with the design assumption that plant operation meets the disinfection requirement for Class A+ water. By maintaining velocity though similar units, the new design flow can be achieved by the addition of extra units.

Table 24: Disinfection Model

Influent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	10.99	mg/L
COD	14.3	mg/L
TSS	4.2	mg/L
TKN	3.91	mg/L
Single Channel Criteria		
Width	11.83	ft
Width	3.61	m
Water Depth	3.54	ft
Water Depth	1.08	m
Total Depth	5	ft
Total Depth	1.52	m
Length	57.00	ft
Length	17.37	m
Volume	2,390.54	ft^3
Volume	67.69	m^3
Flow	8,020,860	ft^3/day
Flow	2.63	m/s
Dose	80,000	uW sec/cm^2
Dose	80	mJ/ cm^2
Banks Per Channel	3	
Modules Per Bank	28	
Lamps Per Module	8	
Lamps Per Channel	672	
Watts Per lamp	250	watts

W Per Channel	168,000	W
J/s Per Channel	168,000	J/s
x-sec area	41.94	ft^2
x-sec area	38,962.87	cm^2
Conversion Factors		
gal to ft^3	0.134	
KW to uW	1,000,000,000	
uW to mW	1,000	
ft^3 to m^3	0.03	
ft per m	3.3	
m^3 per gallon	264.2	
Seconds/day	86,400	

Design Velocity 0.05-.4 m/s			
One Channel		**Two Channel**	
HRT (day)	3.0E-04	HRT (day)	6.0E-04
HRT(hr)	7.2E-03	HRT(hr)	1.4E-02
HRT (min)	0.43	HRT (min)	0.86
HRT (sec)	25.75	HRT (sec)	51.50
Velocity (m/s)	0.675	Velocity	0.337
Energy (kWh)	4.03E+06	Energy (kWh)	8.06E+06
Three Channel		**Four Channel**	
HRT (day)	8.9E-04	HRT (day)	1.2E-03
HRT(hr)	2.1E-02	HRT(hr)	2.9E-02
HRT (min)	1.29	HRT (min)	1.72
HRT (sec)	77.25	HRT (sec)	103.00
Velocity	0.225	Velocity	0.169
Energy (kWh)	12,096,000	Energy (kWh)	16,128,000

Effluent Parameters		
Flow	60	MGD
Flow	60,000,000	GPD
BOD	11	mg/L
COD	14.34	mg/L
TSS	4.2	mg/L
TKN	3.91	mg/L

Blending Tanks

The blending tank is where the solids from the primary clarifiers, and secondary clarifiers are combined with the SEWRP flow to form a uniform solids flow that is fed into the thickening centrifuges. These tanks operate at capacity for the current buildout. The three solids streams are assumed to form a homogeneous mixture and leave the tank at a uniform solids percent. While the plants was hydraulically modeled for 60 MGD, the solid stream is based on 30MGD, with the assumption that peak flows will have less associated solids with them.

Table 25: Blending Tank Model

Influent Parameters			Percent Solids %
Flow From SEWRP	300,000	GPD	1.51
Flow From Primary Clarifiers	268,302	GPD	3
Flow From Secondary Treatment	419,562	GPD	0.51
Total	987,864	GPD	1.49
Total	686.1	GPM	1.49

Influent Parameter		
Primary Clarifier	67,290	lb/day
Secondary Clarifier	18,352	lb/day
Flow from other plant	37,826	lb/day
Total	123,468	lb/day
Total	5,145	lb/hr

Outflow Parameters			Percent Solids
Flow out of Blending tanks	987,864	GPD	1.48
Mass Rate	123,468	lb/day	

Sludge Thickening

Two centrifuges are operated with one on standby each have a capacity to process up to 600GPM of liquid hydraulic loading and 1,300lb/hr of solids loading. The water removed is returned to the head works and the thickened sludge flows into the holding tank then on to the digesters. The current system will not meet design flow. Based on a flow of 5,145GPM average one additional centrifuge will need to be added to meet the required flow with one unit on standby.

Table 26: Sludge Thickening Model

	Operating	Standby	Hydraulic (GPM)	Solids (lbs/hr)
Centrifuge	2	1	600	4,600
Centrifuge	3	1	1,200	6,900
Centrifuge	4	1	1,600	9,200

Egg Digesters

The two egg shaped digesters have a volume of 1.2 million gallons and additional units will be required to achieve an appropriate SRT of 15 to 20 days. A retention time under 15 days was used because the addition of the thermal hydrolysis processed. With the addition of thermal hydrolysis digestion is sped up by breaking down complex organic matter before entering the digesters. The equation below describes the volatile solid destruction based on the SRT [6].

Equation 4: Volatile Solids Destruction [6]

$$V_d = 13.7 \ln(SRT_{des}) + 18.9$$

Where:

V_d= Volatile solid destruction %

SRT=time of digestion, d (range 15 to 20 day)

The SRT was determined by dividing the flow of 6% solid sludge from the thickener over the total volume of the digester units. The balance of fixed solids to VSS was then determined to find a value of solids leaving the digesters.

Table 27: Digester Model

Inflow to Digesters Parameters			**Percent Total Solids**
Flow out of Thickener	245,314	GPD	6
Flow out of Thickener	170	GPM	6
Flow out of Thickener	123,468	lbs/day	
Flow out of Thickener	5,144	lbs/hr	
Volatile solids	80	%	
Fixed Solids	20	%	

Units	**Total Capacity (MG)**	**HRT (days)**	**VSS Destruction**	**VSS Final**	**Final FSS**	**Final Volume**	**Final Percentage**
2	2,400,000	9.8	50.1	66.6	33.4	59.9	3.59
3	3,600,000	14.7	55.7	63.9	36.1	55.4	3.33
4	4,800,000	19.6	59.6	61.7	38.3	52.3	3.14
5	6,000,000	24.5	62.7	59.9	40.1	49.8	2.99
6	7,200,000	29.4	65.2	58.2	41.8	47.8	2.87

Outflow Parameters			**Percent Total Solids**
Flow out of Digesters	245,314	GPD	3.33
Flow out of Digesters	170	GPM	3.33
Flow out of Digesters	68,450	lbs/day	
Flow out of Digesters	2,852	lbs/hr	
Volatile solids	61.75		
Fixed Solids	38.25		

Inflow Parameters			**Percent Total Solids**
Flow out of Digesters	245,314	GPD	3.32
Flow out of Digesters	170	GPM	3.32
Flow out of Digesters	68,450	lbs/day	
Flow out of Digesters	2,852	lbs/hr	

Dewatering

Dewatering design was determined similar to the sludge thickener. Design flow from the digester was divided by the capacity of each unit to determine the number of units that are required for expansion. Although the current centrifugal units meet capacity, an additional unit will be added because the solids flow is close to the operation capacity of the unit.

Table 28: Dewatering Model

Centrifugal Units	**Operation**	**Standby**	**Operation Capacity (GPM)**	**Operation Capacity (lbs/day)**
Centrifugal Units	1	1	200	2900
Centrifugal Units	2	1	400	5800
Centrifugal Units	3	1	600	8700

Outflow Parameters			**Percent Total Solids**
Flow out of Digesters	30,784	GPD	25
Flow out of Digesters	21	GPM	25
Flow out of Digesters	64,557	lbs/day	
Flow out of Digesters	2,690	lbs/hr	
Wet tons Hauled	32.3	tons/day	25

8.0 Appendix B: Wastewater Characteristics Analysis

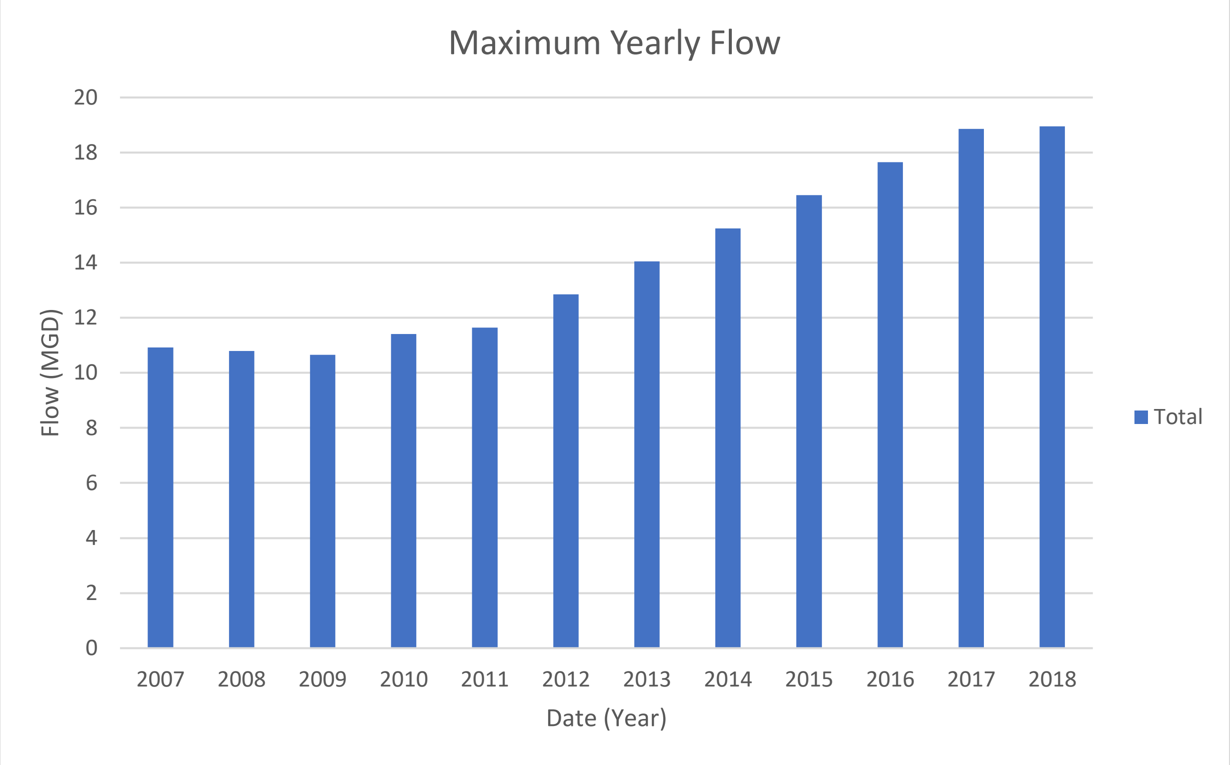


Figure 3: Yearly average of daily influent flow in MGD at GWRF

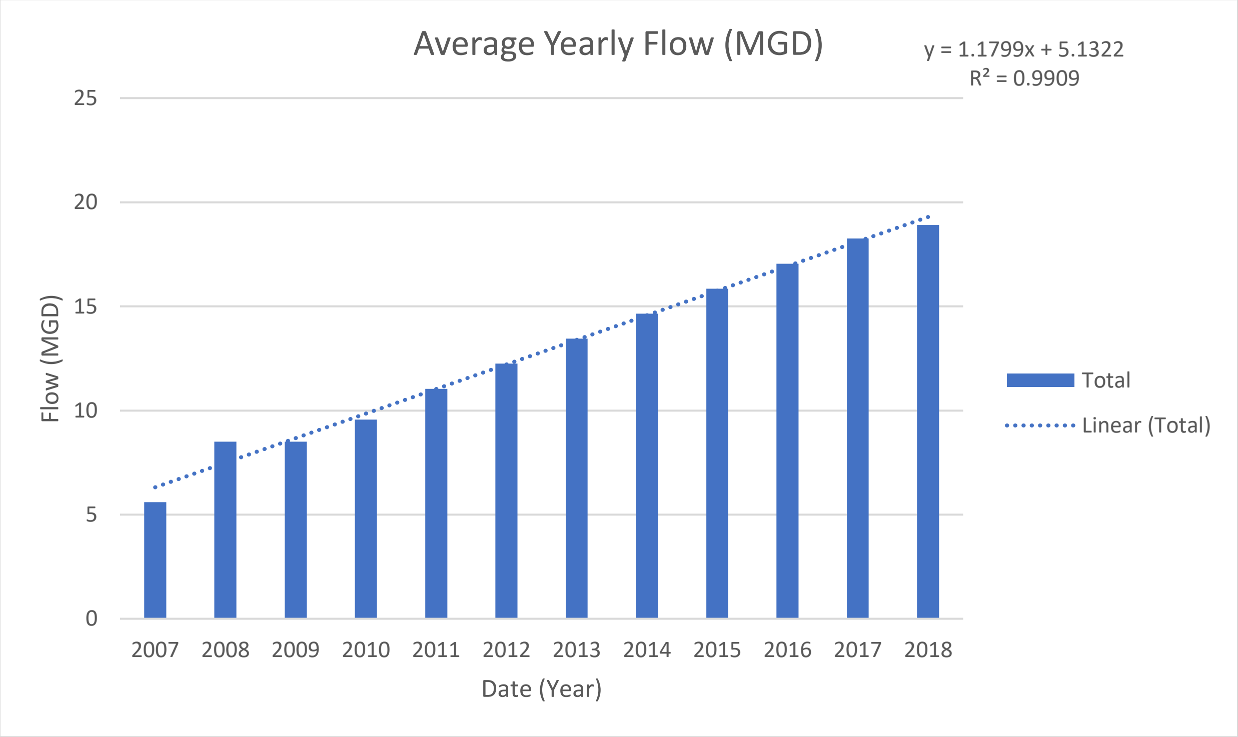


Figure 4: Monthly average of daily influent flow data in MGD at GWRF

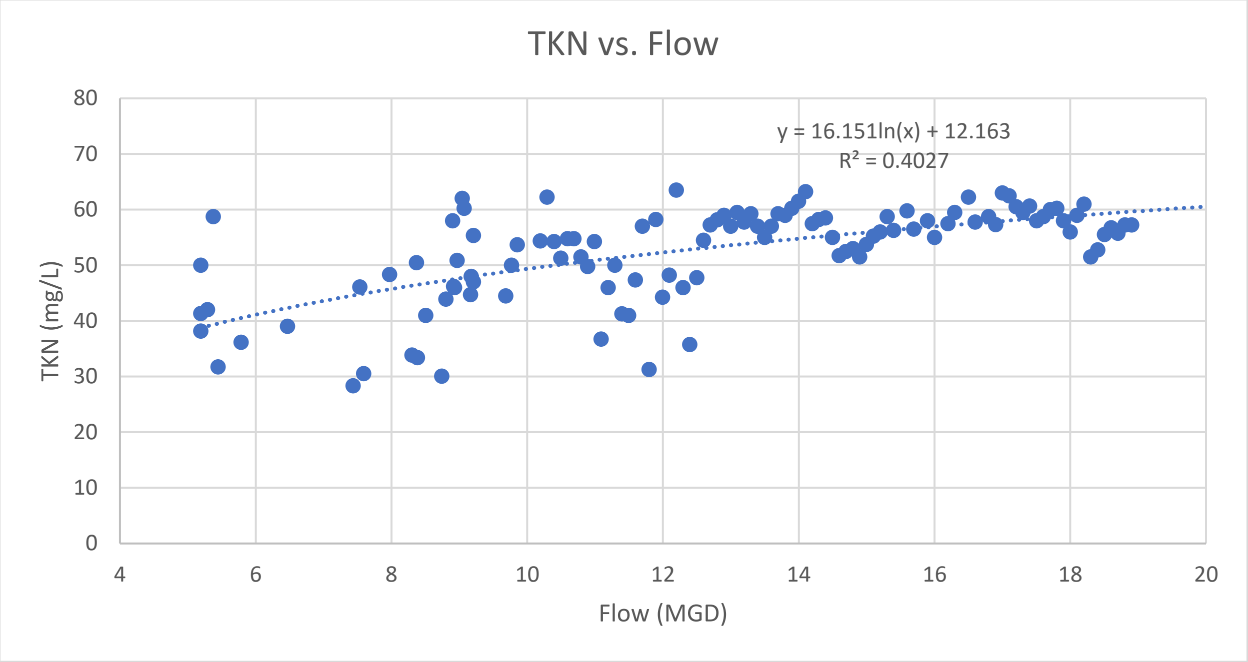


Figure 5: Total Kjedahl Nitrogen (TKN) per MGD daily flow data

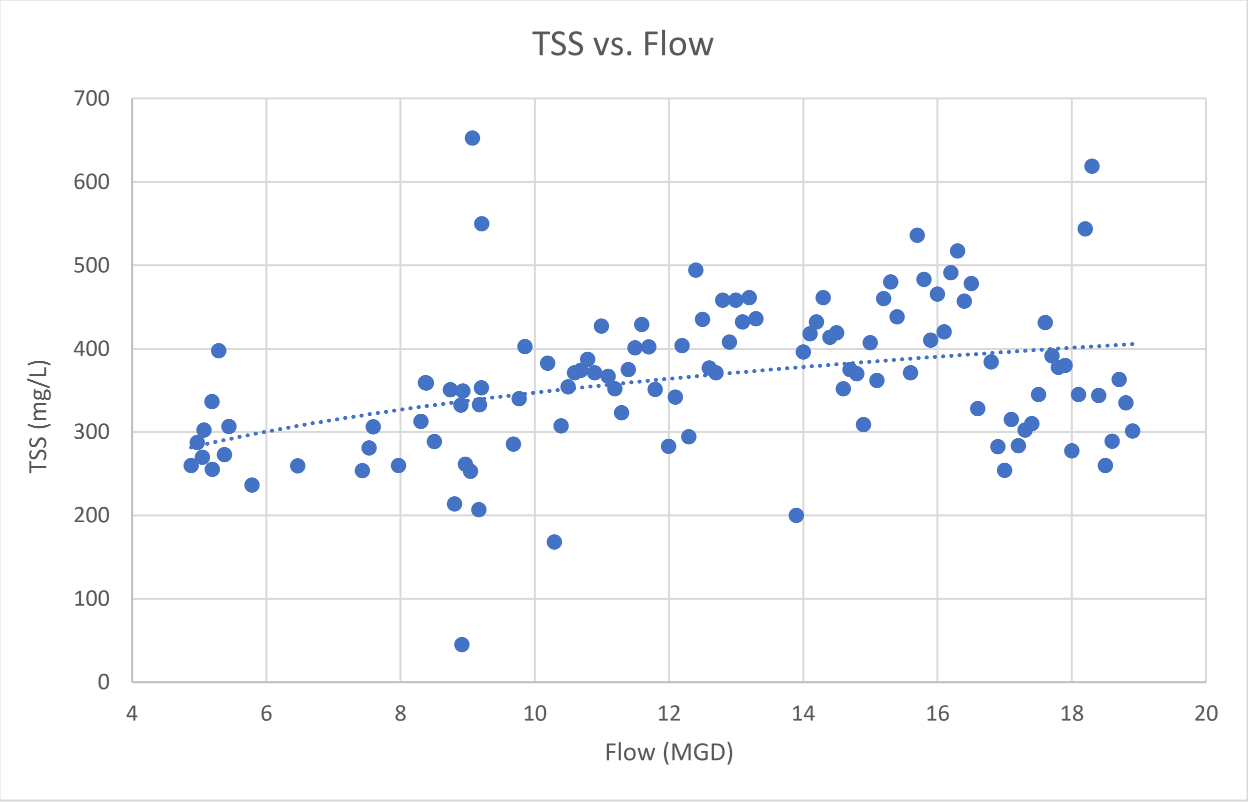


Figure 6: Total Suspended Solids (TSS) per MGD daily flow data

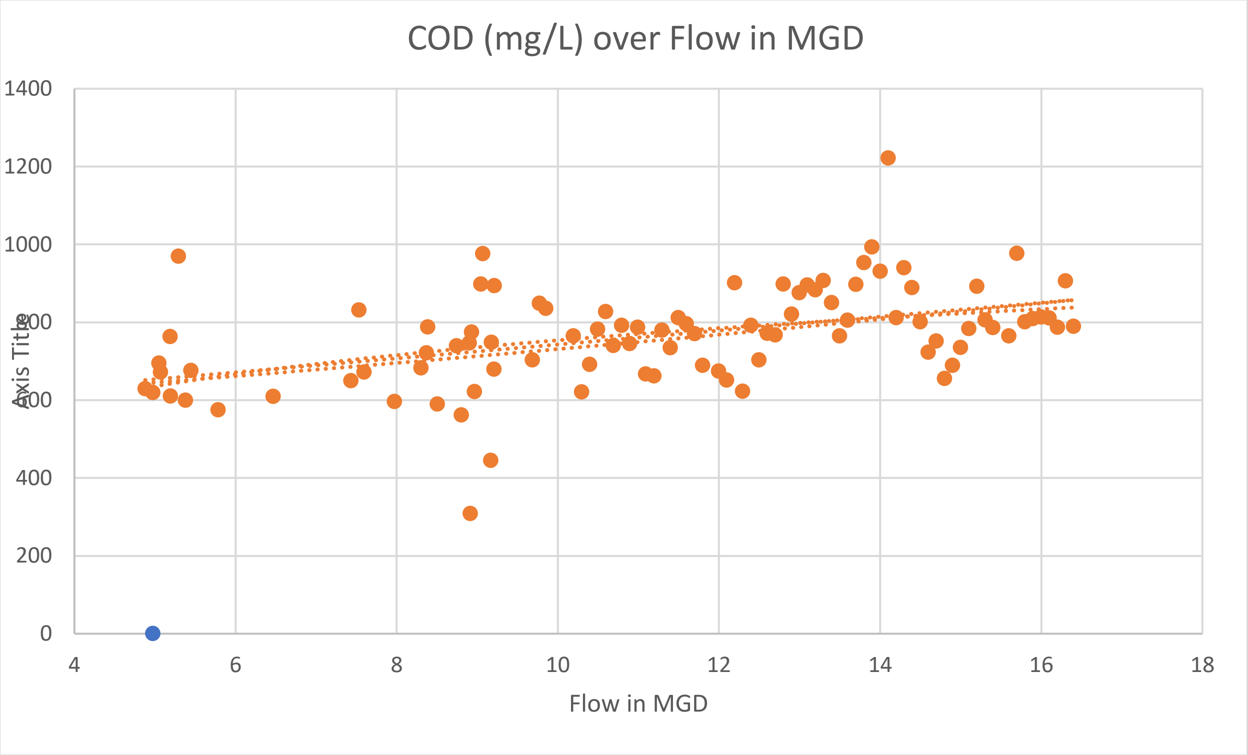


Figure 7: Chemical Oxygen Demand (COD) per MGD daily flow data

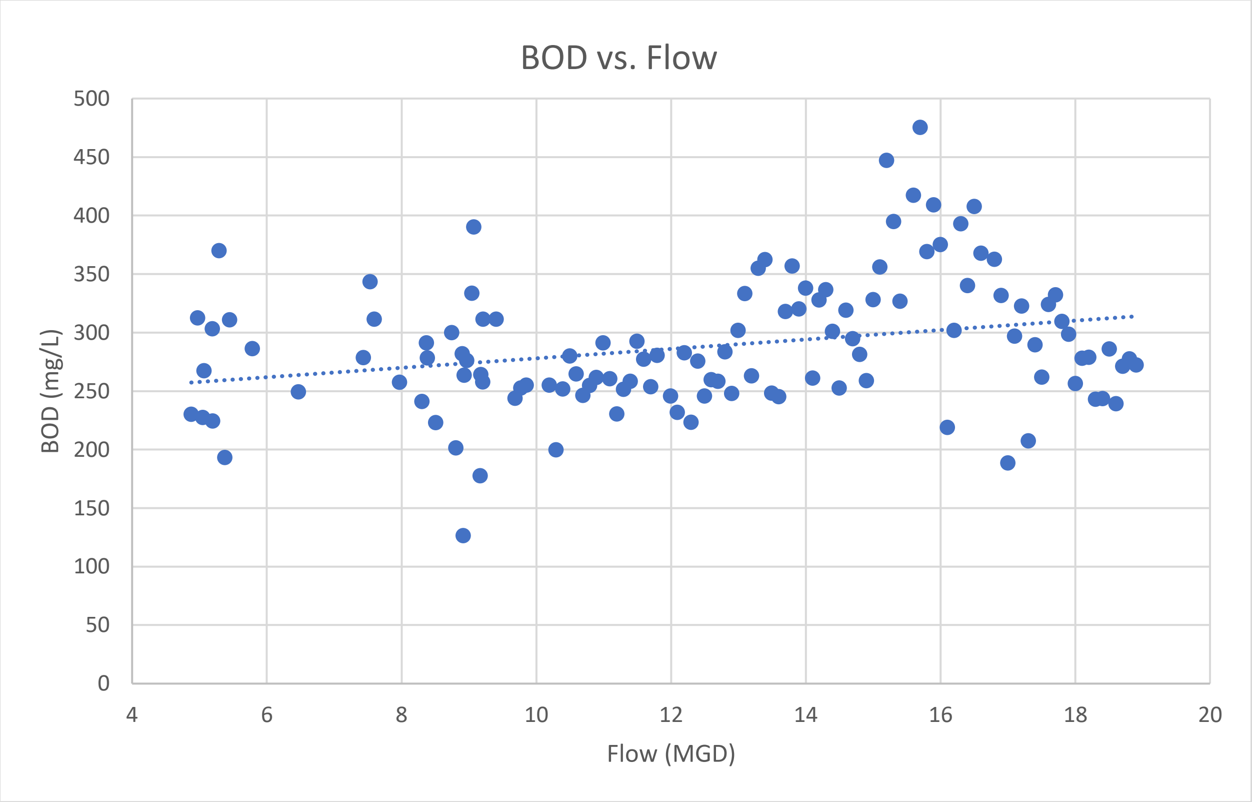
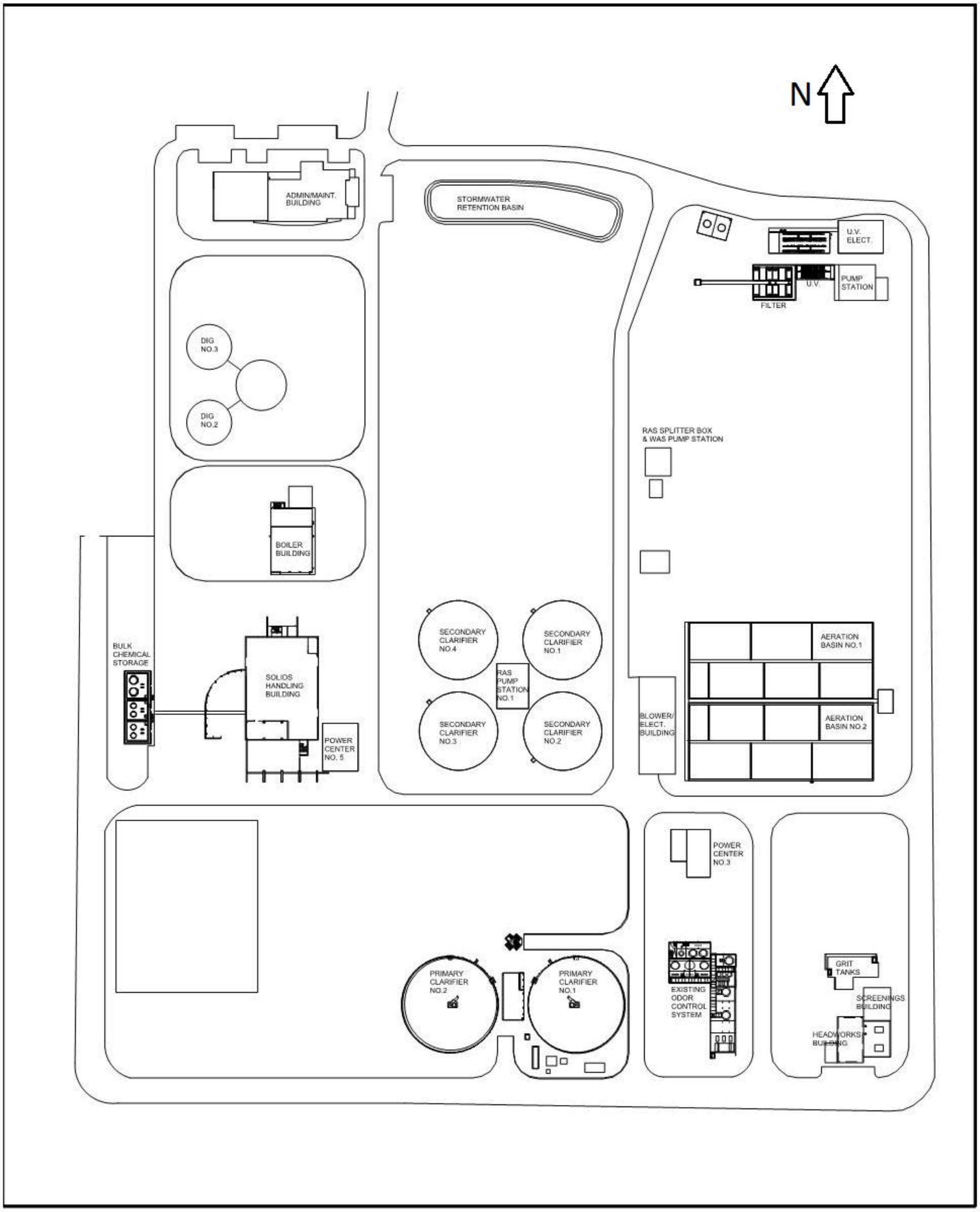


Figure 8: Biological Oxygen demand (BOD) per MGD daily flow data

9.0 Appendix C: Drawings



Greenfield Water Reclamation Facility
Existing Site Layout

DRAWN BY: Nicholas Babcock
CHECKED BY: Ryan Winter
DATE: 03/13/2018
SCALE: 1:40

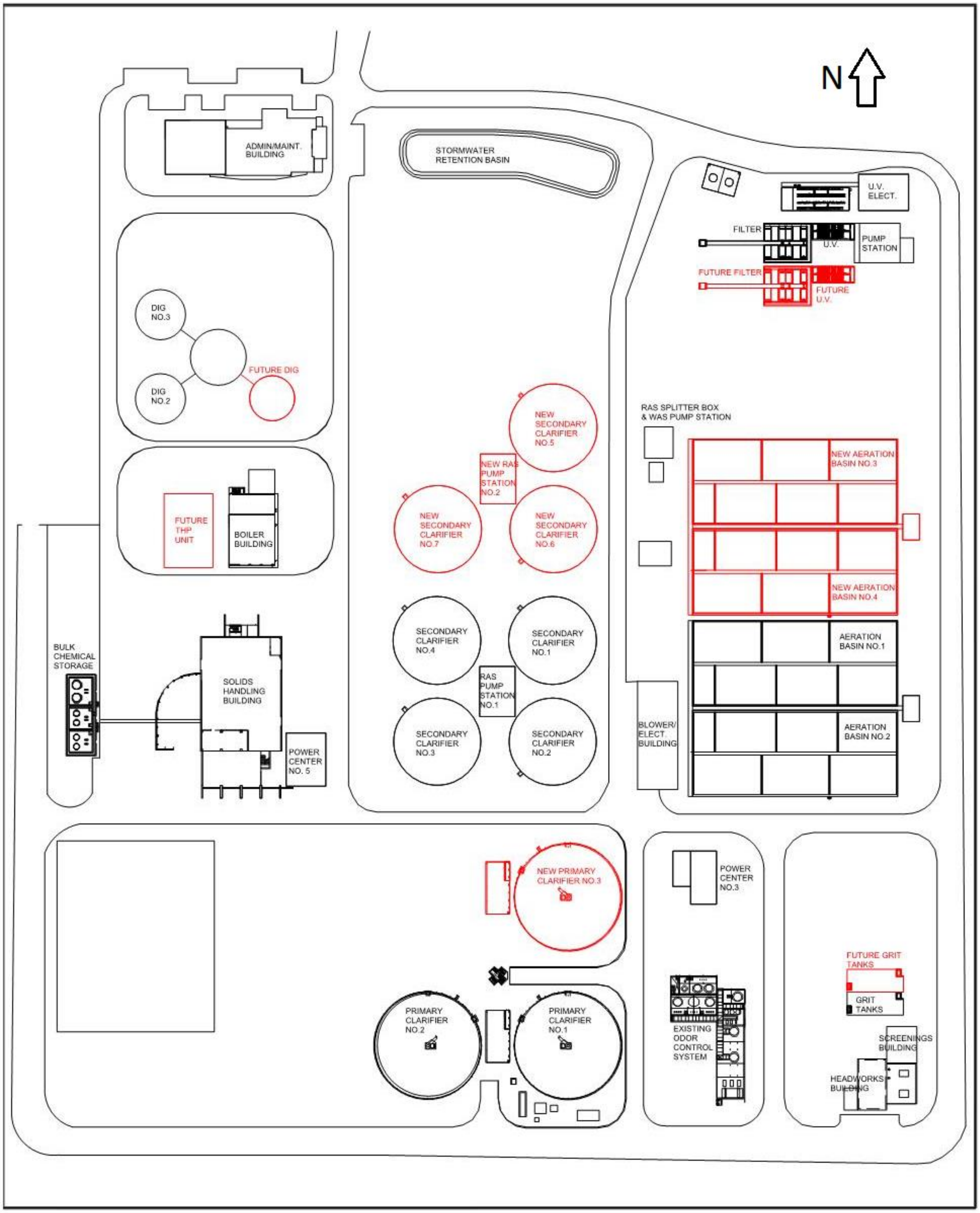
REVISIONS

NO.	DATE	COMMENTS
1	03/14/2018	

Northern Arizona University
Department of Civil Engineering, Construction Management and Environmental Engineering

~SHEET~ 1 OF 1

Figure 9: GWRF Existing Site Layout [1]



Greenfield Water Reclamation Facility

Updated Site Layout

DRAWN BY: Nicholas Babcock
CHECKED BY: Ryan Winter
DATE: 04/08/2018
SCALE: 1:40

REVISIONS NO.	DATE	COMMENTS
1	04/08/2018	

Northern Arizona University
Department of Civil Engineering, Construction Management and Environmental Engineering

SHEET 1 OF 1

Figure 10: GWRF Expansion Site Layout [1]

10.0 Appendix D: Decision Matrices

Table 29: Decision Matrix Table

Grit Removal	**Operations & Maintenance**	**Social**	**Feasibility/Constructability**	**Efficiency Improvements**	**Life Cycle Cost**	**Score**
Weight	2	3	5	4	6	/100
Option 1: Add one redundant WesTech mechanically-induced vortex grit removal system	3	3	5	3	3	70
Option 2: Add one WesTech aerated grit chamber	2	3	2	2	1	37
Primary Sedimentation Basins	**Operations & Maintenance**	**Social**	**Feasibility/Constructability**	**Efficiency Improvements**	**Life Cycle Cost**	**Score**
Weight	2	3	5	4	6	/100
Option 1: Add one redundant primary sedimentation basin	3	3	4	3	3	65
Option 2: Add one rectangular sedimentation basin	2	3	3	2	2	48
Option 3: Replace with Huber primary drum screens	2	4	3	5	1	57
Aeration Basins	**Operations & Maintenance**	**Social**	**Feasibility/Constructability**	**Efficiency Improvements**	**Life Cycle Cost**	**Score**
Weight	2	3	5	4	6	/100
Option 1: Add two redundant MLE aeration basins	3	3	5	3	3	70
Secondary Clarifiers	**Operations & Maintenance**	**Social**	**Feasibility/Constructability**	**Efficiency Improvements**	**Life Cycle Cost**	**Score**
Weight	2	3	5	4	6	/100
Option 1: Add three redundant secondary clarifiers	3	3	5	3	3	70
Option 2: Add three rectangular clarifiers	2	3	3	2	4	60

Tertiary Filters	**Operations & Maintenance**	**Social**	**Feasibility/Constructability**	**Efficiency Improvements**	**Life Cycle Cost**	**Score**
Weight	2	3	5	4	6	/100
Option 1: Add six redundant Kruger cloth-media disk filters	3	3	5	3	3	70
Option 2: Add additional dual media filters	2	3	2	3	1	41
Disinfection	**Operations & Maintenance**	**Social**	**Feasibility/Constructability**	**Efficiency Improvements**	**Life Cycle Cost**	**Score**
Weight	2	3	5	4	6	/100
Option 1: Add two redundant UV channels with WEDECO lamps	3	3	5	3	3	70
Option 2: Replace with chlorine contact	1	2	2	3	5	60
Thickening Centrifuges	**Operations & Maintenance**	**Social**	**Feasibility/Constructability**	**Efficiency Improvements**	**Life Cycle Cost**	**Score**
Weight	2	3	5	4	6	/100
Option 1: Add two redundant Westfalia centrifuges	3	3	5	3	3	70
Option 2: Add two Komline-Sanderson gravity belt thickeners	2	3	2	3	4	59
Option 3: Add two Parkson rotating drum thickeners	2	3	2	3	5	65
Egg-Shaped Digesters	**Operations & Maintenance**	**Social**	**Feasibility/Constructability**	**Efficiency Improvements**	**Life Cycle Cost**	**Score**
Weight	2	3	5	4	6	/100
Option 1: Add two redundant anaerobic digester	3	3	5	3	3	70
Option 2: Add Cambi Thermal Hydrolysis prior to digestion and one redundant digester	2	4	5	5	2	73

Dewatering Centrifuges	**Operations & Maintenance**	**Social**	**Feasibility/Constructability**	**Efficiency Improvements**	**Life Cycle Cost**	**Score**
Weight	2	3	5	4	6	/100
Option 1: Add one redundant Westfalia solid bowl dewatering centrifuge	3	3	5	3	3	70
Option 2: Add one FRC belt press dewatering system	2	3	2	2	2	43

11.0 Appendix E: Cost Estimates

Cost was estimated using actual past project budgets, and then were adjusted using inflation rates to bring past values into present day worth. In addition, costs were adjusted based on location using Metro Denver Economic Corporation's construction cost index for selected cities. If a city was not found in the index the nearest city was used. Finally, these estimates were then entered into a spread sheet that found the 30 year life cycle cost based on the cost of construction operation and maintenance with some units requiring major part replacements every ten years or other specific challenges. The charts below describes the alternatives for each unit and their total lifecycle cost. The life cycle cost in the main document is the sum of all the chosen technologies and their operation and maintenance costs. It is worth noting that additional design and cost will be associated with updating the pump systems and air treatment.

Equation 5: Cost Estimate

$$Estimated\ Cost = \frac{Cost\ of\ Project}{Inflatuion\ Factor} * \frac{City\ Index\ Number\ of\ site}{Pheonix\ City\ index\ (.87)} * Size\ Adjustment\ when\ Nesscary$$

The life cycle cost was estimated by adding construction cost to all operation, maintenance, materials and replacement costs over a thirty-year period. Demolition costs were not included in this projection.

Grit Removal

Table 30: Life cycle cost analysis of alternative grit removal systems [7]

	Vortex Grit Removal	**Aerated Grit Removal**
Construction	870,000	1,200,000
O & M /year	26,000	509,611
Life Cycle Cost	1,379,611	3,160,044

Primary Clarifiers

Table 31: Life cycle cost of Primary clarifiers [7]

	One 140' Round Clarifier	**Square Clarifier**	**Primary Screening**
Construction	4,033,500	3,668,500	6,000,000
O & M /year	8,000	12,000	80,000
Life Cycle Cost	4,190,304	4,390,368	7,568,035

Aeration

Table 32: Life cycle cost of aeration basin [8]

	One Additional Basin
Construction	30,000,000
O & M /year	800,000
Life Cycle Cost	45,680,353

Secondary Clarifiers

Table 33: Life cycle cost of secondary clarifiers [7] [9] [10]

	Three 120' Clarifiers	Square Clarifiers
Construction	10,948,500	8,123,158
O & M /year	20,952	35,769
Chain Replacement 10/yr		1,117,784
Life Cycle Cost	11,359,168	10,274,872

Tertiary Filtration

Table 34: Life cycle cost of tertiary filtration [7]

	Additional Disc Filters	Cloth Media Filter
Construction	8,384,696	9,571,571
O & M /year	101,000	180,240
Replacement of Media 10/yr	104,000	234,430
Life Cycle Cost	11,549,663	15,283,007

Disinfection

Table 35: Life cycle cost of UV disinfection units or replacement with a chlorine system [11]

	Additional UV Units	Total Replacement with Chlorine System
Construction	6,101,000	11,440,000
O & M /year	143,000	67,000
NaOCl	0	400,000
Sodium Bisulfate	0	67,000
Bulbs	31,500	0
Electricity	603,000	0
Life Cycle Cost	27,938,863	21,906,636

Thickening

Table 36: Life cycle cost estimate of thickeners [12]

	Centrifuge	Gravity Belt Thickener
Construction	2,495,000	1,342,500
O & M /year	103,907	129,500
Life Cycle Cost	4,531,623	3,880,757

Digestion

Table 37: Life cycle cost of different digester configurations [11] [13] [14] [15]

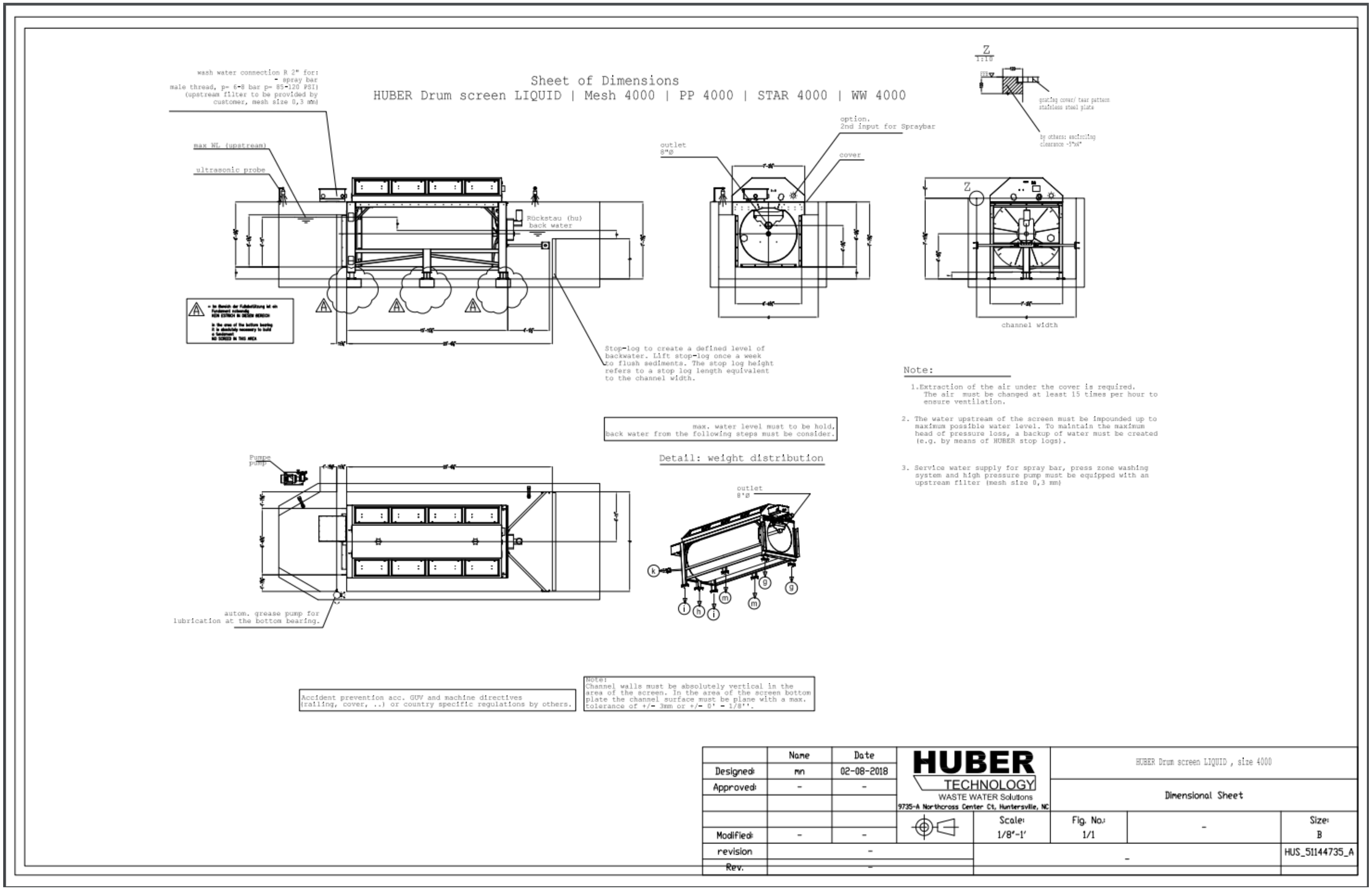
	Egg Shaped Digester	Two Digesters	Hydrolysis and One Digester
Construction	10,263,000	20,526,000	40,263,000
O & M /year	103,000	411,000	514,000
Sludge Disposal	589,000	500,000	0
Sludge Sale	0	0	564,000
Life Cycle Cost	23,826,000	34,364,000	39,291,000

Dewatering

Table 38: Life cycle cost of dewatering systems [16]

	Centrifuge	**Gravity Belt Thickener**
Construction	4,466,000	3,336,000
O & M /year	103,907	129,500
Life Cycle Cost	6,502,623	5,874,257

12.0 Appendix F: Vendor Submittals



Sheet of Dimensions
HUBER Drum screen LIQUID | Mesh 4000 | PP 4000 | STAR 4000 | WW 4000

wash water connection R 2" for:
- spray bar
male thread, p= 6-8 bar p= 85-120 PSI)
(upstream filter to be provided by customer, mesh size 0,3 mm)

In the area of the bottom bearing it is absolutely necessary to build a fundament
NO SCREED IN THIS AREA

Stop-log to create a defined level of backwater. Lift stop-log once a week to flush sediments. The stop log height refers to a stop log length equivalent to the channel width.

max. water level must to be hold, back water from the following steps must be consider.

Detail: weight distribution

autom. grease pump for lubrication at the bottom bearing.

Note:

1. Extraction of the air under the cover is required. The air must be changed at least 15 times per hour to ensure ventilation.
2. The water upstream of the screen must be impounded up to maximum possible water level. To maintain the maximum head of pressure loss, a backup of water must be created (e.g. by means of HUBER stop logs).
3. Service water supply for spray bar, press zone washing system and high pressure pump must be equipped with an upstream filter (mesh size 0,3 mm)

Accident prevention acc. GUV and machine directives (railing, cover, ..) or country specific regulations by others.

Note:
Channel walls must be absolutely vertical in the area of the screen. In the area of the screen bottom plate the channel surface must be plane with a max. tolerance of +/- 3mm or +/- 0' - 1/8''.

	Name	Date
Designed:	mn	02-08-2018
Approved:	-	-
Modified:	-	-
revision	-	
Rev.	-	

HUBER
TECHNOLOGY
WASTE WATER Solutions
9735-A Northcross Center Ct, Huntersville, NC

HUBER Drum screen LIQUID , size 4000
Dimensional Sheet

Scale:	Fig. No:		Size:
1/8"-1'	1/1	-	B
	-		HUS_51144735_A

13.0 Appendix G: Construction Schedule

Table 39: Expansion Construction Schedule

Expansion Construction Schedule

Tasks	Duration (months)	2018								2019												2020												2021			
		M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Total Construction Period	36	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Preliminary Site Work	3	🟨	🟨	🟨																																	
Earthwork	6				🟦	🟦	🟦	🟦	🟦	🟦																											
Formwork, Concrete Placement	9						🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨																						
Mechanical Equipment Installation	8													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																
Piping and Pumping Installation	4																					🟨	🟨	🟨	🟨												
Demolition	3																									🟦	🟦	🟦									
Site Finishing	3																												🟨	🟨	🟨						
Testing and Training	6																									🟦	🟦	🟦	🟦	🟦	🟦						
Completion	6																															🟨	🟨	🟨	🟨	🟨	🟨

14.0 Appendix H: Arizona department of Environmental Quality Reuse Criteria

Table 40: Class A+ Water Reuse Criteria [17]

Water Class	**Water Quality Criteria**
A+	24-hour average turbidity ≤ to 2 NTU
	Turbidity of filtered effluent required to be < 5 NTU
	No detectable fecal coliform bacteria in four of the last seven daily water samples taken
	The maximum concentration of fecal coliform bacteria in a single water sample < 23/100mL
	5 sample concentration average < 10mg/L of total nitrogen
	Wastewater must have undergone secondary treatment, filtration, nitrogen removal treatment, and disinfection or by a similar process

Table 41: Class A and B Solids Reuse Criteria [18]

Classification	**Fecal Coliform**	**Salmonella**
Class A	< 1,000 MPN/g TS or 3 MPN/4 g TS	
Class B	< 2,000,000 MPN/g TS or < 2,000,000 CFU/g TS	-
Abbreviations: MPN = most probable number TS = total solids CFU = colony forming units PFU = plaque forming units		

15.0 Appendix I: Existing Units

Table 42: Existing Liquid Stream Units

INFLUENT SCREENING		
Manufacturer/Type	Duperon Flex Rake	
# Influent Channels	Operation	2
	Bypass	2
	Total	4
Channel Dimensions	Width (ft)	4.5
	Depth (ft)	8
	Bar Spacing (in)	0.5
Flow Characteristics	Max Velocity (ft/sec)	5
	Capacity (MGD)	64
GRIT REMOVAL SYSTEM		
Manufacturer/Type	WesTech Induced Vortex Grit Removal Unit	
# Units	Operation	1
	Standby	1
Capacity	Rated (MGD)	16
	Total (MGD)	32
Diameter (ft)		18
PRIMARY SEDIMENTATION BASINS		
Manufacturer/Type	Circular, Hopper Bottom, Center Feed, Spiral Scrapper	
# Units	Operation	1
	Standby	1
	Total	2
Volume each basin (gal)		1,875,000
Capacity	Average day (MGD)	16
	Maximum Day (MGD)	32
Hydraulic Retention Time (hrs)	Average design flow (all basins in service)	5.6
	Maximum month (all basins in service)	3.8
Basin Dimensions (ft)	Diameter (ft)	140
	Side Water Depth (ft)	14.5
	Center Depth (ft)	19.83
	Free Board (ft)	3.5
AERATION BASINS		
Manufacturer/Type	MLE Process, Uses Coarse Bubble Diffusers	
# Units	Operation	2
	Standby	0
Dimensions	Length (ft)	240.33
	Width (ft)	297.17
Hydraulic Retention Time (hrs)		10.6
Capacity	Operating (MGD)	32

SECONDARY CLARIFIERS		
Manufacturer/Type	Circular, Center feed	
# Units	Operation	3
	Standby	1
Basin Dimensions	Interior Wall-to-Wall Diameter (ft)	120
	Side Water Depth (ft)	15
	Freeboard (ft)	2.5
Volume	Each Basin (gal)	1,270,000
	One basin out of service (gal)	3,810,000
	All Basins (gal)	5,080,000
Hydraulic Retention Time	Average Day (hrs)	7.6
	Maximum Month (hrs)	5
Capacity	Operating (MGD)	32
TERTIARY FILTRATION		
Manufacturer/Type	USF/Kruger, Model HSF-3110	
# Filter Cells	Operation	5
	Standby	1
	Total	6
Number of Modules per Cell		12
Hydraulic Loading Rate	Average Daily Flow (GPM/ft^2)	2.9
	Peak Daily Flow (GPM/ft2)	5.7
Effective Filtration Area	Per Cell(ft^2)	645.6
Capacity	Total (MGD)	32
DISINFECTION		
Manufacturer/Type	Concrete channel with Wedeco TAK55 system	
# Units		2
Capacity	Annual Average (MGD)	16
	Peak Hourly (MGD)	48
Design Dose (µW sec/cm^2)		80,000

Table 43: Existing Solids Stream Units

BLENDED SLUDGE TANKS		
# Units		2
Capacity		Buildout
SLUDGE THICKENEING		
Manufacturer/Type	Westfalia Centrifuge horizontal, solid bowl	
# Units	Operation	2
	Standby	1
Loading Rates (@ Max Month)	Hydraulic (GPM)	300
	Solids (lbs/hour)	1500
THICKENED SLUDGE TANKS		
# Units		1
Capacity		Buildout
SLUDGE DIGESTION		
Manufacturer/Type	Egg-shaped, steel	
# Units	Operating	2
Unit Size/ Capacity (Nominal)	MG	1.2
Loading Criteria (@ Max Month)	Hydraulic Retention Time (days)	29.3
	VSS Loading (ppd/cf)	0.1
DIGESTED SLUDGE STORAGE		
# Units		1
Capacity		Buildout
SLUDGE DEWATERING		
Manufacturer/Type	Westfalia Centrifuge horizontal, solid bowl	
# Units	Operating	1
	Standby	1
Max Month Loading Rates	Hydraulic (GPM)	150
	Solids (lbs/hr)	2,500
DEWATERED CAKE STORAGE		
# Units		2
Capacity		Buildout