Hazen *Technical Memorandum*

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To: OWASA

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Mason Farm WWTP 2017-2018 Secondary Treatment Evaluations Compilation TM

FINAL

The purpose of this technical memorandum (TM) is to summarize the objectives and results of three evaluations that were completed by Hazen and Sawyer between 2017 and 2018 for the Mason Farm WWTP. These three evaluations include:

- *The Secondary Clarifier Rehabilitation Study (completed in June 2017)*
- *The Process Model Update and Internal Recycle Evaluation (completed in September 2017)*
- *The RAS Pumping Rehabilitation Study (completed in August 2018)*

The purpose of these evaluations was to determine how OWASA can mitigate several issues related to the liquid treatment train of the WWTP, and assess their impacts to treatment plant performance. The results of each evaluation provide recommendations for how OWASA can improve treatment plant reliability and reduce maintenance requirements while minimizing total project costs. The specific results and recommendations from each evaluation are described within this TM.

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1. Background

The Mason Farm wastewater treatment plant (WWTP) is an advanced activated sludge treatment facility that is permitted to discharge up to 14.5 million gallons per day (mgd) on a maximum month basis to Morgan Creek in the Jordan Lake watershed. The secondary treatment process at the WWTP consists of aeration basins, secondary clarifiers, nutrified sludge (NSL) cells, return activated sludge (RAS) and waste activated sludge (WAS) pumping, and aeration equipment for providing oxygen to the biological process. The aeration basins can be operated in numerous configurations with varying numbers of trains and cells per train. Currently, the basins are configured such that three treatment trains operate with four cells per train. The first, second, third, and fourth cells in each train operate as aerobic, anoxic, anoxic, and aerobic zones, respectively. Mixed liquor from the three trains is conveyed to Cell 5 which alternates between an aerobic and anoxic zone depending on the season. Historically, primary effluent had been conveyed to the Aeration Basin Influent Channel to be distributed to the first cell of each aeration basin in service. However, more recently, WWTP staff began to operate in step-feed mode in which primary effluent is fed to the first two cells of the aeration basins. This process provides carbon to the second (anoxic) cell for denitrification to ultimately enhance total nitrogen removal while decreasing chemical usage.

The Mason Farm WWTP has a total of five secondary clarifiers. With the exception of Clarifiers 2 and 3, each clarifier was constructed at different times and have different sizing and configurations. Clarifiers 1 and 5 are in service while the remaining clarifiers are out of service under normal operating conditions. The plant briefly operated with only Clarifiers 1 and 4 in service in 2017 due to RAS pump repairs that were being completed for Clarifier 5.

RAS is pumped from the secondary clarifiers to the NSL cells via four RAS pump stations. One RAS pump station serves Clarifiers 2 and 3, and there are dedicated RAS pump stations for Clarifiers 1, 4, and 5. RAS combines with acetic acid in the NSL cells to provide for RAS denitrification and biological phosphorus release before recycling the activated sludge back to the aeration basins.

Hazen and Sawyer performed a WWTP Hydraulic and Treatment Capacity Study (Mason Farm Wastewater Treatment Plant Hydraulic and Treatment Capacity Study) in 2010 in response to proposed nutrient limitations resulting from the Jordan Lake Rules. The purpose of this study was to determine the treatment and hydraulic capacity of existing facilities and to identify improvements required to comply with the Jordan Lake Rules. Hazen evaluated nutrient removal optimization alternatives, aeration capacity alternatives, secondary treatment capacity expansion alternatives, recycle stream treatment alternatives, and chemical feed optimization to develop recommended plant improvements. The evaluations and results of the 2010 Capacity Study have served as a reference for all subsequent Mason Farm WWTP evaluations developed by Hazen described herein.

Hazen was retained by OWASA in 2017 and 2018 to address several operating concerns that have impacted equipment maintenance and operability related to the secondary treatment process at the Mason Farm WWTP. These concerns were addressed in three evaluations. Although the evaluations were conducted as separate projects, their outcomes relate to the operation of the wastewater treatment process and bear impact on one another.

The first study developed by Hazen evaluated rehabilitation alternatives for Secondary Clarifiers 2, 3, and 4. Concerns identified by plant staff include corrosion in sludge removal mechanisms, dated Stamford baffles, unstable centerwell, and effluent launder design. In addition to the mechanical and structural failures associated with the clarifiers, the hydraulic imbalances at the WWTP increase the stress placed on the clarifiers in service and consequently exacerbate the existing issues. In order to improve the overall performance, increase longevity, and reduce operational and maintenance issues for Secondary Clarifiers 2, 3, and 4, Hazen developed an evaluation of various secondary clarifier rehabilitation alternatives. This evaluation is included in **Appendix A** and is titled Mason Farm WWTP Secondary Clarifier Rehabilitation Study.

The second evaluation conducted by Hazen was the Process Model Update and Internal Recycle Evaluation. Mason Farm WWTP staff have implemented new operating strategies within the past several years to improve plant performance while minimizing operating costs. Specifically, the WWTP transitioned to step feed as recommended in the 2010 Capacity Study, which lead to an increase in the return activated sludge (RAS) recycle rates. OWASA retained Hazen in September 2017 to determine the feasibility of adding NRCY pumps to the Mason Farm WWTP. In order to model the impacts of adding NRCY pumps, Hazen updated the calibrated process model that was developed as part of the 2010 Capacity Study. The PowerPoint presentation which summarizes the method and results of this evaluation is included in **Appendix B.**

The third study completed by Hazen was an alternatives evaluation for the rehabilitation of the existing RAS pumping system to address design, maintenance, reliability, and operability issues related to the RAS pumps. The plant recently increased RAS recycle flow rates, which has highlighted the importance of RAS pumping capacity, as well as equipment redundancy. The existing RAS pumps were originally designed without any standby or redundant capacity. If one RAS pump fails, the associated final clarifier must be taken out of service until the pump has been repaired. Furthermore, the existing RAS pumping infrastructure does not provide for a back-up pump to be utilized while an existing pump is out of service.

Another factor that has increased the burden on the existing RAS pumps is the number of secondary clarifiers typically in service. Under normal operating conditions, Clarifiers 1 and 5 are in service while the remaining clarifiers are out of service. When only Clarifiers 1 and 5 are operating in lieu of all five clarifiers, the influent flow rate to the clarifiers in service increases by approximately 80%. In addition to the issues related to the existing RAS pump capacities and lack of redundancy, the RAS pumps have become obsolete. Pumps parts needed to make repairs and replacements can no longer be purchased off-the-shelf. Due to the limitations of the existing RAS pumps described herein, OWASA retained Hazen to evaluate various alternatives that could alleviate deficiencies and ease the operation of the existing RAS pumping system. Detailed information about this evaluation is included in **Appendix C**, in the TM titled Mason Farm WWTP RAS Pumping Rehabilitation Study.

2. Summary of the Secondary Clarifier Rehabilitation Study

Due to various age, performance, mechanical failures, configurations, and maintenance challenges associated with Secondary Clarifiers 2, 3, and 4, several alternatives were evaluated to improve the overall performance of these clarifiers. The specific concerns that were identified by plant staff for Clarifiers 2 and 3, and 4 are listed in **Table 2-1** and **Table 2-2**, respectively.

Table 2-1: Secondary Clarifiers 2 and 3 Operational and Maintenance Concerns

Clarifiers 2 and 3
1. Rust and Cracks in Sludge Removal Headers
2. Weir Plate Corrosion
3. Dated Stamford Baffles
4. Rust and Cracks in Mechanism
5. Gear Balancing Issues and Unstable Centerwell
6. Scum Accumulation in Centerwell

Table 2-2: Secondary Clarifier 4 Operational and Maintenance Concerns

Clarifier 4
1. Effluent Launder Design / Weir Brush Issues
2. Corrosion in Mechanism
3. Scum Accumulation in Centerwell
4. Unstable Centerwell

Additionally, in order to assess the clarifier improvement alternatives on a holistic basis, the mixed liquor distribution hydraulics and secondary clarifier performance analyses that were developed for the 2010 Capacity Study were updated as part of this study.

2.1 Alternatives Evaluated

Five alternatives were evaluated for the rehabilitation and replacement of Clarifiers 2 and 3, and two alternatives were evaluated for Clarifier 4. **Tables 2-3** and **2-4** provide descriptions of each alternative for Clarifiers 2 and 3, and for Clarifier 4, respectively.

Table 2-3: Alternatives for Clarifiers 2 and 3

	Description	Issues Addressed (from Table 2-1)	Cost [1]
Alternative 1A	Replace the sludge removal headers with 304 stainless steel headers, replace the Stamford baffles, and replace the v-notch weir plates.	2, 3, 4	$410,000
Alternative 1B	Includes all the components in Alternative 1A, with the addition of replacing the existing centerwell and adding an energy dissipating inlet (EDI) to improve overall settleability.	1, 2, 3, 6	$960,000
Alternative 2	Replace the entire sludge removal mechanism with 304 stainless steel, including sludge removal headers, clarifier drives and motors, centerwells, scum removal mechanisms, Stamford baffles, v-notch weir plates, and energy dissipating inlets.	All issues addressed (1-6)	$1,290,000
Alternative 3	Demolition of Clarifiers 2 and 3 and construction of a new 130-ft diameter clarifier to replace their capacities.	All issues addressed (1-6)	$3,100,000
Alternative 4	Construction of a new 130-ft diameter clarifier while keeping existing Clarifiers 2 and 3 in service.	None [2]	$3,060,000
Alternative 5	Re-build the mechanisms for Clarifiers 2 and 3 as part of a turnkey package from a reputable clarifier manufacturer.	All issues addressed (1-6)	$616,000

[1] Opinions of probable capital costs are in 2017 dollars. For detailed breakdown of cost estimates, reference the Secondary Clarifier Rehabilitation Study TM in **Appendix A**.

[2] Clarifier performance advantages were identified if Alternative 4 was implemented: the performance of the secondary clarifiers would improve such that there is only one scenario in which the clarifiers fail: at 43.5 mgd with Clarifier 5 out of service and at an SVI of 86.

Table 2-4: Alternatives for Clarifier 4

	Description	Issues Addressed (from Table 2-2)	Cost [1]
Alternative 1	Replacement of the entire sludge collection mechanism with a 304 stainless steel suction header, including a new centerwell to replace the existing influent feedwell.	2, 3	$772,000
Alternative 2A	Conversion of the inboard effluent launder to the traditional outboard design by installing a series of fiberglass reinforced plastic (FRP) troughs along the periphery of the clarifier and supporting them with new aluminum beams.	All issues addressed (1-4)	$1,250,000
Alternative 2B	Conversion of the inboard effluent launder to the traditional outboard design by installing a concrete effluent launder along the periphery of the clarifier.	All issues addressed (1-4)	$1,270,000

[1] Opinions of probable capital costs are in 2017 dollars. For detailed breakdown of cost estimates, reference the Secondary Clarifier Rehabilitation Study TM in **Appendix A**.

2.2 Hydraulics and Distribution Review

Mixed liquor is currently distributed to the secondary clarifiers in service using five 9-ft long cutthroat flumes. When the flumes are operating under non-submerged conditions, flow is distributed based on the throat width of the flume serving each clarifier. When the flumes are submerged, however, flow is not uniformly distributed to the clarifiers in service, resulting in an imbalance of flow conveyed to the secondary clarifiers for treatment. Research indicates that for nine-foot long cutthroat flumes, such as the ones used to distribute mixed liquor at the Mason Farm WWTP, the transition submergence at which distribution is compromised is equal to 80%. As part of the 2010 Capacity Study, a complete hydraulic capacity analysis of existing facilities was developed to identify the capacities of each treatment process and areas of hydraulic bottlenecks. The results of the Study indicate that there is a substantial difference between the theoretical flow distribution that would occur with unsubmerged flumes, and the predicted flow distribution based on submerged flumes. This impacts how each of the clarifiers are loaded given specific flow and operating conditions.

The Secondary Clarifier Rehabilitation Study updated the hydraulics and distribution analyses presented in the 2010 Capacity Study to incorporate the operating approach currently implemented at the WWTP (two secondary clarifiers in service). Hydraulic calculations indicate that when Clarifiers 1 and 5 are in service, the distribution flume to Clarifier 1 becomes submerged at a plant flowrate greater than 10.3 and less than 14.5 mgd. As the flume to Clarifier 1 approaches the transition submergence of 80%, discharge flow through the flume decreases and more flow is distributed to Clarifier 5. This explains observations made by plant staff that more flow appears to be diverted to Clarifier 5 than to Clarifier 1. When Clarifiers 1 and 4 are in service, the flumes to both clarifiers become submerged at a plant flowrate between 10.3 and 14.5 mgd. When both flumes are submerged, flow is distributed to the two clarifiers such that the headloss through both flow paths are equal. At 14.5 mgd, the flow path to Secondary Clarifier 1 has approximately 20% more headloss than the path to Secondary Clarifier 4, indicating that Clarifier 4 may be overloaded during these operating conditions. Since Clarifiers 4 and 5 are deeper than Clarifier 1, this hydraulic imbalance is not expected to significantly impact clarifier performance.

In order to identify additional hydraulic factors that could contribute to the imbalance of flow to the secondary clarifiers, OWASA hired Vision NC to perform an inspection of the Clarifier 1 influent pipe line. The observations made during this initial inspection, performed in June 2018, are as follows:

- The influent pipe had a thick layer of foam that appeared to be similar to polymer and/or grease throughout the entire pipe line.
- It is possible the RAS pipe has a similar buildup of material to that of the influent pipe.
- The water level was not low enough at the time to inspect the clarifier wet well.
- The rolling camera ran into an obstruction within the pipe (suspected to be grease) that prevented the camera from moving forward.

OWASA determined that the next step would be to reduce the water level in the centerwell to identify any obstructions located in the clarifier center column. Therefore, in October 2018, Vision NC returned to the Mason Farm WWTP and worked with OWASA Maintenance staff to perform a complete inspection of the influent pipe to Secondary Clarifier 1. During the second inspection, no hydraulic restrictions were identified in the influent pipe; any foam or grease that had built up in the pipe may have washed out during Hurricane Florence. The most significant discovery from this inspection, however, was the obstruction in the influent pipe where it connects to the clarifier centerwell, as shown in **Figure 2-1**. The pipe shown at the top of the figure is the 18-inch RAS pipe which protrudes into the 24-inch influent pipe. Additionally, there appears to be a buildup of grease and rags located in the lower-right portion of the pipe circumference that would even further restrict clarifier influent flow. The combination of these two obstructions appear to reduce the pipe cross-sectional area by at least one third. Since the pipe protrusion is not portrayed in the secondary clarifier drawings, the minor loss K-factor associated with this obstruction was not accounted for when developing the hydraulic profile for the Mason Farm WWTP. The findings of this inspection does explain why Clarifier 1 receives less flow than what it is rated for, and generally receives less flow than Clarifiers 4 and 5 as observed by plant staff.

Figure 2-1: Clarifier 1 Pipe Survey

2.3 Clarifier Performance Evaluation

The treatment performance of the secondary clarifiers was also evaluated as part of the Secondary Clarifier Rehabilitation Study. The performance of the existing secondary clarifiers was assessed using state point analyses (SPA) and recent SVI data collected by plant staff. The average SVI value at the Mason Farm WWTP from 2015 to 2017 was 76, indicating very good settling sludge. The results of state point analyses suggest that failure in clarifier performance occurs at the peak wet weather flow of 43.5 mgd. The clarifiers do not fail at the maximum month flow of 14.5 mgd. The specific observations made for Clarifiers 2, 3, and 4 are as follows:

- When all clarifiers are in service, the SPA indicates clarifier failure at an SVI of 86 and a mixed liquor suspended solids (MLSS) concentration of 4,000 mg/L.
- When Clarifier 5 is taken out of service, the SPA indicates clarifier failure at the average SVI of 76 and an MLSS concentration of 4,000 mg/L.

There are two general operational modifications that can be implemented to improve the performance of secondary clarifiers: the first is to increase the RAS pumping rate, with the caveat that an adequate RAS blanket should be maintained, and the second is to decrease the target MLSS concentration in the aeration basins while still maintaining sufficient a mixed liquor concentration adequate for reliable nitrification. During the time of this study, the RAS pumping rate was approximately 100% of the plant influent flow, or 6 mgd, (as determined based on the concentration ratio of mixed liquor to RAS), and the average MLSS concentration averaged approximately 4,100 mg/L. Furthermore, the settleability of sludge can be improved by adding settling aid polymer to the mixed liquor. In addition to developing SPAs to evaluate existing secondary clarifier performance, the potential performance improvements associated with building a new clarifier (Clarifiers 2 and 3 Alternatives 3 and 4) were evaluated. The results of the performance improvements associated with Alternatives 3 and 4 indicate that adding one new 130-ft diameter secondary clarifier while keeping clarifiers 2 and 3 in service significantly improvements the overall performance of the secondary clarifiers.

In general, based on the results of the state point analyses, the existing secondary clarifiers are adequately sized for the permitted flow of 14.5 mgd and at the design MLSS concentration of 4,000 mg/L. At the peak wet weather flow of 43.5 mgd, however, clarifier treatment performance is compromised, particularly when not all clarifiers are being utilized. Furthermore, since the unequal distribution of mixed liquor at peak wet weather flows results in Clarifier 2 to be overloaded, implementing either Alternatives 3 or 4 (for Clarifiers 2 and 3) would alleviate the impacts caused by poor distribution. Specific SPA results at each SVI and operating scenario evaluated as part of this study can be found in Appendix C of the original TM.

2.4 Results and Recommendations

Table 2-5 includes a comparison of each evaluated alternative based on capital cost and other non-cost related factors. As part of a short-term solution to rehabilitate Clarifiers 2 and 3, it is recommended that OWASA negotiate with secondary clarifier manufacturers and proceed with Alternative 5 while keeping in mind that the quoted cost of $616,000 for the recommended option (304 stainless steel materials with new walkway I-beams and new weirs and baffles) may increase as some of the services and conditions are fully negotiated.

For the rehabilitation of Clarifier 4, it is recommended that OWASA consider converting the inboard launder to an outboard design with concrete effluent troughs (Alternative 2B) to significantly alleviate the operational and maintenance concerns identified by OWASA staff and increase design life and longevity.

Table 2-5: Comparison of Secondary Clarifier Rehabilitation Alternatives

Alternative	Capital Cost Opinion (2017)	Percent of Improved Operation and Maintenance	Are Hydraulic Impacts Alleviated?	Improved Clarifier Performance Based on SPA?	Additional Years of Design Life, Mechanical / Structural
Clarifiers 2 and 3					
Clarifiers 2 and 3: Alternative 1A	$410,000	50%	No	No	+25 / +0
Clarifiers 2 and 3: Alternative 1B	$960,000	67%	No	No	+25 / +0
Clarifiers 2 and 3: Alternative 2	$1,290,000	100%	No	No	+25 / +0
Clarifiers 2 and 3: Alternative 3	$3,100,000	100%	Yes	Yes	+25 / +40
Clarifiers 2 and 3: Alternative 4	$3,060,000	0%	Yes	Yes	+25 / +40
Clarifiers 2 and 3: Alternative 5 [1]	$616,000	100%	No	No	+25 / +0
Clarifier 4					
Clarifier 4: Alternative 1	$772,000	50%	No	No	+25 / +0
Clarifier 4: Alternative 2A	$1,250,000	100%	No	No	+25 / +0
Clarifier 4: Alternative 2B	$1,270,000	100%	No	No	+25 / +0

[1] Cost includes 304 stainless steel mechanism, new walkway bridge I-beams, and new 304 stainless steel weir plates and baffles. Cost does not include markups and contingencies.

The recommended Alternatives for Clarifiers 2, 3, and 4 address the short-term concerns associated with the operation and maintenance of these clarifiers. However, as a long-term solution, it is recommended that OWASA increase the secondary clarifier capacity in the future to improve clarifier performance at peak wet weather flows.

3. Process Model and Nitrified Recycle Evaluation Summary

The Mason Farm WWTP currently operates an activated sludge system consisting of a step-feed nutrient removal process and nutrified sludge cells. RAS is pumped at a flowrate of approximately 100% of the plant influent flow, or 6 mgd, to the NSL cells to promote RAS denitrification and biological phosphorous removal prior to return to the step-feed aeration basins. Hazen completed the Mason Farm WWTP Nutrient Removal Optimization Study in May 2013, which evaluated adding nitrified recycle (NRCY) to the step-feed basins to improve nutrient removal. The study concluded that adding NRCY could be cost-effective if acetic acid or glycerin addition is required to be added to the filters to provide tertiary denitrification.

The potential advantages of adding NRCY at the Mason Farm WWTP were reassessed in the Process Model Update and Internal Recycle Evaluation due to the potential process impacts of secondary clarifier improvements and the recent changes in operation that have taken place at the WWTP. The purpose of this evaluation was to:

- Update the BioWin process model with recent plant operations data
- Evaluate the costs and process impacts of adding NRCY
- Quantify the impacts of increased RAS flow on current alum feed rates

3.1 Process Model Update

The first step of the Process Model Update and Internal Recycle Evaluation was to update the Mason Farm WWTP process model previously developed in 2010 with BioWin version 5.2. At the time during which the original process model was being developed, WWTP influent samples were taken downstream of where the rotary press filtrate combines with plant influent. Therefore, the original process model accounted for the sidestream flow combining with plant influent prior to the sample collection point. The sample collection point, however, has subsequently move to a location upstream of where the rotary press filtrate combines with influent flow. The updated process model developed in 2017 was modified to account for rotary press filtrate combining with plant influent flow downstream of the sample collection point. Furthermore, influent wastewater characterization was adjusted to better match current performance as reported in the daily monitoring reports. In general, the updated model accurately predicted MLSS and effluent phosphorus, ammonia, nitrate, and TKN concentrations.

3.2 NRCY Evaluation

3.2.1 NRCY Modification Scenarios

Table 3-1 summarizes the eight different NRCY scenarios simulated with the process model. The modification scenarios assumed the following:

- NRCY flow of 14.5 mgd per train
- Four NSL cells in operation
- Fermentate added in the Aeration Basin Influent Channel
- 600 gallons per day (gpd) of alum is added upstream of the secondary clarifiers
- 500 gpd of 20% acetic acid is added in the NSL cells
- NRCY is pumped from Effluent Channel No. 1
- NRCY is pumped to Cell 1 for the modified Ludzack Ettinger (MLE) process scenarios
- NRCY is pumped to Cell 3 for the step-feed process scenarios

Figures 3-1 and **3-2** illustrate the MLE and step-feed processes, respectively.

Table 3-1: NRCY Modification Scenarios

Scenario	Plant Configuration	Cell 5 Operation	RAS
1	Step Feed	Aerobic	100%
2	Step Feed	Aerobic	200%
3	Step Feed	Anoxic	100%
4	Step Feed	Anoxic	200%
5	MLE	Aerobic	100%
6	MLE	Aerobic	200%
7	MLE	Anoxic	100%
8	MLE	Anoxic	200%

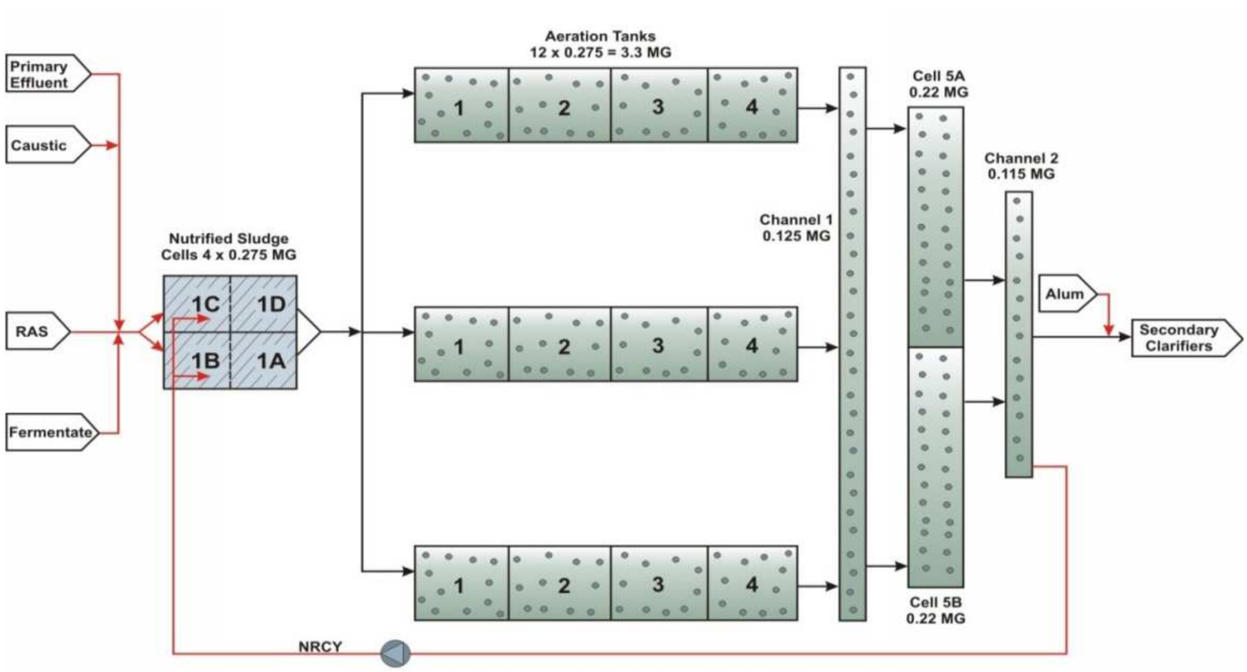

Figure 3-1: MLE Process Schematic

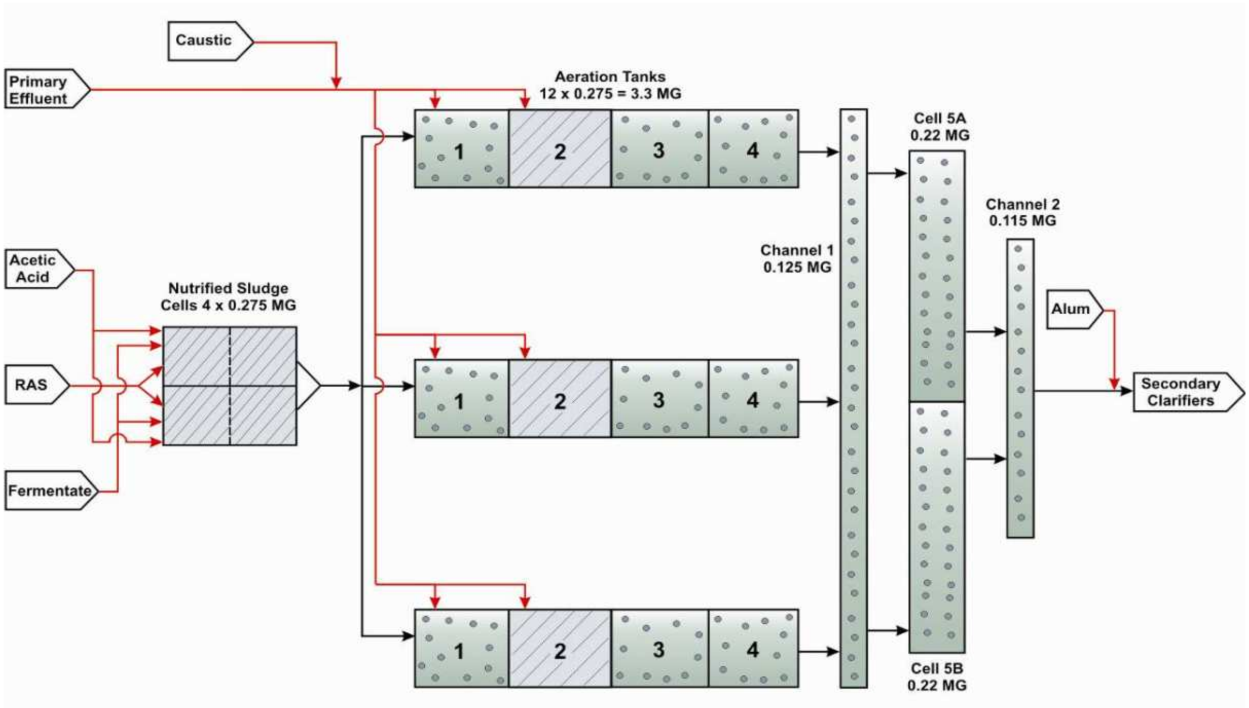

Figure 3-2: Step-Feed Process Schematic

Table 3-2 summarizes the predicted effluent nutrient concentrations for each of the eight NRCY scenarios.

Table 3-2: NRCY Modification Scenario Results

Final Effluent	Current	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
TN, mg/L	7.9	9.4	7.6	8.0	6.2	11.2	8.8	9.9	8.9
NH_3-N, mg/L	0.3	0.1	0.1	0.5	0.4	0.1	0.1	0.3	0.2
TKN, mg/L	1.2	1.2	1.2	1.4	1.3	1.2	1.3	1.2	1.2
NO_3-N, mg/L	6.4	8.1	6.3	6.3	4.6	10.0	7.5	8.5	7.6
TP, mg/L	0.50	0.60	0.50	0.80	0.70	0.30	1.1	0.2	1.2

The simulations indicate that converting from the current step-feed process to a MLE process is not expected to reduce effluent TN concentrations, although effluent TP decreased under the 100% RAS flow scenarios. Adding NRCY to the step-feed process only had a substantial impact on nitrogen reduction when RAS was increased to 200% and Cell 5 was operated anoxically.

3.2.2 NRCY Pump Selection and Layout

Hazen evaluated the mechanical changes that would be required to successfully implement NRCY. NRCY pumps would be required to pump MLSS from Effluent Channel No. 1 to the anoxic zones in the aeration tanks. Submersible window propeller pumps are typically implemented for NRCY because of their low-head, high-flow pumping capabilities and comparative ease of installation. The Flygt Ultra-Low-Head Pump Series model PP 4660 was selected as a potential NRCY pump for the Mason Farm WWTP. The pump design flow would be 14.5 mgd, and the pump would be equipped with an 11-horsepower motor. **Figure 3-3** compares the proposed NRCY pump curve at its minimum and maximum speed to the calculated system curve. This pump selection would provide an approximate 50% turndown in flowrate.

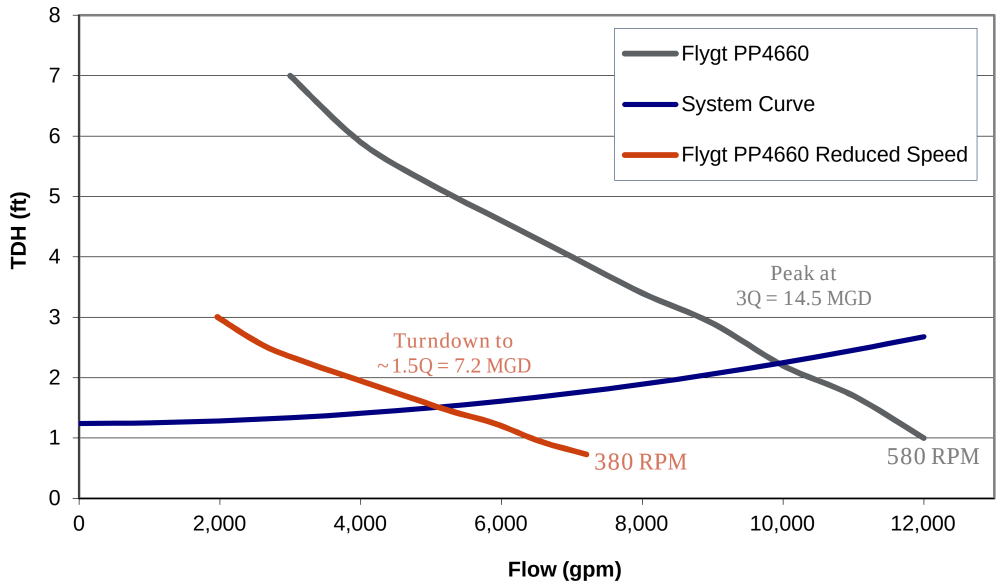

Figure 3-3: NRCY Pump Curve

Although the WWTP currently operates in a three-train, four-cell configuration, discussions with plant staff have indicated interest in evaluating the capability of operating two trains with six cells per train. As such, two different train and cell configurations were evaluated: a three train / four cell configuration and a two train / six cell configuration. A hydraulic profile was developed for each configuration to determine the impact of pumping NRCY flow through the aeration basins, and to identify what modifications would be required to mitigate those impacts. **Figure 3-4** illustrates how the aeration basins could be configured with NRCY in a three train / four cell configuration, while **Figure 3-5** illustrates a potential two train / six cell configuration. Both figures illustrate the structural improvements that would be required to mitigate the hydraulic impacts of adding NRCY. Flow would be conveyed as indicated by the blue arrows.

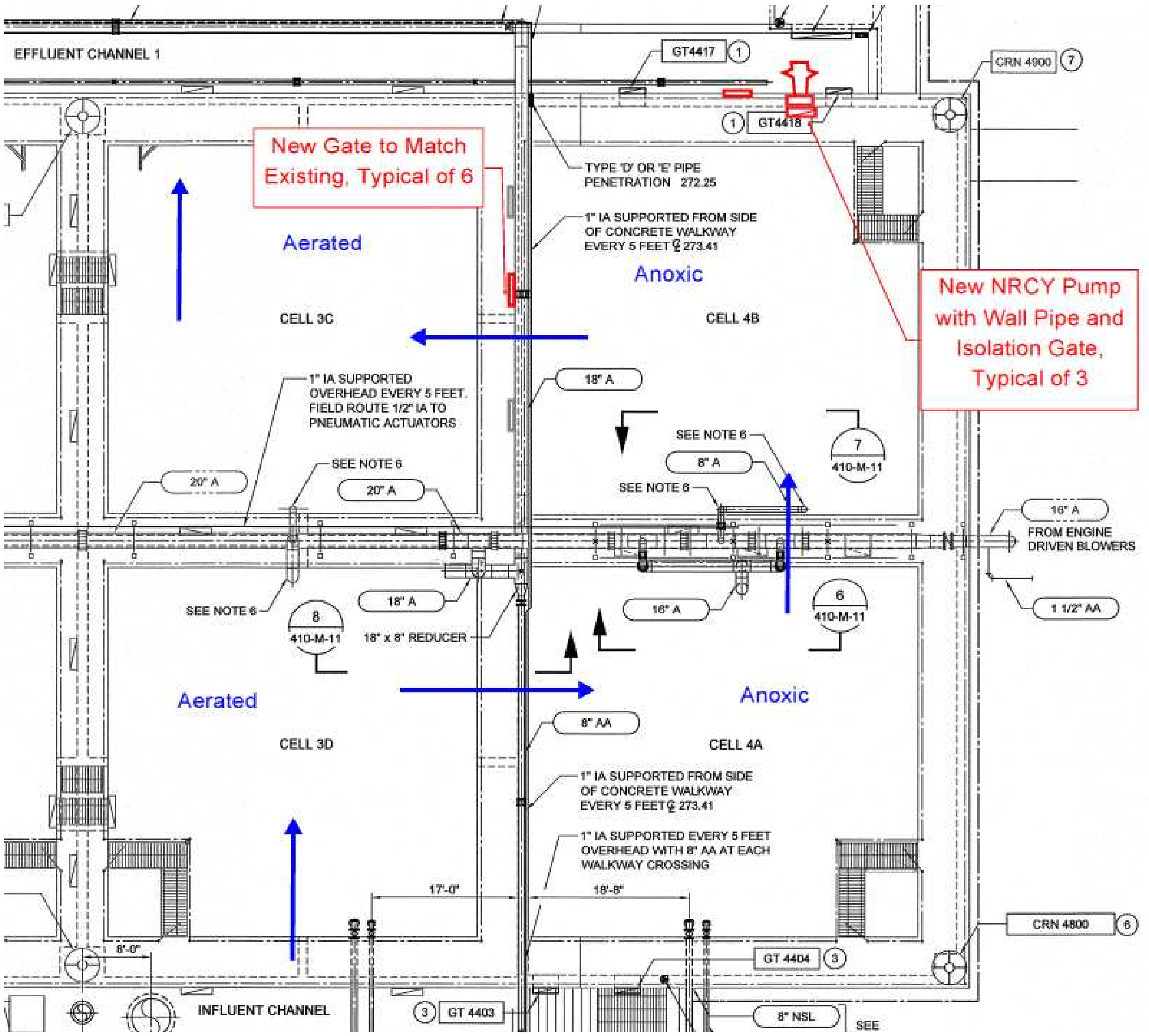

Figure 3-4: Three Train/ Four Cell Configuration

A total of three NRCY pumps, wall pipes, and isolation gates would be required at the wall between the aeration basin cells and Effluent Channel No. 1 in the three train / four cell configuration. A total of six new gates would be required to reduce headloss in-between each cell.

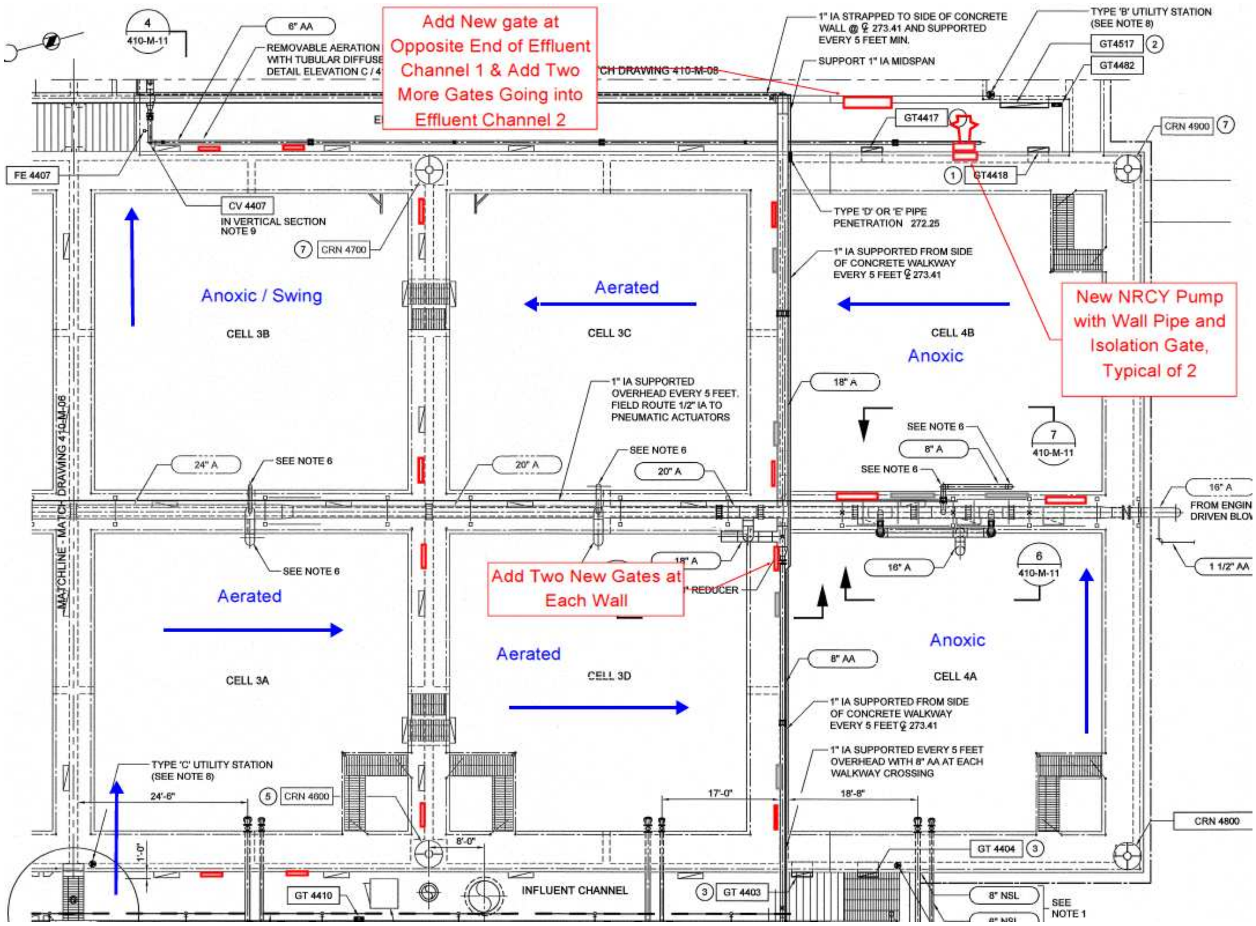

Figure 3-5: Two Train/ Six Cell Configuration

A total of two NRCY pumps, wall pipes, and isolation gates would be required at the wall between the aeration basin cells and Effluent Channel No. 1 to implement the two train / six cell configuration. At least 16 new gates would be required in the walls between each cell to alleviate the hydraulic impacts of operating in this configuration at maximum NRCY flow. **Table 3-3** compares the opinion of probable costs for each configuration.

Table 3-3: Opinion of Probable Cost for NRCY Improvements

	Three Train / Four Cell	Two Train / Six Cell
Construction Subtotal	$300,000	$550,000
Electrical and I/C (15%)	$45,000	$82,500
General Conditions / Mobilization (5%)	$17,300	$31,600
Contractor Overhead and Profit (15%)	$54,300	$99,600
Bonds and Insurance (2%)	$8,300	$15,300
Contingencies (20%)	$85,000	$155,800
Total (2017)	**$510,000**	**$935,000**

The capital cost for adding NRCY capabilities at the Mason Farm WWTP would range from $500,000 to $900,000 (based on 2017 dollars). A cost adder of approximately $425,000 is estimated to be required to accommodate a two-train configuration in lieu of a three-train configuration.

3.3 Results and Recommendations

Given the high capital cost associated with implementing NRCY, it is recommended that the Mason Farm WWTP defer implementing NRCY and continue to operate in the step-feed mode. The specific observations and recommendations made based on the NRCY simulation results are as follows:

- Maximizing RAS pumping rates provides a greater reduction in nitrate under step-feed operation. The impacts of increasing RAS flows on clarifier performance and biological phosphorus removal should be considered before being implemented.
    - Increased RAS flows can result in reduced blanket control, reduced waste activated sludge (WAS) concentrations, and increased hydraulic loadings to WAS thickening and potentially digestion.
    - Increased RAS flows to the NSL basins can further reduce available carbon for biological phosphorus removal, potentially increasing chemical phosphorus removal requirements.
- Re-establish adding fermentate to the NSL basin instead of the Aeration Basin Influent Channel.
- All four NSL cells should be in service to maximize denitrification capacity and promotion of biological phosphorous removal.
- WWTP staff should continue to operate Cell 5 as a swing zone to optimize denitrification.

Hazen recommends that RAS fermentation be considered as a means to improve biological nutrient removal while making minimal structural and mechanical improvements at the WWTP. Some of the advantages of RAS fermentation include the creation of additional volatile fatty acids (VFAs) and the growth of more diverse phosphate accumulating organisms (PAOs). Having a more diverse selection of PAOs increases the organisms that denitrify, utilize substrates other than VFAs, and potentially ferment complex organics. Based on research and experience within the last several years, RAS fermentation is much more understood now than it was during the time of the 2010 Capacity Study. As such, it is recommended that OWASA re-consider its application at the Mason Farm WWTP.

RAS fermentation could be implemented by diverting a portion (less than 10%) of the RAS and all of the fermentate to two NSL cells in series. The remainder of the RAS would be diverted to a third NSL cell for denitrification, and the fermented and denitrified RAS would be recombined in the fourth NSL cell to promote anaerobic phosphate release prior to return to the aeration basins. **Figure 3-6** presents a potential schematic for RAS fermentation in the NSL cells.

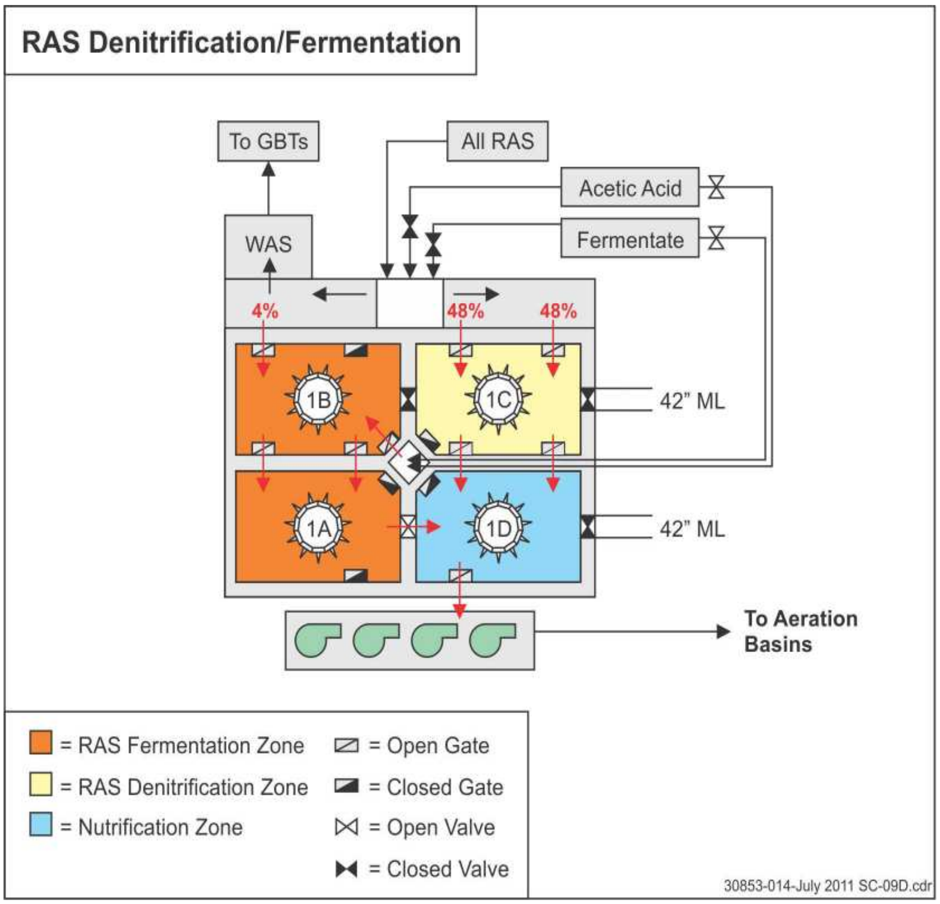

Figure 3-6: RAS Fermentation

4. Summary of the RAS Pumping Rehabilitation Study

The Mason Farm WWTP is equipped with five (5) secondary clarifiers and four (4) recycle activated sludge (RAS) pump stations. The RAS pumps are reaching the end of their useful life and are considered to be obsolete pieces of equipment. Therefore, starting in 2017, plant staff began to incrementally replace existing RAS pumps with larger pumps to increase the RAS pumping capacity.

The purpose of developing the RAS Pumping Rehabilitation Study was to summarize various alternatives to improve the overall performance, increase reliability, and reduce operational and maintenance issues for the Mason Farm WWTP RAS pumping systems. The specific RAS pumping system deficiencies identified by plant staff are listed in **Table 4-1**.

Table 4-1: RAS Pumping System Operational and Maintenance Concerns

System Deficiencies
1. Lack of redundancy
2. Pump design capacities with Clarifiers 1 and 5 in service
3. RAS flow measurement and control for Clarifiers 2 and 3
4. Flow measurement and control for Clarifiers 1, 4 and 5
5. Issues with flowmeter readings
6. Metering, isolation, and plug valves downstream of Clarifier 5 RAS pumps

4.1 Alternatives Evaluated

A total of five alternatives were evaluated based on mechanical, hydraulic, and performance considerations to determine the most cost-effective alternative for OWASA to implement moving forward. The five alternatives that were evaluated are summarized in **Table 4-2**. It is important to note that the alternatives should not be compared on a cost basis. While some alternatives address capacity issues, others address redundancy issues. As such, a few of the alternatives can be applied in conjunction with one another.

Table 4-2: RAS Pumping Alternatives

	Description	Issues Addressed (from Table 4-1)	Cost [1,2]
Alternative 1	Replacement of the RAS pumps with in-kind pumps while making minimal modifications to the existing structures, valves, and piping.	None	$630,000
Alternative 2	Replacement of existing RAS pumps with larger pumps such that significant modifications to existing structures, valves, and piping are required.	2	$1,310,000
Alternative 3	Purchase a new mobile standby pump in combination with Alternative 1 or Alternative 2, allowing the plant to have a firm RAS capacity of 20 MGD.	1 and 2	$290,000
Alternative 4	Replacement of all the existing RAS pumps with a consolidated RAS pump station to serve all clarifiers.	All issues addressed (1-6)	$3,020,000

	Description	Issues Addressed (from Table 4-1)	Cost [1,2]
Alternative 5	Permanent installation of backup pumps for each set of clarifiers. A third pump would be installed for each of Clarifiers 1, 4, and 5 and one pump would be installed for Clarifiers 2 and 3.	1	$670,000

[1] The listed alternatives should not be compared on a cost basis because they do not equally address the issues identified in Table 4-1.
[2] Opinions of probable capital costs are in 2018 dollars. For detailed breakdown of cost estimates, reference the RAS Pumping Rehabilitation Study TM in **Appendix C**.

Hazen worked with WWTP staff to identify additional general improvements to the RAS pumping system that can be applied in conjunction with Alternatives 1-3, and 5 to address existing system deficiencies. The total cost for all of the identified improvements is $340,000. These improvements include:

- New RAS piping for Clarifiers 2 and 3 to the NSL chimney to combine with RAS from Clarifiers 1, 4, and 5.
- New isolation valves in the RAS pipes from each clarifier (total of 5).
- New ultrasonic level sensors and staff gauges in each of the cutthroat flumes to secondary clarifiers (total of 5) to replace existing.
- Replace existing ultrasonic flow meters with mag meters on RAS suction pipes (total of 5).
- Replace plug valves downstream of Clarifier 5 RAS pumps (total of 2).
- Heat trace and insulate all RAS pumps.

4.2 Alternative Flow Scenarios

Hazen also evaluated the possibility of sizing the RAS pumps big enough to pump RAS to the NSL basins and have RAS flow by gravity to the aeration basins via a distribution channel and weir system. **Table 4-3** summarizes how high the NSL basin walls would have to be raised and to what extent the pipes would have to be replaced to mitigate the hydraulic impacts. As shown in the table, walls would have to be raised by approximately 5 feet if the 12" and 8" NSL pipes increase to 14" and 10", respectively. However, due to the existing structural design and capacity of the NSL basin walls and slabs, a significant amount of construction will be required to raise the existing NSL walls by 5 feet or more.

Table 4-3: NSL Basin Wall Requirements at 43.5 MGD and with 2 Feet of Design Freeboard

	Existing Pipe Sizes	Increase the size of select pipes [1]	Increase the size of all pipes to 30"
Headloss (feet)	4.0	2.8	1.6
Raise Walls by (feet)	16.8	5.2	0.8

[1] Increase the existing 12" pipe to 14" and the existing 8" parallel pipes to 10".

Furthermore, RAS flow by gravity from the secondary clarifiers to the NSL basins was evaluated and it was determined that this could not be accomplished without significantly decreasing the operating level in the NSL cells. The use of RAS pumps is necessary due to high headloss in the pipes conveying RAS to the NSL cells.

4.3 System Curve Calibration

In order to assess the WWTP's RAS pumping system, system curves were calculated for each clarifier as part of the RAS Rehabilitation Study. In December 2017, Hazen visited the WWTP to measure flow and pressure on the RAS pump discharge pipes to calibrate the calculated system curves. The field measurements recorded during the site visit were compared to the flow and pressures points that had been calculated for each clarifier. Based on this comparison, the calculated system curves for Clarifiers 4 and 5 closely matched what was measured in the field. Therefore, the system curves for Clarifiers 4 and 5 were not modified. The system curve for Clarifier 1, however, was calibrated with a lower pipe C-value to align with the operating point measured in the field. It was suspected that this discrepancy could be due to plugging in the old RAS suction pipe installed beneath Clarifier 1. Hence, it was recommended that OWASA inspect the Clarifier 1 RAS suction pipe to determine if there is buildup of material that could be clogging the pipe. A description of the Clarifier 1 influent pipe inspection that was conducted by OWASA is included in **Section 2.2**.

4.4 Results and Recommendations

Table 4-4 presents a summary of the five alternatives that were evaluated. Hazen recommends that plant staff continue to replace pumps with pumps of larger design flows than existing (Alternative 1), as has been done for Clarifiers 4 and 5, in conjunction with purchasing a portable diesel backup pump to be used as a standby pump for all clarifiers (Alternative 3). Modifications to each RAS pump station is recommended to facilitate the use of a portable standby pump.

Table 4-4: Summary of RAS Rehabilitation Alternatives

Alternative	Capital Cost Opinion (2018) [1]	Total Firm Capacity	Addresses all system deficiencies?	Improves Clarifier Performance?
Alternative 1 – Replace In-Kind	$630,000	<20 MGD	No	No
Alternative 2 – Larger Pumps	$1,310,000	<28 MGD	No	Yes
Alternative 3 – Portable Backup	$290,000	<20 MGD or <28 MGD	No	No
Alternative 4 – New RAS PS	$3,020,000	21 MGD	Yes	Yes
Alternative 5 – Standby Pumps	$670,000	20 MGD	No	No

[1] The listed alternatives should not be compared on a cost basis because they do not equally address the issues identified in Table 4-1.

It is also recommended that OWASA implement the overall RAS pumping system improvements, as listed in **Section 4-1** to alleviate existing deficiencies. The total estimated capital cost of the recommended improvements is listed in **Table 4-5**.

Table 4-5: Cost of Recommended RAS Rehabilitation Alternatives

Recommended Alternative	Capital Cost Opinion (2018)
Alternative 1 – Replace In-Kind	$630,000
Alternative 3 – Portable Backup	$290,000
Additional Improvements	$340,000
Total Cost	**$1,260,000**

5. Summary of Recommendations

Hazen completed three different evaluations between 2017 and 2018 related to the secondary treatment process at the Mason Farm WWTP. The purpose of this technical memorandum is to serve as a standalone reference for OWASA staff to understand each of the evaluations that were completed.

Specific drivers for each evaluation are as follows:

- Secondary Clarifier Rehabilitaiton
  - Aging equipment
  - Maintenance issues
  - Distribution and capacity concerns
  - Hydraulic imbalances
- Process Model Update and Internal Recycle Evaluation
  - BioWin model has not been updated since 2010 Capacity Study

  - Operational change to step-feed
  - Re-assess the benefits of RAS fermentation given recent plant performance
  - Impacts of implementing NRCY
  - Impacts of increased RAS flows
- RAS Pumping Rehabilitation Study
  - Increased RAS flows
  - Equipment redundancy
  - Operation of only two secondary clarifiers due to challenges associated with Clarifiers 2, 3, and 4 further increases stress on the RAS pumps and decreases reliability
  - RAS pumps and pump parts have become obsolete

Figure 5-1 illustrates the correlation between each of the processes evaluated, and the associated recommendations based on improving plant performance, minimizing maintenance, improving equipment longevity and reliability, and minimizing project costs.

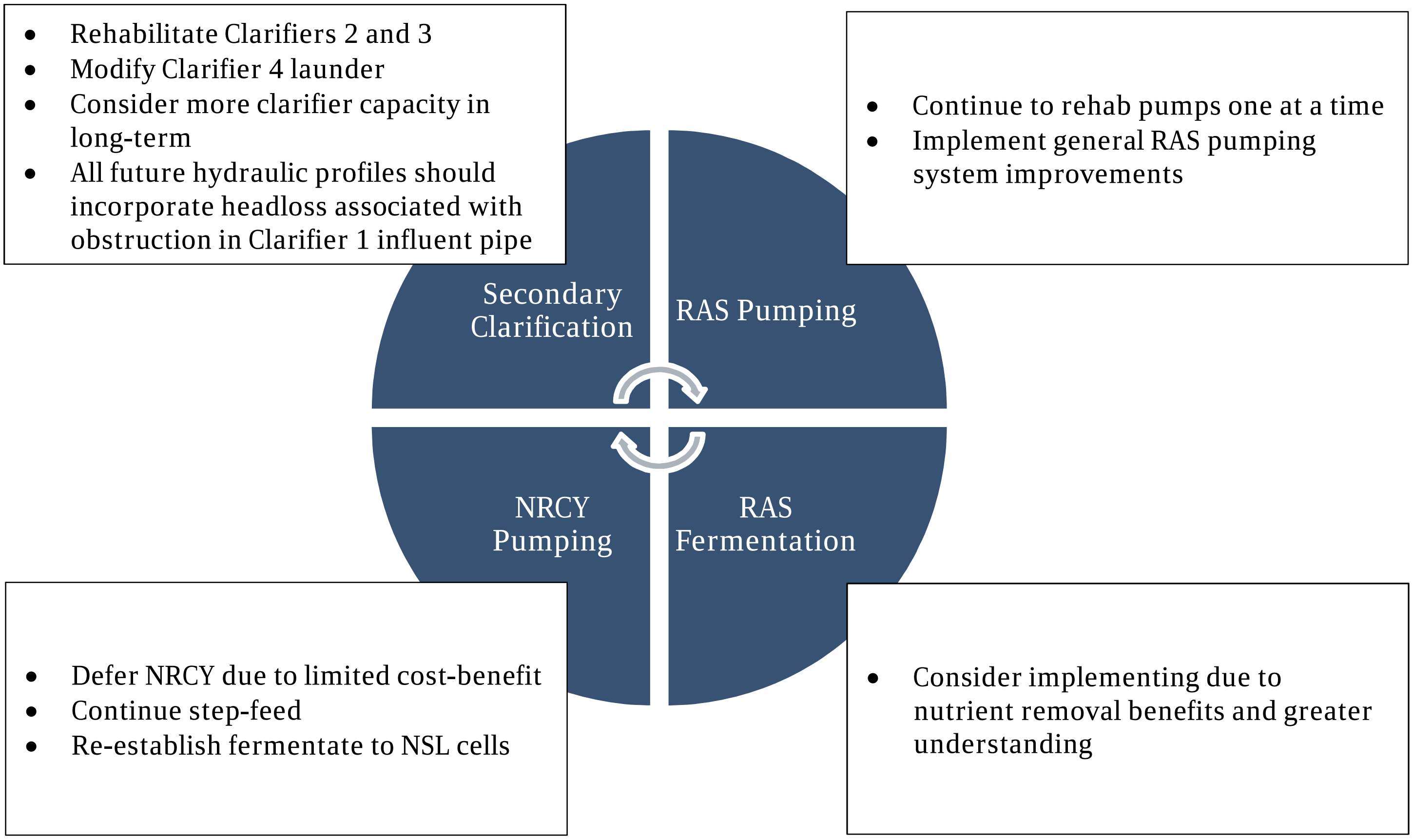

Figure 5-1: Summary of Recommendations

January 22, 2019

Compilation TM Appendix A: Mason Farm WWTP Secondary Clarifier Rehabilitation Study - Final

June 27, 2017

To: OWASA

From: Lamya King, Hazen and Sawyer

Patricia Drummey Stiegel, Hazen and Sawyer

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Ron Taylor, Hazen and Sawyer

Mason Farm WWTP Secondary Clarifier Rehabilitation Study

FINAL

Introduction

The Orange Water and Sewer Authority (OWASA) operates the Mason Farm Wastewater Treatment Plant, which is an activated sludge treatment facility currently equipped with five (5) secondary clarifiers. Due to the age, performance, mechanical failures, and maintenance challenges associated with Secondary Clarifiers 2, 3, and 4, a conditions assessment has been developed for each of these clarifiers. The purpose of this technical memorandum (TM) is to summarize various alternatives that will improve the overall performance, increase longevity, and reduce operational and maintenance issues for Secondary Clarifiers 2, 3, and 4. A description and cost estimate for each alternative is included in Section 2 of this TM. Additionally, in order to assess the clarifier improvement alternatives on a holistic basis, the mixed liquor distribution hydraulics and secondary clarifier performance analyses that were developed as part of the 2010 Capacity Study were updated as part of this study. Sections 3 and 4 summarize the hydraulic evaluation and clarifier treatment performance updates, respectively. The results and recommendations presented herein incorporate a myriad of mechanical, hydraulic, and performance considerations to determine the most cost-effective alternative for OWASA to implement moving forward.

Table of Contents

1. Background

1.1 Existing Facilities

The Mason Farm Wastewater Treatment Plant (WWTP) is an advanced treatment facility that is permitted to discharge up to 14.5 million gallons per day (mgd) on a maximum month basis to Morgan Creek. The WWTP implements an activated sludge process for the oxidation of organic matter and ammonia, and is equipped with five secondary clarifiers. With the exception of Clarifiers 2 and 3, each clarifier was constructed at different times and designed with various sizes and configurations. **Table 1-1** is a summary of the existing secondary clarifiers at the Mason Farm WWTP.

	Clarifier 1	Clarifier 2	Clarifier 3	Clarifier 4	Clarifier 5
Year Constructed	1976	1984	1984	1997	2008
Year Rehabilitated	2008 [1]	2008 [2]	2008 [2]	2008 [3]	NA
Diameter, ft	120	85	85	110	142.3
Centerwell Diameter, ft	30	9	9	28	32
Side Water Depth, ft	13	13	13	19	17.8
EDI Diameter, ft	15	None	None	18	16.4
Effluent Launder	Outboard	Outboard	Outboard	Inboard	Inboard
Sludge Withdrawal	Suction Header	Suction Header	Suction Header	Organ Pipe	Suction Header
RAS Capacity, mgd	4	2	2	4	6

[1] The Clarifier 1 mechanism was replaced in 2008.

[2] All submerged internal tank components in Clarifiers 2 and 3 were sandblasted and re-coated in 2008.

[3] Organ pipes in Clarifier 4 were demolished and replaced with PVC in 2008.

Table 1-1: Summary of Existing Secondary Clarifiers

Due to various age, performance, mechanical failures, configurations, and maintenance challenges associated with Secondary Clarifiers 2, 3, and 4, several alternatives have been evaluated to improve the overall performance of these clarifiers. The specific concerns that have been identified by plant staff for Clarifiers 2, 3, and 4 are listed in **Table 1-2**. **Appendix A** includes photographs that illustrate some of these concerns.

Clarifiers 2&3	Clarifier 4
Rust & Cracks in Sludge Removal Headers	Effluent Launder Design / Weir Brush Issues
Weir Plate Corrosion	Corrosion in Mechanism
Dated Stamford Baffles	Scum Accumulation in Centerwell
Rust & Cracks in Mechanism	Unstable Centerwell
Gear Balancing Issues & Unstable Centerwell	
Scum Accumulation in Centerwell	

Table 1-2: Secondary Clarifier Operational and Maintenance Concerns

Secondary Clarifiers 2 and 3 were constructed in the mid-1980's, and since then, there has been several advances in the design and implementation of secondary clarifiers based on modeling, experience, and testing implemented nation-wide. For example, the size of the influent centerwell would have been designed differently today than in the mid-1980's. The centerwells in Clarifiers 2 and 3 are approximately 11 percent of the overall clarifier diameter. Based on Hazen and Sawyer's experience, a centerwell that is 11 percent of the clarifier diameter is undersized and the optimum centerwell diameter is typically between 20 to 30 percent of the overall clarifier diameter. The undersized centerwells, along with the lack of scum ports, has led to poor flow distribution and scum accumulation in the centerwell as observed by plant staff.

1.2 2010 WWTP Hydraulic and Treatment Capacity Study

In 2010, a WWTP Hydraulic and Treatment Capacity Study (2010 Capacity Study) was conducted by Hazen and Sawyer in response to proposed nutrient limitations resulting from the Jordan Lake Rules. The purpose of this study was to determine the treatment and hydraulic capacity of existing facilities in order to identify process deficiencies that will hinder the plant's compliance of the Jordan Lake Rules. Furthermore, Hazen and Sawyer evaluated nutrient removal optimization alternatives, aeration capacity alternatives, secondary treatment capacity expansion alternatives, recycle stream treatment alternatives, and chemical feed optimization in order to develop recommendations for plant improvements. The results and recommendations of the 2010 Capacity Study are summarized in Sections 3 and 4 as they pertain to the secondary clarifier evaluation update developed as part of this study.

2. Clarifier Rehabilitation Alternatives

Several alternatives were evaluated for the rehabilitation and replacement of Clarifiers 2, 3, and 4. Five alternatives were evaluated for Clarifiers 2 and 3, and two alternatives were evaluated for Clarifier 4; each alternative is described in the sections below.

2.1 Clarifiers 2 & 3: Alternatives 1A &1B

The first alternative for improving Clarifiers 2 and 3 is to perform minimal improvements to the clarifiers. Alternative 1A is to replace the sludge removal headers with 304 stainless steel headers, replace the Stamford baffles, and replace the v-notch weir plates. The components which would remain unchanged as part of this alternative include: the scum removal mechanism, the centerwell, the walkways, the mechanism motor and drive, and all remaining components of the clarifier mechanism with exception to the sludge headers such as the truss arms, center cage, and center pier. Alternative 1B includes all of the components in Alternative 1A, with the addition of replacing the existing centerwell and adding an energy dissipating inlet (EDI). Installing an EDI will improve overall settleability by decreasing influent velocities. Furthermore, installing a centerwell with well-designed scum ports will help promote the movement of scum from the centerwell to the clarifier for ultimate removal. The implementation of Alternatives 1A and 1B address three and four out of the six identified operational issues described in **Table 1-2**, respectively:

Alternative 1A:

1. Rust & Cracks in Sludge Removal Headers
2. Weir Plate Corrosion
3. Dated Stamford Baffles

Alternative 1B:

1. Rust & Cracks in Sludge Removal Headers
2. Weir Plate Corrosion
3. Dated Stamford Baffles
4. Scum Accumulation in Centerwell

To evaluate the economic feasibility for each clarifier rehabilitation alternative, opinions of probable capital cost were developed. The assumptions associated with each cost opinion are applicable to each alternative, with the exception of Alternative 5, presented herein, and are as follows:

- Use 30% of equipment cost for installation
- Use 15% of subtotal to account for electrical and instrumentation improvements
- Use 5% of subtotal for general conditions and mobilization
- Use 15% of subtotal for contractor overhead and profit
- Use 2% of subtotal for bonds and insurance
- Use 20% of subtotal for contingencies
- All costs are presented on a loaded basis to include the markups listed above
- All costs are presented in 2017 dollars

The costs for Alternatives 1A and 1B, for all work in both Clarifiers 2 and 3, are presented in **Table 2-1** below.

	Alternative 1A (Both Clarifiers)	Alternative 1B (Both Clarifiers)
Demolition	$2,000	$6,000
Sitework	$0	$0
Mechanical	$410,000	$960,000
Structural	$0	$0
Total (2017)	**$410,000**	**$960,000**

Table 2-1: Cost Opinion for Secondary Clarifiers 2&3 Alternatives 1A & 1B

2.2 Clarifiers 2 & 3: Alternative 2

Alternative 2 is the replacement of the entire sludge removal mechanism with 304 stainless steel in lieu of replacing just the sludge removal headers. As such, the complete scope of rehabilitation includes: new sludge removal headers, new clarifier drives and motors, new centerwells, new scum removal mechanisms, new Stamford baffles, new v-notch weir plates, and new energy dissipating inlets. The implementation of this alternative addresses all six of the identified failed components in Clarifiers 2 and 3:

1. Rust & Cracks in Sludge Removal Headers
2. Weir Plate Corrosion
3. Dated Stamford Baffles
4. Scum Accumulation in Centerwell
5. Rust & Cracks in Mechanism
6. Gear Balancing Issues & Unstable Centerwell

The cost opinion for Alternative 2 includes the work for both Clarifiers 2 and 3 and is presented in **Table 2-2** below.

	Alternative 2 (Both Clarifiers)
Demolition	$7,000
Sitework	$0
Mechanical	$1,280,000
Structural	$0
Total (2017)	**$1,290,000**

Table 2-2: Cost Opinion for Secondary Clarifiers 2&3 Alternative 2

2.3 Clarifiers 2 & 3: Alternative 3

Alternative 3 is the demolition of Clarifiers 2 and 3 and the construction of a new clarifier to replace their capacities. For the purpose of the cost estimate, it is assumed that a 130-foot diameter clarifier would replace Clarifiers 2 and 3, providing almost 2,000 square feet of additional clarifier surface area. It is important to note that the location of the new clarifier has not been completely vetted for the evaluation of this alternative. The construction of a new secondary clarifier eliminates all six of the identified operation and maintenance concerns. Furthermore, there are additional clarifier performance advantages associated with this alternative that are discussed in **Section 4**.

The cost associated with this alternative includes concrete and mechanical demolition, sitework, new recycle activated sludge (RAS) pumping, scum, and drain piping, and all of the internal mechanical and structural components associated with a new clarifier. The cost opinion for Alternative 3 is presented in **Table 2-3** below.

	Alternative 3
Demolition	$170,000
Sitework	$260,000
Mechanical	$1,890,000
Structural	$790,000
Total (2017)	**$3,100,000**

Table 2-3: Cost Opinion for Secondary Clarifiers 2&3 Alternative 3

2.4 Clarifiers 2 & 3: Alternative 4

Alternative 4 is the construction of a new 130-foot diameter clarifier while keeping existing Clarifiers 2 and 3 in service. This alternative does not address any of the six identified operation and maintenance concerns associated with Clarifier 2 and 3. However, similarly to Alternative 3, there are clarifier performance advantages associated with this alternative. These advantages are summarized in **Section 4**.

The cost associated with this alternative does not include demolition, but does include sitework, new RAS pumping, scum, and drain piping, and all of the internal mechanical and structural components associated with a new clarifier. It is assumed the cost of scum, drain, RAS, and mixed liquor piping would be slightly higher than for Alternative 3 based on the potential location of the new clarifier. Furthermore, potential site constraints and associated permitting is not incorporated into the cost estimate. The cost opinion for Alternative 4 is presented in **Table 2-4** below.

	Alternative 4
Demolition	$0
Sitework	$260,000
Mechanical	$2,010,000
Structural	$790,000
Total (2017)	**$3,060,000**

Table 2-4: Cost Opinion for Secondary Clarifiers 2&3 Alternative 4

2.5 Clarifiers 2 & 3: Alternative 5

On March 8, 2017, representatives with Evoqua Water Technologies (Evoqua), a reputable secondary clarifier equipment manufacturer, met with OWASA staff and visited the Mason Farm WWTP to assess the existing conditions of Clarifiers 2 and 3. Following the site visit, Evoqua submitted a budgetary proposal to re-build the mechanisms for Clarifiers 2 and 3 as part of a turnkey package. Unlike Alternatives 1 through 4, OWASA would purchase the materials and installation services directly from the clarifier manufacturer in lieu of through a general contractor. At a minimum, the materials and services included in this proposal include: new sludge removal headers, new clarifier drives and motors, new centerwells and center columns, new scum removal tough and skimmer assemblies with associated supports, new torque cages, new energy dissipating inlet, demolition of equipment to be replaced, installation and startup services, shop and field painting, and electrical controls.

It is important to note that the following components are not included in this proposal and should be coordinated between OWASA and the clarifier manufacturer:

1. Removal and re-installation of the weir brush system
2. FRP density current baffles
3. Electrical control panels
4. Lubricants
5. Walkway bridge handrails

The implementation of this alternative addresses all of the six identified failed components in Clarifiers 2 and 3:

1. Rust & Cracks in Sludge Removal Headers
2. Weir Plate Corrosion (if chosen to be included in scope of proposal)
3. Dated Stamford Baffles (if chosen to be included in scope of proposal)
4. Undersized Centerwell (Scum Accumulation)
5. Rust & Cracks in Mechanism

6. Gear Balancing Issues & Unstable Centerwell

The budgetary pricing provided by Evoqua was divided into two sets of alternatives: one for material of construction (carbon steel versus 304 stainless steel) and one for the inclusion of new walkway bridge I-beam supports and cross-members. If the existing walkway bridge I-beams are re-used, the scope of improvements include blasting, painting, and the installation of a new bridge slide plate to allow for the expansion and contraction of the bridge. If the existing bridge I-beams are replaced, the scope of improvements include new bridge I-beams, new cross-members, and new walkway handrails. The proposal, dated March 15, 2017, is included as **Appendix B** of this Report; **Table 2-5** presents a summary of the proposed budgetary pricing.

	Alternative 5
A36 Carbon Steel – Re-use Existing Walkway Bridge I-Beam	$401,350
304 Stainless Steel – Re-use Existing Walkway Bridge I-Beam	$482,450
A36 Carbon Steel – New Walkway Bridge I-Beam	$408,900
304 Stainless Steel – New Walkway Bridge I-Beam	$507,000
Additional Items:	
A36 Carbon Steel – Effluent Weirs and Baffles	$83,200
304 Stainless Steel – Effluent Weirs and Baffles	$109,000
Recommended Alternative:	
304 Stainless Steel - New Walkway Bridge I-Beam with 304 Stainless Steel Effluent Weirs and Baffles	**$616,000**

Table 2-5: Budgetary Pricing for Evoqua Turnkey Proposal Alternative 5

2.6 Clarifier 4: Alternative 1

The first alternative for the rehabilitation of Clarifier 4 is the replacement of the entire sludge collection mechanism with a 304 stainless steel suction header system; this alternative includes a new centerwell to replace the existing influent feedwell. An in-kind replacement of the existing organ pipes was not considered to maintain uniformity amongst the clarifiers. The components that would remain unchanged as part of this alternative include the scum collection mechanism, inboard launder, weir plates, walkway, and centerwell. The implementation of this alternative addresses two out of the four identified operational issues listed in **Table 1-2**:

1. Corrosion in Mechanism
2. Scum Accumulation in Centerwell

The cost opinion for Alternative 1 is presented in **Table 2-6** below.

	Alternative 1
Demolition	$7,000
Sitework	$0
Mechanical	$765,000
Structural	$0
Total (2017)	**$772,000**

Table 2-6: Cost Opinion for Secondary Clarifier 4 Alternative 1

2.7 Clarifier 4: Alternatives 2A & 2B

Alternatives 2A and 2B evaluate the conversion of the inboard effluent launder in Secondary Clarifier 4 to the traditional outboard design in which the effluent launder is installed along the circumference of the clarifier. Alternative 2A is the installation of a series of fiberglass reinforced plastic (FRP) troughs along the periphery of the clarifier that are supported by new aluminum beams. One fiberglass manufacturer indicated that the FRP toughs can be custom-molded to be curved to follow the circumference of the clarifier. The demolition included in Alternative 2A includes that of the influent feed well, the effluent launder, scum box, and all of the associated supports.

Alternative 2B is the installation of a concrete effluent launder in lieu of FRP, and would require the demolition of a portion of the exterior concrete wall and existing launder supports. The implementation of either of these alternatives resolves each of the four identified failed components listed in **Table 1-2**.

The cost opinion for Alternatives 2A and 2B is presented in **Table 2-7** below. The cost for both Alternatives 2A and 2B include new scum piping, v-notch weir plates, stairs and handrails, Stamford baffles, a new suction header collection mechanism, and a new influent feedwell. The costs, however, do not include a new walkway.

	Alternative 2A	Alternative 2B
Demolition	$40,000	$70,000
Sitework	$0	$0
Mechanical	$920,000	$920,000
Structural	$290,000	$280,000
Total (2017)	**$1,250,000**	**$1,270,000**

Table 2-7: Cost Opinion for Secondary Clarifier 4 Alternatives 2A & 2B

3. Hydraulics and Distribution

Mixed liquor is distributed to the secondary clarifiers using five cutthroat flumes. When the flumes are not significantly submerged, flow is distributed based on the throat width of the flume serving each clarifier. The submergence of a flume is measured as the ratio of the downstream depth to the upstream depth; the transition submergence is that at which the discharge from the flume is reduced and flow distribution is compromised. Research indicates that for nine-foot long cutthroat flumes, such as the ones used to distributed mixed liquor at the Mason Farm WWTP, the transition submergence is equal to 80% (Skogerboe). Hence, when headloss downstream of the flumes is significant enough to submerge the flumes at 80% and above, the flumes partially lose their ability to uniformly distribute flow to the clarifiers in service. This results in an imbalance of flow conveyed to the secondary clarifiers for treatment, this imbalance is discussed in more detail in the following sections.

3.1 Overview of 2010 Capacity Study Results

As part of the 2010 Capacity Study, a complete hydraulic capacity analysis of existing facilities was developed to identify the capacities of each treatment process and areas of hydraulic bottlenecks. The results of the Master Plan effort identified the following observations specific to the distribution of mixed liquor to the secondary clarifiers:

- With all clarifiers in service, the flume serving Secondary Clarifier 3 will begin to submerge when plant flow exceeds approximately 25 mgd. This is due to the high headloss in the influent piping to Secondary Clarifier 3, as it is longer than that influent piping serving Secondary Clarifier 2.
- As flow continues to increase, the same submergence effect occurs at the flumes serving Secondary Clarifiers 4, 1, 2, and 5 (in that order).
- When all of the cutthroat flumes are submerged beyond 80%, mixed liquor will follow the path of least resistance.
- At the peak flow of 43.5 mgd, the flumes serving all secondary clarifiers except for Secondary Clarifier 5 are submerged.
- At peak flow conditions, Secondary Clarifiers 2 and 5 are loaded 10% more heavily than the theoretical distribution, and Secondary Clarifier 3 will be under-loaded by nearly 20%.

Table 3-1 compares the theoretical flow distribution based on unsubmerged flumes with the predicted flow distribution based on submerged flumes as predicted by the hydraulic model developed for the 2010 Capacity Study.

Clarifier	Clarifier Diameter	Flume Throat Width (feet)	Theoretical Flow Distribution	Predicted Flow Distribution [1]
1	120	4	22.2%	22%
2	85	2	11.1%	12%
3	85	2	11.1%	9%
4	110	4	22.2%	21%
5	142.3	6	33.3%	36%

[1] The predicted flow distributions at 43.5 mgd are from Table 3-5 in Section 3.0 of the 2010 Capacity Study.

Table 3-1: Secondary Clarifier Flow Distribution at 43.5 MGD

The evaluation in the 2010 Capacity Study indicated that parallel piping to Secondary Clarifier 3 could improve flow distribution between Secondary Clarifiers 2 and 3, which would consequently improve the performance of Clarifier 2 under peak flow conditions. It was recommended, however, that investment in this modification be deferred until peak flows begin to approach the design peak flow of 43.5 mgd. It was also noted that flow distribution to the secondary clarifiers be given higher priority than other potential hydraulic improvements due to its impact on clarifier treatment performance.

3.2 Hydraulics and Distribution Evaluation Update

The hydraulic calculations as part of the 2010 Capacity Study were developed with the assumption that all clarifiers are in service. However, the operating conditions that are currently implemented by plant staff are as follows:

1. Only Secondary Clarifiers 1 and 5 in service: According to plant staff, this represents the plant normal operating condition during average flows.
2. Only Secondary Clarifiers 1 and 4 in service: During the time at which this study was conducted, Secondary Clarifier 5 was taken out of service for repair, and only Clarifiers 1 and 4 remained in service.

As part of this secondary clarifier conditions assessment, it was determined that updating the distribution hydraulic calculations to reflect current operating conditions would provide a holistic approach in evaluating the clarifier rehabilitation alternatives.

Table 3-2 summarizes the observations of the hydraulic profile update as it pertains to cutthroat flume submergence and impacts to flow distributions.

	Clarifiers 1 and 5 In Service	Clarifiers 1 and 4 In Service
8 MGD	Not Submerged	Not Submerged
10.3 MGD	Not Submerged	Not Submerged
14.5 MGD	Flume to Clarifier 1 Submerged	Flume to Clarifiers 1 and 4 Submerged

[1] Determination of submergence is based on a transition submergence of 80%.

Table 3-2: Summary of Flume Submergence [1]

The results of the hydraulic analysis update indicate that when Clarifiers 1 and 5 are in service, the flume to Clarifier 1 becomes submerged at a plant flowrate greater than 10.3 and less than 14.5 mgd. When the flume to Clarifier 1 approaches the transition submergence, discharge flow through the flume decreases and the flume no longer acts as a control structure. This explains observations made by plant staff that more flow appears to be diverted to Clarifier 5 than to Clarifier 1.

When Clarifiers 1 and 4 are in service, the flumes to both clarifiers become submerged at a plant flowrate between 10.3 and 14.5 mgd. When both flumes are submerged, flow is distributed to the two clarifiers such that the headloss through both flow paths are equal. At 14.5 mgd, the flow path to Secondary Clarifier 1 has approximately 20% more headloss than the path to Secondary Clarifier 4, indicating that Clarifier 4 may be overloaded during these operating conditions. Since Clarifiers 4 and 5 are deeper than Clarifier 1, this hydraulic imbalance is not expected to significantly impact clarifier performance.

4. Clarifier Performance Evaluation

There are various approaches that can be taken to evaluate the overall treatment performance of a secondary clarifier. Some of these methods include calculating clarifier overflow and solids loading rates, generating computational fluid dynamics (CFD) modeling, and developing state point analyses (SPAs). For the purpose of this study, state point analyses were used to assess the impact that each alternative would have on clarifier performance. A state point analysis determines the failure point of a clarifier under specific flow and sludge conditions utilizing the principles of solids-flux analyses. The results of a state point analysis for a single condition can be presented in a graph in which the underflow rate, overflow rate, and solids settling flux (in lbs/sf/day) are plotted as a function of solids concentration (in 1,000 mg/L). The point at which the underflow and overflow rates intersect is defined as the state point. Several parameters, such as sludge settleability, mixed liquor suspended solids (MLSS) concentrations, and clarifier dimensions are incorporated into the SPA to determine its loading capacity before clarification failure occurs. The sludge volume index (SVI) is a common measure of secondary sludge settling characteristics and is a function of the thirty-minute settled sludge volume and the operating MLSS concentration. These parameters are easy to measure, and SVI is the industry standard metric for sludge settleability, routinely measured by treatment plant staff.

The results of a state point analysis determine if a specific operating condition results in clarification failure or not. There are two conditions that can cause clarification failure: a raised sludge blanket and a full solids washout. A failure due to a raised sludge blanket condition occurs when the state point is located inside the solids settling flux and the underflow rate is plotted outside of the solids settling flux. A full solids washout condition occurs when the state point is located outside of the solids settling flux.

4.1 Overview of 2010 Capacity Study Results

In addition to a comprehensive hydraulic treatment capacity analysis, the 2010 Capacity Study included a wet weather analysis to determine the treatment capacity of the Mason Farm WWTP at process peak wet weather flows. A combination of BioWin process simulation software and the Clarifier 2Dc CFD clarifier modeling program was implemented to simulate the effects of the increased hydraulic flows and solids loading rates on the existing secondary clarifiers. The secondary clarifier assessments were developed assuming that all secondary clarifiers are in service, and three flow distribution scenarios were evaluated: peak wet weather flow at the theoretical flow distribution, peak wet weather flow at the predicted flow distribution, and reduced peak flow. As described in **Section 3** of this TM, the hydraulic calculations developed as part of the 2010 Capacity Study predicts that Secondary Clarifiers 2 and 5 will experience higher loading conditions and the remaining clarifiers will be under-loaded. Therefore, only Clarifiers 2 and 5 are impacted in the predicted flow distribution scenario. Three different SVI values were used for the secondary clarifier assessment: 90, 120, and 150 mL/g. The SVI value of 90 corresponds to a field measurement that was taken on August 25th, 2009, and the SVI values of 120 and 150 represent average and poor settling sludge, respectively. The Vo and K values were estimated using the Ekama & Marais and Wahlberg & Keinath relationships. A summary of the results of the secondary clarifier performance evaluation as determined from the 2010 Capacity Study are as follows:

- At theoretical flow distribution:
    - The secondary clarifiers can treat 43.5 mgd peak flow at a MLSS concentration of 4,000 mg/L and an SVI of 90 mL/g.
    - The MLSS concentration needs to be reduced to approximately 2,800 mg/L to effectively treat 43.5 mgd assuming an SVI of 120 mL/g.
    - The MLSS concentration needs to be reduced to approximately 2,600 mg/L to effectively treat 43.5 mgd assuming an SVI of 150 mL/g.
- At predicted flow distribution:
    - Secondary Clarifier 2 becomes the limiting unit in the secondary clarifier system.
    - The secondary clarifiers can treat 43.5 mgd peak flow at a MLSS concentration of 3,500 mg/L and an SVI of 90 mL/g. Operation at a MLSS concentration of 4,000 mg/L could result in clarifier failure if peak flows are sustained for more than 24 hours.
    - The MLSS concentration needs to be reduced to approximately 2,800 mg/L to effectively treat 43.5 mgd assuming an SVI of 120 mL/g.
    - The MLSS concentration needs to be reduced to less than 2,600 mg/L to effectively treat 43.5 mgd assuming an SVI of 150 mL/g.

- At reduced peak flow:
  - The MLSS concentration needs to be reduced to approximately 4,000 mg/L to effectively treat 40 mgd assuming an SVI of 120 mL/g.

4.2 Clarifier Performance Evaluation Update

4.2.1 Introduction and Assumptions

As part of this clarifier rehabilitation conditions assessment, the performance of the existing secondary clarifiers was assessed using state point analyses and updated SVI data collected by plant staff. Furthermore, similarly to the hydraulic analysis, the clarifier performance evaluation was developed to reflect the operating conditions currently implemented by plant staff (only Secondary Clarifiers 1 and 5 in service and only Secondary Clarifiers 1 and 4 in service) at the maximum month and peak wet weather flows of 14.5 and 43.5 mgd, respectively. **Table 4-1** summarizes the SVI data collected from March 2015 to January 2017.

	SVI (mL/g)
Min	38
Max	114
Average	**76**
25th Percentile	68
50th Percentile	75
75th Percentile	83
80th Percentile	86
90th Percentile	91
95th Percentile	96
98th Percentile	101
99th Percentile	105
100th Percentile	114

Table 4-1: SVI for March 2015 to January 2017

As shown in **Table 4-1**, the average SVI value at the Mason Farm WWTP from 2015 to 2017 was 76, indicating very good settling sludge at the WWTP. In general, sludge with an SVI above 150 is considered bulking sludge, and sludge with SVIs between 60 and 120 is considered to have favorable settling characteristics.

The state point analyses presented herein generally follow a more conservative approach in comparison to the CFD Modeling developed for the 2010 Master Plan. The specific assumptions used to develop state point analyses are as follows:

- Use an Ekama factor 0.8 for Clarifiers 1, 2, and 3 to account for the shallow side water depths.

- Use an Ekama factor of 0.9 for Clarifiers 4 and 5 to represent clarifiers with relatively deeper side water depths.
- Assume MLSS concentrations of 4,000 mg/L.
- Assume that the RAS pumping flow capacities are equal to the capacities presented in **Table 1-1**.
- Use SVI values corresponding to the average, 80^{th}, and 95^{th} percentiles based on plant data collected from March 2015 to January 2017. The 95^{th} SVI percentile is not evaluated at the peak wet weather flow due to the high level of conservatism associated with this scenario.
- Use the estimated kinetics coefficients, V_o and K, as summarized in **Table 4-2**. The kinetic coefficients were estimated using a combination of the following published relationships: Ekama & Marais, Wahlberg & Keinath, Hartel & Popel, and Wilson relationships.

SVI (mL/g)	Vo (ft/h)	K (L/g)
76	32.40	0.311
86	31.66	0.348
96	30.91	0.385

Table 4-2: Settling Properties for Clarifier Evaluation

- Use the predicted flow distribution, included in **Table 3-1**, in lieu of theoretical flow distribution for Clarifiers 2 and 5 at the peak flow of 43.5 mgd.

4.2.2 Clarifier Performance Results

The results of state point analyses indicate that failure in clarifier performance occurs at the peak weather flow of 43.5 mgd. The clarifiers do not fail at the maximum month flow of 14.5 mgd. The specific observations made for Clarifiers 2, 3, and 4 are as follows:

- When all clarifiers are in service, the SPA indicates clarifier failure at an SVI of 86 and an MLSS concentration of 4,000 mg/L.
- When Clarifier 5 is taken out of service, the SPA indicates clarifier failure at the average SVI of 76 and an MLSS concentration of 4,000 mg/L.

There are two operational modifications that can be implemented to improve the performance of the secondary clarifiers: the first is to increase the RAS pumping rate and the second is to decrease the target MLSS concentration in the aeration basins. Furthermore, the settleability of sludge can be improved by adding settling aid polymer to the mixed liquor; adding polymer typically increases the settling velocity of sludge by a factor of 1.65. A list of specific operating parameters that would prevent the secondary clarifiers from failing based on the state point analyses are listed below. It is important to note that the ideal method to improving secondary clarifier performance is to simultaneously increase the RAS pumping flow rate and decrease the MLSS concentrations; the observations listed below assumes that either the RAS pumping rate is increased or the MLSS concentration is decreased at the peak wet weather flow of 43.5 mgd.

- Increasing the RAS pumping rate for Clarifiers 2 and 3 to from 2 to 3 mgd and for Clarifier 4 from 4 to 5 mgd would prevent clarifier failure for these clarifiers at an SVI of 86. This would require replacing the existing RAS pumps to increase the RAS pumping capacity. It is assumed that no changes are made to the operating MLSS concentration.

- Decreasing the MLSS concentration to approximately 2,000 mg/L would prevent clarifier failure under the worst case operating scenario during which only Clarifiers 1 and 4 are in service at an SVI of 86. It is important to note that there are process implications associated with operating at an MLSS concentration of 2,000 mg/L and that this mode of operation is not recommended. It is assumed that no changes are made to the RAS pumping rate.

In addition to developing SPAs to evaluate existing secondary clarifier performance, the potential performance improvements associated with building a new clarifier (Clarifiers 2 & 3 Alternatives 3 and 4) were evaluated. The results of the performance improvements associated with Alternatives 3 and 4 are as follows:

- Adding one new 130-ft diameter secondary clarifier in place of Clarifiers 2 and 3 improves the performance of the secondary clarifiers such that they no longer fail at the peak wet weather flow and at an SVI of 86.

- Adding one new 130-ft diameter secondary clarifier while keeping Clarifiers 2 and 3 in service significantly improves the performance of the secondary clarifiers such that there is only one scenario in which the clarifiers fail: at 43.5 mgd with Clarifier 5 out of service and at an SVI of 86. If the MLSS concentration decreases to 3,800 mg/L, all of the secondary clarifiers would perform adequately with Clarifier 5 out of service. For the purpose of evaluating the clarifier performance under this alternative, it is assumed that Clarifiers 2 and 3 can continue to remain operational in their current condition.

Appendix C includes the detailed SPA results at each SVI and operating scenario evaluated as part of this study. In general, the results of the state point analyses indicate that the existing secondary clarifiers are adequately sized for the permitted flow of 14.5 mgd and at the design MLSS concentration of 4,000 mg/L. At the peak wet weather flow of 43.5 mgd, however, clarifier treatment performance is compromised, particularly when not all clarifiers are being utilized. Furthermore, since the unequal distribution of mixed liquor at peak wet weather flows results in Clarifier 2 to be overloaded, implementing either Alternatives 3 or 4 (for Clarifiers 2 & 3) would alleviate the impacts caused by poor distribution.

5. Results & Recommendations

The various clarifier alternatives evaluated as part of this study provide a myriad of treatment, reliability, flexibility, and operation and maintenance benefits. While evaluating these alternatives, it is important to consider each of these benefits, as well as the impact that each alternative will have on the overall WWTP treatment process. Specifically, the following non-cost related factors should be considered as part of this evaluation:

1. The extent of improvements to existing mechanical and operational concerns as identified by plant staff.
2. The extent at which the impacts due to the maldistribution of mixed liquor are alleviated.
3. The improvements to the secondary clarifier treatment performance as measured by state point analyses.
4. The mechanical and structural design life associated with each alternative.

Table 5-1 includes a comparison of each alternative based on capital cost and the factors listed above. The percent of improved operation and maintenance is calculated with the assumption that the importance of each identified operational issue listed in **Table 1-2** is weighted equally.

Alternative	Capital Cost Opinion (2017)	Percent of Improved Operation & Maintenance	Are Hydraulic Impacts Alleviated?	Improved Clarifier Performance Based on SPA?	Additional Years of Design Life, Mechanical / Structural
Clarifiers 2&3					
Clarifiers 2&3: Alternative 1A	$410,000	50%	No	No	+25 / +0
Clarifiers 2&3: Alternative 1B	$960,000	67%	No	No	+25 / +0
Clarifiers 2&3: Alternative 2	$1,290,000	100%	No	No	+25 / +0
Clarifiers 2&3: Alternative 3	$3,100,000	100%	Yes	Yes	+25 / +40
Clarifiers 2&3: Alternative 4	$3,060,000	0%	Yes	Yes	+25 / +40
Clarifiers 2&3: Alternative 5 [1]	$616,000	100%	No	No	+25 / +0
Clarifier 4					
Clarifier 4: Alternative 1	$772,000	50%	No	No	+25 / +0
Clarifier 4: Alternative 2A	$1,250,000	100%	No	No	+25 / +0
Clarifier 4: Alternative 2B	$1,270,000	100%	No	No	+25 / +0
[1] Cost includes 304 stainless steel mechanism, new walkway bridge I-beams, and new 304 stainless steel weir plates and baffles. Cost does not include markups and contingencies listed in **Section 2.1**.					

Table 5-1: Comparison of Secondary Clarifier Rehabilitation Alternatives

5.1 Clarifiers 2 and 3 Recommendations

Although Alternatives 2 and 5 are the most similar to each other in terms of scope of improvements, these alternatives should be compared to each other with caution. While Alternative 2 includes several markups and contingences listed in **Section 2.1**, Alternative 5 does not. Specifically, the cost opinion associated with Alternative 2 includes an additional 15% of the total project cost allocated for electrical and instrumentation work. The cost associated with Alternative 5, alternatively, does not include materials and installation services associated with electrical and instrumentation improvements. Furthermore, costs that are generally associated with contractor services such as overhead and profit, bonds and insurance, and mobilization are not included in Alternative 5 as the full scope of work is directly negotiated between OWASA and the clarifier manufacturer.

While cost savings could be realized by implementing Alternative 5, it is important to identify the risks associated with purchasing materials and services directly from the secondary clarifier manufacturer. There are several contract requirements typically included in the general contractor's scope of work; these requirements should not be overlooked and should be negotiated as part of this alternative. A non-exhaustive list of these services and conditions to be negotiated include:

- Standard General Conditions to be applicable to contract
- Scope of concrete preparation and repairs (under a General Contractor, minor concrete repairs would typically be included under contingencies)
- Equipment warranty
- Equipment alignment requirements
- Quality control
- Inspection, startup, training, troubleshooting, adjustments, testing, and services after startup
- Provision of cranes and all necessary equipment to perform scope of work
- Disposal of demolished equipment
- Maintenance of plant operations during construction period
- Coordination of electrical and control requirements
- Submittal of shop test reports, shop drawings, start-up reports, and operation and maintenance (O&M) manuals
- Schedule for work to be substantially complete (and associated implications if schedule is not met)
- Limits of work area
- Site cleanup and restoration
- Site security/access and use of site facilities
- Consider possibility of clarifier manufacturer subcontracting field and installation work

Additionally, it is important to note that by implementing Alternative 5, the Owner will inherently acquire much of the work associated with the coordination required with the clarifier manufacturer. In general, purchasing the materials and services directly through the secondary clarifier manufacturer will take more of the Owner's time than if a general contractor is utilized.

As part of a short-term solution to rehabilitate Clarifiers 2 and 3, it is recommended that OWASA continue negotiating with Evoqua and proceed with Alternative 5 while keeping in mind the contractual, cost, and time implications described above. The quoted cost of $616,000 for the recommended option (304 stainless steel materials with new walkway I-beams and new weirs and baffles) may increase as some of the services and conditions are fully negotiated. Although Evoqua is the original manufacturer of Clarifiers 2 and 3 and is likely in the best position to provide these goods and services, proposals can also be solicited from Ovivo (formerly Eimco), Walker Process, or WesTech to ensure the proposal is competitive.

5.2 Clarifier 4 Recommendations

While the rehabilitation for Clarifier 4 is not currently as high a priority as for Clarifiers 2 and 3, it is recommended that OWASA considers converting the inboard launder to an outboard design (Alternatives 2A or 2B) to significantly alleviate the operational and maintenance concerns identified by OWASA staff. Since the differences in cost between concrete and FRP effluent troughs are minimal, it is recommended that Clarifier 4 be rehabilitated with concrete effluent troughs to increase design life and longevity.

5.3 Long-Term Recommendations

The recommended Alternatives for Clarifiers 2, 3, and 4 address the short-term concerns associated with the operation and maintenance of these clarifiers. These alternatives, however, do not address the long-term need for additional clarifier capacity as indicated by the SPA analyses described in **Section 4**. As flow to the Mason Farm WWTP increases, the performance of these clarifiers become compromised, impacting the overall treatment performance of the WWTP. It is recommended, therefore, that OWASA consider increasing the secondary clarifier capacity in the future to improve clarifier performance at peak wet weather flows.

6. References

Hazen and Sawyer. Mason Farm Wastewater Treatment Plant Hydraulic and Treatment Capacity Study – Orange Water and Sewer Authority. March 2010. H&S Project 30853-014.

Skogerboe, G.V., "Cutthroat Flumes for Water Measurement", Office of Agriculture, Bureau For Technical Assistance, Agency for International Development, Technical Series Bulletin No. 11, Sept. 1974

Appendix A: Photographs of Secondary Clarifiers 2, 3, and 4

Worn Stamford Baffles – Clarifiers 2&3

Divots in Concrete due to Unstable Centerwell – Clarifiers 2&3

Undersized Centerwell with No Scum Ports - Clarifiers 2&3

Corroded Weir Plates – Clarifiers 2&3

Inboard Effluent Launder – Clarifier 4

Scum Accumulation – Clarifier 4

Weir Brush System – Clarifier 4

Clarifier Mechanism – Clarifier 4

Appendix B: Evoqua Water Technologies Preliminary Turnkey Proposal

Preliminary Proposal

OWASA–Mason Farms
Chapel Hill, NC

Version: 1

Date: 3/15/2017

Prepared By: MSR

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SUMMARY:
Evoqua proposes to furnish two (2) Envirex® H-Type center-feed Tow-Bro® clarifier mechanisms for installation in two (2) existing 85'-0" diameter x 13' – 1 ¾" SWD basins.

Originally installed in 1981, with skimmer modifications completed in 1989, the Envirex Tow-Bro clarifier mechanisms at the Mason Farms WWTP in Chapel Hill, NC have been in service for approximately 36 years. The clarifier mechanisms are now in need of replacement due to deterioration of the structural components from an extended lifetime. With new mechanism components, the capabilities of the WWTP can be expanded to better handle peak flows, or for increased flows in the future.

EQUIPMENT:
INCLUSION:
Equipment will consist of the following: (each mechanism)

- Aluminum I-bar grating
- H40A-LT drive mechanism with micro-switch overload device and shear pin
- Walkway extension for better access to the drive unit
- Center column
- Torque cage
- FEDWA influent energy dissipating baffles
- 19' - 9" diameter x 5' deep influent flocculation well with supports
- 5'-0" submerged sludge manifold
- One (1) unitube sludge collection header
- Two (2) truss arm with A-frame skimmer supports
- Two (2) skimmer assemblies
- One (1) Scum trough with submerged shelf extension and automatic flushing device
- Bridge Replacement Options:
    - Option 1: Re-use existing bridge I-beams
        - Blast and paint to be completed on site by installation crew
        - Install new Bridge slide plate
            - *With modifications completed by Ford Hall Company on the bridge, there is concern they may not have reinstalled a bridge slide plate. One will be provided to the site for use. The bridge slide plate allows for the expansion and contraction of the bridge during cold or hot weather events*.
    - Option 2: Replace existing bridge I-beams
        - New handrails to be sourced as well
- Counterweights
- Associated anchor and attachment bolts

INSTALLATION SERVICES SCOPE:
To allow for an easy transition to the new mechanisms, the services of Evoqua installation crews have been included in this proposal. Evoqua installation crews work in conjunction with the Evoqua manufacturing facility and engineering department to ensure proper equipment installation.

Installation services include the following:

- Removal of bridge, drive and all internal components
- Installation of:
    - Center pier

- Drive and walkway extension
- Feedwell and FEDWA baffles
- Unitube suction header
- Scum trough
- Skimmer
- Bridge assembly

- Touch-up painting

EXCLUDED ITEMS

Please note that our price does not include:

- FRP Density current baffles
- Removal or re-installation of the existing algae control brushes
- Handrail on the periphery of the concrete tank
- Pressure relief valves
- Scum pumps, RAS pumps and nozzle spray systems
- Electrical control panels
- Lubricants
- Bridge beams, handrailing, toe-plate

CONTROLS

Electrical controls included in our price consist of the two (2) micro-switches (one N.O. and one N.C.) in the drive mechanism overload device housing for high torque alarm and motor shut-down.

EMBEDDED ITEMS

Embedded items included in our price are:

- Center pier anchor bolt template
- Anchors for the center pier
- Adhesive anchors for sludge manifold seal ring and bridge
- Adhesive anchors for scum trough supports

SPARE PARTS

- No spare parts are included.
- No special tools are required for the maintenance of this equipment.

REUSE OF EXISTING EQUIPMENT

Evoqua does not take responsibility for the condition or lifetime of the equipment to be reused. Equipment to be reused includes the two I-beam bridge supports, existing handrailing, and toe-boards. Removal and reinstallation of the algae sweeps needs to be coordinated through the Ford Hall Company.

SURFACE PROTECTION

The center drive mechanism will be shipped assembled and finish painted with Evoqua's standard drive paint system.

For the A36 Carbon Steel offering:

- The Tow-Bro unitube sludge collection headers will be hot-dip galvanized after fabrication.
- Non-submerged and submerged components will be prepared by blasting to SSPC-SP10 and prime painted with one (1) shop coat of Sherwin-Williams Dura-Plate 235NSF Red Oxide multi-purpose epoxy to 4-6 mills DFT. Finish coats will be applied following priming and touch-ups to be completed in the field.

For the 304 Stainless Steel offering:

- Submerged and non-submerged components will be fabricated from Type 304 stainless steel and brush passivated per ASTM-A380.

FIELD SERVICES

Mechanical field service for this equipment includes four (4) trips and six (6) days.

BUDGETARY PRICING WITH FIELD WORK & INSTALLATION SERVICES BY EVOQUA:

ITEM:	PRICE
Two (2) 85’ Tow-Bro Mechanisms – A36 Carbon Steel • Including scope detailed above and installation • Re-use of existing bridge I-beam supports and cross-members	**$401,350**
Two (2) 85’ Tow-Bro Mechanisms – 304 Stainless Steel • Including scope detailed above and installation • Re-use of existing bridge I-beam supports and cross-members	**$482,450**
Two (2) 85’ Tow-Bro Mechanisms – A36 Carbon Steel • Including scope detailed above and installation • New bridge I-beam supports and cross-members	**$408,900**
Two (2) 85’ Tow-Bro Mechanisms – 304 Stainless Steel • Including scope detailed above and installation • New bridge I-beam supports and cross-members	**$507,000**

ADDITIONAL COST ITEMS:

The following items are quoted as an extra. They are not included in the base equipment price. Any order for these items will be accepted only when included with the basic equipment order. Installation services are included in the prices listed below.

ITEM:	PRICE
Effluent Weirs and Baffles • A36 Carbon Steel:	**$83,200**
• 304 Stainless Steel:	**$109,000**

MECHANISM PHOTOS:

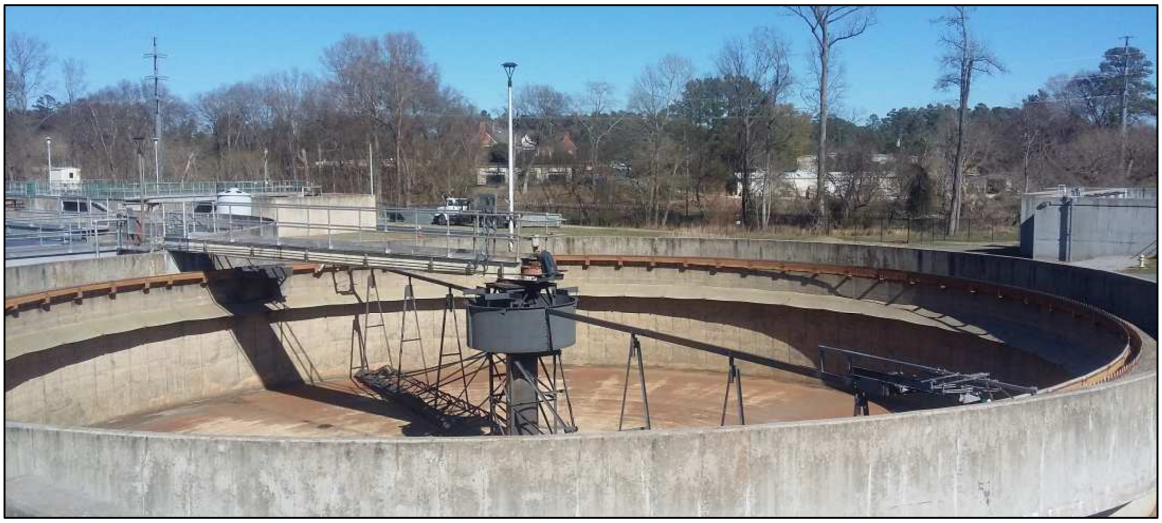


Photo 1: Envirex clarifier not in operation

Photo 2: Envirex clarifier in operation

Photo 3: The above photo shows the poor condition of the existing checker plate

Photo 4: Envirex clarifier out of operation. Grooves are visible on the floor from the plow blades

Photo 5: The scum troughs of both Envirex clarifiers are in a poor shape. Manual hoses are needed to complete flushing of the scum.

Photo 6: The drives for both clarifiers are in poor shape after operating for almost double their design life.

Photo 7: The existing influent well has a diameter of 8’-5”. This is approximately ½ the size recommended for use. The purposed equipment would have an influent well of 19’-9” along with the Envirex patent FEDWA EDI.

Photo 8: During the installation of the Algae Sweep/ Weir-Wolf Brush systems by Ford Hall Company, an additional section of beam bridge was added to the existing Envirex equipment.

Photo 9: The current metal weirs and baffles are in a state of disrepair and need to be replacement.

Photo 10: Severe rust is seen on the underside of the checker plate

Appendix C: Summary of State Point Analyses Results

This table summarizes the SPA results for the Mason Farm WWTP existing clarifiers:

Condition	Flow	SVI	Clarifier 1			Clarifiers 2 & 3			Clarifier 4			Clarifier 5		
			SPA at 4 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 4 MGD RAS	SPA at 2 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 2 MGD RAS	SPA at 4 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 4 MGD RAS	SPA at 6 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 6 MGD RAS
All in Service	Design Max Month = 14.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		96	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
	Peak = 43.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		86	Pass	NA	NA	Fail	3	3800	Fail	5	3900	Fail	7	3800
Clar 5 OOS	Design Max Month = 14.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
		96	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
	Peak = 43.5 MGD	76	Fail	7	3300	Fail	3	3300	Fail	NA [1]	3200			
		86	Fail	NA [1]	2900	Fail	NA [1]	2900	Fail	NA [1]	2900			
Clar 1 & 5 in Service	Design Max Month = 14.5 MGD	76	Pass	NA	NA							Pass	NA	NA
		86	Pass	NA	NA							Pass	NA	NA
		96	Pass	NA	NA							Pass	NA	NA
	Peak = 43.5 MGD	76	Fail	NA [1]	2800							Fail	NA [1]	2900
		86	Fail	NA [1]	2500							Fail	NA [1]	2500
Clar 1 & 4 in Service	Design Max Month = 14.5 MGD	76	Pass	NA	NA				Pass	NA	NA			
		86	Pass	NA	NA				Pass	NA	NA			
		96	Pass	NA	NA				Pass	NA	NA			
	Peak = 43.5 MGD	76	Fail	NA [1]	2300				Fail	NA [1]	2300			
		86	Fail	NA [1]	2100				Fail	NA [1]	2000			

Notes

1. NA indicates the steady point is outside of settling flux.
2. SVI values correspond to: average, 80th, and 95th percentiles based on plant data from March 2015 to Jan 2017.
3. Use RAS pump capacities as initial RAS rates.
4. Use an Ekama factor of 0.9 for Clarifiers 4 & 5, and 0.8 for Clarifiers 1, 2, and 3 to account for the more shallow clarifiers.
5. Use predicted flow distribution for all in service condition for Clarifiers 2 & 5.

This table summarizes the SPA results for the Mason Farm WWTP secondary clarifiers assuming one new clarifier is built and Clarifiers 2 & 3 are demolished (Alternative 3):

Condition	Flow	SVI	Clarifier 1			New Clarifier (130-ft Diameter)			Clarifier 4			Clarifier 5		
			SPA at 4 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 4 MGD RAS	SPA at 6 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 6 MGD RAS	SPA at 4 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 4 MGD RAS	SPA at 6 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 6 MGD RAS
All in Service	Design Max Month = 14.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		96	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
	Peak = 43.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
Clar 5 OOS	Design Max Month = 14.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
		96	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
	Peak = 43.5 MGD	76	Fail	5	3700	Fail	8	3600	Fail	5	3700			
		86	Fail	7	3300	Fail	NA [1]	3200	Fail	NA [1]	3200			

Notes

1 NA indicates the steady point is outside of settling flux.
2 SVI values correspond to: average, 80th, and 95th percentiles based on plant data from March 2015 to Jan 2017.
3 Use RAS pump capacities as initial RAS rates.
4 Use an Ekama factor of 0.9 for Clarifiers 4 & 5, and 0.8 for Clarifiers 1, 2, and 3 to account for the more shallow clarifiers.
5 Assume new clarifier has SWD of 18 feet to match current design (Ekama factor of 0.9 in lieu of 0.8).
6 Assume flow distribution to new clarifier is with 6-ft flume, same as Clarifier 5.
7 Cells in thick borders represent an improvement in performance in compared to existing conditions.

This table summarizes the SPA results for the Mason Farm WWTP secondary clarifiers assuming one new clarifier is built and Clarifiers 2 & 3 remain in service (Alternative 4):

Condition	Flow	SVI	Clarifier 1			Clarifiers 2 & 3			New Clarifier (130-ft Diameter)			Clarifier 4			Clarifier 5		
			SPA at 4 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 4 MGD RAS	SPA at 2 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 2 MGD RAS	SPA at 6 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 6 MGD RAS	SPA at 4 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 4 MGD RAS	SPA at 6 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 6 MGD RAS
All in Service	Design Max Month = 14.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		96	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
	Peak = 43.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
Clar 5 OOS	Design Max Month = 14.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
		96	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
	Peak = 43.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
		86	Pass	NA	NA	Pass	NA	NA	Fail	7	3800	Fail	5	3900			

Notes

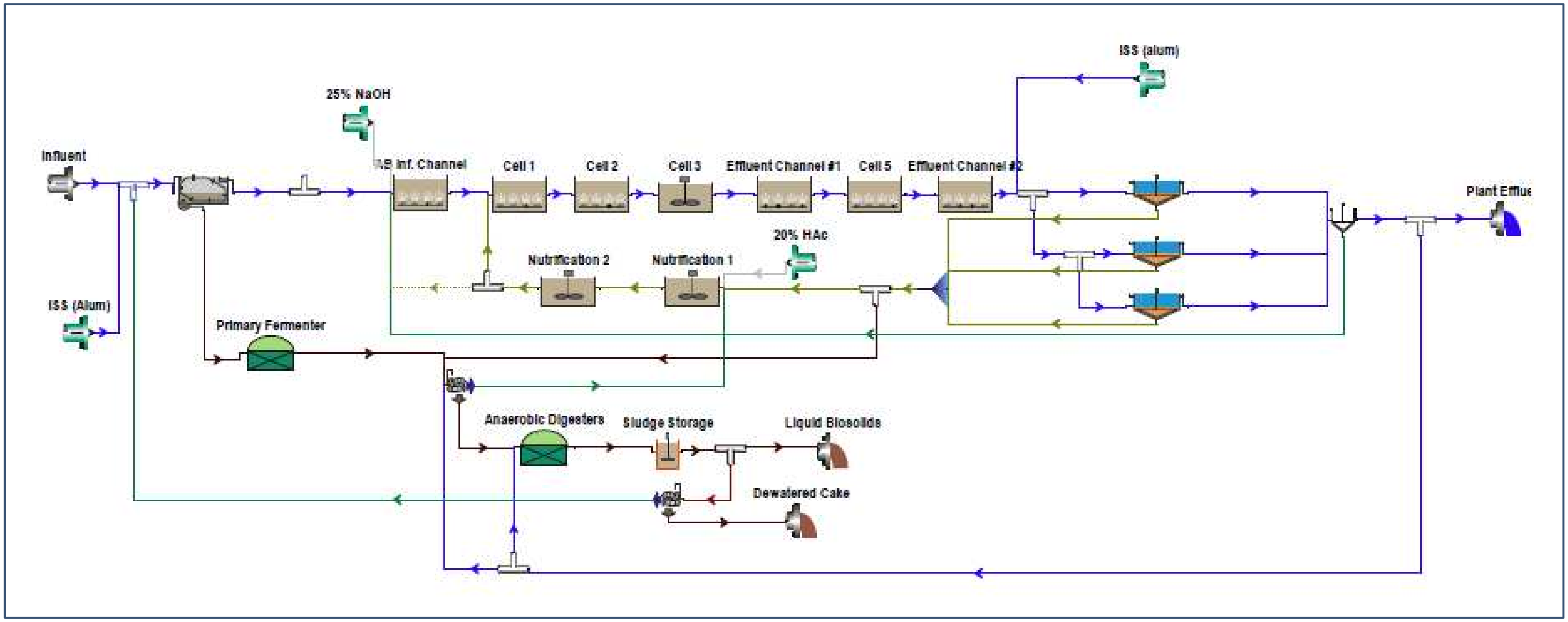
1. NA indicates the steady point is outside of settling flux.
2. SVI values correspond to: average, 80th, and 95th percentiles based on plant data from March 2015 to Jan 2017.
3. Use RAS pump capacities as initial RAS rates.
4. Use an Ekama factor of 0.9 for Clarifiers 4 & 5, and 0.8 for Clarifiers 1, 2, and 3 to account fo the more shallow clarifiers.
5. Assume new clarifier has SWD of 18 feet to match current design (Ekama factor of 0.9 in lieu of 0.8).
6. Assume flow distribution to new clarifier is with 6-ft flume, same as Clarifier 5.
7. Cells in thick borders represent an improvement in performance compared to existing conditions.

Hazen

January 22, 2019

Compilation TM Appendix B: Mason Farm WWTP Process Model & Internal Recycle Evaluation Update

Hazen

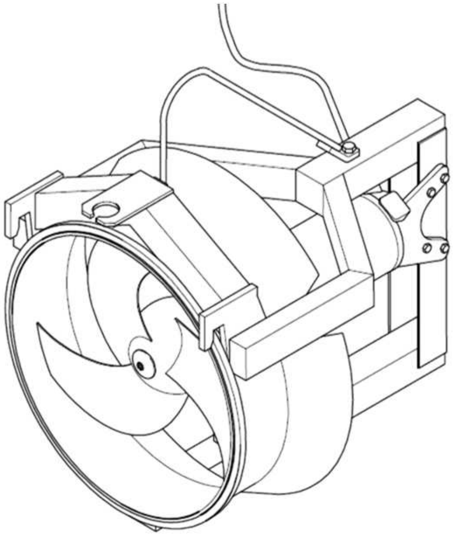


Mason Farm WWTP Process Model & Internal Recycle Evaluation Update

September 12, 2017

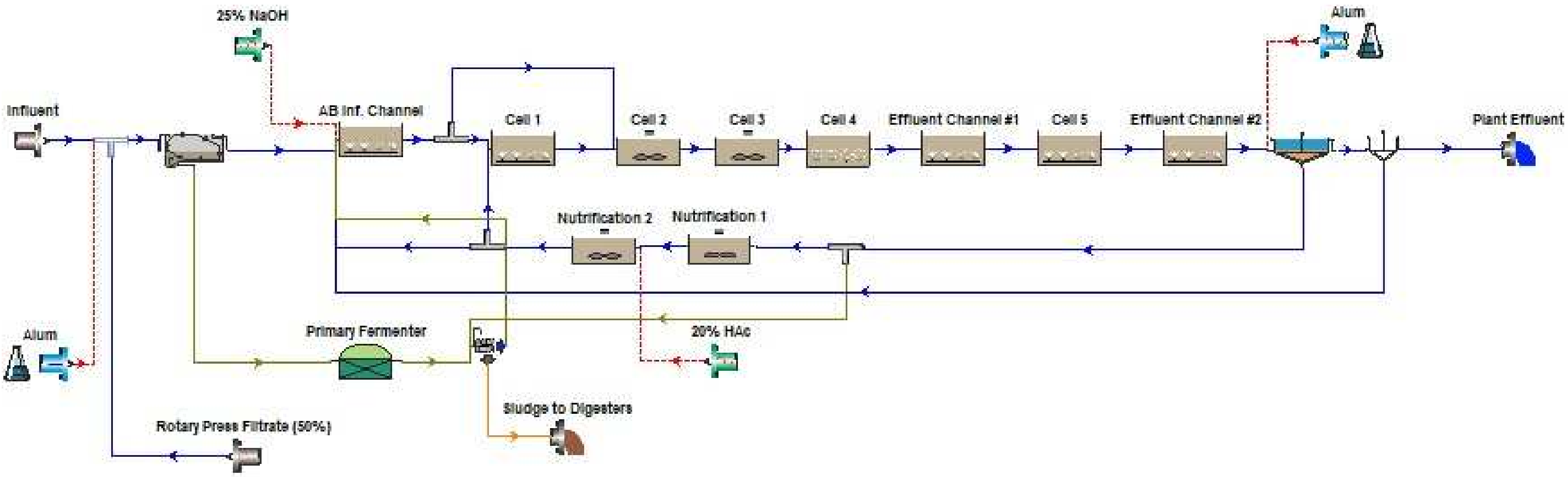
Agenda

1. Process Model Update
2. NRCY Modification Scenarios
3. NRCY Pump Selection
4. Proposed Layouts
5. Opinion of Probable Cost
6. Summary of Results



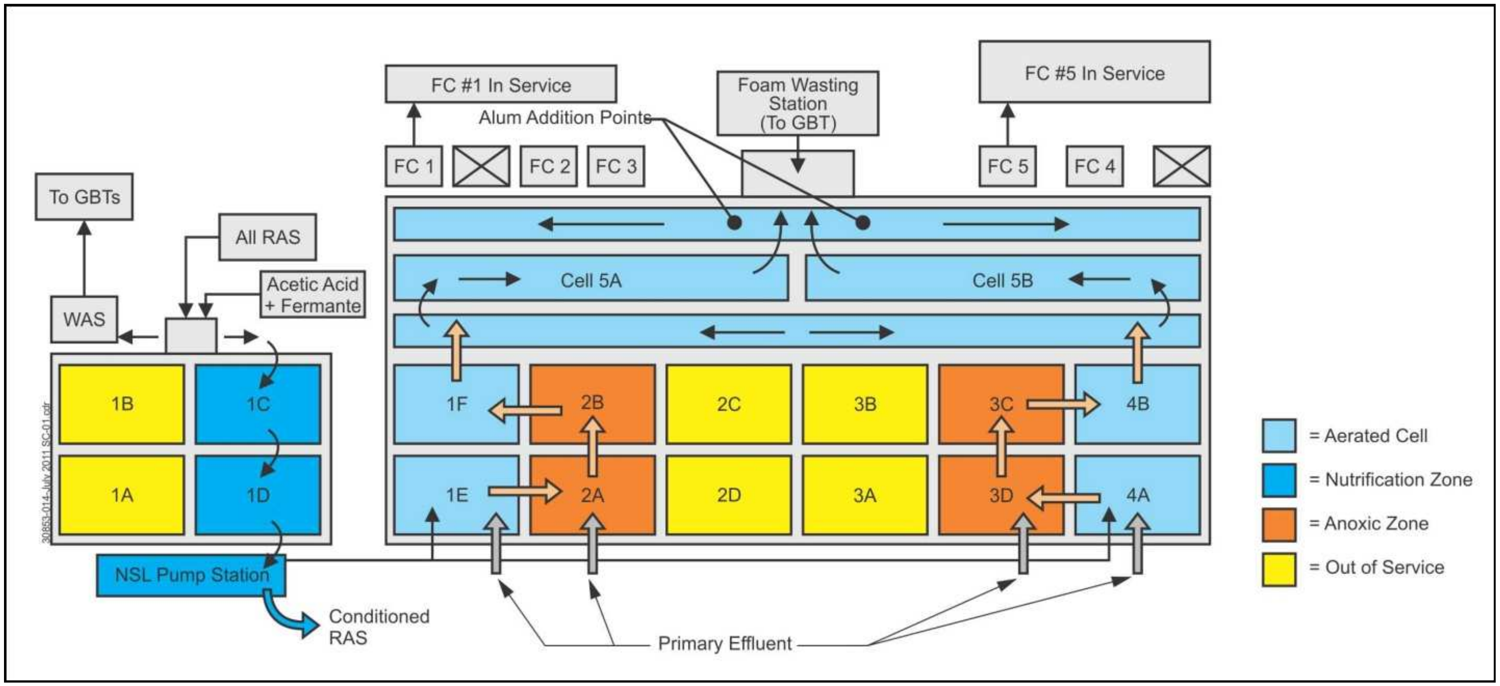
Process Model Update

Mason Farm WWTP Process Model

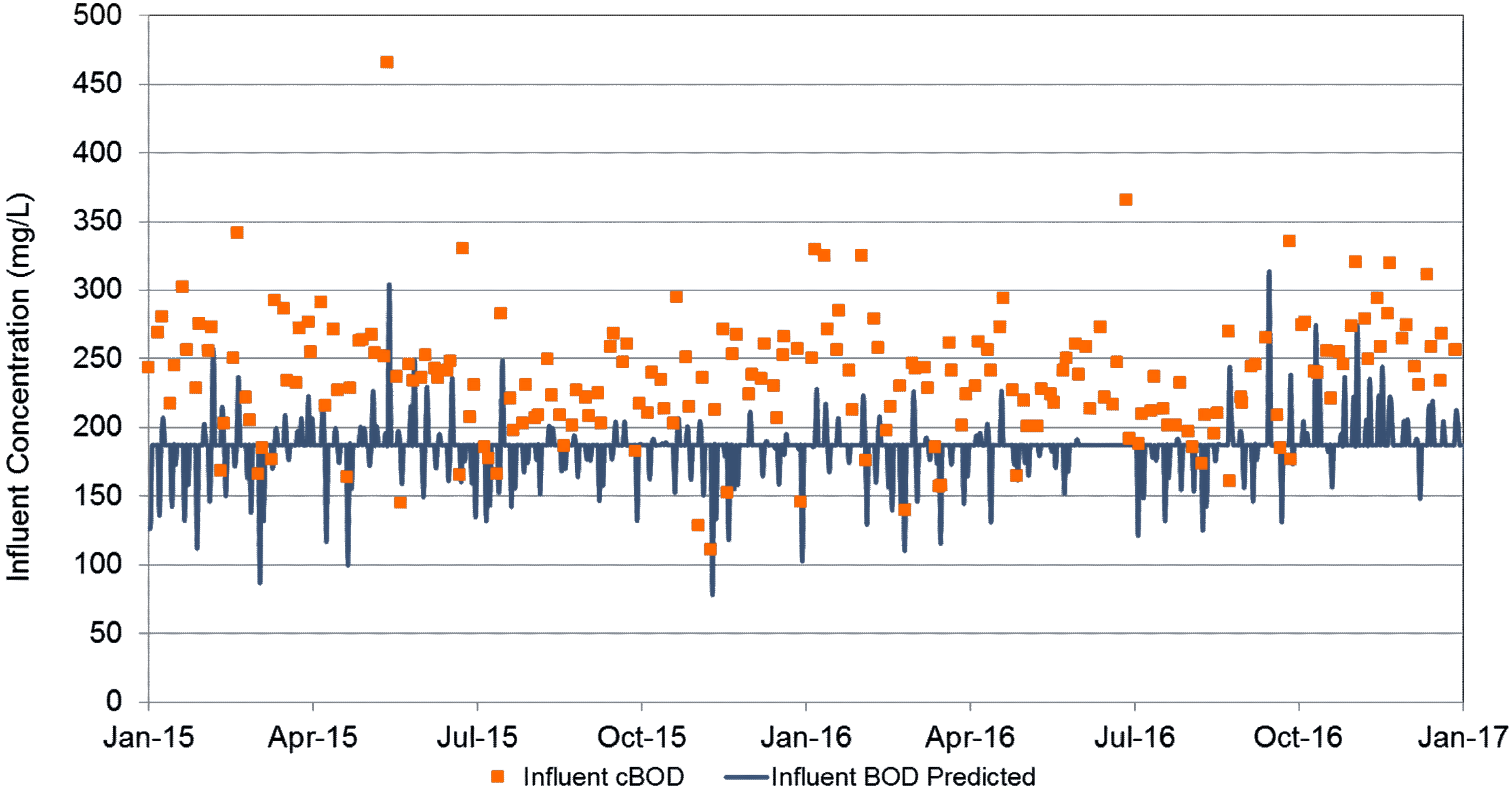


Current Process Configuration

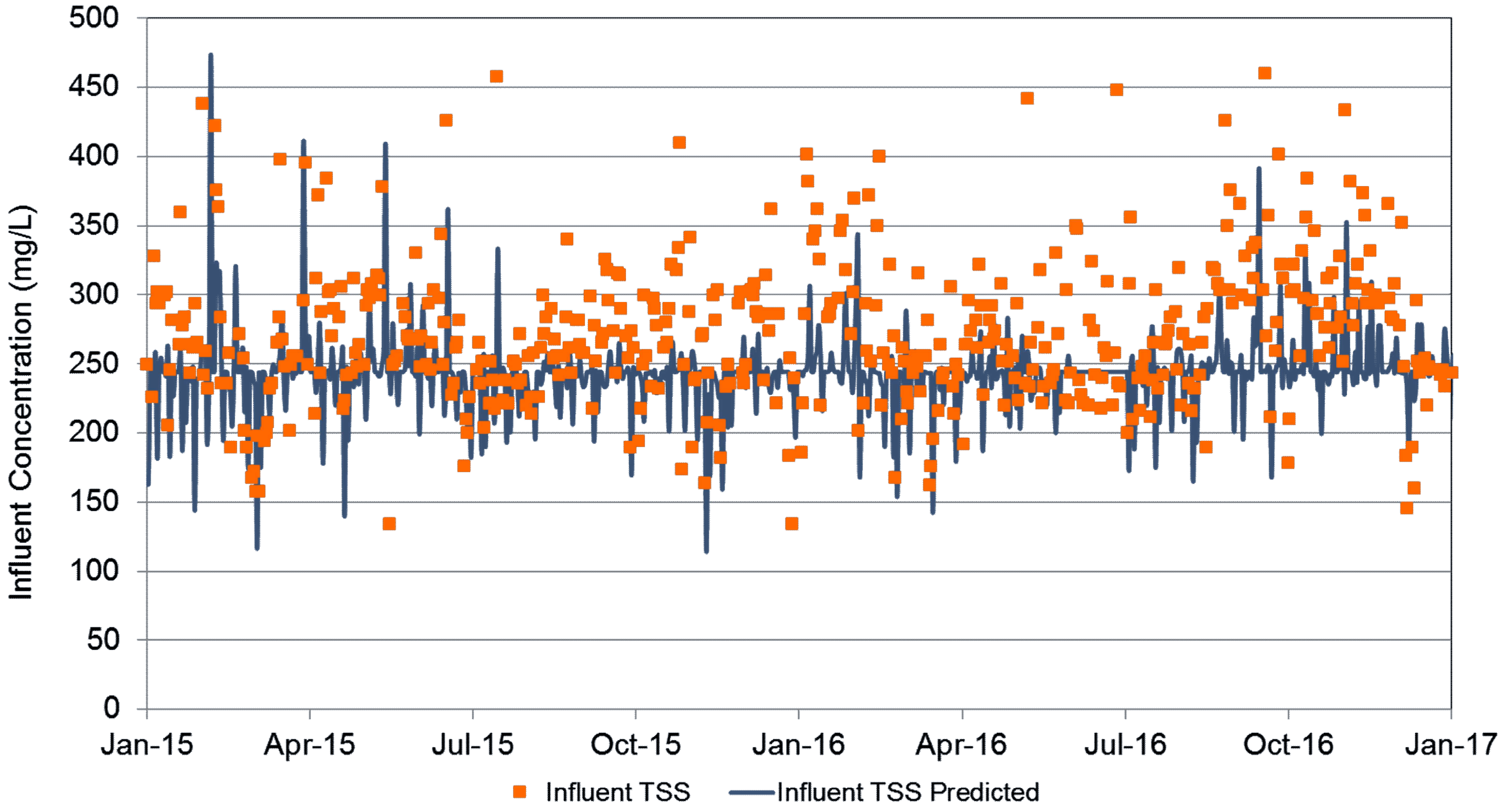
- Three trains of four cells
- Step feed to Cells 1 & 2
- Fermentate to the AB Influent Channel
- Operating Cell 5 anoxically when possible



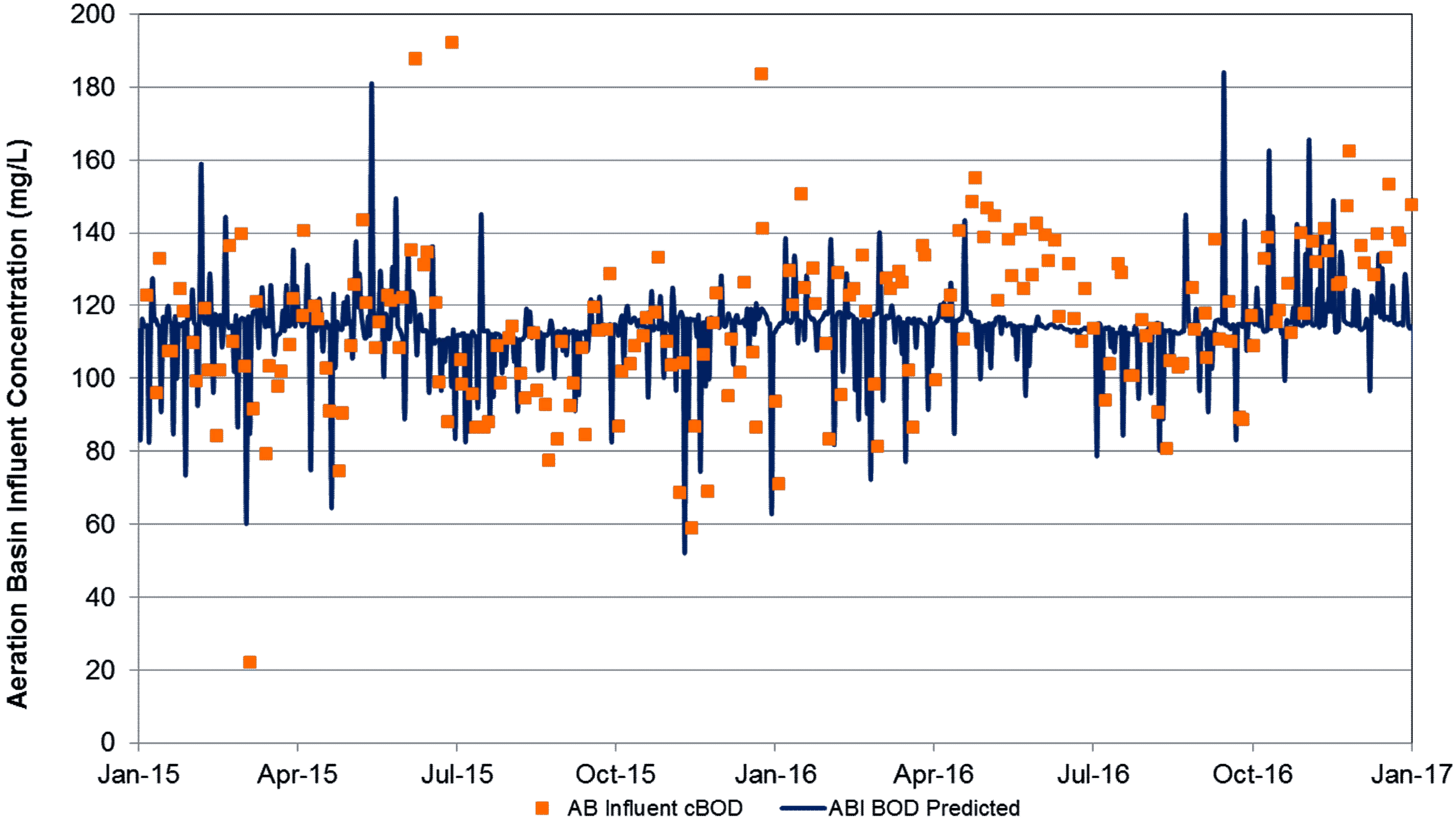
Influent $cBOD_5$ Comparison



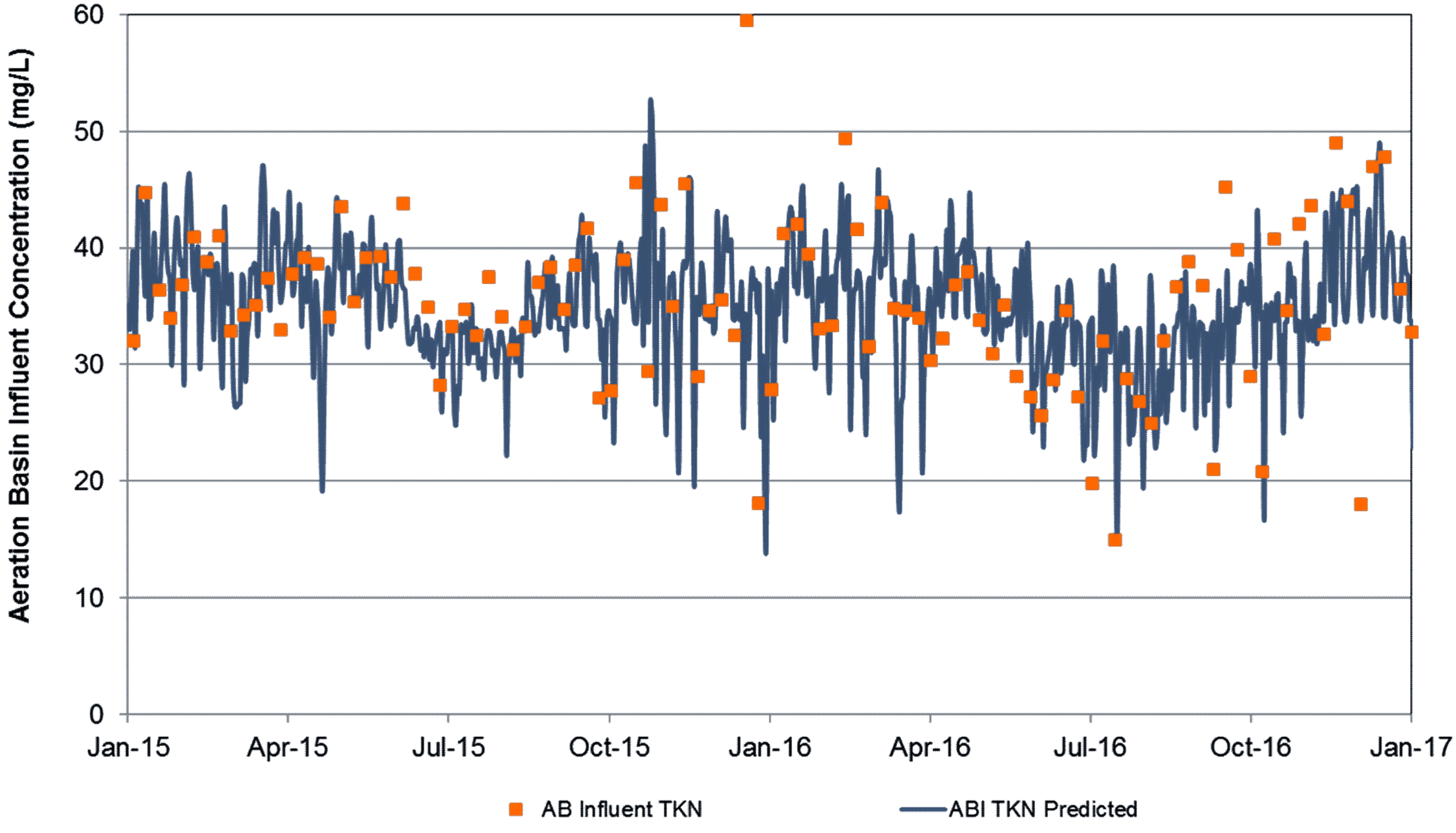
Influent TSS Comparison



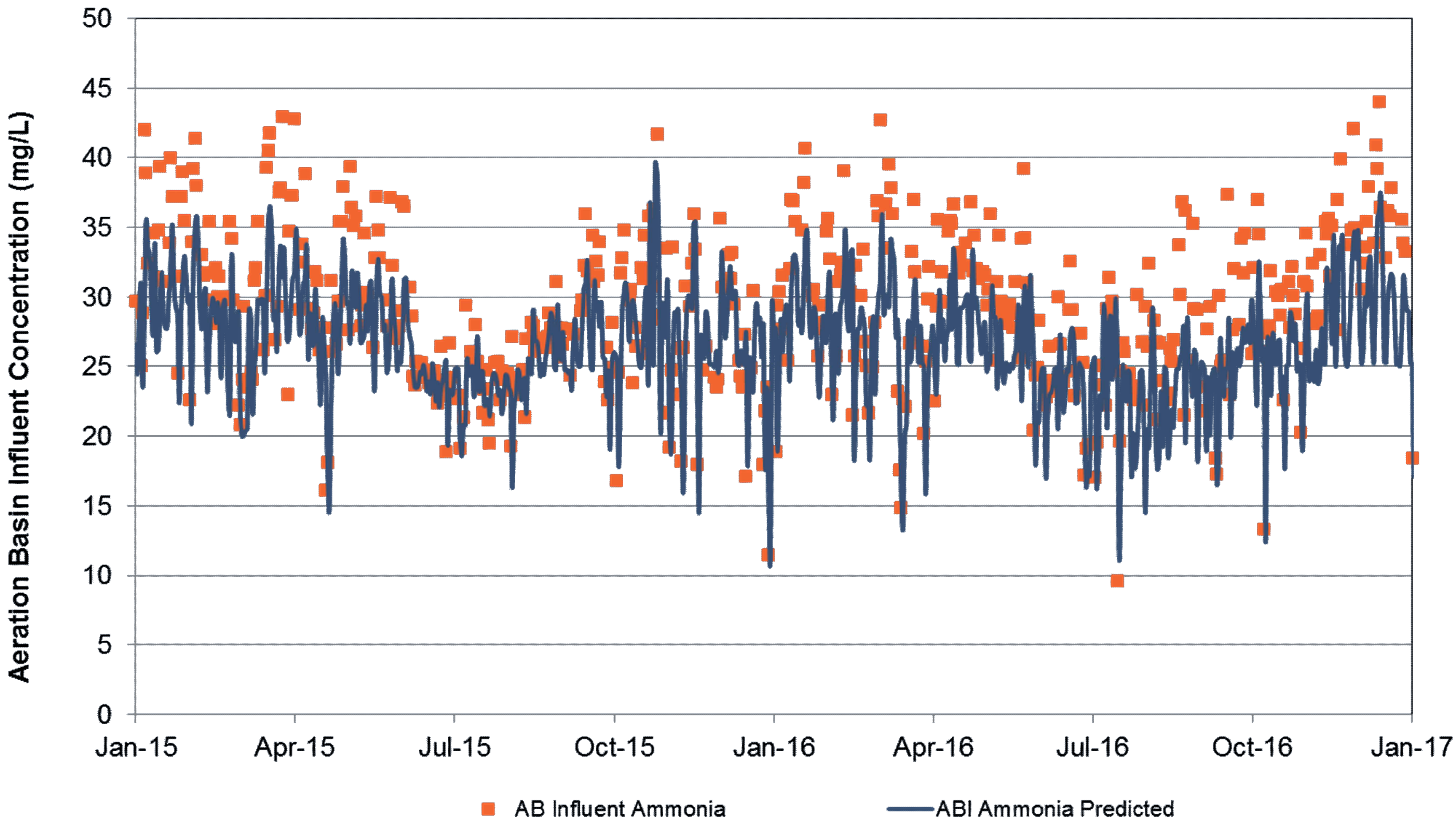
Aeration Basin Influent cBOD5



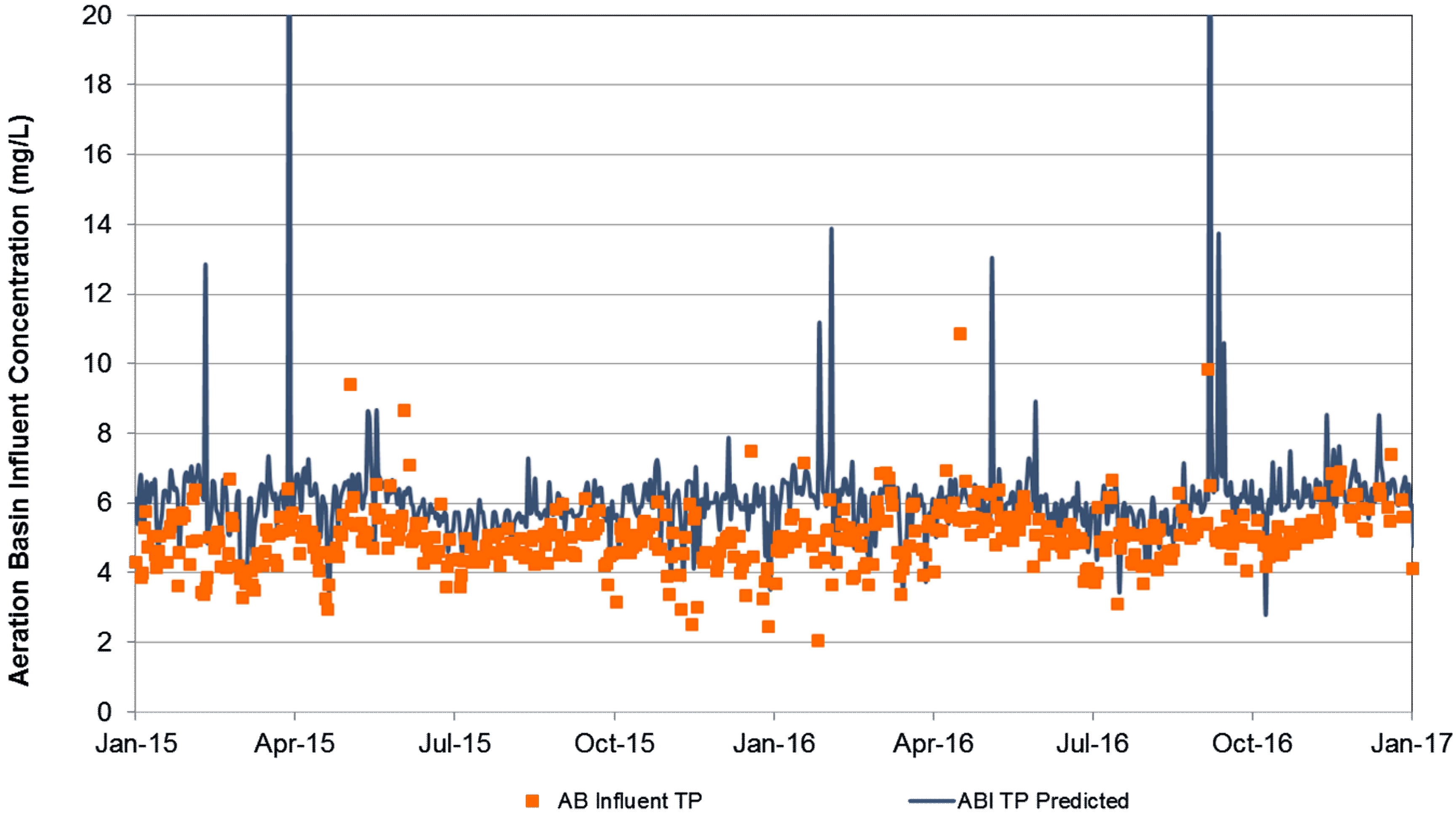
Aeration Basin Influent TKN



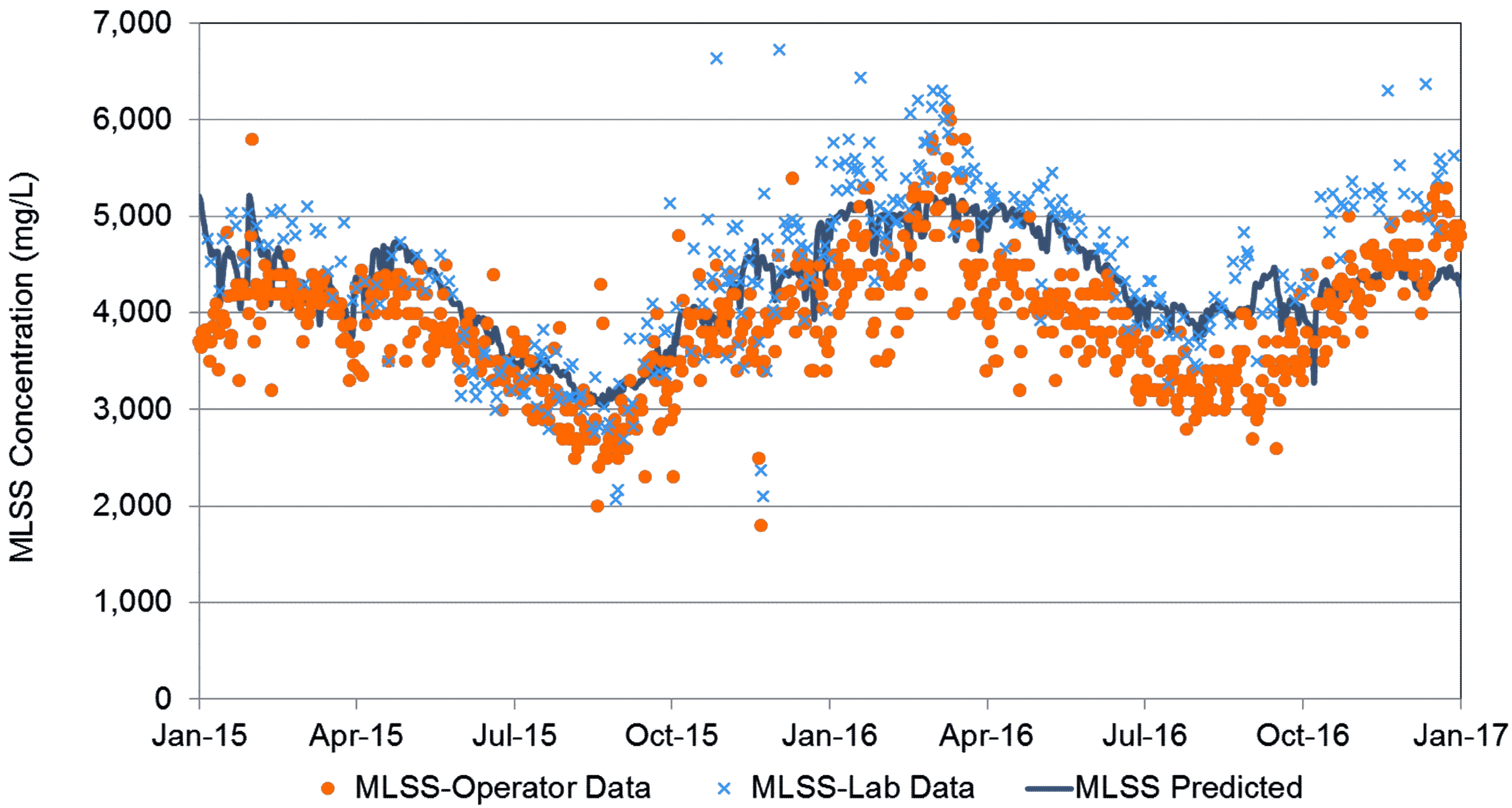
Aeration Basin Influent Ammonia



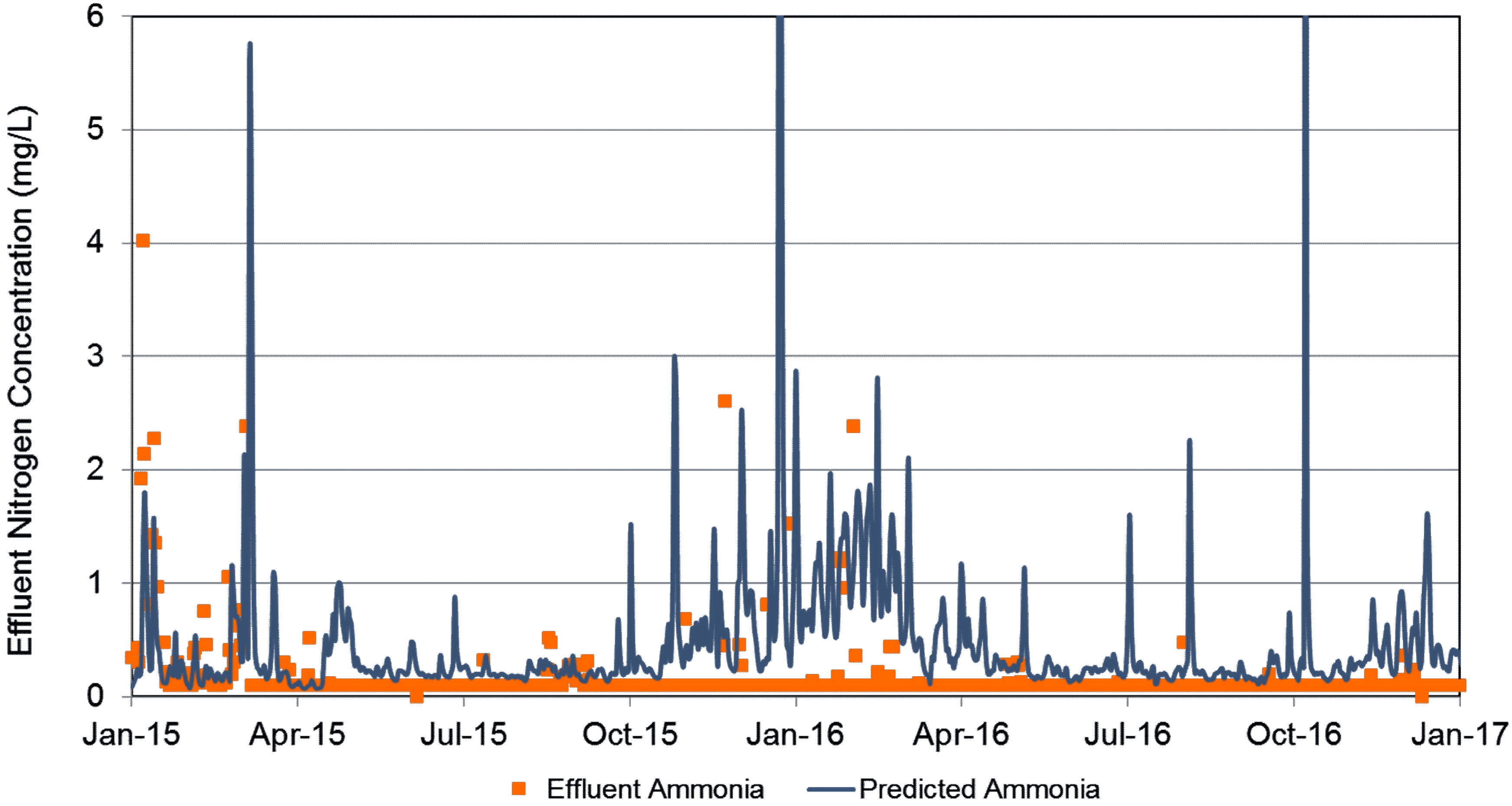
Aeration Basin Influent TP



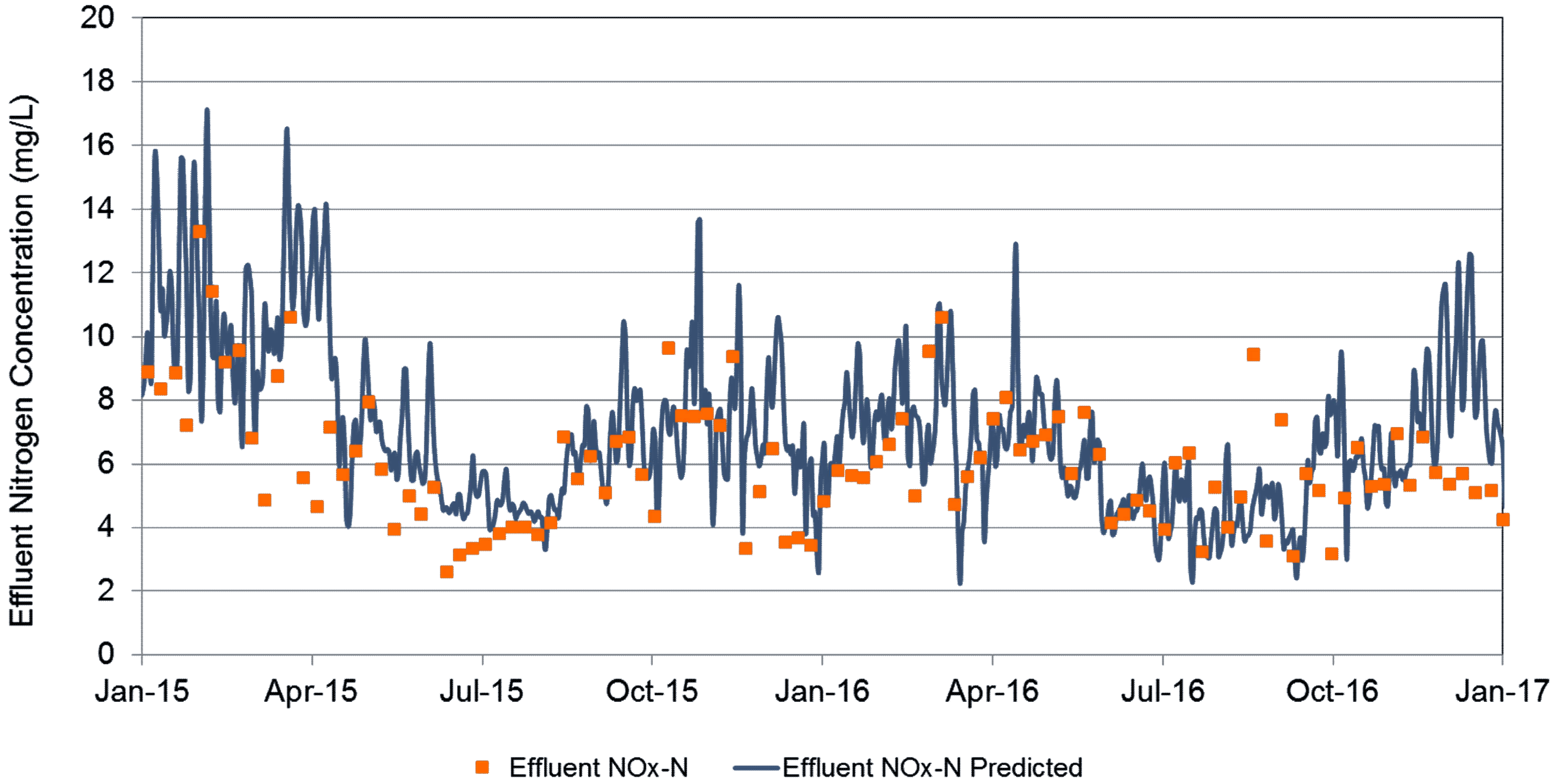
MLSS Comparison



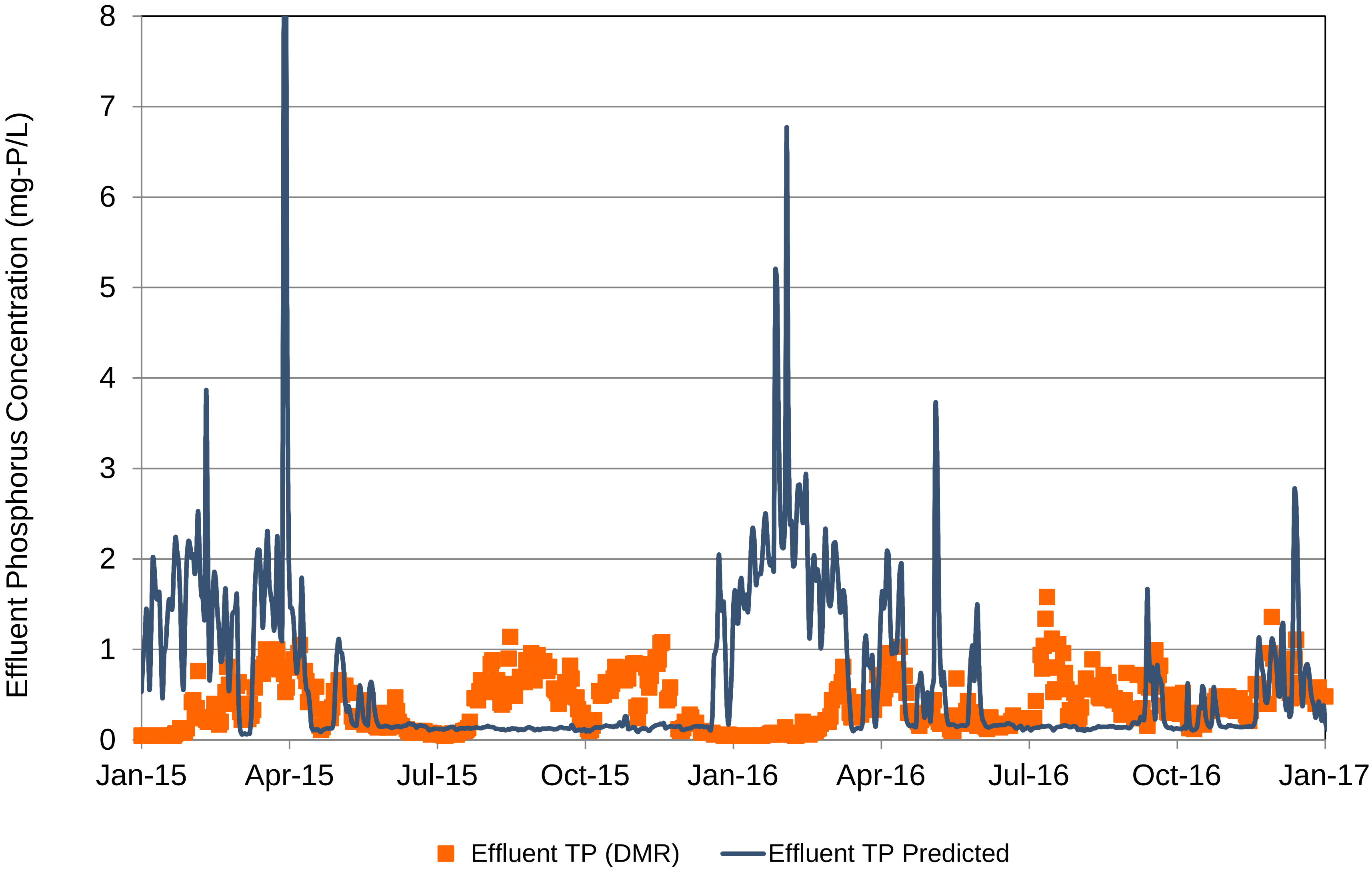
Effluent Ammonia Comparison



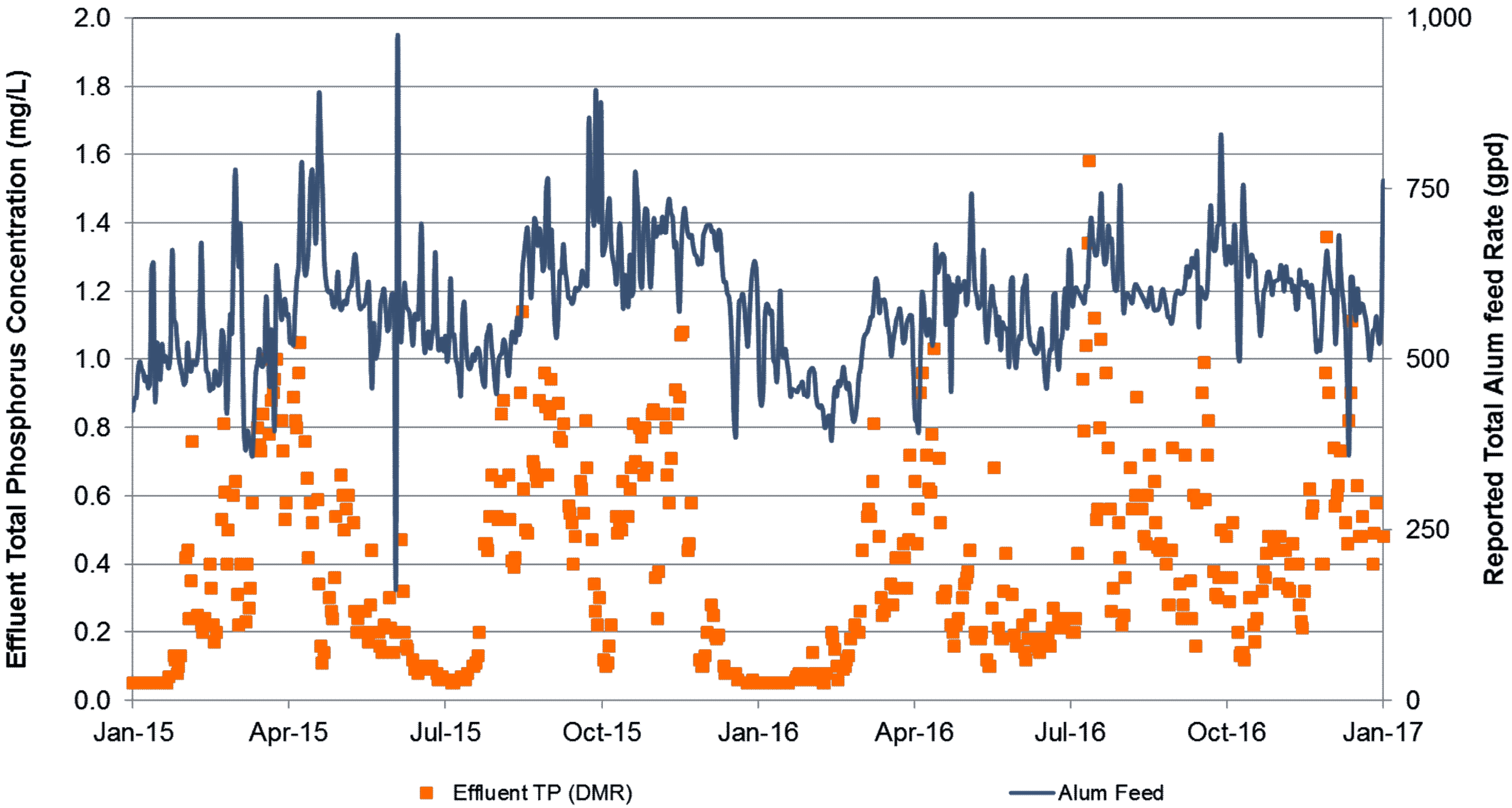
Effluent NO_x-N Comparison



Effluent Total Phosphorus Comparison



Effluent TP vs. Chemical Feed



Simulated vs. Reported Effluent Nutrients and MLSS – 2015 - 2016

	Reported	Steady State Simulation	Average Dynamic Simulation
Effluent $cBOD_5$, mg/L	2.1	< 2	< 2
Effluent TSS, mg/L	2.5	2.5	2.5
Effluent NH_3-N, mg/L	0.2	0.3	0.5
Effluent TKN, mg/L	1.1	1.3	1.5
Effluent NO_X-N, mg/L	6.0	6.6	7.0
Effluent TN, mg/L	6.3*	7.9	8.5
Effluent TP, mg/L	0.40	0.50	0.67
Basin MLSS (Ops), mg/L	3,900	3,800	3,700
RAS MLSS (Ops), mg/L	7,800	7,100	7,100

*Note – Effluent TN and NO3-N reported as same value over much of period

Modification Scenarios

NRCY Modification Scenarios

- NRCY pumped from Effluent Channel #1 for each scenario
- MLE vs Step Feed configuration
  - MLE – NRCY to Cell 1
  - Step-Feed – NRCY to Cell 3
- Cell 5 aerated or unaerated
- RAS rates at 100% and 200% of influent flow

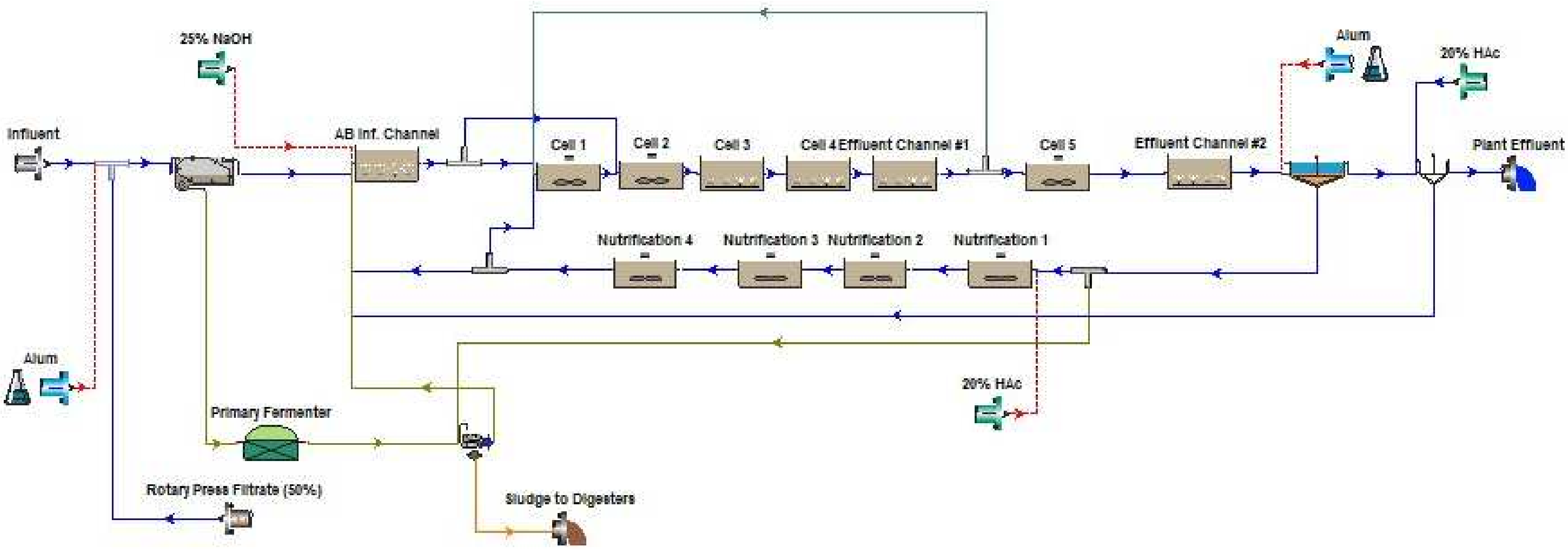
Assumptions

- NRCY flow per Aeration Train = 14.5 MGD
- Four NSL cells in operation
- Fermentate addition to the AB Influent Channel
- 600 gpd of alum before secondary clarifiers
- 500 gpd of acetate addition to NSL

Modification Scenarios

Scenario	Plant Configuration	Cell 5 Operation	RAS
1	Step Feed	Aerobic	100%
2	Step Feed	Aerobic	200%
3	Step Feed	Anoxic	100%
4	Step Feed	Anoxic	200%
5	MLE	Aerobic	100%
6	MLE	Aerobic	200%
7	MLE	Anoxic	100%
8	MLE	Anoxic	200%

Mason Farm WWTP Modified Process Model (MLE Configuration)



NRCY Simulation Results

Final Effluent	Current	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
TN, mg/L	7.9	9.4	7.6	8.0	6.2	11.2	8.8	9.9	8.9
NH_3-N, mg/L	0.3	0.1	0.1	0.5	0.4	0.1	0.1	0.3	0.2
TKN, mg/L	1.2	1.2	1.2	1.4	1.3	1.2	1.3	1.2	1.2
NO_3-N, mg/L	6.4	8.1	6.3	6.3	4.6	10.0	7.5	8.5	7.6
TP, mg/L	0.50	0.60	0.50	0.80	0.70	0.30	1.1	0.2	1.2

Chemical Cost for Denitrification Filters Summary

- No reduction with MLE
- Greatest reduction with Cell E anoxic, 200% RAS
  - May adversely impact BPR

Scenario	Acetic Acid ($0.83/gallon)	Methanol ($1.10/gallon)	Micro C ($1.65/gallon)
1	$-	$-	0
2	$4,500	$1,500	$2,200
3	$4,500	$1,500	$2,200
4	$81,000	$27,000	$40,000

Optimization Observations

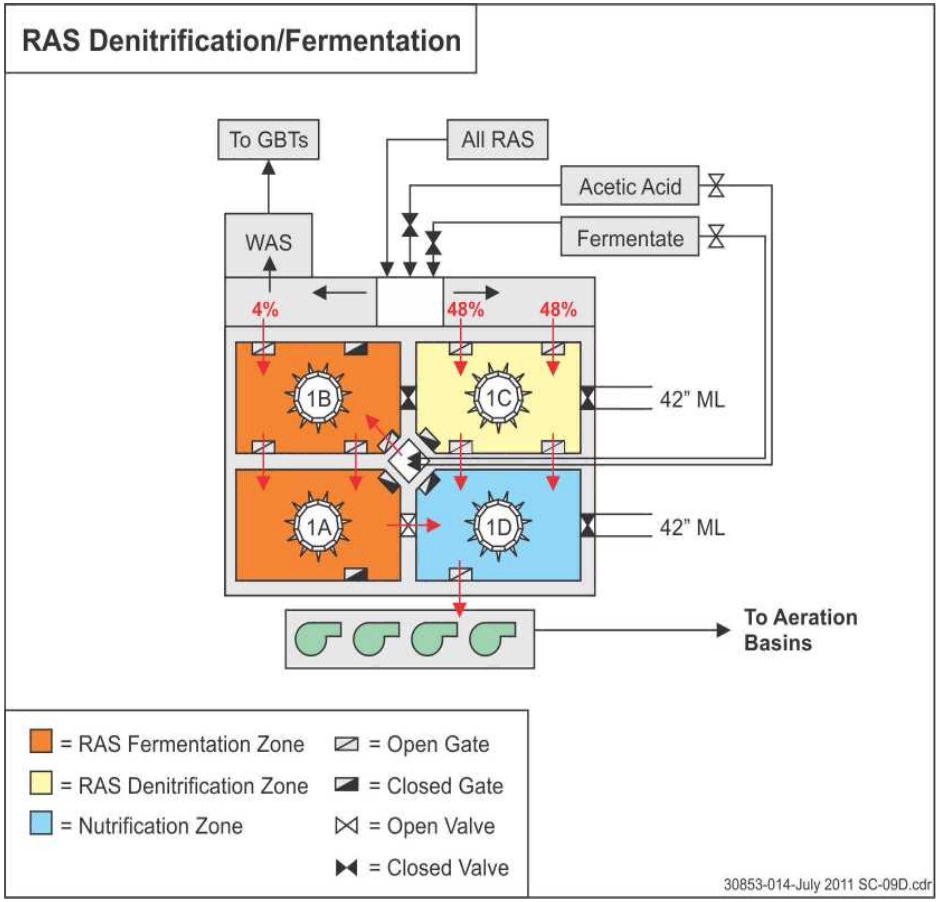
- Continue current step feed operation
- Discontinue fermentate addition to the AB Influent
  - ½ of fermentate is oxidized in step feed mode
- Operate 4 NSL cells for increased denitrification capacity and promotion of bioP
- Continue intermittent aeration in Cell 5 to optimize denitrification
- Maximize RAS flow for denitrification
- Consider RAS fermentation in NSLs
  - May offset reduced BPR efficiency if RAS increased

RAS Fermentation Advantages

Create additional VFAs

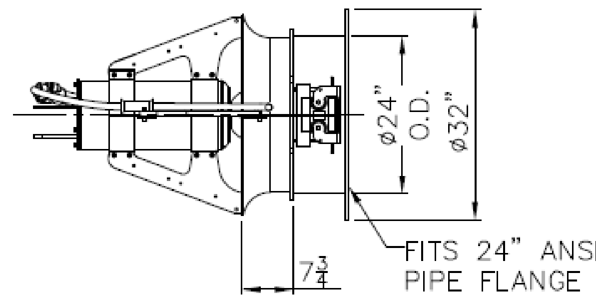
Select for more diverse PAOs

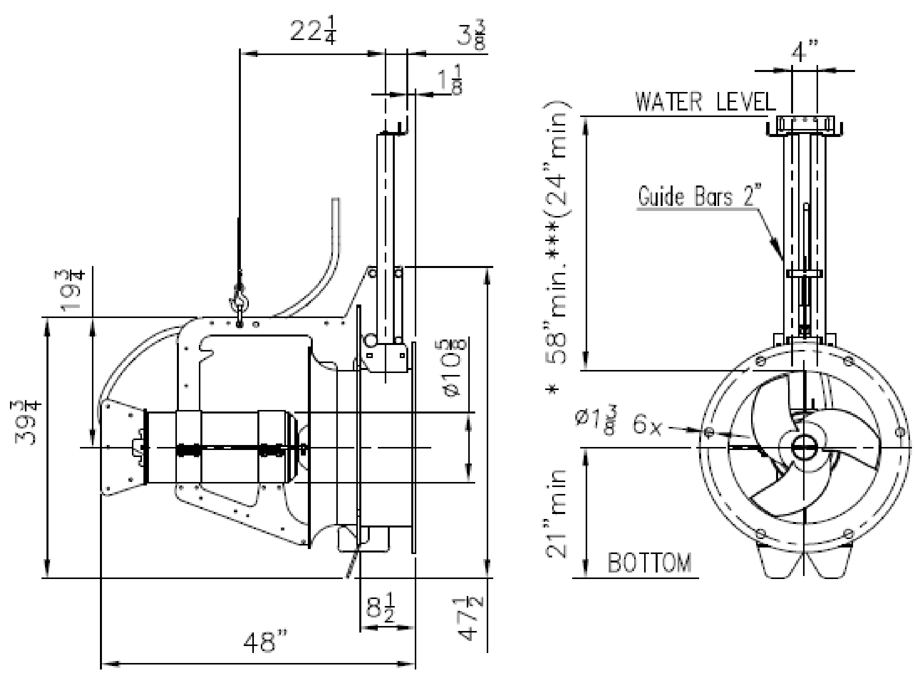
- Denitrifying DPAOs
- Utilize substrates other than VFAs
- Potentially ferment complex organics



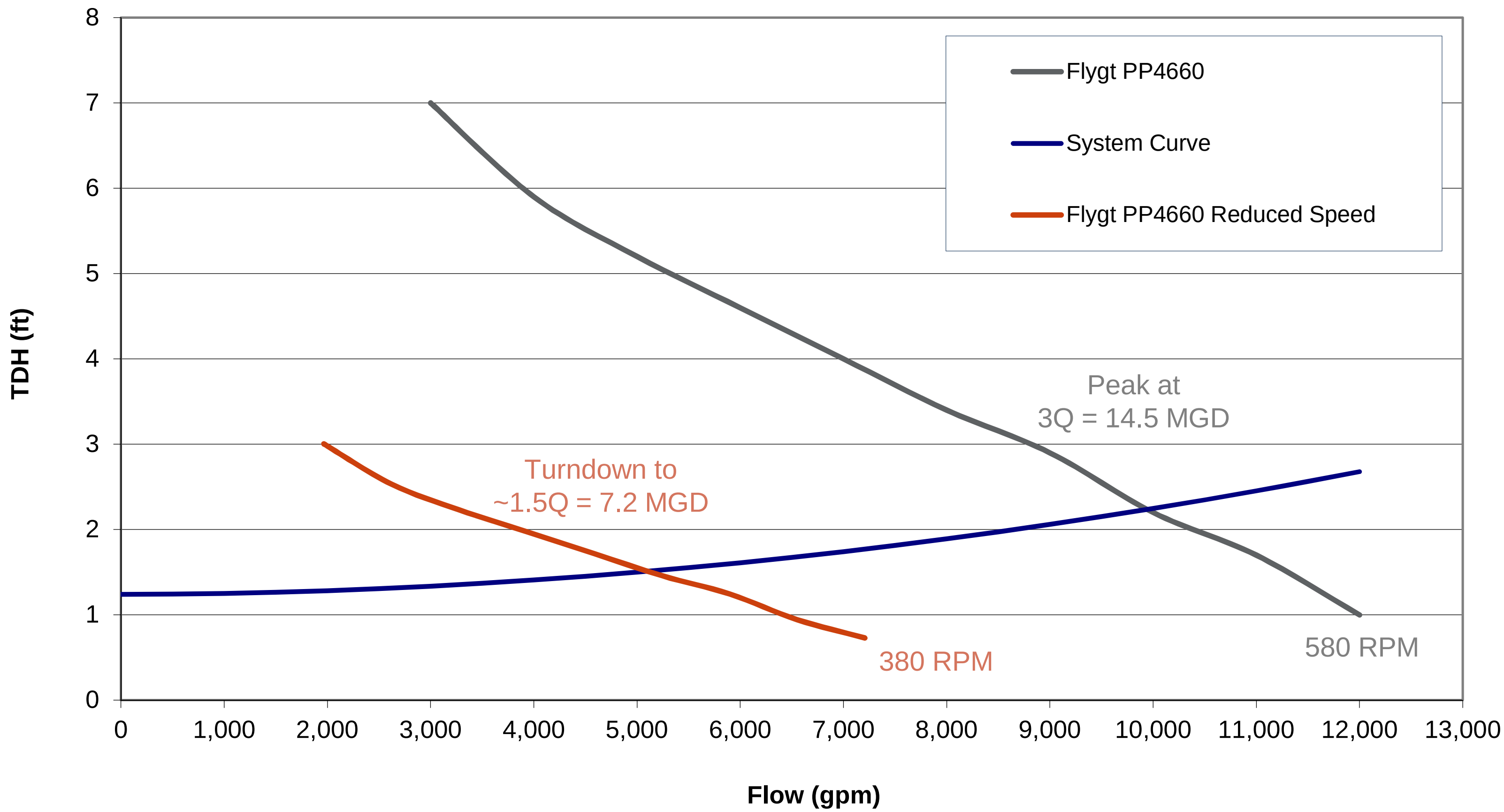
NRCY Pump Selection

- Flygt Ultra-Low-Head Pump Series
- Model PP 4660 24”
- Design Flow = 14.5 MGD
- Can be mounted on wall or discharge pipe
- 11 HP

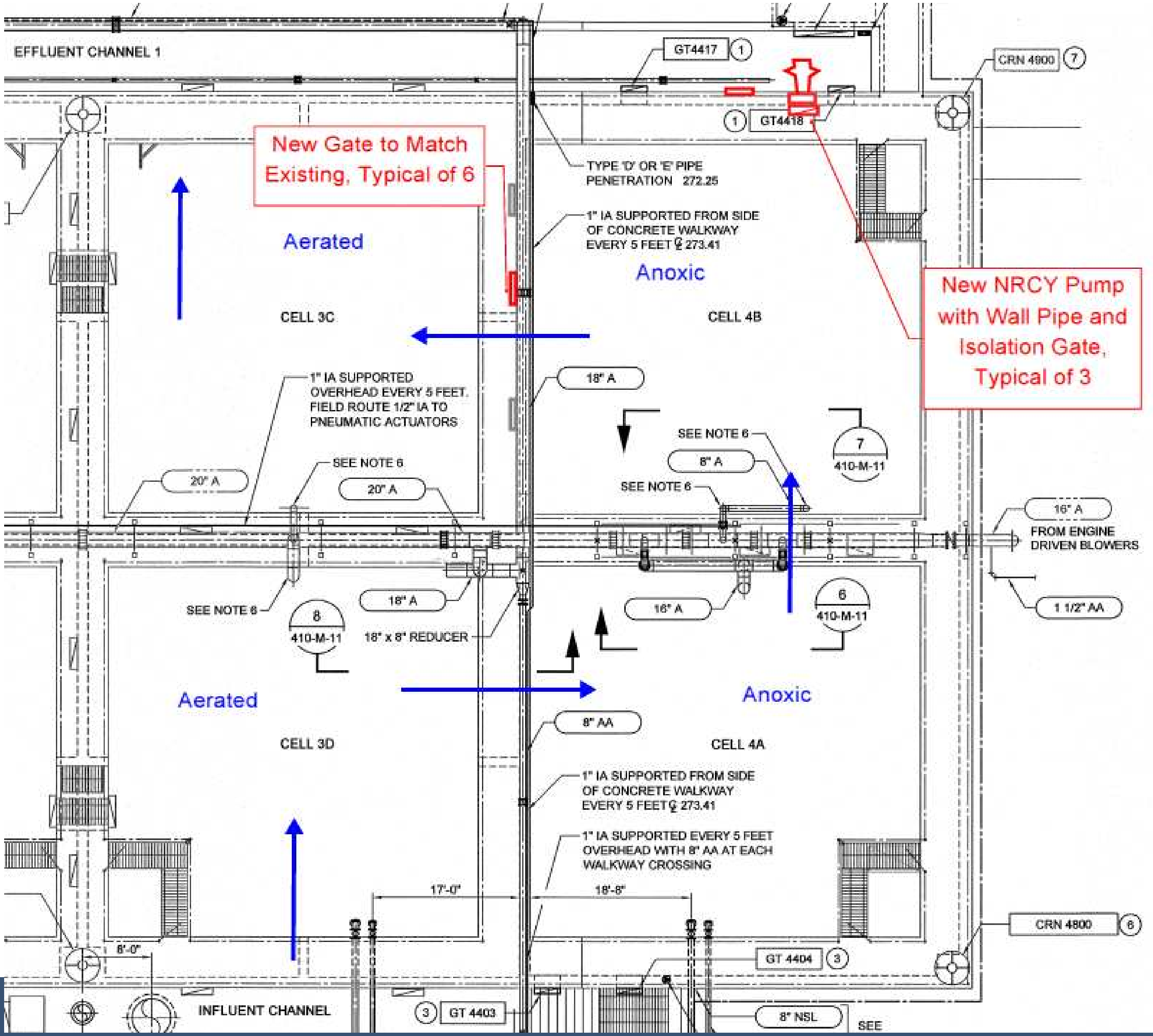




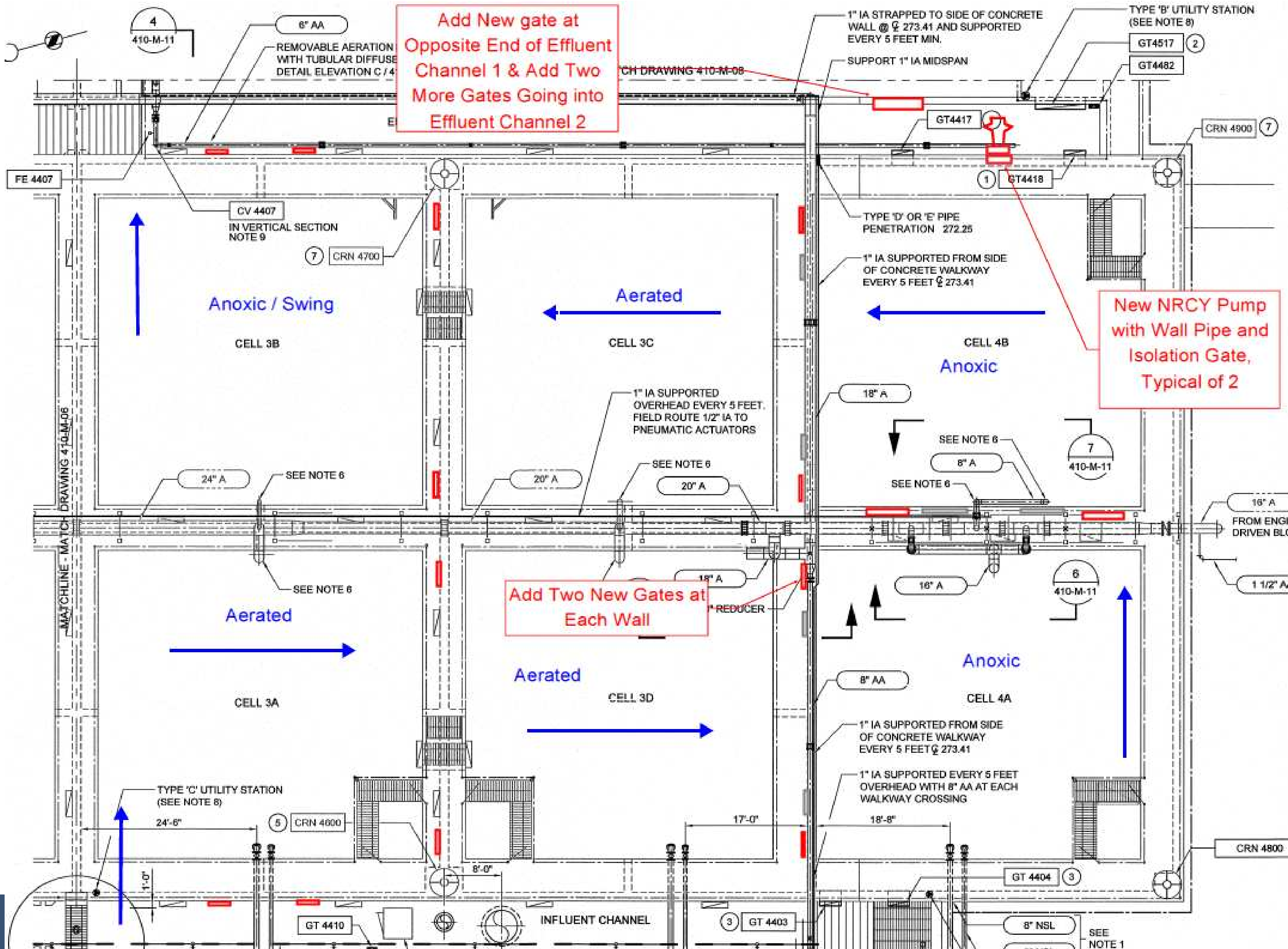
NRCY Pump Curve



Proposed 3 Train / 4 Cell Configuration



Proposed 2 Train / 6 Cell Configuration



Opinion of Probable Cost

Construction Subtotal – 3 Train / 4 Cell	$300,000
Electrical & I/C (15%)	$45,000
General Conditions / Mobilization (5%)	$17,300
Contractor OH&P (15%)	$54,300
Bonds and Insurance (2%)	$8,300
Contingencies (20%)	$85,000
	$510,000

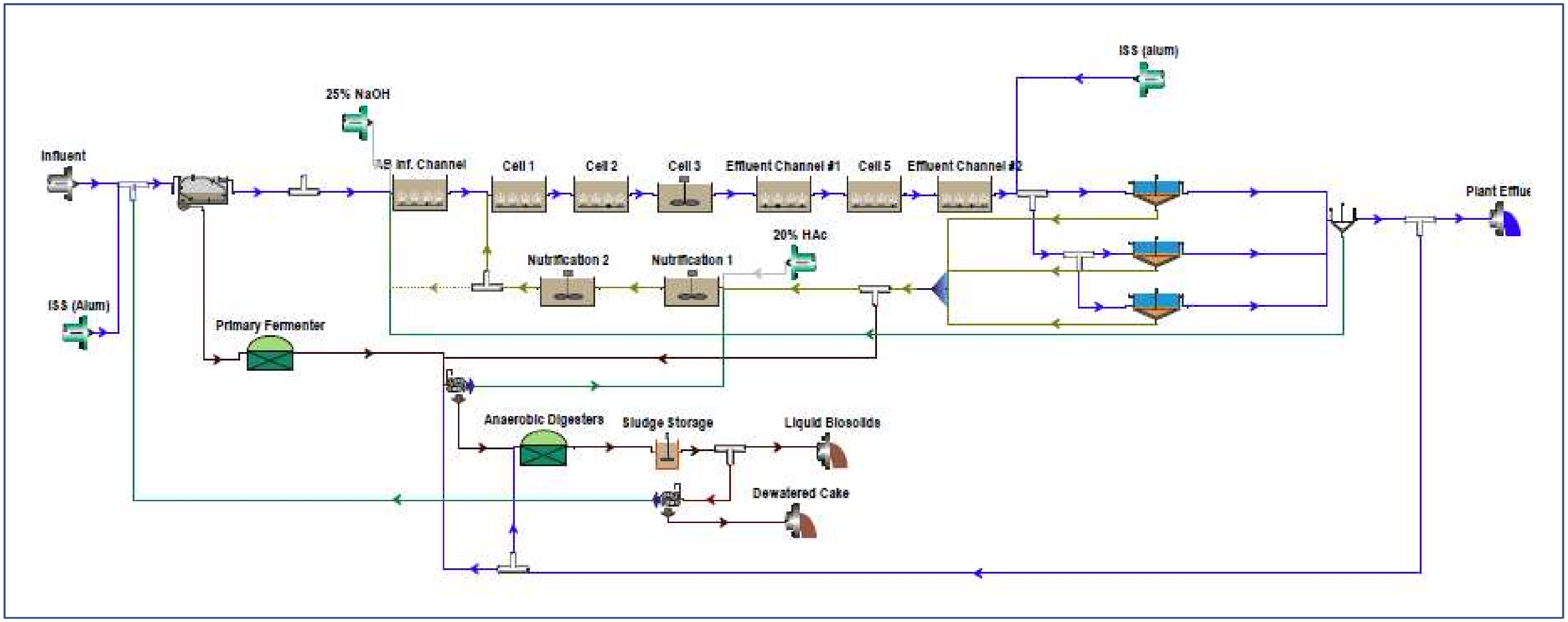
Cost Adder ~ $425,000 to Switch to 6 Cell Configuration

Cons	$550,000
Elect	$82,500
General Conditions / Mobilization (5%)	$31,600
Contractor OH&P (15%)	$99,600
Bonds and Insurance (2%)	$15,300
Contingencies (20%)	$155,800
Total	**$935,000**

Evaluation Summary

- Capital cost of $510,000 to $935,000
- Implementing NRCY w/o increasing RAS results in ~ $5,000/year savings at current flows
  - Assumes continued intermittent aeration in Cell 5
- Maximizing RAS provides greater reduction in nitrate
  - Impacts on clarifier performance
  - Impacts on BPR
- Mitigate BPR impacts by RAS Fermentation

Hazen



Thank You

January 22, 2019

Compilation TM Appendix C: Mason Farm WWTP RAS Pumping Rehabilitation Study - Final

August 17, 2018

To: OWASA

From: Elisa Arevalo, Hazen and Sawyer

Lamya King, Hazen and Sawyer

Patricia Drummey Stiegel, Hazen and Sawyer

Ron Taylor, Hazen and Sawyer

Mason Farm WWTP RAS Pumping Rehabilitation Study

FINAL

Executive Summary

The Orange Water and Sewer Authority (OWASA) operates the Mason Farm Wastewater Treatment Plant, which is equipped with five (5) secondary clarifiers and four recycle activated sludge (RAS) pump stations. Secondary Clarifiers 1, 4, and 5 have dedicated pump stations, while Secondary Clarifiers 2 and 3 have one shared RAS pump station. All RAS pumps were replaced as part of the plant expansion to 14.5 mgd, which took place in 2008. Since then, the pumps have been repaired numerous times over the years, and are reaching the end of their useful life. Furthermore, recent modifications in plant operations have emphasized the importance of RAS pump reliability and increasing RAS pump capacity. As such, starting in 2017, plant staff began to incrementally replace existing RAS pumps with larger pumps to increase the RAS pumping capacity. Specifically, new pumps have been purchased and installed for Clarifier 5, and the pumps that were previously installed for Clarifier 5 were transferred to serve Clarifier 4.

The purpose of this technical memorandum (TM) is to summarize various alternatives that will improve the overall performance, increase reliability, and reduce operational and maintenance issues for the Mason Farm WWTP RAS pumping systems. A total of five alternatives were evaluated based on mechanical, hydraulic, and performance considerations in order to determine the most cost-effective alternative for OWASA to implement moving forward. The five alternatives that were evaluated are as follows: (1) replace pumps with new pumps of similar design flow and head as existing, (2) replace pumps with larger design flow and head than existing, (3) purchase one new mobile standby pump, (4) construct one new consolidated RAS pump station, and (5) permanently install standby pumps.

Hazen recommends that plant staff continue to replace pumps with pumps of larger design flows than existing, as has been done for Clarifiers 4 and 5, in conjunction with purchasing a portable diesel backup pump to be used as a standby pump for all clarifiers. Modifications to each RAS pump station are recommended to facilitate the use of the portable standby pump. It is also recommended that the current condition of the Clarifier 1 RAS suction piping be investigated to assess the extent of material build-up along the pipe (as indicated by flow and pressure measurements taken in the field). Discussions with plant staff indicate that pipe inspections are underway and will be completed prior to ordering the new RAS pump for Clarifier 1. Furthermore, it is recommended that OWASA implement general RAS pumping system improvements to alleviate existing deficiencies. These improvements include: new RAS piping from Clarifiers 2&3 to the NSL chimney, new RAS pipe isolation valves, new ultrasonic level sensors in the mixed liquor distribution flumes, new mag meters on RAS suction pipes, new plug valves downstream of the Clarifier 5 RAS pumps, and freeze protection for all of the RAS pumps. The total estimated capital cost of the recommended improvements is $1,260,000.

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1. Background & Existing Facilities

1.1 Project Background

The Mason Farm wastewater treatment plant (WWTP) is an advanced treatment facility that is permitted to discharge up to 14.5 million gallons per day (mgd) on a maximum month basis to Morgan Creek in the Jordan Lake watershed. The WWTP implements the activated sludge process for the oxidation of organic matter and ammonia, and is equipped with five secondary clarifiers.

In 2010, Hazen was retained by OWASA to perform a Hydraulic and Treatment Capacity Study (2010 Capacity Study) to determine the treatment and hydraulic capacity of existing facilities at the Mason Farm WWTP. The purpose of the 2010 Capacity Study was to identify process deficiencies and how they impact the plant's ability to comply with nutrient limits under the Jordan Lake Rules. Historically, primary effluent had been conveyed to the Aeration Basin Influent Channel to be distributed to the first cell of each of aeration basin in service. One of the several recommendations made in the 2010 Capacity Study was to operate in step feed mode during which primary effluent is diverted to the first two cells of the aeration basins. Operating in step feed provides carbon for denitrification to occur in the second anoxic cell of the aeration basins and, consequently, reduces the total nitrogen concentrations in the filter influent. Operating in step feed is also expected to reduce sodium hydroxide consumption, aeration energy, and acetic acid addition for biological phosphorus removal.

As a result of the recommendations made in the 2010 Capacity Study, plant staff at the WWTP have implemented new operating strategies within the past several years to improve plant performance while minimizing operating costs. Specifically, the WWTP transitioned to step feed which lead to an increase in the return activated sludge (RAS) recycle rates. During this transition, the RAS pumping rates increased from approximately 50 to 100 percent of the plant influent flow in order to increase the rate of nitrogen returning back to the anoxic zones and enhance denitrification. Ultimately, the RAS pumps began serving as internal nitrogen recycle (NRCY) pumps, in addition to controlling the sludge blanket in the secondary clarifiers.

In order to determine the feasibility of adding NRCY pumps to the Mason Farm WWTP, in September 2017, Hazen conducted a Process Model and Internal Recycle Evaluation. The results of the study indicated that adding NRCY pumps would be cost-prohibitive, and that the WWTP should continue to operate in step feed while maximizing RAS pumping flowrates for denitrification. As such, the RAS pumps currently operate at their maximum capacity to compensate for the WWTP's lack of internal nitrogen recycle (NRCY) pumps.

This recent increase in RAS recycle flow rates has highlighted the importance of RAS pumping capacity, as well as equipment redundancy. The existing RAS pumps were originally designed to pump half of the clarifier capacity associated with each set of pumps. Therefore, if one RAS pump fails, the associated final clarifier must be taken out of service until the pump has been repaired. The existing RAS pumping infrastructure does not provide for a back-up pump to be utilized while an existing pump is out of service.

An additional factor that has increased the burden on the existing RAS pumps is the number of secondary clarifiers typically in service. Under normal operating conditions, Clarifiers 1 and 5 are in service while the remaining clarifiers are out of service. This operational strategy is due to various age, performance, mechanical failures, and maintenance challenges associated with Secondary Clarifiers 2, 3, and 4. When only Clarifiers 1 and 5 are operating in lieu of all five clarifiers, the influent flow rate to the clarifiers in service increases by approximately 80%. Plant staff has indicated that during Hurricane Matthew in the fall of 2016, Clarifiers 1, 4, and 5 were in operation while Clarifiers 2 and 3 remained out of service.

In addition to the issues related to the existing RAS pump capacities and lack of redundancy, plant staff have observed that the RAS pumps have come obsolete. Pumps parts needed to make repairs and replacements can no longer be purchased off-the-shelf.

Due to the limitations of the existing RAS pumps described herein, OWASA retained Hazen and Sawyer to evaluate various alternatives that could alleviate deficiencies and ease the operation of the existing RAS pumping system.

1.2 Existing Facilities

The Mason Farm WWTP currently has four RAS pump stations: one for Clarifiers 2 and 3, and dedicated pump stations for Clarifiers 1, 4, and 5. Pumping for each of Clarifiers 1, 4, and 5 is with two dry pit submersible pumps, each sized for half of the design RAS flow.

Starting in 2017, plant staff began to incrementally replace existing RAS pumps with larger pumps to increase the RAS pumping capacity. Specifically, new pumps have been purchased and installed for Clarifier 5, and the pumps that were previously installed for Clarifier 5 were transferred to serve Clarifier 4. Plant staff can now run one pump, in lieu of two, for each of Clarifiers 4 and 5 to meet target flow rates. Discussions with plant staff indicate that the replacement pumps for Clarifiers 4 and 5 are performing well and are more suited to meet RAS pumping demands than the old pumps. OWASA plans to purchase new pumps for Clarifier 1 to replace the existing pumps within the next few months. A summary of the existing RAS pumps, which incorporates the latest RAS pump improvements made internally by OWASA, is presented in **Table 1-1**.

Table 1-1: Existing RAS Pumping Conditions

	Clarifier Diameter	Total Pump Rated Capacity	Rated Capacity as % of Flow [1]	Rated Capacity as % of Flow [2]	Pump Rated Flow	TDH	Pump HP
Clarifier 1	120 ft	2,776 gpm 4 mgd	125%	69%	1,388 gpm	19.5 ft	16
Clarifiers 2 & 3	85 ft	4,200 gpm 4 mgd	125%	--	1,388 gpm	24.0 ft	15
Clarifier 4 [3]	110 ft	4,164 gpm 6 mgd	187%	--	2,082 gpm	21.5 ft	23
Clarifier 5 [4]	142.3 ft	4,200 gpm 6 mgd	126%	70%	2,100 gpm	21.9 ft	23

[1] With all clarifiers in services
[2] With Clarifiers 1 & 5 in service
[3] Based on ABS O&M manual for the previous Clarifier 5 pumps that have since been installed for Clarifier 4.
[4] Based on Sulzer/ABS pump shop drawing submittal received on April 28th, 2017.

All of the RAS pumps are on VFDs which are located several hundred feet away from the pumps. Flow measurement is provided on the suction side for Clarifiers 2 and 3 and on the discharge side of the pump stations for Clarifiers 1, 4, and 5. While RAS pumping limitations are primarily due to the pumps being under-sized, pumping RAS from Clarifiers 2 and 3 is specifically limited as a result of the current suction-side flow control scheme.

Return sludge from the secondary clarifiers is pumped to the nutrified sludge (NSL) cells, where it combines with gravity belt thickener overflow and acetic acid. Effluent from the NSL cells is pumped to the aeration basins. Plant staff reported a recent peak flow event of 39 mgd, during which the secondary clarifiers and return pumps were able to keep up with the peak flow only because the operators manually decreased mixed liquor flow from the aeration basins to Clarifier 5. At the time, Clarifier 5 only had one of two RAS pumps operational.

In June 2017, Hazed developed a secondary clarifier conditions assessment in which several secondary clarifier improvement alternatives were evaluated to improve the overall performance, increase longevity, and reduce operational and maintenance issues for Secondary Clarifiers 2, 3, and 4. As part of this evaluation, state point analyses (SPA) were conducted to determine RAS pumping rates that would be required to improve secondary clarifier performance during peak flows. Sludge volume index (SVI) values of 76, 86, and 96 were used to correspond to the average, 80th percentile, and 95th percentile, respectively. The results of this evaluation are used to determine the design criteria for the new RAS pumps, as described in **Section 2.2**. More detailed results of this evaluation can be found in the technical memorandum titled *Mason Farm WWTP Secondary Clarifier Rehabilitation Study*.

1.3 System Curve Development and Callibration

In order to assess the WWTP's RAS pumping system, system curves were calculated for each clarifier. Various scenarios were modeled to represent different combinations of clarifiers in service. On December 20th, 2017, Hazen visited the site to measure flow and pressure to calibrate the calculated system curves. Measurements were taken with one and two pumps running for Clarifiers 1, 4, and 5, which were in service at the time. However, it is suspected that some of the gauge readings were inaccurate due to significantly low pressure readings.

The field measurements recorded during the site visit were compared to the flow and pressures points that had been calculated for each clarifier. Based on this comparison, the calculated system curves for Clarifiers 4 and 5 closely matched what was measured in the field. Therefore, the system curves for Clarifiers 4 and 5 were not modified. The system curve for Clarifier 1, however, was calibrated with a lower pipe C-value to align with the operating point measured in the field. This discrepancy could be due to plugging in the old RAS suction pipe installed beneath Clarifier 1. OWASA plans to inspect the Clarifier 1 suction pipe to determine if there is buildup of material that could be clogging the pipe. The calculated system curves, the flow and pressure points that were measured in the field, and the corrected system curves are included in **Appendix A**.

2. RAS Pumping Rehabilitation Alternatives

Four alternatives were evaluated for the rehabilitation of the RAS pumping systems at the Mason Farm WWTP, each alternative is described in the sections below.

2.1 Alternative 1: Replace Pumps In-Kind

The first alternative for improving the RAS pumping systems is to replace the RAS pumps with in-kind pumps while making minimal modifications to the existing structures, valves, and piping. Suction and discharge diameters will match that of the existing pumps and the horsepower of each pump would remain the same. **Table 2-1** summarizes the proposed pump characteristics for Alternative 1. This alternative assumes that the new pumps have the same design points as the existing pumps as presented in shop drawing submittals and pump curves. Therefore, the installed RAS capacity would remain the same.

In addition to minimal piping modifications required, other advantages of Alternative 1 include straightforward maintenance of plant operations and the potential of using same pump replacement parts if ABS/Sulzer pumps are purchased.

Table 2-1: Alternative 1 Proposed Pump Characteristics

	Proposed Pump
Clarifier 1	8" dry pit submersible
	16 HP
	8" x 8" suction/discharge
Clarifier 2/3	8" submersible
	15 HP
	8" x 8" suction/discharge
Clarifier 4	8" dry pit submersible
	23 HP
	8" x 8" suction/discharge
Clarifier 5	8" dry pit submersible
	23 HP
	12" x 12" suction/discharge

To evaluate the economic feasibility for each RAS pumping rehabilitation alternative, opinions of probable capital cost were developed. The assumptions associated with each cost opinion are applicable to each alternative presented herein, and are as follows:

- Use 30% of equipment cost for installation
- Use 15% of subtotal to account for electrical and instrumentation improvements
- Use 5% of subtotal for general conditions and mobilization
- Use 15% of subtotal for contractor overhead and profit
- Use 2% of subtotal for bonds and insurance
- Use 20% of subtotal for contingencies
- All costs are presented on a loaded basis to include the markups listed above
- All costs are presented in 2018 dollars

The cost for Alternative 1 is presented in **Table 2-2**.

Table 2-2: Cost Opinion for Alternative 1

	Alternative 1
Demolition	$10,000
Sitework	$0
Mechanical	$360,000
Structural	$0
Total (2018)	**$630,000**

The estimated cost for Alternative 1 is $630,000. However, it is important to note that OWASA has already spent approximately $120,000 to replace the RAS pumps for Clarifiers 4 and 5 and that the cost opinion for Alternative 1 includes new pumps for all clarifiers.

2.2 Alternative 2: Replace with Larger Pumps

Alternative 2 is the replacement of existing RAS pumps with larger pumps such that significant modifications to existing structures, valves, and piping will be required. As such, the complete scope of rehabilitation includes: new pumps, significant modifications to RAS piping to keep velocities lower than 10 fps, new power conductors for all new RAS pumps, new disconnect switches to replace existing, new VFDs within existing MCCs, replacement of the existing trip unit MCC-SC2 main, and the replacement of existing cables utilizing the existing raceway system. Alternatively to replacing existing cables, new ductbank can be installed; however, this is not recommended due to the extent of work required and associated cost.

For this alternative, the design points were determined based on recently developed and calibrated system curves. The design criteria for the proposed pumps are listed in **Table 2-3**. The maximum flowrate of 21 MGD was determined based on the state point analyses (SPAs) documented in the Secondary Clarifier Rehabilitation Memo. **Appendix B** of this TM includes a table taken from the Secondary Clarifier Rehabilitation memo which summarizes the performance of the existing clarifiers. The worst case scenario of having Clarifier 5 out of service and a peak influent flow of 43.5 MGD was used to determine the maximum capacity that the new pumps should be able to pump. The minimum flow was based on the 7-day minimum plant influent flow measurement taken from November 2008 until May 2017.

Table 2-3: Design Criteria for Alternative 2

	Design Criteria
Max Flow	21 MGD & Clarifier 5 OOS [1]
Min Flow	3.2 MGD & all clarifiers in service [2]

1 Based on the SPA from the Secondary Clarifier Rehabilitation TM (**Appendix B** of this TM).
2 Based on the 7-day minimum flow from November 2008 until May 2017.

New pumps were selected based on the flowrates listed in **Table 2-3** and on the calibrated system curves. This alternative would increase the RAS capacity from 20 MGD total to 21 MGD firm capacity (i.e. largest clarifier and associated RAS pumps out of service). A comparison of the existing and proposed pumps is included in **Table 2-4.**

Table 2-4: Proposed Pump Characteristics for Alternative 2

	Existing Design Point	Proposed Peak Design Point	Existing HP	Proposed HP
Clarifier 1	1,388 gpm 19.5 ft TDH	2,406 gpm 31.7 ft TDH	16 HP (x 2)	25 HP (x 2)
Clarifier 2/3	1,388 gpm 24 ft TDH	2,435 gpm 24.8 ft TDH	15 HP (x 2)	20 HP (x 2)
Clarifier 4	2,082 gpm 21.5 ft TDH	2,430 gpm 26.3 ft TDH	23 HP (x 2)	25 HP (x 2)
Clarifier 5	2,100 gpm 21.9 ft TDH	2,430 gpm 20.1 ft TDH	23 HP (x 2)	25 HP (x 2)

The cost opinion for Alternative 2 is presented in **Table 2-5**.

Table 2-5: Cost Opinion for Alternative 2

	Alternative 2
Demolition	$20,000
Sitework	$0
Mechanical	$680,000
Structural	$0
Electrical	$180,000
Total (2018) [1]	**$1,310,000**

[1] The total cost incorporates the assumptions listed in **Section 2.1**.

2.3 Alternative 3: Purchase New Mobile / Standby Pump

Alternative 3 evaluates the option of purchasing a new mobile standby pump in combination with Alternative 1 or Alternative 2, allowing the plant to have a firm RAS capacity of 20 MGD. Ideally, the mobile standby pump would be used for other applications within the Mason Farm WWTP. For this alternative, minor modifications would be required for bypass piping, fittings, and blind flanges. Additionally, a dedicated parallel pipe to route RAS flow from Clarifiers 2 and 3 to the NSLs is included. **Figures 2-1**, **2-2**, **2-3**, and **2-4** illustrate where the standby pump could potentially be located for Clarifiers 1, 2 and 3, 4, and 5, respectively.

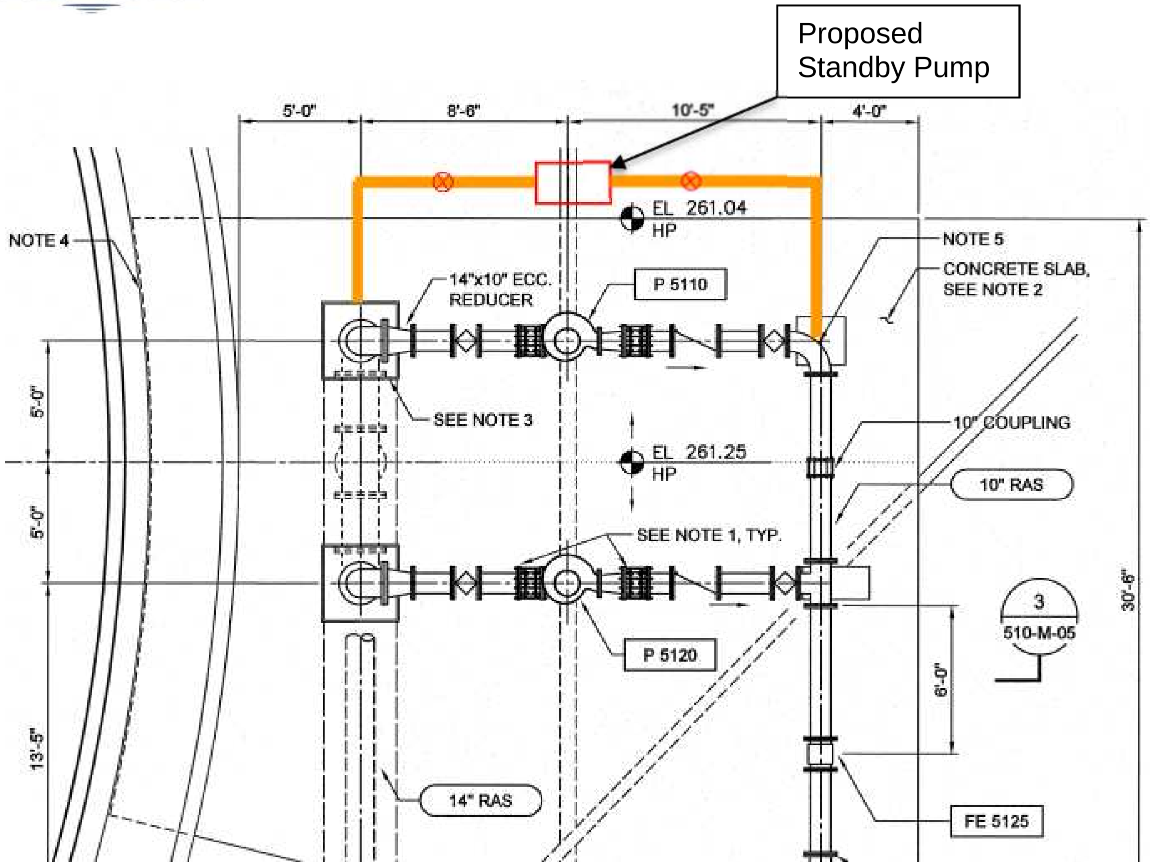


Figure 2-1: Proposed Standby RAS Pump and Piping for Clarifier 1

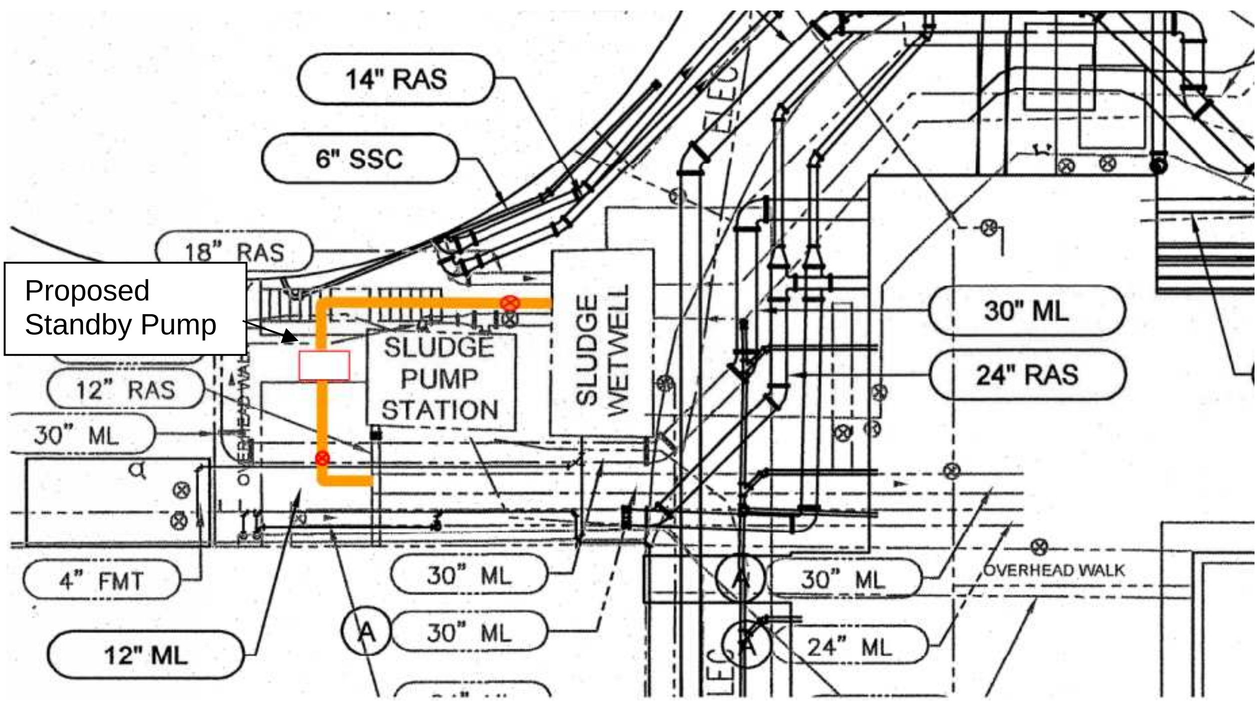


Figure 2-2: Proposed Standby RAS Pump and Piping for Clarifiers 2 and 3

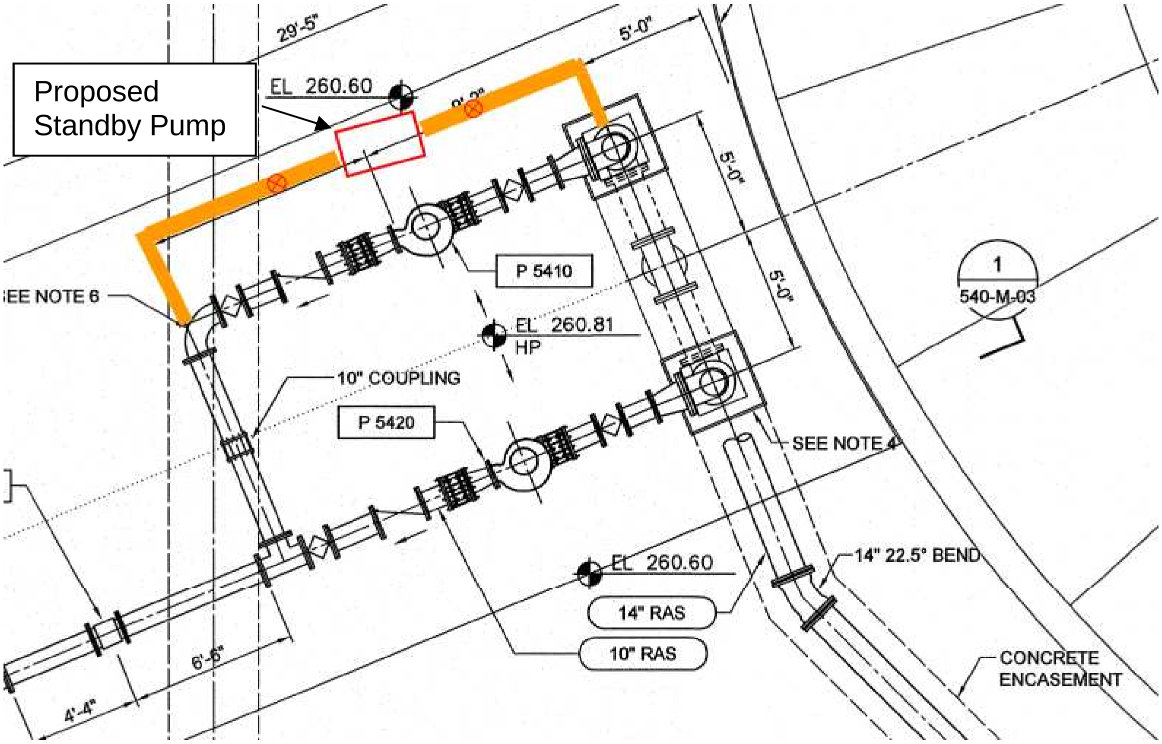


Figure 2-3: Proposed Standby RAS Pump and Piping for Clarifier 4

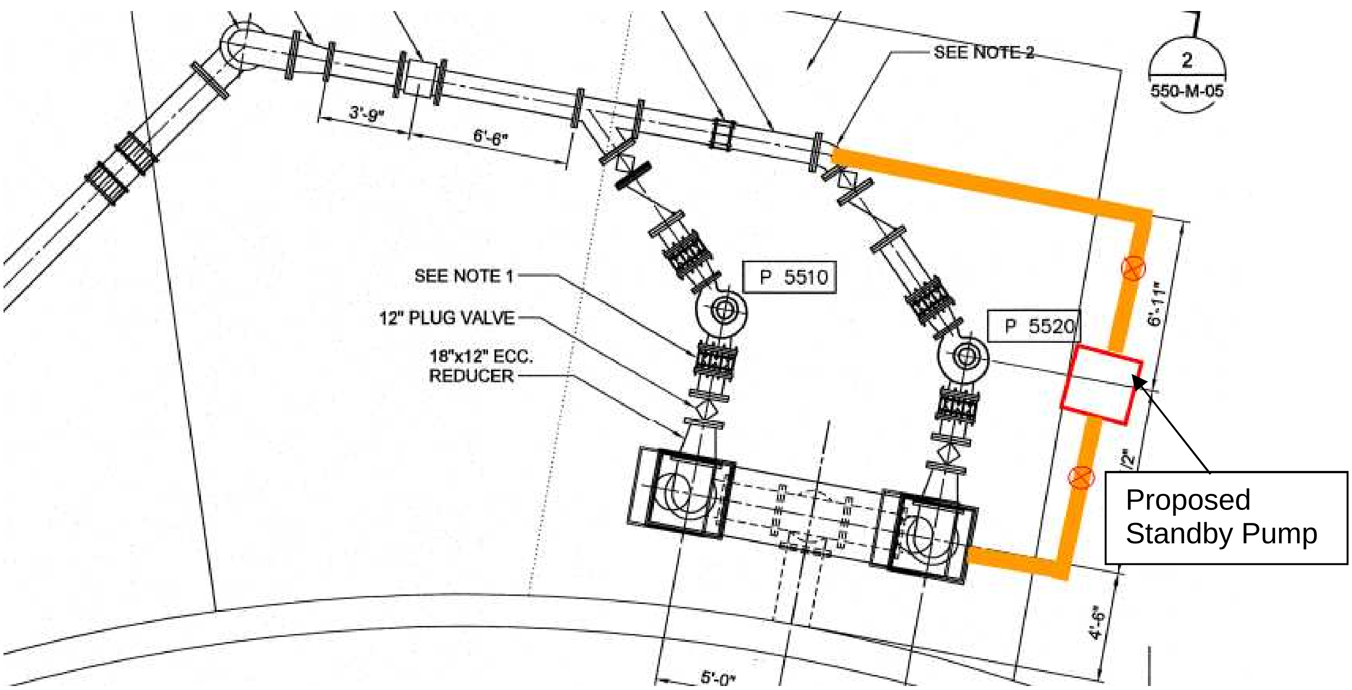


Figure 2-4: Proposed Standby RAS Pump and Piping for Clarifier 5

There are two standby pump options: a diesel engine-driven or an electrically-driven portable pump. **Appendix D** contains proposed pump cut sheets and curves for both types of pumps. The electric pump could be operated using one of the existing generators located on site, eliminating the requirement for additional electrical work. Some advantages of electric motors are that they require less maintenance than diesel motors and that there are more electrically-driven pump options available in the market. Due to Tier 4 emission standards for non-road diesel engines, there is currently a limited number of options available in the market for diesel engines. Furthermore, there is a significant amount of maintenance associated with a diesel pump that is not constantly in use. While the available diesel pumps do not meet the head conditions, valves could be throttled to increase the head as needed. One advantage of a diesel engine-driven pump is that it would be easier to transport around the WWTP. In order to compare the operating costs associated with electric and diesel engine motors, a net present worth analysis was developed. The capital, operating, and net present worth costs are presented in **Table 2-6**. It is important to note that the net present worth costs presented herein do not include the cost associated with pump maintenance.

Table 2-6: Net Present Worth Cost Comparison for Alternative 3

	Diesel	Electric
Capital Cost	$290,000	$170,000
Net Present O&M – Energy [1]	$64,566	$12,308
20-Year Net Present Worth Cost	**$354,566**	**$182,308**

[1] Assume 4 weeks per year of continuous operation, electricity cost of 7c/kW-hr, and diesel cost of $3.06/gallon.

The cost opinion for Alternative 3 is presented in **Table 2-7**.

Table 2-7: Cost Opinion for Alternative 3

	Diesel [1]	Electric [2]
Mechanical	$190,000	$110,000
Total (2018) [3]	**$290,000**	**$170,000**

[1] Cost does not account for annual expenses associated with diesel.

[2] Cost assumes that an existing generator is used.

[3] The total cost incorporates the assumptions listed in **Section 2.1**.

2.4 Alternative 4: New Consolidated Pump Station

Alternative 4 is the replacement of all of the existing RAS pumps with a consolidated RAS pump station to serve all clarifiers. This alternative would require new suction and discharge piping, as well as significant electrical improvements including new motor control centers with VFDs and new local control panels. The Authority also has the option of constructing a new prefabricated electrical building next to the new RAS Pump Station.

Similar to Alternative 2, the design points were determined based on recently developed system curves and calibration. The design criteria are listed in **Table 2-3**. The maximum flow of 21 MGD was determined based on the state point analyses as documented in the Secondary Clarifier Rehabilitation Memo; while the minimum flow was based on the 7-day minimum flow from November 2008 until May 2017.

Table 2-8 lists the proposed design points, as well as horsepower requirements, for Alternative 4. To accommodate the increase in installed pump horsepower, significant electrical modifications will be required, including new motor control centers with VFDs and new local control panels. It is also recommended that a new prefabricated electrical building with a PLC be constructed to serve the new RAS Pump Station.

Table 2-8: Design Points for Alternative 4 Proposed Pumps

	Existing Design Point	Proposed Design Point	Proposed Min Design Point	Existing HP	Proposed HP / BHP
Clarifier 1	1,388 gpm 19.5 ft TDH	2,916 gpm 58.3 ft TDH	2,222 gpm 11.5 ft TDH	16 HP (X 2)	75 HP / 63 BHP (X 6)
Clarifier 2/3	1,388 gpm 24 ft TDH			15 HP (X 2)	
Clarifier 4	1,388 gpm 17.5 ft TDH			23 HP (X 2)	
Clarifier 5	1,388 gpm 21.9 ft TDH			23 HP (X 2)	

A Hydraulic Institute trench-style pump station was initially considered. However, since one suction pipe would be required to convey RAS from each clarifier, it was determined that a trench-style pump station would be difficult to implement with more than one suction pipe entering the wet well. Furthermore, it is understood that plant staff has a preference for submersible pumps. In general, trench-style pump stations with submersible pumps have larger footprints than those with VTSH pumps, making the trench-style pump station an ideal application for VTSH pumps. Rather, a rectangular wet well pump station (Appendix E in Hydraulic Institute Standards) with submersible pumps would be better suited for this particular application. The size of the pump station would be considerably smaller than a trench-style and multiple suction pipes could be conveyed into the pump station wet well.

Figures 2-5 and **2-6** illustrate a rectangular wet well pump station which would be proposed for Alternative 4. This pump station is not designed for storage and is not self-cleaning. However, the design prevents the buildup of solids and promotes small vortices for scum entrainment. Additionally, a partition wall ensures that the flow does not surge into the wet well.

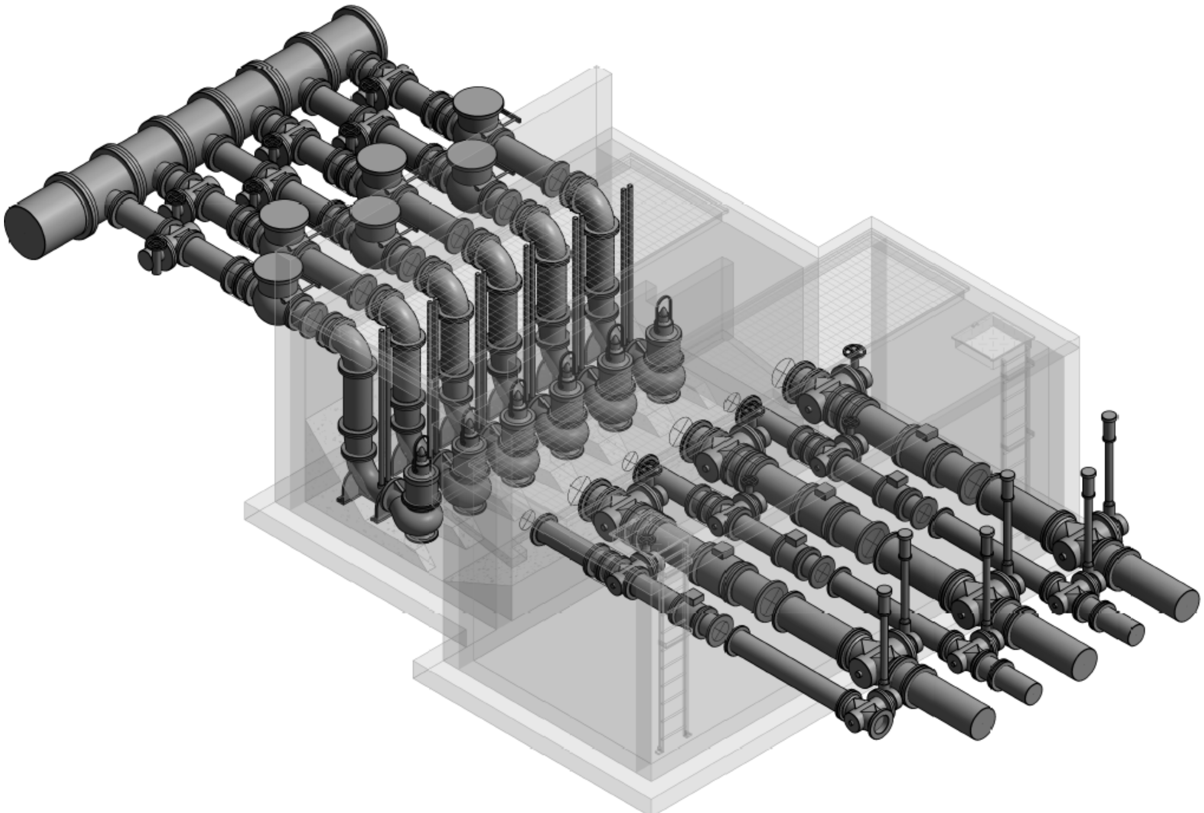


Figure 2-5: Proposed Pump Station for Alternative 4

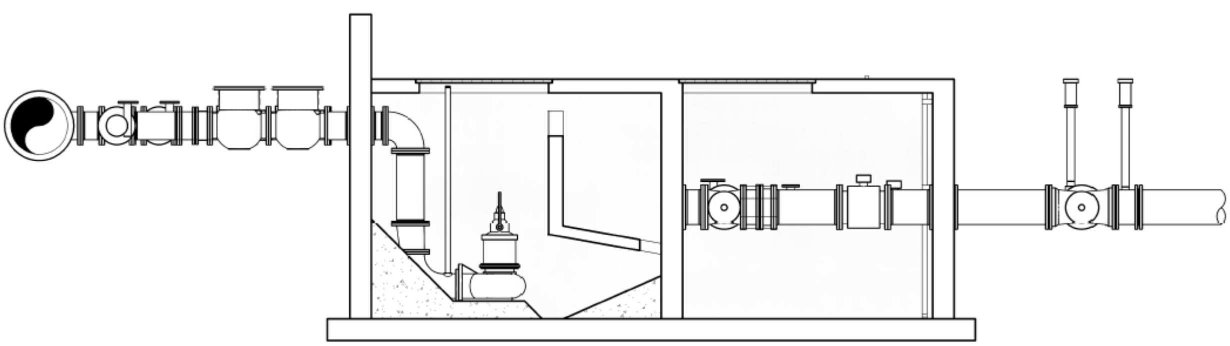


Figure 2-6: Proposed Pump Station for Alternative 4 – Section View

The pump station can be located mostly above grade, or could be built deeper with controls to prevent accidental overflow at the pump station. Other items that would need to be considered for future evaluation are access to the meter vault, the possibility of reducing the number of pumps to 4 duty / 1 standby, the piping layout, pump access, and the pump station location. **Figure 2-7**, presents two potential pump station locations.

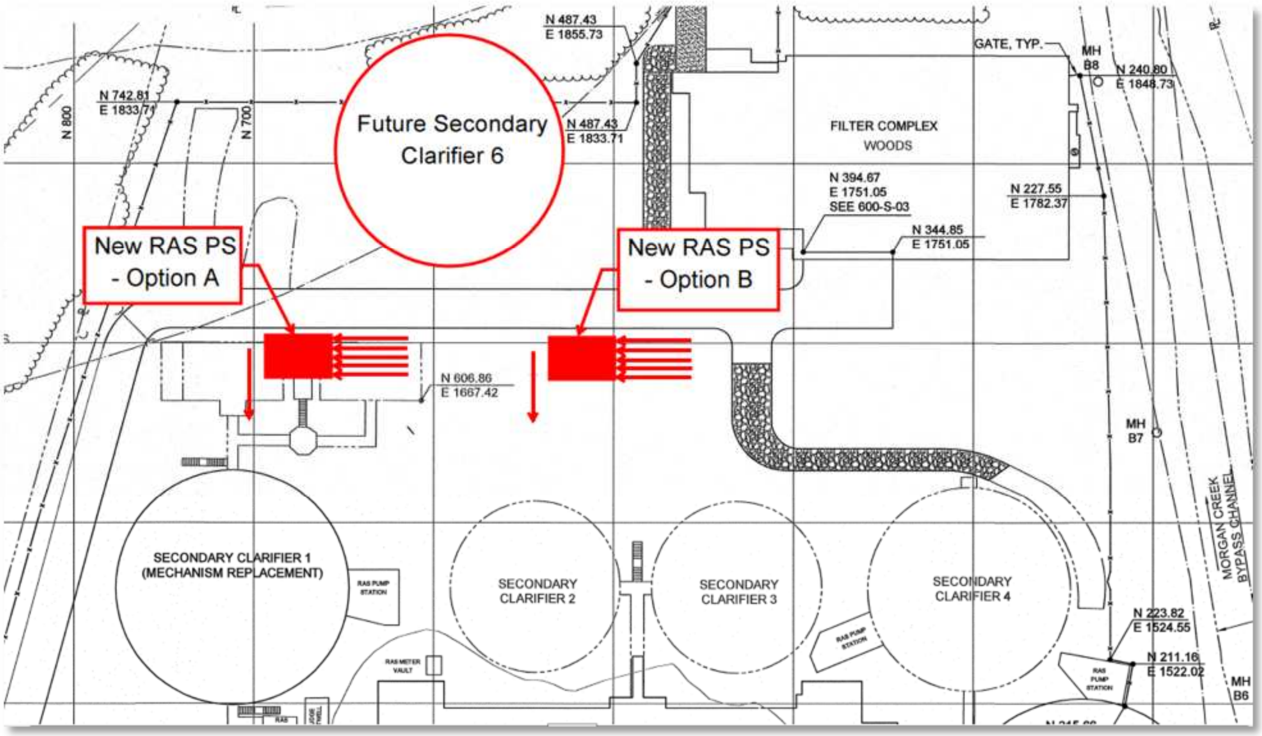


Figure 2-7: New RAS Pump Station Locations

The cost associated with this alternative assumes that the pump station is located in Location A, as presented in **Figure 2-7** and includes demolition of the Chlorine Contact Basins. The cost opinion for Alternative 4 is presented in **Table 2-9** below.

Table 2-9: Cost Opinion for Alternative 4

	Alternative 4
Demolition	$100,000
Sitework	$20,000
Mechanical	$1,260,000
Structural	$40,000
Electrical	$620,000
Total (2018) [1]	**$3,020,000**

[1] The total cost incorporates the assumptions listed in **Section 2.1**.

2.4.1 Deferred Cost of Clarifier 6 RAS Pumps

One primary advantage of Alternative 4 is that it provides cost savings related to the construction of RAS pumping and piping systems for the future Clarifier 6, which is not anticipated to be constructed until approximately 2030. A new consolidated pump station eliminates the need for future RAS pumping to serve the new clarifier. As part of this evaluation, a cost estimate was developed for the RAS pumping associated with Clarifier 6 to determine the deferred cost associated with constructing one consolidated RAS pump station. This cost estimate, as shown on **Table 2-10**, includes new discharge piping to the NSLs, assuming the same set up as existing pumps, and assumes that the future clarifier is constructed in 2030.

Table 2-10: Cost Opinion for Alternative 4

	Cost Opinion
Demolition	$0
Sitework	$10,000
Mechanical	$350,000
Structural	$20,000
Total (2018) [1]	**$650,000**
Net Present Value	**$517,000**

[1] Total includes 15% for electrical & I/C, 5% for general conditions / mobilization, 15% OH&P, 2% bonds and insurance, and 20% contingencies.

2.5 Alternative 5: Permanently Install Redundant Pumps

Alternative 5 is the permanent installation of backup pumps for each set of clarifiers. A third pump would be installed for each of Clarifiers 1, 4, and 5 and one pump would be installed for Clarifiers 2 and 3. For this alternative, it was assumed that pumps with the same design points and characteristics as the existing pumps would be installed. **Table 2-11** summarizes the design points and horsepower associated with the proposed pumps.

Table 2-11: Proposed Pump Characteristics for Alternative 5

	Existing Design Point	Existing HP	Additional HP
Clarifier 1	1,388 gpm 19.5 ft TDH	16 HP (x 2)	16 HP (x 1)
Clarifier 2/3	1,388 gpm 24 ft TDH	15 HP (x 2)	15 HP (x 1)
Clarifier 4	1,388 gpm 17.5 ft TDH	23 HP (x 2)	23 HP (x 1)
Clarifier 5	1,388 gpm 21.9 ft TDH	23 HP (x 2)	23 HP (x 1)

Permanent new suction and discharge piping would also be included for each set of RAS pumps so that the new backup pump could be used if either Pump 1 or Pump 2 failed or were being maintained. **Figure 2-8** illustrates the proposed permanent suction and discharge piping for Clarifiers 2 and 3. The standby pump would sit at grade, as shown; and the stairs would have to be demolished and rebuilt afterwards to allow for the pipe installation.

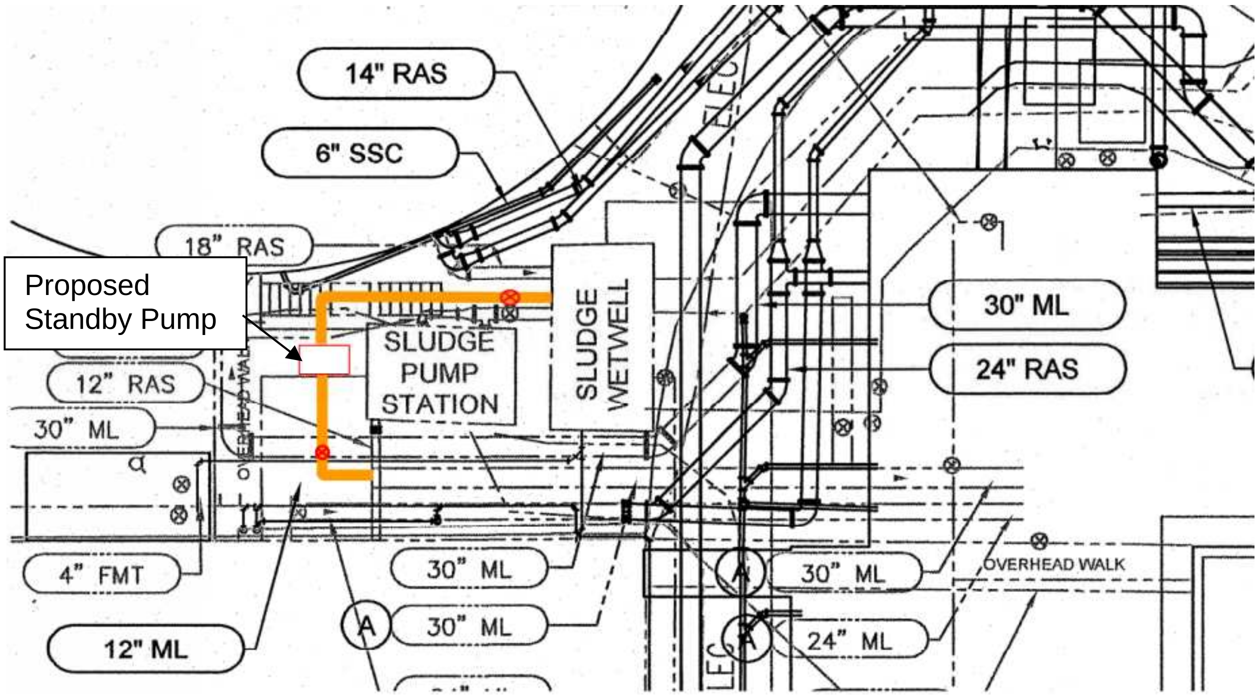


Figure 2-8: Proposed Permanent RAS Piping for Clarifiers 2 and 3

In terms of electrical requirements, the duty load will not increase because the standby pump will only be operated if one of the duty pumps for a given clarifier is not operating. Although recommended, no modifications are required to the existing electrical power distribution equipment if only two pumps are operating at one time. This alternative will require, however, a new VFD for each of the new RAS pumps (total of 4), new conduit and wire from the starters to the pumps, new disconnect switches for each pump, and a new ductbank from the electrical room to each RAS pump pad associated with each clarifier. The existing cable tray has been assumed to be full based on conversations with OWASA staff. Moreover, the existing tray does not go all the way to each pump location, so new ductbank would be required in some amount for each location. As an alternative, the OWASA could choose to forgo these electrical improvements and manually connect the cable of the new standby pump to the disconnect switch of the pump that is being repaired. Due to the time and effort that would be required to connect the new standby pump during emergency operations, it is not recommended that OWASA forgo the electrical improvements listed above; the costs summarized herein assume that the recommended electrical improvements are implemented.

The cost associated with this alternative includes new pumps and associated piping, as well as the required electrical improvements. The cost opinion for Alternative 5 is presented in **Table 2-12**.

Table 2-12: Cost Opinion for Alternative 5

	Alternative 5
Demolition	$0
Sitework	$0
Mechanical	$240,000
Structural	$0
Electrical	$210,000
Total (2018) [1]	**$670,000**

[1] The total cost incorporates the assumptions listed in **Section 2.1**.

3. Additonal Improvements

Hazen evaluated additional general improvements that can be applied in conjunction with Alternatives 1-3, and 5 to address existing system deficiencies. These improvements include:

- New RAS piping for Clarifiers 2&3 to the NSL chimney to combine with RAS from Clarifiers 1, 4, & 5.
- New isolation valves in the RAS pipes from each clarifier (total of 5).
- New ultrasonic level sensors and staff gauges in each of the cutthroat flumes to secondary clarifiers (total of 5) to replace existing.
- Replace existing ultrasonic flow meters with mag meters on RAS suction pipes (total of 5).
- Replace plug valves downstream of Clarifier 5 RAS pumps (total of 2).
- Heat trace & insulate all RAS pumps.

The cost breakdown for each improvement is listed in **Table 3-1**.

Table 3-1: Cost Opinion for Additional Improvements

Unit Process	Quantity Required	Total Capital Cost with Installation ($)
New RAS piping for Clarifiers 2 & 3		
12" Piping	1,200 ft	$50,000
New Isolation Valves		
12" PV for Clarifiers 1,2,3,4	4	$17,000
16" PV for Clarifier 5	1	$9,000
New Ultrasonic Level Sensors		
Ultrasonic Level Sensors	5	$31,000
Replace Ultrasonic Flowmeters with Mag Meters		
18" Mag Meters	5	$70,000
Replace Plug Valves - Clarifier 5 RAS Pumps		
12" PV	2	$10,000
Heat Trace Pumps for Weather Protection		
Unitherm Freeze Protection Jacket	8	$5,000
Staff Gauges for the Flumes		
Staff Gauges	5	$1,300
Total (2018) [1]		**$340,000**

[1] Total includes 15% for electrical & I/C, 5% for general conditions / mobilization, 15% OH&P, 2% bonds and insurance, and 20% contingencies.

3.1 RAS Flow Measurement and Control Strategy

OWASA currently uses a 7-day average flow to control RAS flow. This control strategy was discussed among Hazen experts, who agreed that using this strategy is preferable to controlling RAS based on instantaneous flowrate. Implementing a 7-day average flow control strategy avoids having to drastically increase RAS flow during peak flow events, as well as decreasing flow during diurnal flows.

Another feasible strategy that could be implemented is to control RAS flow based on a proportion of the WWTP influent flow while setting maximum and minimum limits to prevent excessive pump turndown. This is a common flow control strategy that reduces the requirement of manual control during wet weather events. Additionally, staff gauges can be added as a method for backup flow measurement to each clarifier. Staff gauges are included in **Table 3-1**.

4. Alternative Flow Scenarios

4.1 Flow by Gravity from NSLs to Aeration Basins

Hazen evaluated the possibility of sizing the RAS pumps big enough to pump RAS to the NSL basins and have RAS flow by gravity to the aeration basins via a distribution channel and weir system. Based on hydraulic modeling, the NSL walls would have to be raised by approximately 15 ft to meet peak flow conditions, which cannot be accomplished without rebuilding the tanks, or performing significant structural and piping modifications.

With additional minor piping modifications, the walls would need to be raised by 5.2 ft to be able to pass the peak flow. More extensive work, which includes increasing all pipe sizes to 30-inch pipes, would be required to avoid raising the NSL walls. **Table 4-1** summarizes the length at which the NSL walls would have to be raised to accommodate the peak flow of 43.5 mgd and while maintaining a design freeboard of 2 feet.

Table 4-1: NSL Wall Requirements at 43.5 MGD and with 2 ft of Design Freeboard

	Existing Pipe Sizes	Increase the size of select pipes [1]	Increase the size of all pipes to 30”
Headloss (ft)	4.0	2.8	1.6
Raise Walls by (feet)	16.8	5.2	0.8

[1] Increase the existing 12” NSL to 14” and the existing 8” NSL parallel pipes to 10”.

Raising the existing NSL walls and water level 5 feet or more is not possible without significant structural modifications due to the existing structural system and design capacity of the tank walls and slabs. The walkways at the top of the tank and buttress walls within the tank both support the tank walls and cannot be removed without modifying the tank structural system to take the proposed loads. The NSL tank walkways are shown in **Figure 4-1** and the buttress walls are illustrated in **Figure 4-2**.

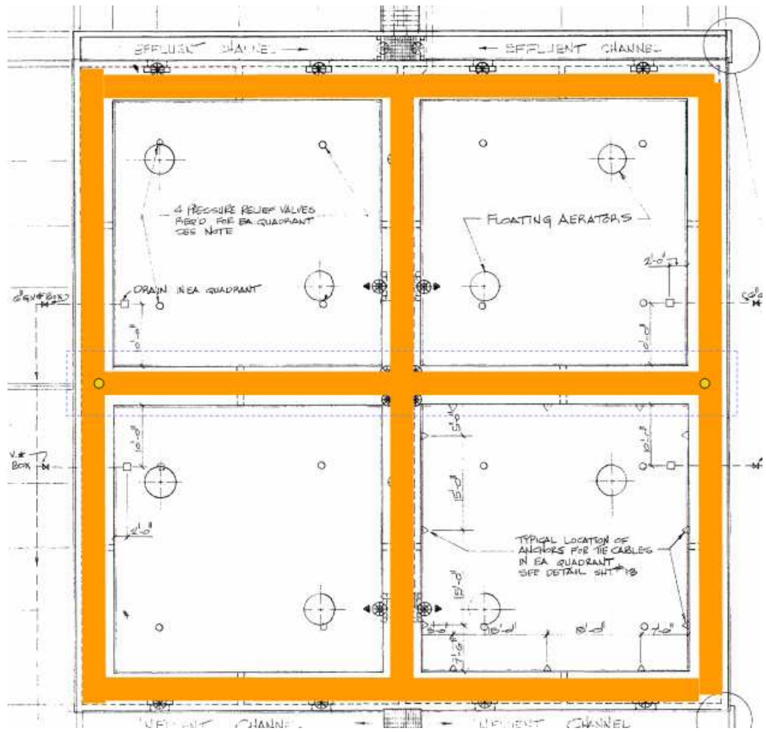


Figure 4-1: Walkways of Existing NSL Tanks

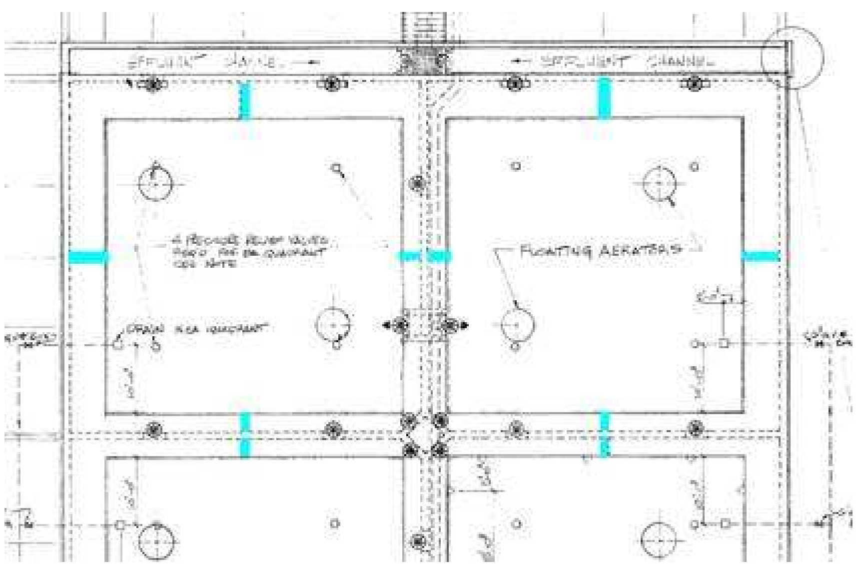


Figure 4-2: Buttress Walls of Existing NSL Tanks

If flow by gravity is not implemented and the RAS pumps are upgraded while utilizing the existing NSL pumps, it is important to consider the potential of water level rise in the NSL tanks. OWASA staff has three options to remediate this:

1. Utilize the existing 42" ML pipes and valves located in between NSL Cell # 1C and 1D and Aeration Basins Cells 2B and 2A, respectively. These existing pipes are illustrated in **Figure 4-3**.
2. Add a new passive bypass spillway from the NSL to Cell 1E – this would be an open channel overflow.
3. Plant staff could utilize the drain lines that convey flow from the NSLs to the Intermediate Pump Station to reduce the water level in the NSLs. Discussions with plant staff indicate that a few valves would have to be repaired or replaced to implement this remediation alternative.

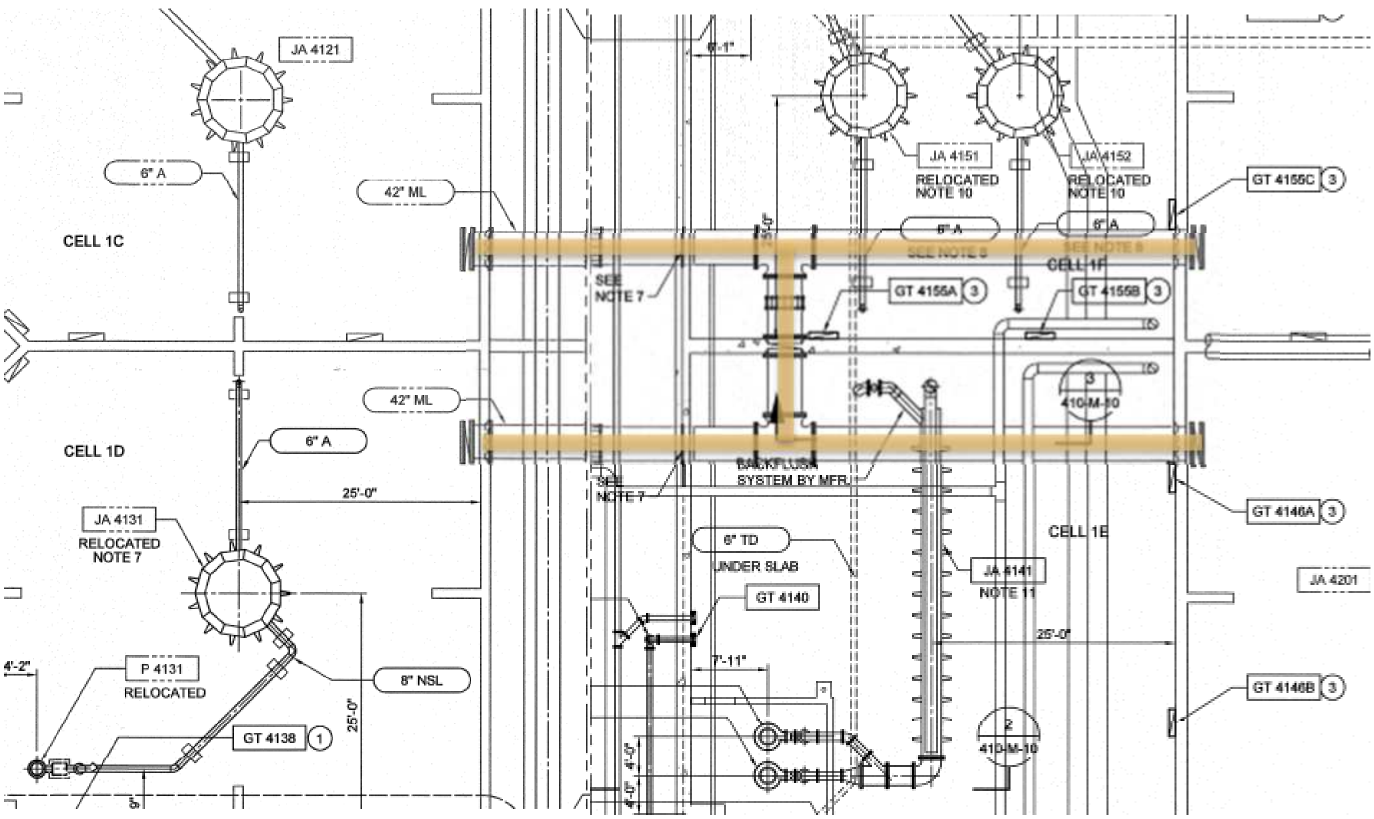


Figure 4-3: Existing 42" ML Pipes Connecting the NSLs to the Aeration Basins

4.2 Flow by Gravity from Secondary Clarifiers to NSLs

RAS flow by gravity from the secondary clarifiers to the NSLs was also evaluated and it was determined that this could not be accomplished without significantly decreasing the operating level in the NSLs. The use of RAS pumps is necessary due to high headloss in the pipes conveying RAS to the NSLs.

5. Alternatives Analysis

5.1 Cost Comparison

A cost comparison of the different alternatives and additional cost adders is presented in **Table 5-1**. This table represents several combinations of possible improvements. Since Alternative 3 could be applied in conjunction with any of the alternatives, the cost for Alternative 3 is represented as a cost adder. Additional cost adders that could be applied to some of the alternatives include: the cost adder for general RAS system reliability improvements (as presented in **Table 3-1**), one new electrical building for Alternative 4, and the net present value of the future Clarifier 6 RAS pumping system to incorporate the cost savings of implementing Alternative 4.

Table 5-1: Alternatives Cost Comparison

Alternative	Capital Cost	Alternative 3 Cost Adder (Diesel)	Additional Improvements Cost Adder	New Electrical Building & PLC	NPV of Future Clarifier 6 RAS Pumps	Total Project Cost
Alternative 1 - In-Kind	$630,000	$0	$0	$0	$517,000	**$1,147,000**
	$630,000	$290,000	$0	$0	$517,000	**$1,437,000**
	$630,000	$0	$340,000	$0	$517,000	**$1,487,000**
	$630,000	$290,000	$340,000	$0	$517,000	**$1,777,000**
Alternative 2 - Larger Pumps	$1,310,000	$0	$0	$0	$517,000	**$1,827,000**
	$1,310,000	$290,000	$0	$0	$517,000	**$2,117,000**
	$1,310,000	$0	$340,000	$0	$517,000	**$2,167,000**
	$1,310,000	$290,000	$340,000	$0	$517,000	**$2,457,000**
Alternative 4 - New RAS PS (6 Pumps)	$3,020,000	$0	$0	$0	$0	**$3,020,000**
	$3,020,000	$0	$0	$280,000	$0	**$3,300,000**
Alternative 5- Permanent Standby Pumps	$670,000	$0	$0	$0	$517,000	**$1,187,000**
	$670,000	$0	$340,000	$0	$517,000	**$1,527,000**

5.2 Non-Cost Factors

In addition to cost, other factors like capacity and performance were evaluated for each alternative and are included in **Table 5-2**. During the kick-off meeting for this project, a number of system deficiencies were listed that plant staff would like to see alleviated. These system deficiencies are listed below and are used to compare each alternative based on the number of deficiencies that are eliminated.

i. Lack of redundancy

ii. Pump design capacities with Clarifiers 1 and 5 in service

iii. RAS flow measurement and control for Clarifiers 2 and 3

iv. Flow measurement and control for Clarifiers 1, 4 and 5

v. Issues with flowmeter readings

vi. Others: metering, isolation, and plug valves downstream of Clarifier 5 RAS pumps

Table 5-2: Alternatives Non-Cost Comparison

	Existing	Alt 1 - In-Kind Replacement	Alt 2- Larger Pumps	Alt 3 - Portable Back-Up	Alt 4 - New Pump Station	Alt 5 - Permanent Standby Pumps
Total Firm Capacity[1]	<20 MGD	<20 MGD	<28 MGD	<20 MGD or <28 MGD	21 MGD	20 MGD
Turndown Available	4 : 1	4 : 1	5.5 : 1	4 : 1 or 5.5 : 1	6 : 1	4 : 1
System Deficiencies[2]	0/6	0/6	1/6	1/6	6/6	1/6
Improves Secondary Clarifier Performance?	No	No	Yes	No	Yes	No
Accommodates future clarifier?	No	No	No	No	Yes	No

[1] A total capacity of 20 mgd is required for a firm RAS capacity of 100% of the plant influent flow.

[2] Number of system deficiencies that are alleviated out of 6.

6. Results & Recommendations

6.1 RAS Pumping Recommendations

Table 6-1 presents a summary of the five alternatives that were evaluated. This summary table does not include any additional improvements that could be implemented in combination with these alternatives, as presented in **Table 3-1** and **Table 5-1**.

Table 6-1: Summary of RAS Rehabilitation Alternatives

Alternative	Capital Cost Opinion (2018)	Total Firm Capacity	Addresses all system deficiencies?	Improves Clarifier Performance?
Alternative 1 – Replace In-Kind	$630,000	<20 MGD	No	No
Alternative 2 – Larger Pumps	$1,310,000	<28 MGD	No	Yes
Alternative 3 – Portable Backup	$290,000	<20 MGD or <28 MGD	No	No
Alternative 4 – New RAS PS	$3,020,000	21 MGD	Yes	Yes
Alternative 5 – Standby Pumps	$670,000	20 MGD	No	No

Based on the results of this evaluation, the recommendations for improving the RAS pumping system at the Mason Farm WWTP are as follows:

1. Hazen recommends that OWASA continue to replace pumps with higher-capacity pumps as has already been completed for Clarifiers 4 and 5. The total cost estimate, as listed in **Table 6-1**, is $630,000 (Alternative 1). OWASA has already spent some of those funds to replace pumps for Clarifier 5. Implementing Alternative 1 is recommended for two primary reasons. First, the pumps can be replaced without having to make significant modifications to existing pipes and valves. Secondly, implementing this alternative incorporates the cost that has already been spent on replacing the pumps for Clarifiers 4 and 5. Implementing Alternatives 2 or 4, however, would render the dollar amount that has already been spent on pump replacement as a sunken cost.

2. Additionally, Hazen recommends purchasing a portable backup pump to be used as a standby for all clarifiers. This would be a Diesel Gorman-Rupp or Godwin pump instead of an electric pump to eliminate the need for additional electrical work. Although there is a significant amount of maintenance associated with a diesel pump that is not constantly in use, having a diesel-powered engine is also preferred for ease of transport.

3. It is also recommended that the current condition of the Clarifier 1 suction piping be investigated. As discussed in **Section 1.2**, the C-value for Clarifier 1 had to be adjusted to line up with the operating point measured in the field, indicating that the Clarifier 1 suction pipe could be plugged. Discussions with plant staff indicate that pipe inspections are underway and will be completed prior to ordering the new RAS pump for Clarifier 1.

4. Finally, Hazen recommends implementing all of the improvements listed in **Section 3** to alleviate existing deficiencies of the RAS system and to improve overall operability.

The total cost of the recommended alternatives is presented in **Table 6-2.**

Table 6-2: Cost of Recommended RAS Rehabilitation Alternatives

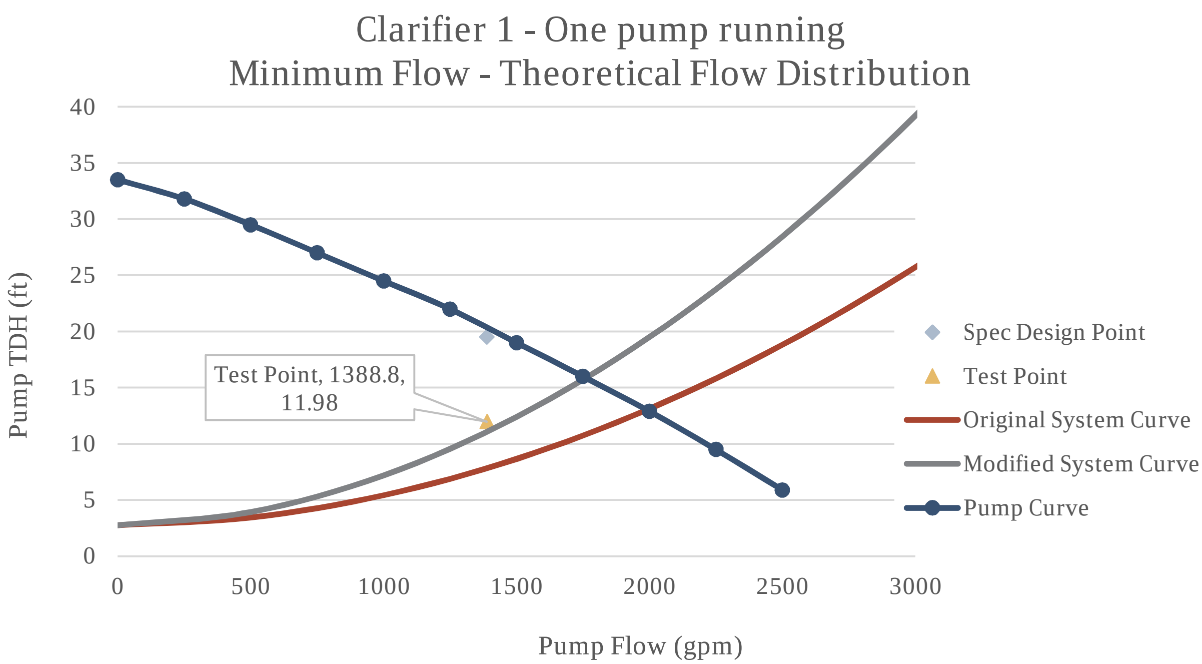
Recommended Alternative	Capital Cost Opinion (2018)
Alternative 1 – Replace In-Kind	$630,000
Alternative 3 – Portable Backup	$290,000
Additional Improvements	$340,000
Total Cost	**$1,260,000**

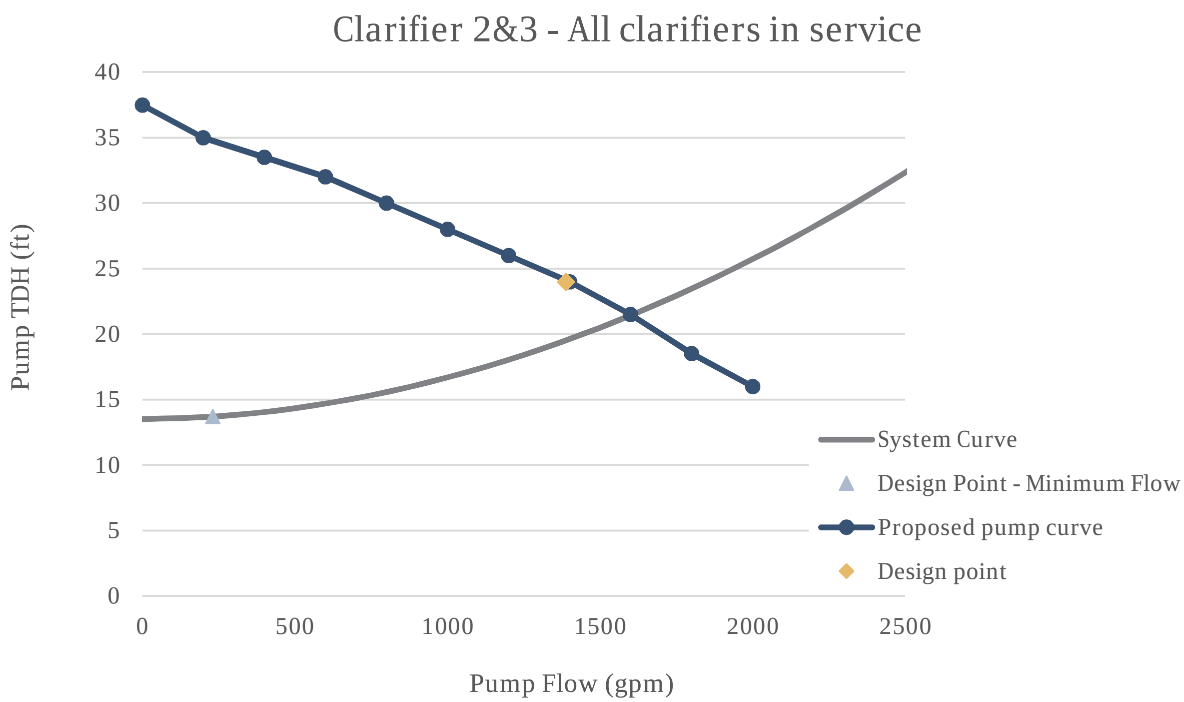
7. References

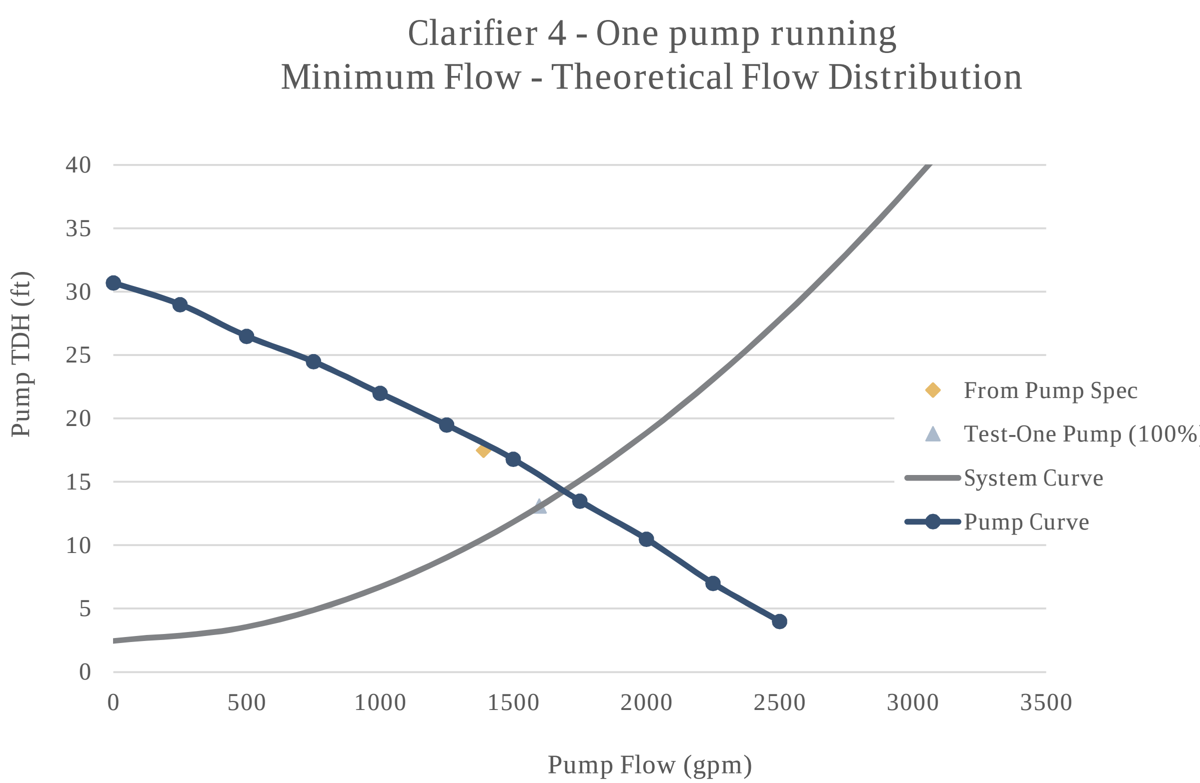
Hydraulic Institute Standards. American National Standard for Rotodynamic Pumps for Pump Intake Design. Parsippany: Hydraulic Institute, 2012.

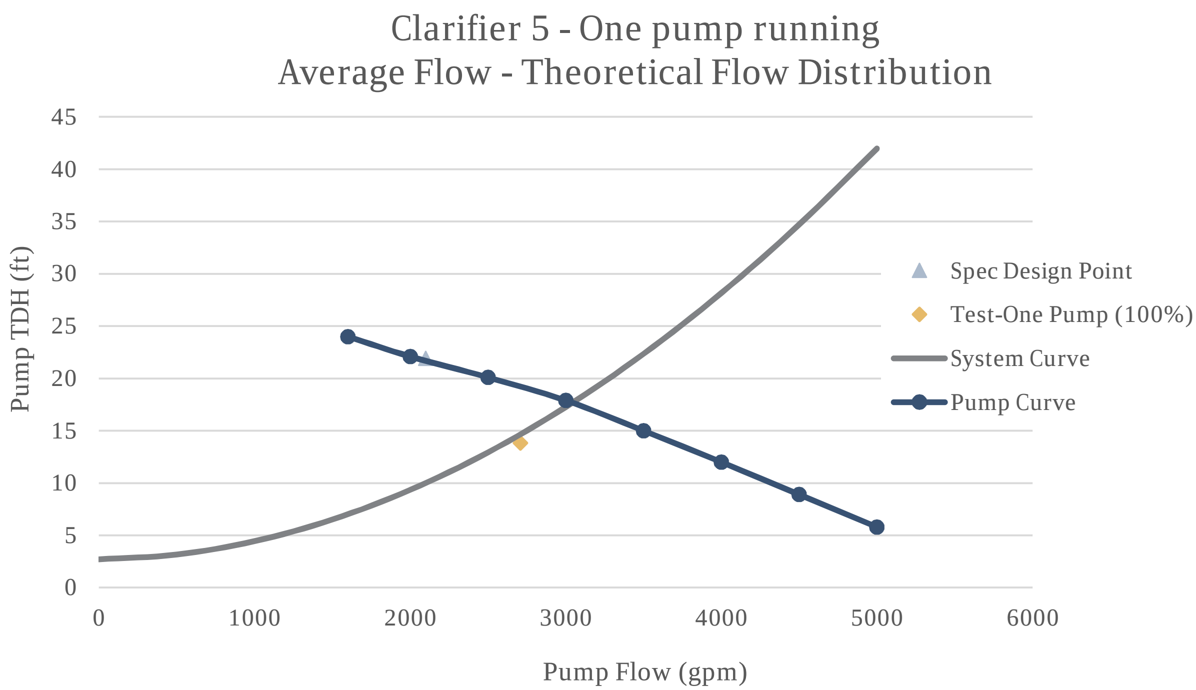
Appendix A: RAS Pumps System Curves

Original and Modified System Curves After Field Calibration

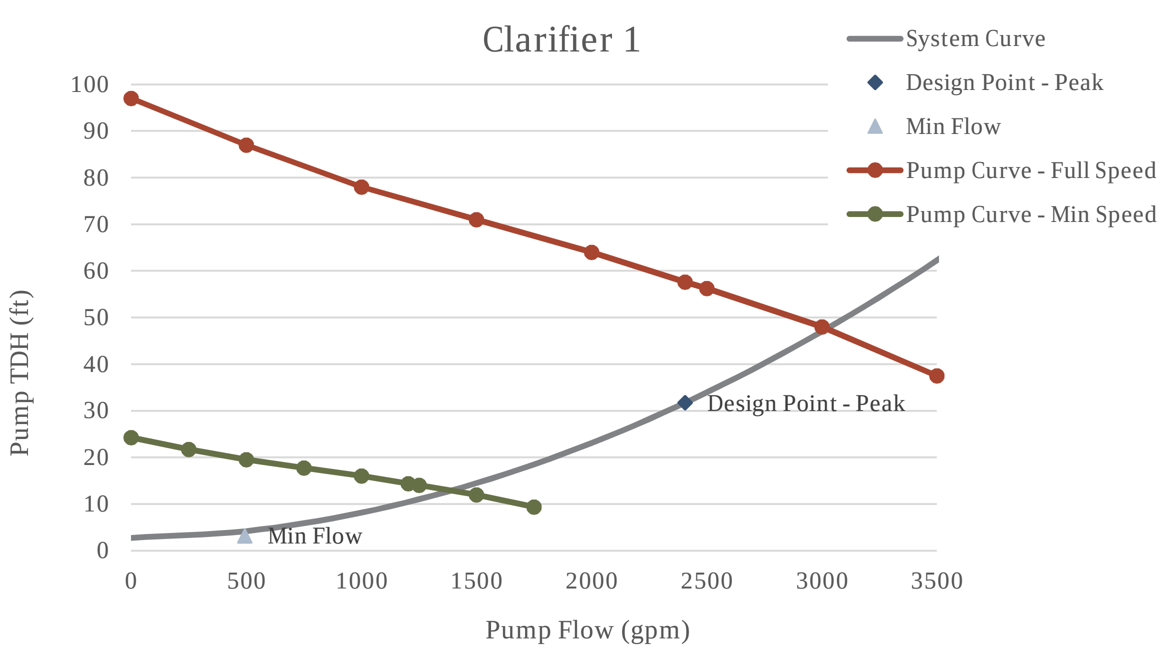


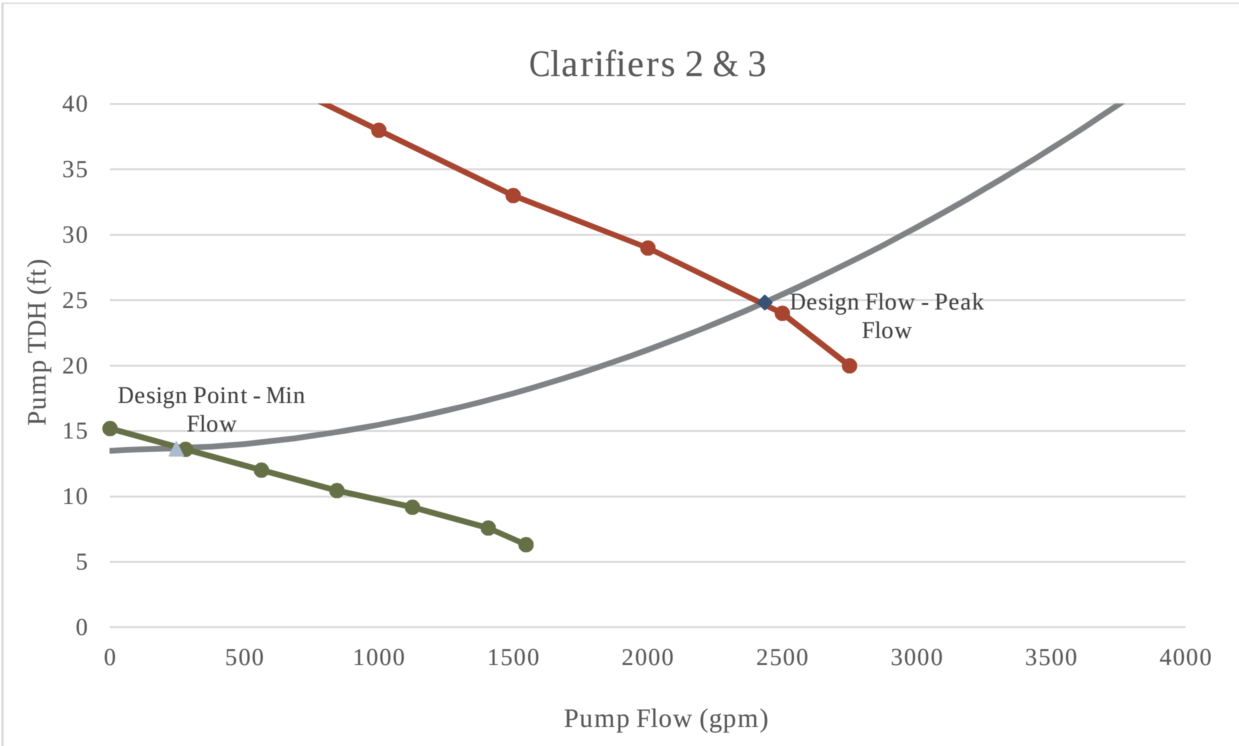

Clarifier 2&3 - All clarifiers in service
Pump TDH (ft)
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
Pump Flow (gpm)
System Curve
Design Point - Minimum Flow
Proposed pump curve
Design point

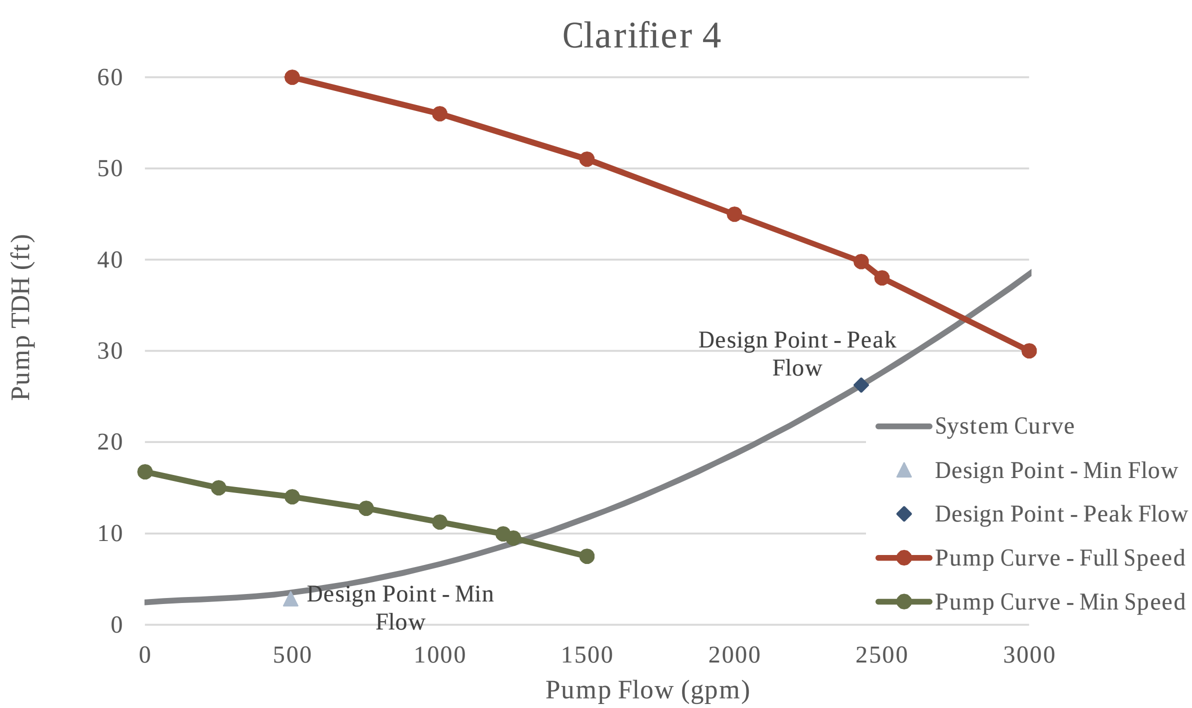

Clarifier 4 - One pump running
Minimum Flow - Theoretical Flow Distribution
Pump TDH (ft)
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
3500
Pump Flow (gpm)
From Pump Spec
Test-One Pump (100%)
System Curve
Pump Curve

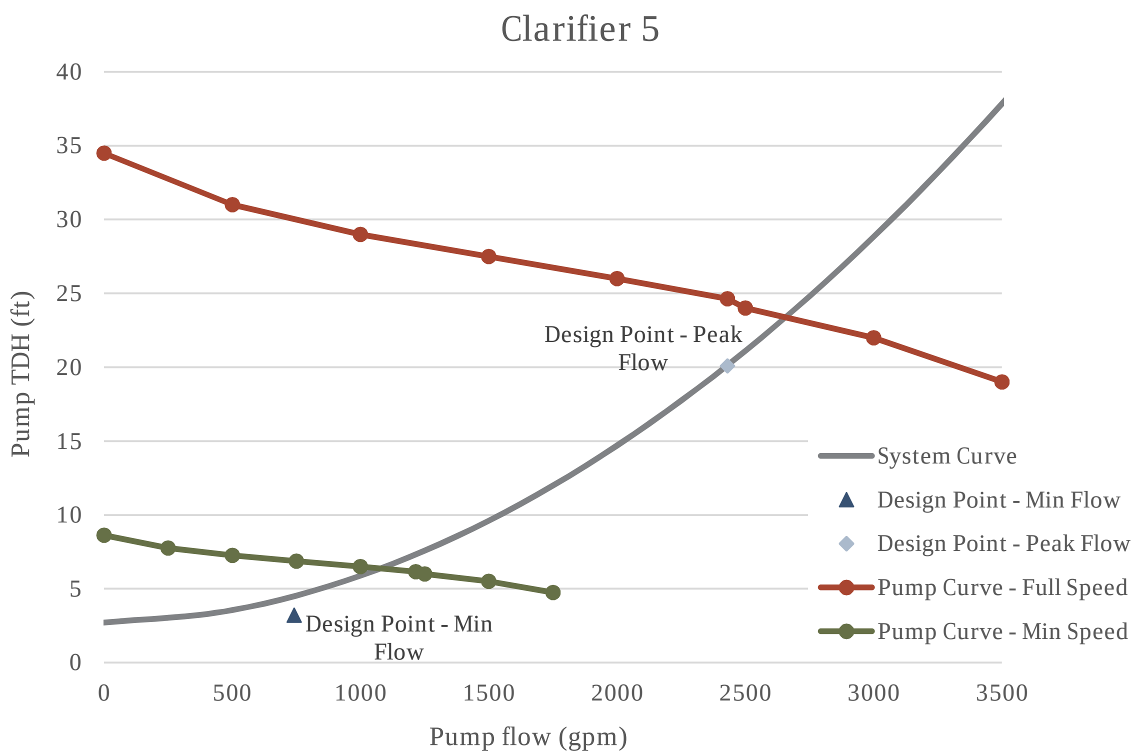


Proposed Pump Curves for Alternative 2 (Replace with Larger Pumps)




Clarifiers 2 & 3
Pump TDH (ft)
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
3500
4000
Pump Flow (gpm)
Design Flow - Peak Flow
Design Point - Min Flow


Clarifier 4
Pump TDH (ft)
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
Pump Flow (gpm)
Design Point - Peak Flow
Design Point - Min Flow
System Curve
Design Point - Min Flow
Design Point - Peak Flow
Pump Curve - Full Speed
Pump Curve - Min Speed


Clarifier 5
Pump TDH (ft)
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
3500
Pump flow (gpm)
Design Point - Peak Flow
Design Point - Min Flow
System Curve
Design Point - Min Flow
Design Point - Peak Flow
Pump Curve - Full Speed
Pump Curve - Min Speed

Appendix B: Summary of State Point Analyses Results from the Mason Farm WWTP Secondary Clarifier Rehabilitation Study

This table summarizes the SPA results for the Mason Farm WWTP existing clarifiers:

Condition	Flow	SVI	Clarifier 1			Clarifiers 2 & 3			Clarifier 4			Clarifier 5		
			SPA at 4 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 4 MGD RAS	SPA at 2 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 2 MGD RAS	SPA at 4 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 4 MGD RAS	SPA at 6 MGD RAS & 4000 MLSS	Required RAS MGD to Pass at 4000 MLSS	Required MLSS to Pass at 6 MGD RAS
All in Service	Design Max Month = 14.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		96	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
	Peak = 43.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA
		86	Pass	NA	NA	Fail	3	3800	Fail	5	3900	Fail	7	3800
Clar 5 OOS	Design Max Month = 14.5 MGD	76	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
		86	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
		96	Pass	NA	NA	Pass	NA	NA	Pass	NA	NA			
	Peak = 43.5 MGD	76	Fail	7	3300	Fail	3	3300	Fail	NA [1]	3200			
		86	Fail	NA [1]	2900	Fail	NA [1]	2900	Fail	NA [1]	2900			
Clar 1 & 5 in Service	Design Max Month = 14.5 MGD	76	Pass	NA	NA							Pass	NA	NA
		86	Pass	NA	NA							Pass	NA	NA
		96	Pass	NA	NA							Pass	NA	NA
	Peak = 43.5 MGD	76	Fail	NA [1]	2800							Fail	NA [1]	2900
		86	Fail	NA [1]	2500							Fail	NA [1]	2500
Clar 1 & 4 in Service	Design Max Month = 14.5 MGD	76	Pass	NA	NA				Pass	NA	NA			
		86	Pass	NA	NA				Pass	NA	NA			
		96	Pass	NA	NA				Pass	NA	NA			
	Peak = 43.5 MGD	76	Fail	NA [1]	2300				Fail	NA [1]	2300			
		86	Fail	NA [1]	2100				Fail	NA [1]	2000			

Notes

1 NA indicates the steady point is outside of settling flux.
2 SVI values correspond to: average, 80th, and 95th percentiles based on plant data from March 2015 to Jan 2017.
3 Use RAS pump capacities as initial RAS rates.
4 Use an Ekama factor of 0.9 for Clarifiers 4 & 5, and 0.8 for Clarifiers 1, 2, and 3 to account for the more shallow clarifiers.
5 Use predicted flow distribution for all in service condition for Clarifiers 2 & 5.

Appendix C: Fairbanks Morse Pump Proposals

Clarifier 1

PENTAIR

Customer :
Project name : Default

Pump Performance Datasheet

Encompass 2.0 - 18.0.0.0

Item number	: 004	Size	: 8" 5434S (W, MT, WD)
Service	:	Stages	: 1
Quantity	: 1	Based on curve number	: 8-54x4S-1200-T8D1A
Quote number	: 386164	Date last saved	: 12 Feb 2018 3:19 PM

WD
drypit sub

Operating Conditions

Flow, rated	: 2,406.0 USgpm
Differential head / pressure, rated (requested)	: 57.60 ft
Differential head / pressure, rated (actual)	: 57.66 ft
Suction pressure, rated / max	: 0.00 / 0.00 psi.g
NPSH available, rated	: Ample
Frequency	: 60 Hz

Performance

Speed, rated	: 1185 rpm 1200
Impeller diameter, rated	: 13.91 in
Impeller diameter, maximum	: 14.00 in
Impeller diameter, minimum	: 11.00 in
Efficiency	: 82.17 % 81.1%
NPSH required / margin required	: 16.31 / 0.00 ft
nq (imp. eye flow) / S (imp. eye flow)	: 53 / 139 Metric units
Minimum Continuous Stable Flow	: 500.0 USgpm
Head, maximum, rated diameter	: 95.52 ft
Head rise to shutoff	: 65.83 %
Flow, best eff. point	: 2,383.5 USgpm
Flow ratio, rated / BEP	: 100.94 %
Diameter ratio (rated / max)	: 99.36 %
Head ratio (rated dia / max dia)	: 97.11 %
Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010]	: 1.00 / 1.00 / 1.00 / 1.00
Selection status	: Acceptable

Liquid

Liquid type	: Water
Additional liquid description	:
Solids diameter, max	: 0.00 in
Solids concentration, by volume	: 0.00 %
Temperature, max	: 68.00 deg F
Fluid density, rated / max	: 1.000 / 1.000 SG
Viscosity, rated	: 1.00 cP
Vapor pressure, rated	: 0.34 psi.a

Material

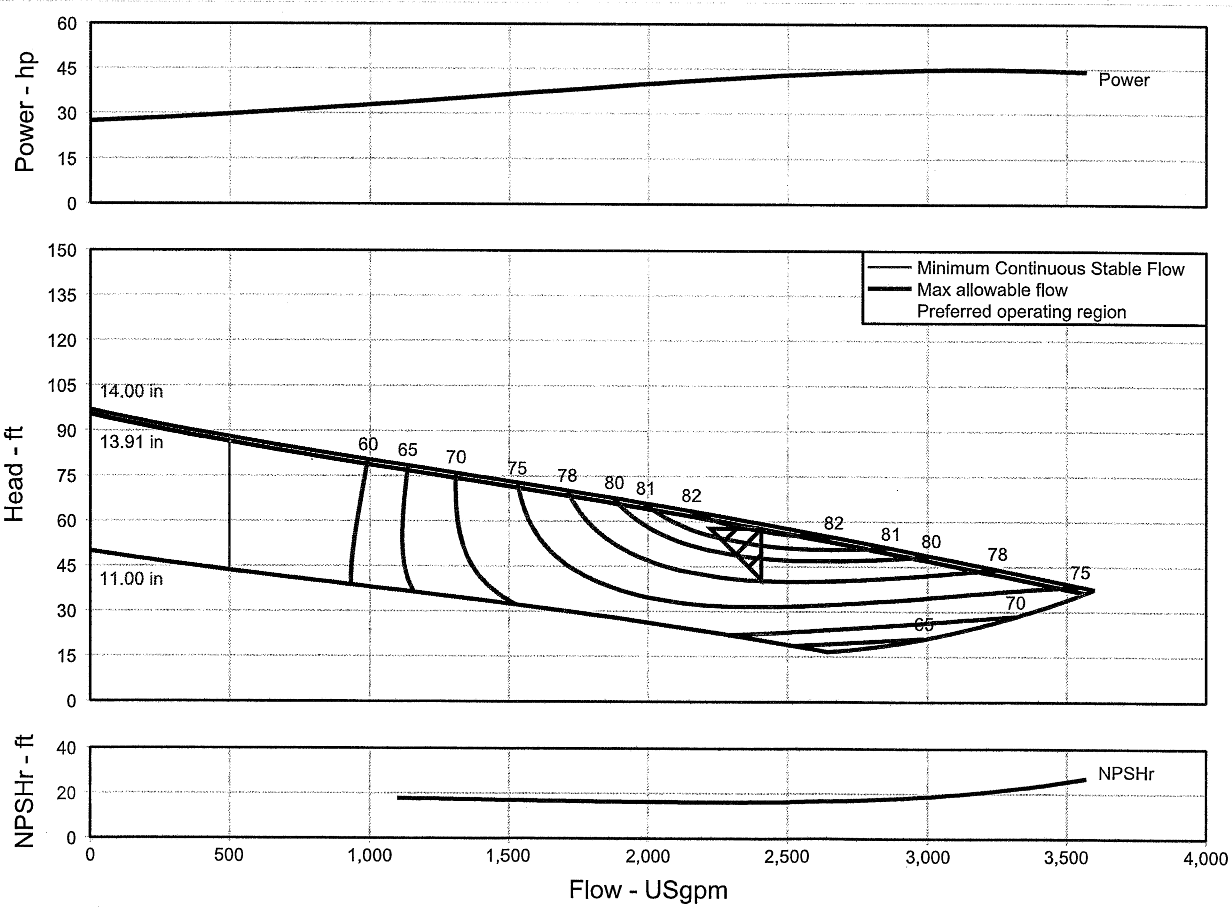
Material selected	: Cast Iron

Pressure Data

Maximum working pressure	: 41.34 psi.g
Maximum allowable working pressure	: 75.00 psi.g
Maximum allowable suction pressure	: N/A
Hydrostatic test pressure	: 80.00 psi.g

Driver & Power Data (@Max density)

Driver sizing specification	: Maximum power
Margin over specification	: 0.00 %
Service factor	: 1.00
Power, hydraulic	: 34.99 hp
Power, rated	: 42.58 hp
Power, maximum, rated diameter	: 44.95 hp
Minimum recommended motor rating	: 50.00 hp / 37.28 kW 50HP



MAX - 1200
MIN - 600

PENTAIR

CLEARWATER, INC.
PO BOX 1469 · HICKORY, NC 28602

PHONE: (828) 855-3182 · FAX: (828) 855-3183

Clarifier 2/3

PENTAIR

Customer :
Project name : Default

Pump Performance Datasheet

Encompass 2.0 - 18.0.0.0

Item number	: 004	Size	: 6" 5433MV MV
Service	:	Stages	: 1
Quantity	: 1	Based on curve number	: 6-5433MV-1800-T6C1C sub pump
Quote number	: 386164	Date last saved	: 12 Feb 2018 3:27 PM

Operating Conditions

Flow, rated	: 1,218.0 USgpm
Differential head / pressure, rated (requested)	: 31.40 ft
Differential head / pressure, rated (actual)	: 31.40 ft
Suction pressure, rated / max	: 0.00 / 0.00 psi.g
NPSH available, rated	: Ample
Frequency	: 60 Hz

Performance

Speed, rated	: 1183 rpm 1200
Impeller diameter, rated	: 10.72 in
Impeller diameter, maximum	: 12.00 in
Impeller diameter, minimum	: 9.00 in
Efficiency	: 77.88 % 76.8%
NPSH required / margin required	: 8.38 / 0.00 ft
nq (imp. eye flow) / S (imp. eye flow)	: 47 / 164 Metric units
Minimum Continuous Stable Flow	: 199.9 USgpm
Head, maximum, rated diameter	: 55.56 ft
Head rise to shutoff	: 76.94 %
Flow, best eff. point	: 1,122.2 USgpm
Flow ratio, rated / BEP	: 108.54 %
Diameter ratio (rated / max)	: 89.33 %
Head ratio (rated dia / max dia)	: 68.00 %
Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010]	: 1.00 / 1.00 / 1.00 / 1.00
Selection status	: Acceptable

Liquid

Liquid type	: Water
Additional liquid description	:
Solids diameter, max	: 0.00 in
Solids concentration, by volume	: 0.00 %
Temperature, max	: 68.00 deg F
Fluid density, rated / max	: 1.000 / 1.000 SG
Viscosity, rated	: 1.00 cP
Vapor pressure, rated	: 0.34 psi.a

Material

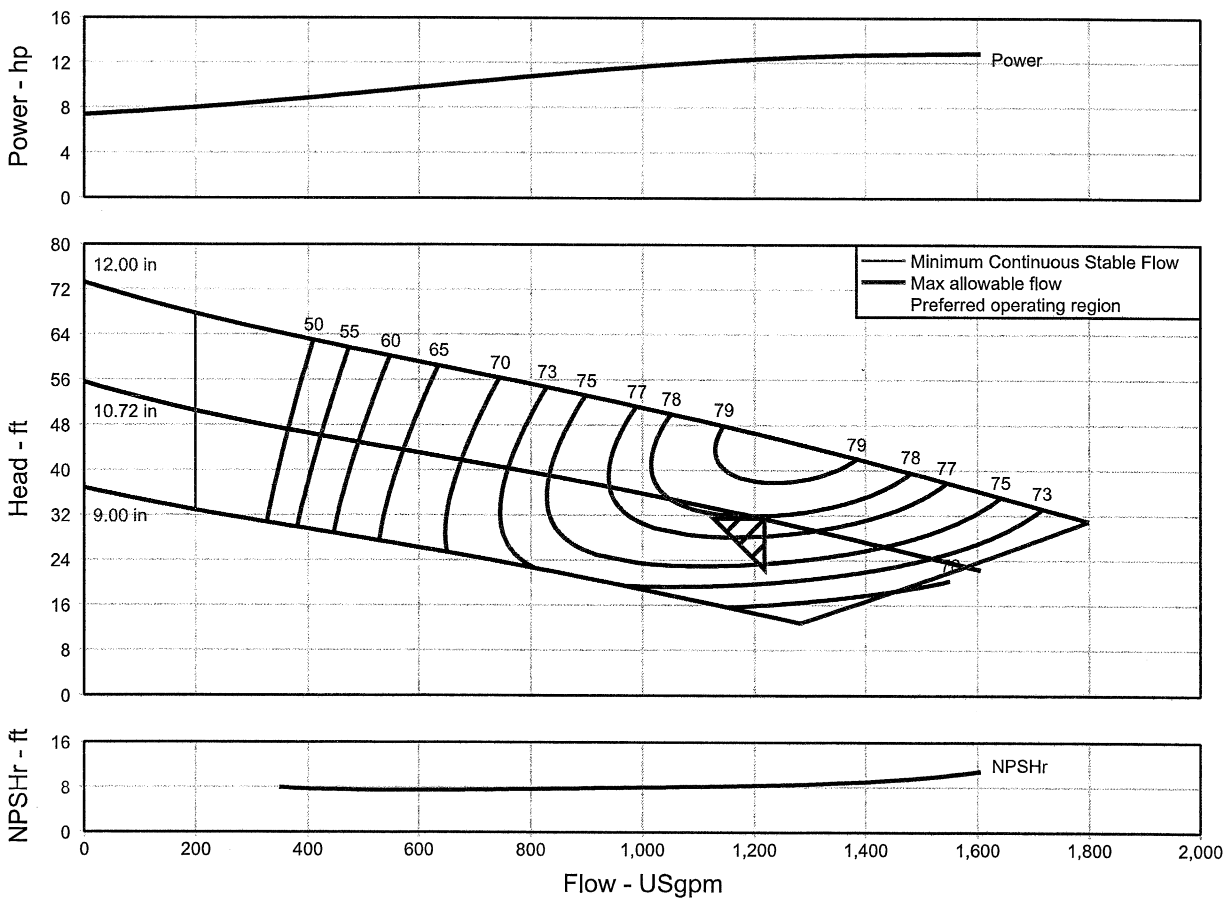
Material selected	: Cast Iron

Pressure Data

Maximum working pressure	: 24.05 psi.g
Maximum allowable working pressure	: 85.00 psi.g
Maximum allowable suction pressure	: N/A
Hydrostatic test pressure	: 125.0 psi.g

Driver & Power Data (@Max density)

Driver sizing specification	: Maximum power
Margin over specification	: 0.00 %
Service factor	: 1.00
Power, hydraulic	: 9.66 hp
Power, rated	: 12.40 hp
Power, maximum, rated diameter	: 12.87 hp
Minimum recommended motor rating	: 15.00 hp / 11.19 kW 15HP



MAX = 1200
MIN - 600

PENTAIR

CLEARWATER, INC.
PO BOX 1469 · HICKORY, NC 28602

PHONE: (828) 855-3182 · FAX: (828) 855-3183

Clarifier 4

PENTAIR

Customer :
Project name : Default

Pump Performance Datasheet

Encompass 2.0 - 18.0.0.0

Item number	: 004	Size	: 8" 5435 (TAKE5N) (W, MT, WD)
Service	:	Stages	: 1
Quantity	: 1	Based on curve number	: 8-54x5-1200-TAKE5N
Quote number	: 386164	Date last saved	: 12 Feb 2018 3:19 PM

WD
dry-pit sub

Operating Conditions

Flow, rated	: 2,430.0 USgpm
Differential head / pressure, rated (requested)	: 39.70 ft
Differential head / pressure, rated (actual)	: 39.79 ft
Suction pressure, rated / max	: 0.00 / 0.00 psi.g
NPSH available, rated	: Ample
Frequency	: 60 Hz

Performance

Speed, rated	: 889 rpm 900
Impeller diameter, rated	: 15.56 in
Impeller diameter, maximum	: 18.00 in
Impeller diameter, minimum	: 15.00 in
Efficiency	: 79.45 %
NPSH required / margin required	: 11.05 / 0.00 ft
nq (imp. eye flow) / S (imp. eye flow)	: 44 / 145 Metric units
Minimum Continuous Stable Flow	: 530.4 USgpm
Head, maximum, rated diameter	: 66.87 ft
Head rise to shutoff	: 68.43 %
Flow, best eff. point	: 2,541.6 USgpm
Flow ratio, rated / BEP	: 95.61 %
Diameter ratio (rated / max)	: 86.44 %
Head ratio (rated dia / max dia)	: 63.34 %
Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010]	: 1.00 / 1.00 / 1.00 / 1.00
Selection status	: Acceptable

Liquid

Liquid type	: Water
Additional liquid description	:
Solids diameter, max	: 0.00 in
Solids concentration, by volume	: 0.00 %
Temperature, max	: 68.00 deg F
Fluid density, rated / max	: 1.000 / 1.000 SG
Viscosity, rated	: 1.00 cP
Vapor pressure, rated	: 0.34 psi.a

Material

Material selected	: Cast Iron

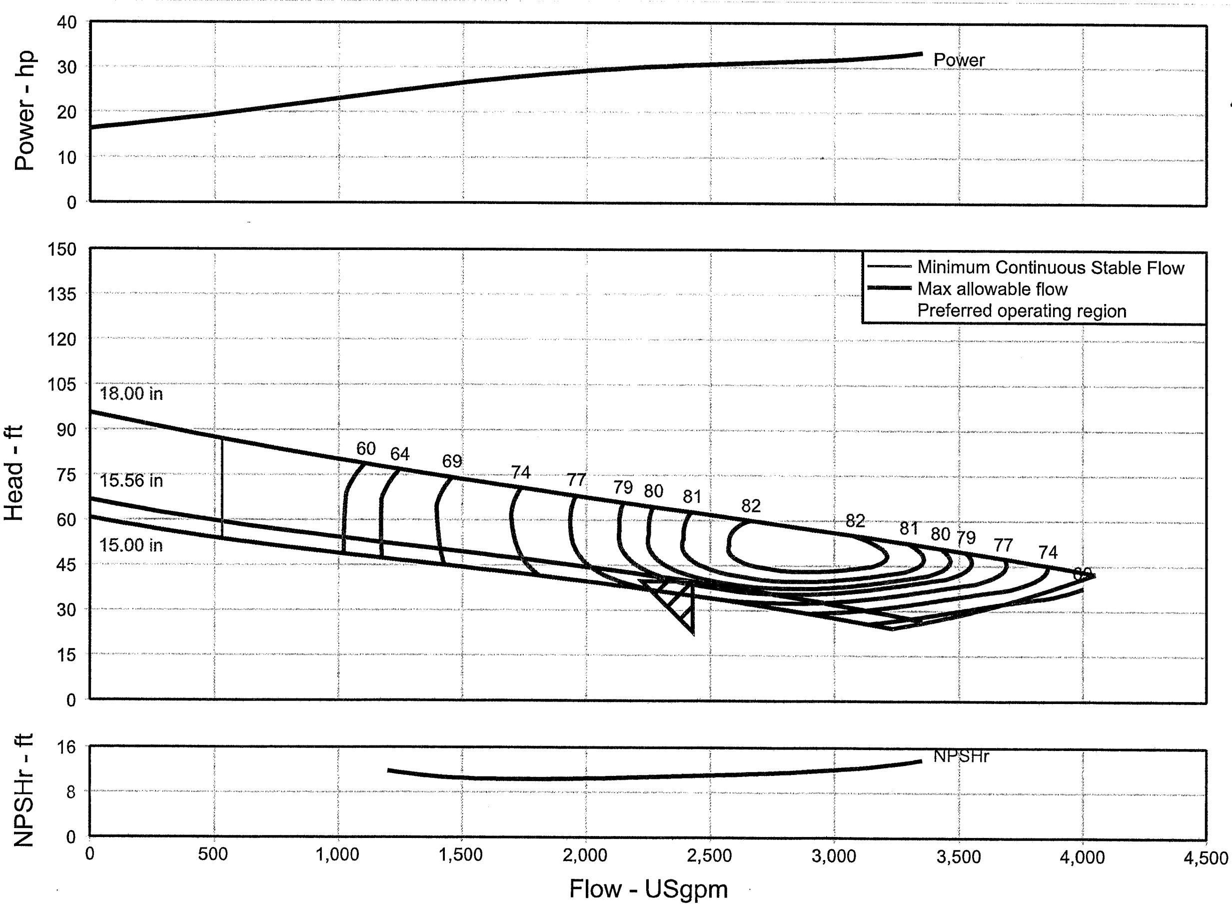
Pressure Data

Maximum working pressure	: 28.94 psi.g
Maximum allowable working pressure	: 75.00 psi.g
Maximum allowable suction pressure	: N/A
Hydrostatic test pressure	: 115.0 psi.g

Driver & Power Data (@Max density)

Driver sizing specification	: Maximum power
Margin over specification	: 0.00 %
Service factor	: 1.00
Power, hydraulic	: 24.36 hp
Power, rated	: 30.65 hp
Power, maximum, rated diameter	: 33.52 hp
Minimum recommended motor rating	: 40.00 hp / 29.83 kW

40HP



MAX 900
MIN 450

PENTAIR

CLEARWATER, INC.
PO BOX 1469 · HICKORY, NC 28602

PHONE: (828) 855-3182 · FAX: (828) 855-3183

PENTAIR

Customer :
Project name : Default

Pump Performance Datasheet

Encompass 2.0 - 18.0.0.0

Item number	: 004	Size	: 12" 5731 (W, WD) (WD)
Service	:	Stages	: 1
Quantity	: 1	Based on curve number	: 12-57X1-900-L12A1N
Quote number	: 386164	Date last saved	: 12 Feb 2018 3:21 PM

Operating Conditions

Flow, rated	: 2,430.0 USgpm
Differential head / pressure, rated (requested)	: 24.50 ft
Differential head / pressure, rated (actual)	: 24.64 ft
Suction pressure, rated / max	: 0.00 / 0.00 psi.g
NPSH available, rated	: Ample
Frequency	: 60 Hz

Performance

Speed, rated	: 885 rpm 900
Impeller diameter, rated	: 12.66 in
Impeller diameter, maximum	: 13.87 in
Impeller diameter, minimum	: 12.00 in
Efficiency	: 73.30 % 72.3%
NPSH required / margin required	: 18.85 / 0.00 ft
nq (imp. eye flow) / S (imp. eye flow)	: 87 / 127 Metric units
Minimum Continuous Stable Flow	: 750.0 USgpm
Head, maximum, rated diameter	: 34.31 ft
Head rise to shutoff	: 40.03 %
Flow, best eff. point	: 3,294.6 USgpm
Flow ratio, rated / BEP	: 73.76 %
Diameter ratio (rated / max)	: 91.28 %
Head ratio (rated dia / max dia)	: 70.15 %
Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010]	: 1.00 / 1.00 / 1.00 / 1.00
Selection status	: Acceptable

Liquid

Liquid type	: Water
Additional liquid description	:
Solids diameter, max	: 0.00 in
Solids concentration, by volume	: 0.00 %
Temperature, max	: 68.00 deg F
Fluid density, rated / max	: 1.000 / 1.000 SG
Viscosity, rated	: 1.00 cP
Vapor pressure, rated	: 0.34 psi.a

Material

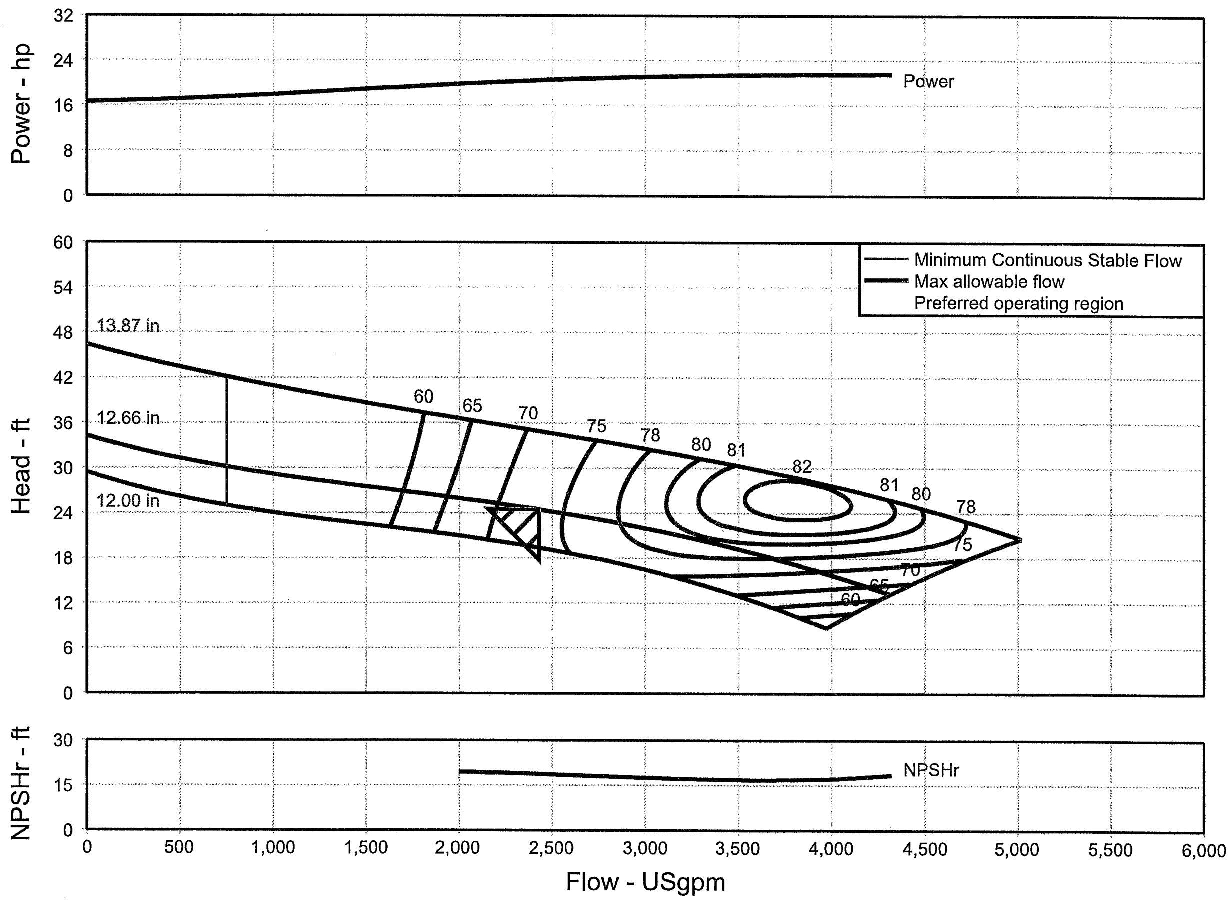
Material selected	: Cast Iron

Pressure Data

Maximum working pressure	: 14.85 psi.g
Maximum allowable working pressure	: 50.00 psi.g
Maximum allowable suction pressure	: N/A
Hydrostatic test pressure	: 75.00 psi.g

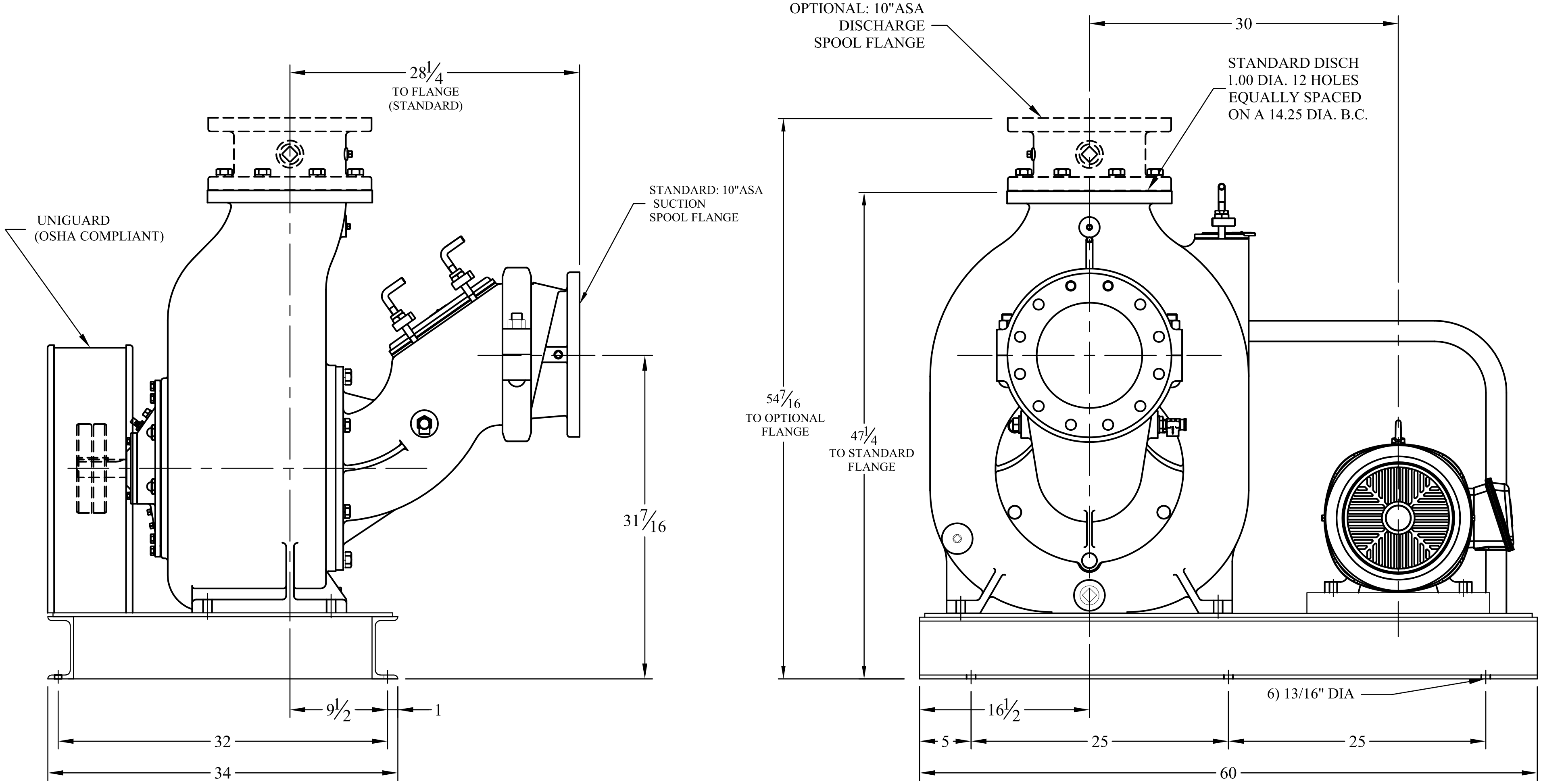
Driver & Power Data (@Max density)

Driver sizing specification	: Maximum power
Margin over specification	: 0.00 %
Service factor	: 1.00
Power, hydraulic	: 15.03 hp
Power, rated	: 20.50 hp
Power, maximum, rated diameter	: 21.61 hp
Minimum recommended motor rating	: 25.00 hp / 18.64 kW 25HP



MAX 900
MIN 450

Appendix D: Gorman Rupp and Godwin Pump Proposals



MOTOR FRAME	SKID WEIGHT
254T-256T	2359
284T-286T	2494
324T-326T	2669
364T-365T	2924
404T-405T	3249

NOTES:
- ALL DIMENSIONS IN INCHES
- TOLERANCE ±1/2" UNLESS NOTED OTHERWISE
- OPTIONAL ASA DISCHARGE SPOOL FLANGE AVAILABLE (SHOWN HIDDEN)
- NOT TO BE USED FOR CONSTRUCTION PURPOSES UNLESS CERTIFIED
- GUARD: GHS502608 (non-stock)
- SKID WEIGHT IS APPROXIMATE
- THIS DRAWING SUPERSEDES A10-295A

FOR:

HORIZONTAL "V" BELT DRIVE BASE (RIGHT HAND)

TENCARVA MACHINERY COMPANY

DRAWN:	CTP	MODEL:	T10 A-B
DATE:	01/12/2014	DWG NO.:	F01157-10
REVISION:			

PERFORMANCE CURVE

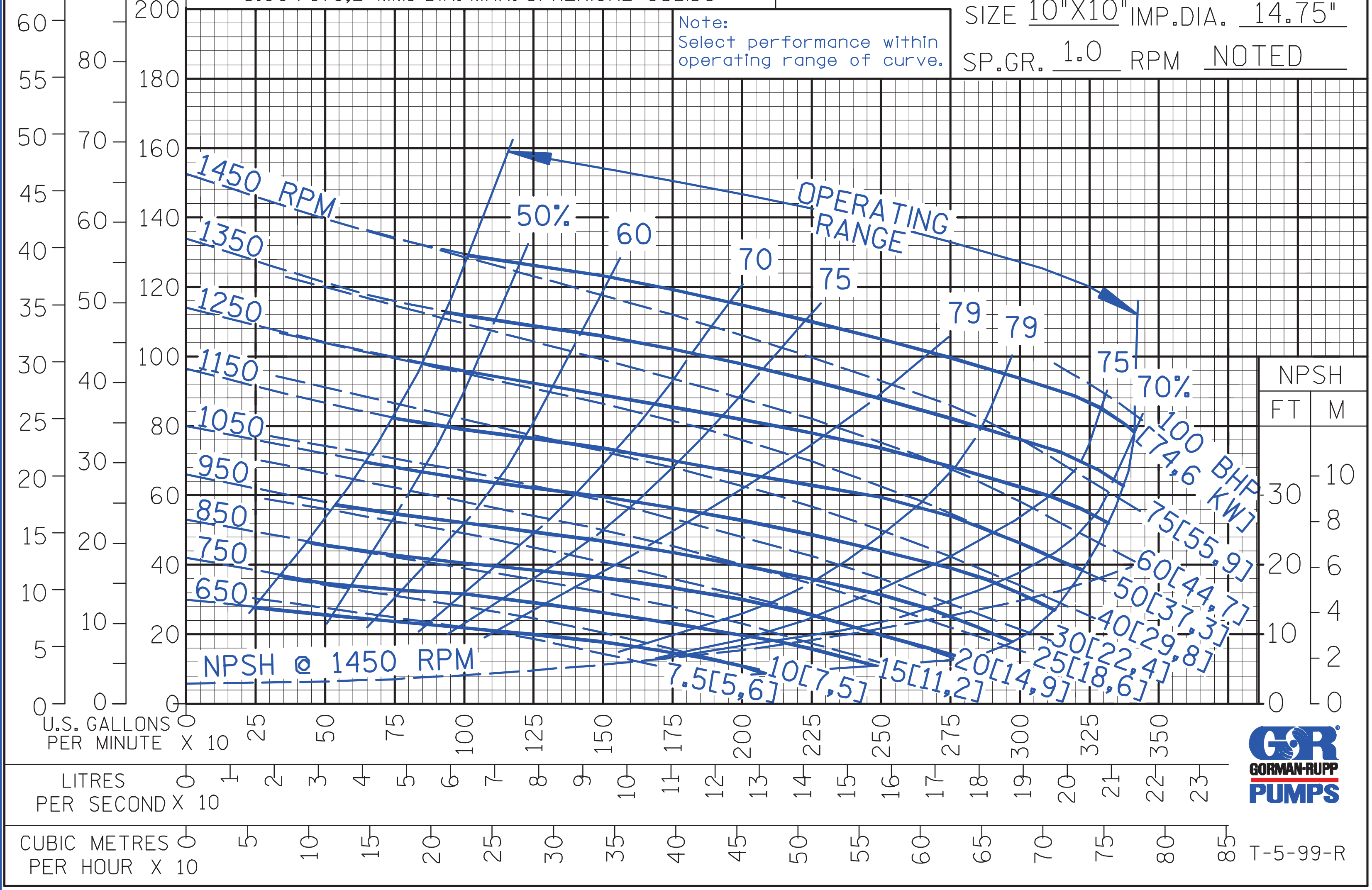
VOLUTE 38222-701 CURVE T10A-B-4
IMPELLER 38615-014 MODEL T10A-B
SIZE 10"X10" IMP.DIA. 14.75"
SP.GR. 1.0 RPM NOTED

REPRIMING LIFTS

RPM	650	750	850	950	1050-1150	1250	1350-1450
FEET	7	11	14	17	18	19	22
METERS	2,1	3,4	4,3	5,2	5,5	5,8	6,7

Figure NPSH required prior to using above table. DO NOT use as available Suction Lifts.
3.00"/[76,2 MM] DIA. MAX. SPHERICAL SOLIDS

Note:
Select performance within operating range of curve.



T-5-99-R

THE GORMAN-RUPP COMPANY • MANSFIELD, OHIO
GORMAN-RUPP OF CANADA LIMITED • ST. THOMAS, ONTARIO, CANADA
www.grpumps.com
Specifications Subject to Change Without Notice

Sound Attenuated Diesel Engine Driven Environmental Silent Pump

Priming Assisted Centrifugal Pump w/Autostart

Model PA6H60-4045H FT4-ESP

Size 8" x 6"

VARIOUS PATENTS APPLY

Total Head		Capacity of Pump in U.S. Gallons per Minute (GPM) at Continuous Performance			
P.S.I.	Feet				
76.7	177	725	725	725	725
65.0	150	1375	1375	1375	1375
54.2	125	1650	1850	1875	1875
43.4	100	1720	2000	2225	2225
32.5	75	1760	2050	2350	2480
21.7	50	1800	2080	2400	2625
10.8	25	1850	2125	2450	2700
Suction Lift		23'	20'	15'	10'

Photo not available at time of publishing

PUMP SPECIFICATIONS

Size: 8" x 6" (203 mm x 152 mm) Flanged.
Casing: Ductile Iron 65-45-12.
Maximum Operating Pressure 115 psi (793 kPa).*
Semi-Open, Two Vane Impeller: Ductile Iron 65-45-12.
Handles 3" (76,2 mm) Diameter Spherical Solids.
Impeller Shaft: Stainless Steel 17-4 PH.
Replaceable Wear Plate: Ductile Iron 80-60-03.
Seal Plate: Gray Iron 30.
Seal: Mechanical, Oil-Lubricated. Silicon Carbide Rotating and Stationary Faces. Stainless Steel 316 Stationary Seat. Fluorocarbon Elastomers (DuPont Viton® or Equivalent). Stainless Steel 18-8 Cage and Spring. Maximum Temperature of Liquid Pumped 160°F (71°C).*
Shaft Sleeve: Stainless Steel 17-4 PH.
Priming Chamber: Gray Iron 30 Housing W/Stainless Steel Float and Linkage.
Discharge Check Valve: Ductile Iron 30 Housing W/Buna-N Flapper.
Radial and Thrust Bearings: Open Double Ball.
Bearing and Seal Cavity Lubrication: SAE 30 Non-Detergent Oil.
O-Rings: Buna-N, and Fluorocarbon Elastomers (DuPont Viton® or Equivalent). PTFE.
Gaskets: Red Rubber, and Vegetable Fiber.
Hardware: Standard Plated Steel.
Bearing and Seal Cavity Oil Level Sight Gauges.

**Consult Factory for Applications Exceeding Maximum Pressure and/or Temperature Indicated.*

Standard Equipment: Gear-Driven Air Compressor. Hoisting Bail. Soundproof (EPA Average 72 dBA at 23 feet [7 meters] Under Load) Lightweight Aluminum Enclosure - Removable for Maintenance of Pump or Engine - W/Lockable Door Panels. Single Ball Type Float Switch. Combination Skid Base w/Fuel Tank. Strainer. Full Feature Control Panel .**

Optional Equipment: Battery. Suction and Discharge NPT Threaded Flange Kits. Skid Drag Base Kit, High Speed (55 MPH/89 KM/H) Single Axle Pneumatic-Tired Wheel Kit W/ DOT-Approved Lights and Electric Brakes. Tandem Axle Over-the-Road Trailer (Meets DOT Requirements) Submersible Transducer Liquid Level Sensor. **
***50 Ft. (15 m) Standard Length; Dual Switches and Alternate Cable Lengths Available From the Factory.*

WARNING!
Do not use in explosive atmosphere or for pumping volatile flammable liquids.

ENGINE SPECIFICATIONS

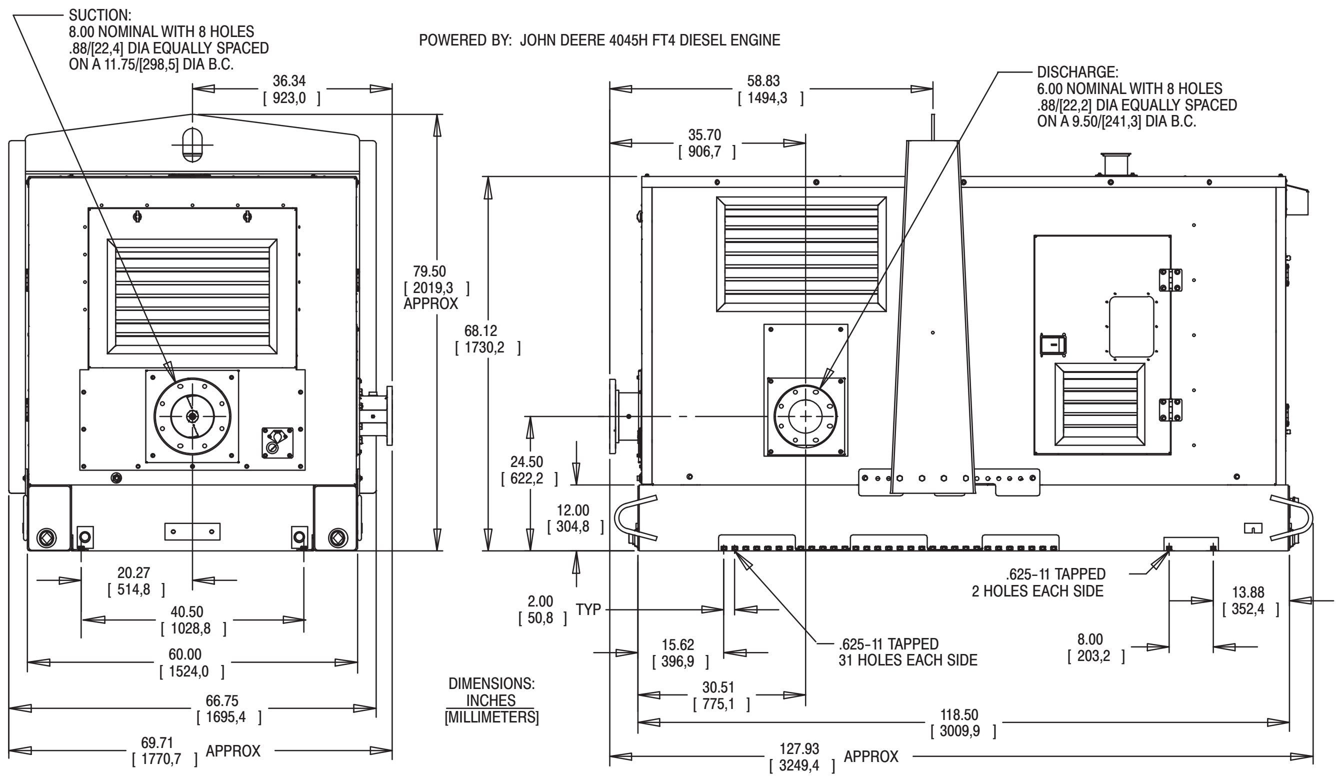
Model: John Deere 4045HFC04.
EPA Tier Tier 4.
Type: Turbocharged Four Cylinder, Diesel Engine w/Air Compressor.
Displacement: 276 Cu. In. (4,5 liters).
Governor: Electronic Isochronous.
Lubrication: Forced Circulation.
Air Cleaner: Dry Type.
Fuel Tank: 110 U.S. Gals. (416 liters).
Full Load Operating Time: 17.8 Hrs.
Starter: 12V Electric.

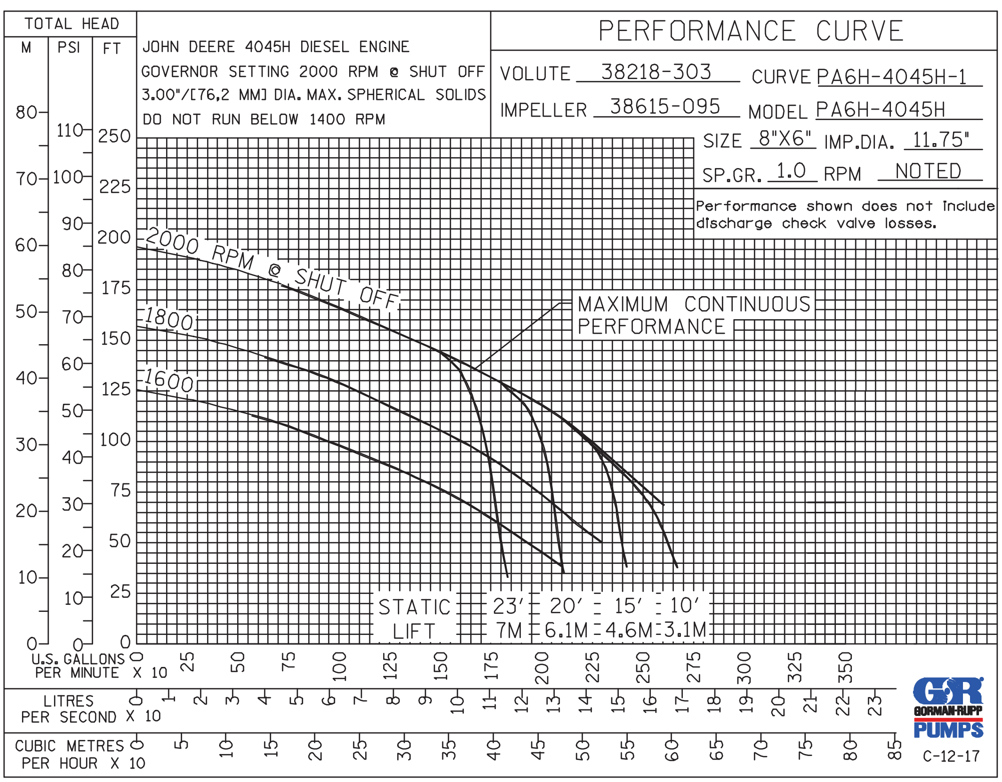
Optional: Electronic Fuel Level Sensor.

Engine Control Features: Padlockable Box with Throttle Control, Tachometer, Coolant Temperature, Oil Pressure, Voltage and Overstart Indicators/Shutdowns. Manual/Stop/Auto Keyswitch. Audible Startup Warning Delay. Fuel Level Display/Alarm/Shutdown (For Use With Optional Fuel Level Sensor).

JOHN DEERE PUBLISHED PERFORMANCE:
Maximum Gross BHP (Continuous)
115 (86 kW) @ 2200 RPM

Specification Data	APPROXIMATE DIMENSIONS and WEIGHTS	NET WEIGHT: 5300 LBS. (2404,0 KG.)
SECTION 42, PAGE 1142		SHIPPING WEIGHT: 5500 LBS. (2494,8 KG.)
		EXPORT CRATE SIZE: 473 CU. FT. (13,4 CU. M.)





GORMAN-RUPP PUMPS

www.grpumps.com

Specifications Subject to Change Without Notice

Printed in U.S.A.

CD225M Dri-Prime® Pump

WITH FINAL TIER 4 (FT4) DIESEL ENGINE

The Godwin Dri-Prime CD225M pump offers flow rates to 3240 USGPM and has the capability of handling solids up to 3.0" in diameter.

The CD225M is able to automatically prime to 28' of suction lift from dry. Automatic or manual starting/stopping available through integral mounted control panel or optional wireless-remote access.

Indefinite dry-running is no problem due to the unique Godwin liquid bath mechanical seal design. Solids handling, dry-running, and portability make the CD225M the perfect choice for dewatering and bypass applications.

Features and Benefits

- Simple maintenance normally limited to checking fluid levels and filters.
- Dri-Prime (continuously operated Venturi air ejector priming device) requiring no periodic adjustment. Optional compressor clutch available.
- Extensive application flexibility handling sewage, slurries, and liquids with solids up to 3.0" in diameter.
- Dry-running high pressure liquid bath mechanical seal with high abrasion resistant solid silicon carbide faces.
- Close-coupled centrifugal pump with Dri-Prime system coupled to a diesel engine or electric motor.
- All cast iron construction (stainless steel construction option available) with cast steel impeller.
- Also available in a critically silenced unit which reduces noise levels to less than 70 dBA at 30'.
- Standard engine John Deere 4045HFC04 (FT4). Also available with JCB TCAE-93 (FT4).

Suction connection	8" 150# ANSI B16.5
Delivery connection	8" 150# ANSI B16.5
Max capacity	3240 USGPM †
Max solids handling	3.0"
Max impeller diameter	11.4"
Max operating temp	176°F*
Max working pressure	80 psi
Max suction pressure	73 psi
Max casing pressure	120 psi
Max operating speed	2200 rpm

* Please contact our office for applications in excess of 176°F.

† Larger diameter pipes may be required for maximum flows.

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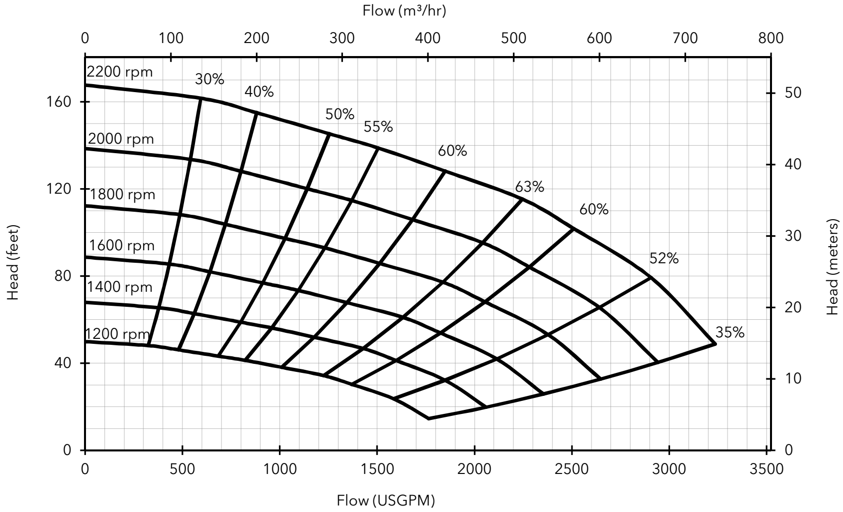
Performance Curve



Materials

Pump casing & suction cover	Cast iron BS EN 1561 - 1997
Wearplates	High Chromium Cast Iron HC403:1977
Pump Shaft	Carbon steel BS 970 - 1991 817M40T
Impeller	Cast Steel BS3100 A5 Hardness to 200 HB Brinell
Non-return valve body	Cast iron BS EN 1561 - 1997
Mechanical seal	Silicon carbide face; Viton elastomers; Stainless steel body

Engine option 1

John Deere 4045HFC04 (FT4), 99 HP @ 2200 rpm

Impeller diameter 11.4"

Pump speed 2200 rpm

Suction Lift Table

Total Suction Head (feet)	Total Delivery Head (feet)				
	42	70	101	121	137
	Output (USGPM)				
10	3148	2906	2325	-	-
15	2906	2543	2058	1695	-
20	1695	1695	1695	1453	-
25	1211	1211	1211	969	387

Fuel capacity: 100 US Gal

Max fuel consumption @ 2200 rpm: 6.4 US Gal/hr

Max fuel consumption @ 1800 rpm: 3.3 US Gal/hr

Weight (Dry): 5,500 lbs

Weight (Wet): 6,220 lbs

Dim.: (L) 155" x (W) 77" x (H) 97"

Performance data provided in tables is based on water tests at sea level and 20°C ambient. All information is approximate and for general guidance only. Please contact the factory or office for further details.

Engine option 2

JCB TCAE-93 (FT4), 118 HP @ 2200 rpm

Impeller diameter 11.4"

Pump speed 2200 rpm

Suction Lift Table

Total Suction Head (feet)	Total Delivery Head (feet)				
	42	70	101	121	137
	Output (USGPM)				
10	3148	2906	2325	-	-
15	2906	2543	2058	1695	-
20	1695	1695	1695	1453	-
25	1211	1211	1211	969	387

Fuel capacity: 100 US Gal

Max fuel consumption @ 2200 rpm: 6.2 US Gal/hr

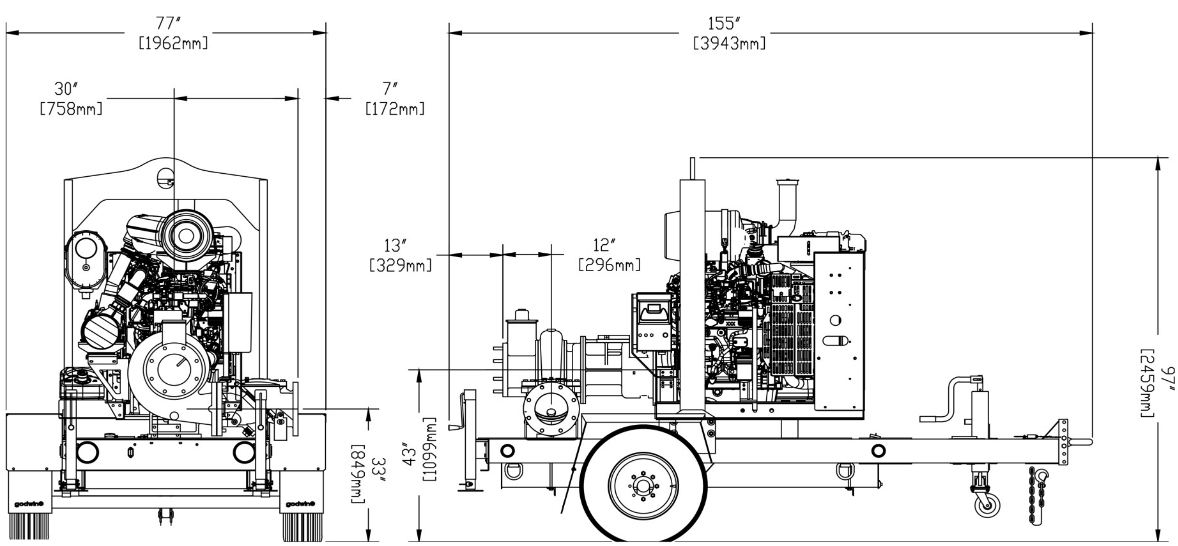
Max fuel consumption @ 1800 rpm: 3.3 US Gal/hr

Weight (Dry): 5,230 lbs

Weight (Wet): 5,950 lbs

Dim.: (L) 155" x (W) 77" x (H) 97"

Performance data provided in tables is based on water tests at sea level and 20°C ambient. All information is approximate and for general guidance only. Please contact the factory or office for further details.



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