

OUR BLOWERS ARE TOO LARGE! WE'RE WASTING TOO MUCH ENERGY!....HMMM..MAYBE NOT!

Authors: ¹B. Hodgson, ²R. Subramanian, ²B. Cavanaugh, ³D. Rosso, ¹K. Brischke, ³M. Garrido-Baserba

Affiliation: ¹AECOM, CO, ²Colorado Springs Utilities, CO, ³University of California, Irvine, CA

Keywords: Blower replacement, BNR, diffuser replacement, blower modifications, aeration system improvements

Key Takeaway: The payback of partial or complete blower replacement may not be justified even in the event of excessive aeration, and sequencing of aeration system improvements including diffuser replacement, process controls, and blower modifications / improvements should be considered and evaluated together.

1. Introduction

Aeration system requirements represent one of the largest energy costs for water resource recovery facilities (WRRFs), therefore, it is important for WRRFs to maximize the efficiency of the aeration operations. As operational improvements or plant upgrades are made, WRRFs may consider replacing existing blowers to achieve more efficient aeration operations. The benefit and payback of blower replacement is largely dependent on the reduction of aeration energy. Therefore, it can be challenging to know when the replacement cost is offset by the energy savings.

A study was performed at the Las Vegas Street WRRF (LVS WRRF), a 75 MGD Biological Nutrient Removal (BNR) WRRF, shown on Figure 1 that is operated by Colorado Springs Utilities (CSU). Since the blowers were installed, CSU has gone through a variety of system improvements that impact the aeration requirements at LVS WRRF. Primarily, CSU constructed the J.D. Phillips WRRF (JDP WRRF) to treat a portion of the city's wastewater that historically was treated at LVS WRRF. Additionally, the State of Colorado recently implemented nutrient regulations through the adoption of Regulation 85 and revisions to Regulation 31. Regulation 85 establishes total inorganic nitrogen (TIN) and total phosphorous (TP) requirements for wastewater treatment facilities (WWTF) and Regulation 31 established stream based total nitrogen (TN) and TP standards that may further limit effluent discharge from WWTFs. Therefore, the facility is currently constructing modifications to convert from Modified Ludzack-Ettinger (MLE) to anaerobic, anoxic, oxic (A2O) as shown on Figure 2.

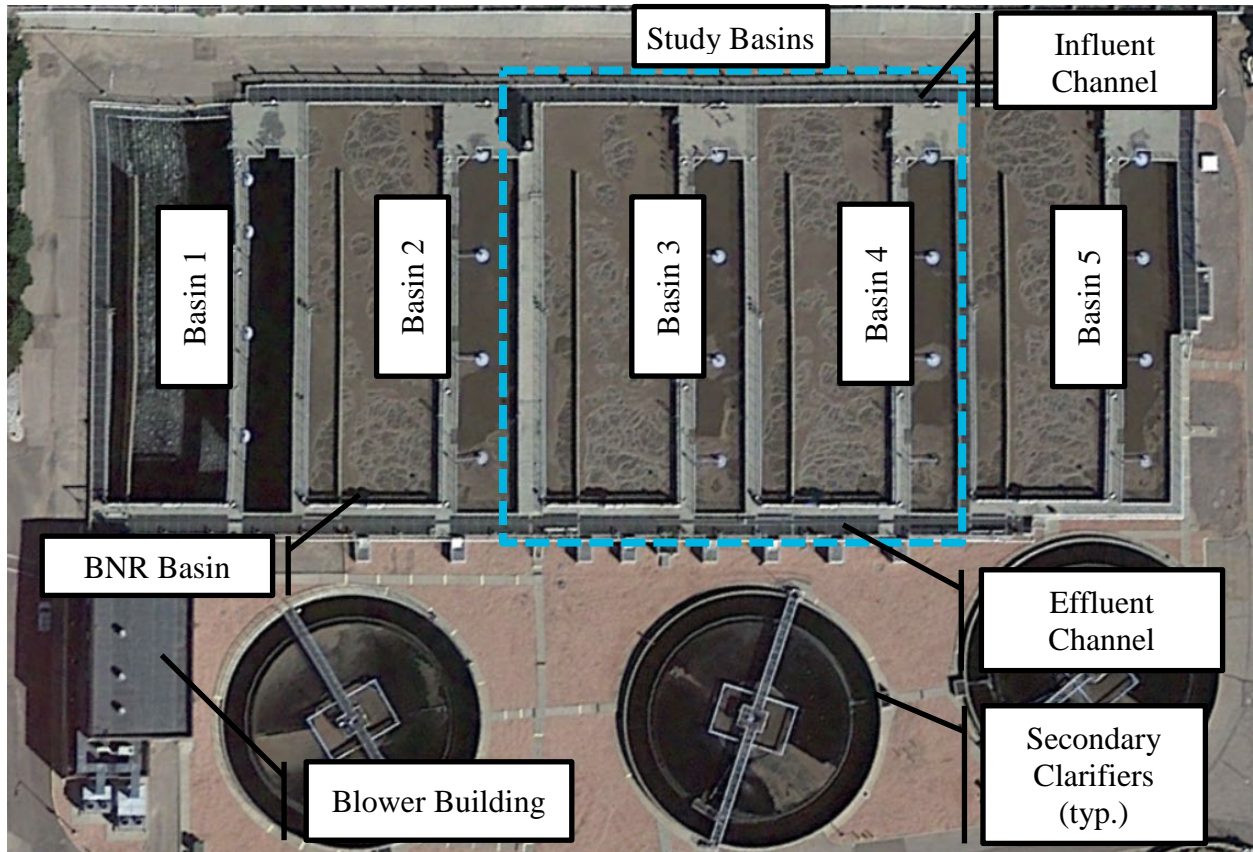


Figure 1. Site Overview

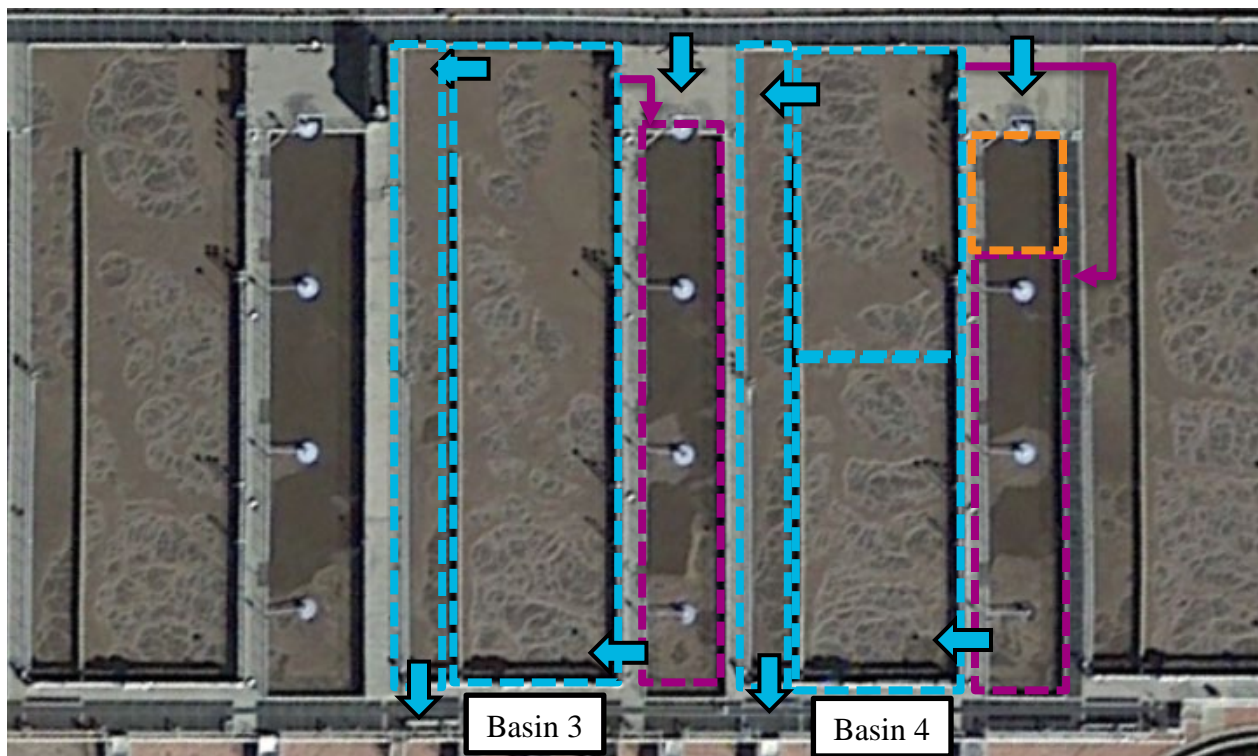


Figure 2. BNR Configuration for Basin 3 (MLE) and Basin 4 (A2O) aerobic zone indicated in blue, anoxic zone and mixed liquor return indicated in purple and anaerobic zone indicated in orange.

The existing blowers and aeration system at LVSRRF were installed during previous activated sludge facility upgrades and started operation in October 1995. With LVSRRF process improvements to A2O and completion of the JDPWRRF there has been a reduction in the aeration system demands as a result of carbon consumption in the anaerobic basin and with some flow and loads now diverted to JDPWRRF. The WRRF has three existing blowers, but only one is necessary to meet typical aeration requirements under all operating conditions. Additionally, there is a blow-off valve on the aeration system that regularly operates wasting excess air when the aeration system requirements are below the minimum capacity of the existing blower(s). Therefore, it was hypothesized that there may be a benefit in replacing the blowers resulting from these significant process changes.

The objective of this study was to evaluate and identify opportunities for improved aeration system operations and the potential value of replacing one or more of the existing blower(s) to better meet the low end aeration requirements and negate the need to blow-off excess process air thereby leading to energy savings resulting in lower O&M costs. Providing excess aeration not only wastes energy, but can also have negative process implications if dissolved oxygen is not minimized in the mixed liquor recycle (MLR) and return activated sludge (RAS) streams. Carrying oxygen back to the anaerobic and anoxic zones in these streams will have a deleterious effect on denitrification and phosphorus removal efficiency.

2. Methods

To determine the cost-benefit of blower replacement the evaluation reviewed historical data, completed a condition assessment of existing equipment, performed off-gas testing to characterize oxygen transfer efficiency, and utilized wastewater process modeling (BioWin™, EnviroSim Associates, Hamilton, Ontario, version 5.3) to consider the impacts of various process changes. This information was used to develop alternatives for modifying the existing blowers, replacing some or all of the existing blowers, and/or implementing other process improvements. These alternatives were evaluated against the no change alternative to develop a cost benefit for each blower improvement alternative. An overview of the methods for each of these evaluations is described in the section below.

2.1. Historical Data Review

Historical data was reviewed and served as the basis for evaluating the current and future system aeration performance and requirements. The historical data review primarily included review of historical and projected flow rates, water quality data, measured air flow, and operational information provided by CSU.

Air Flow

CSU has a total of 10 air flow meters at the aeration basins, one air flow meter to the Mixed Liquor (ML) channel, and one air flow meter at the blow-off valve. CSU provided historical air flow data from August 6, 2017 to December 4, 2017.

Influent Flow

The historical plant influent flow rates were reviewed from 2009 through 2017 to characterize normal influent flow conditions. Over this period of time the historical flows into the plant have been fairly consistent. A typical annual flow pattern was developed based on the observed influent flow. Additionally, considerations were made to the future flow projections to LVSWRRF developed from the Clear Spring Ranch Resource Recovery Facility Plan (CSRRRFP) which projected an increase in flow by 30% at buildout.

Influent Water Quality

The influent water quality characteristics define the influent loading into the plant and have significant impacts on the aeration system requirements. Historical water quality data was reviewed for Carbonaceous Biochemical Oxygen Demand (CBOD), Total Suspended Solids (TSS), Ammonia (NH_3), and Phosphate (PO_4) based on influent load and concentration into the plant. Based on the historical data, a daily average concentration value was developed representing the typical influent concentrations into the LVSWRRF. At build-out, it is assumed that the influent concentrations will not significantly change and therefore the influent load into the plant will increase as a function of the influent flow.

2.2. Condition Assessment

A condition assessment was performed to assess and quantify the useful life remaining of all components associated with the aeration equipment to include remaining life as part of the alternative scoring. The assessment included the blowers, blower building, electrical and controls, instrumentation, associated piping, blow-off valve, control valves, diffuser piping and diffusers. With exception of the blow-off valve and diffusers, the equipment was found to be in satisfactory condition with remaining useful life that would not justify replacement.

2.3. Off-Gas Testing

The oxygen transfer efficiency (OTE) and diffuser performance of the facility significantly impacts the overall aeration system requirements. To characterize the oxygen uptake rate (OTR) and standardized oxygen transfer efficiency (SOTE), an Off-Gas Test was conducted in accordance with ASCE Standard for testing in process water (ASCE, 1997). LVSWRRF currently utilizes 9" Sanitaire Ceramic Disc diffusers that were installed at the same time as the blowers. The diffusers are periodically maintained, but were assessed to be in overall poor condition nearing end of life.

The off gas testing was performed at two of the aeration basins, one aeration basin that has been converted to the A2O configuration and another basin that was still configured as MLE at the time of testing. The results of the off-gas testing were input into the process model to assess the benefit of replacing diffusers and the potential impact on replacing blowers.

2.4. Process Modeling

Process modeling was performed to quantify the existing system aeration requirements and evaluate process modifications or system improvements that would impact those requirements. CSU provided AECOM with the current BioWinTM model which includes the latest BNR

project's improvements. AECOM reviewed the model to ensure that the model accurately depicts the process configuration after the BNR improvements and created an updated model to reflect the process configuration during the off-gas testing. The revised models were used to determine the impacts of different process configurations on airflow requirements at LVSRRF.

Since the external environmental conditions such as air temperature, influent flow temperature, relative humidity, etc., exert an influence on aeration requirements and change throughout the year, the representative year was divided into three segments representing winter, summer and spring/fall for influent flow, water quality and temperature. Each model file was run for 30 days to generate diurnal airflow requirements for that seasonal period.

Various process control options and configurations were modeled to estimate air demands including ammonia based airflow control (ABAC), anaerobic/anoxic/oxic (A2O) representing existing configuration, nitrite shunt, and 5-stage Bardenpho®. Additionally, the modeling considered the aeration impacts of future regulation (Regulation 85 and Regulation 31) effluent limits on TN and TP, and impact of diffuser replacement on the aeration system. The various process configurations were analyzed for the developed summer input period where the widest range of minimum and maximum air flows is estimated.

2.5. Alternatives Evaluation and Payback

An alternatives evaluation was performed to consider various alternatives for replacing the blowers. Each alternative was evaluated against the various scenarios of air flow requirements as determined from the historical data review and process model results. A payback was calculated for each alternative based on the power consumption, operational cost and capital cost of each alternative. The method for determining the power consumption and costs for each alternative is described below.

Power Consumption

The power consumption of blowers is the largest portion of a blower's life cycle cost. The power consumption for each of the alternatives was evaluated using a developed linear relationships between blower air flow rate, power consumption, and energy cost. The power consumption of the existing blowers was determined based on a linear regression of the historic data. Equation 1 shows the linear regression developed to determine the relationship between power usage and air flow rates in SCFM. To determine power consumption of the replacement blowers, linear regression relationships were developed based on the information received from the manufacturer based on air flow rates provided from the process model and historical data review.

$$Power \left(\frac{kW}{h} \right) = 0.0431 \times Air \text{ Flow Rates (SCFM)} + 147.98 \quad \text{Equation 1}$$

Energy Cost

The annual electricity cost was determined based on historical electricity cost data. Three different bills were used to analyze and calculate the average cost of electricity. The energy costs are primarily a function of the energy consumed and a demand

charge where energy consumption is variable based on the kWh of energy use and the demand charges are determined as the highest average kW measured in a 15-min interval during the billing period. The demand charge is set to cover the power utility's fixed costs of having equipment on standby mode to satisfy excess energy needs when needed. On average, usage charges are 2.6 cents per kWh and demand charges are 4.1 cents per kWh which result in an average cost of electricity of 6.7 cents/kWh. As the electricity cost varies based on demand charges, the payback period was evaluated at electricity costs of 6 and 7 cents per kWh.

Blower Maintenance Costs

Maintenance costs of the existing three blowers were obtained from historical data from 1999 to 2017 where there was an average annual maintenance cost of \$5,700 per blower. Annual maintenance costs for the new low end capacity blowers were provided by the equipment manufacturers.

Capital Costs

Budgetary prices were obtained from blower vendors and valve suppliers to prepare an AACE Class 5 Engineer's Opinion of Probable Construction Cost (EOPCC) for each developed alternative. Capital costs for each alternative include cost for major equipment, mechanical and electrical modification, structural, pipeline and appurtenances, mobilization, construction contingency, Engineering, Legal, Administrative, and Construction Management (ELAC), and project contingency.

3. Results and Discussion

3.1. Existing Blower Capacity

The LVSWWRF currently has three KA66SV-GL400 Turblex blowers that were installed in 1995. Based on the current system needs, typically only one blower is in operation. The blowers are regularly maintained but do experience occasional process upsets that may trip off a blower requiring operators to manually restart the blower. While the blowers have been regularly maintained, no significant improvements or modifications have been made to the blowers since startup.

Based on the guaranteed performance testing data, the existing blowers have a capacity of 16,000-37,600 acfm at typical operating conditions (70 deg F, 30% Relative Humidity). Therefore, at standard conditions each blower is individually capable of supplying 12,347 – 29,014 scfm.

3.2. Measured and Wasted Air Flow

A system motorized blow-off valve is installed on the mixed liquor channel aeration header to allow excess air to be discharged into the atmosphere instead of being dumped into the aeration basins creating over-aeration. The process airflow rates measured at the aeration basins and mixed liquor channel excluding blow-off air flow is shown in Figure 3.

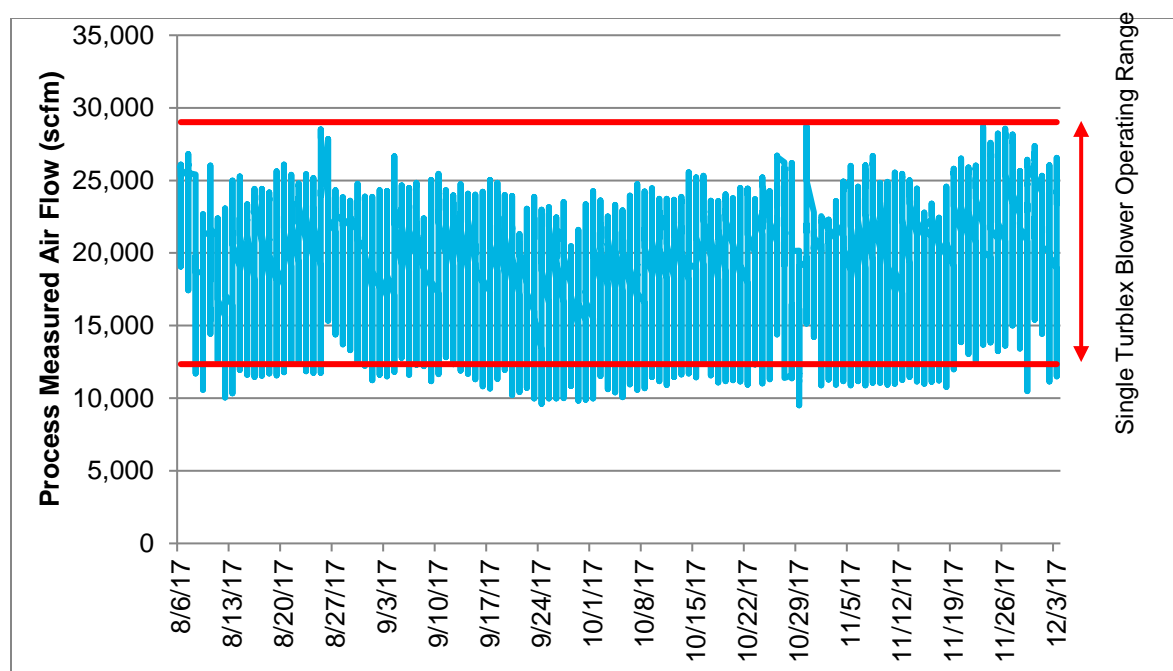


Figure 3. Process Measured Air Flow (excluding Blow-Off)

CSU has indicated that previously the blow-off valve was programmed to remain ~3% open and not fully close. This was done because it was previously believed that the blowers have tripped off due to the blow-off valve failing to properly open. Therefore, an air flow balance was performed by summing up the measured process air requirements (excluding blow-off) and then calculating what the blow-off air should have been based on a minimum blower capacity of 12,347 scfm. These results are indicated in Figure 4.

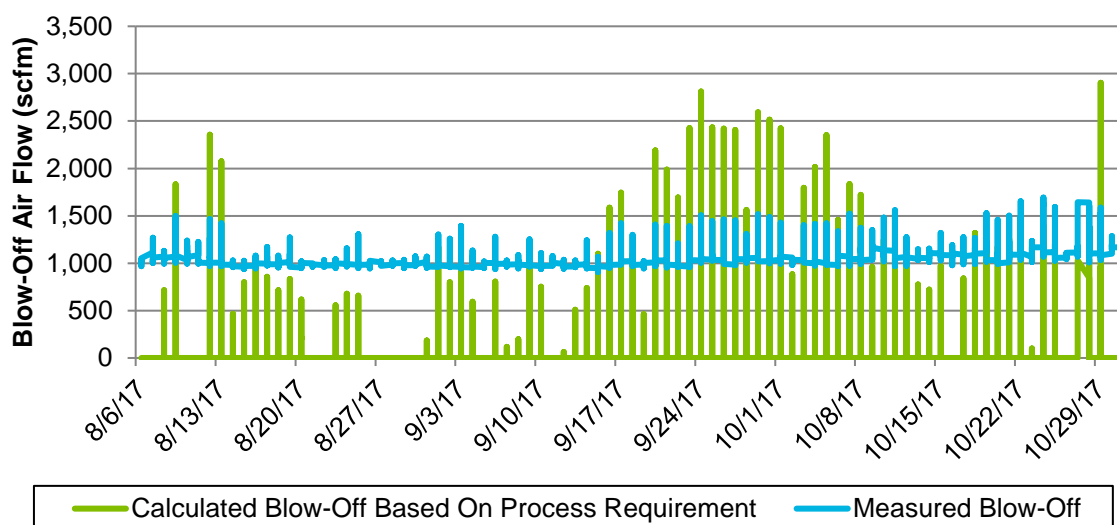


Figure 4. Estimated and Calculated Blow-Off Air at LVSWRRF

The blow-off air flow meter indicates that approximately 1,000 scfm is wasted constantly, with a peak of approximately 1,500 scfm for less than one hour each morning. Comparing that to the air flow balance, it appears that the actual blow-off should not operate continuously, with a blow-off

only occurring approximately once per day each morning. While the blow-off should operate daily, the duration the valve would actually open is less than 30 min/day on average during low influent loading into the plant at around 6:00 am when the process aeration requirements are at a minimum.

It is important to note that the air flow meters have not been recalibrated since installation and therefore there is some uncertainty in terms of meter accuracy. To verify the existing air flow estimate measured by the meters, the reported meter values were checked against the manufacturer provided power to air flow capacity curves of the blowers, the estimated air flow based on the power meter data, and air flow estimates measured during the off-gas testing. While there is uncertainty about the individual meter accuracy, the net meter accuracy was consistent with the reported blower capacity and the other approaches used to estimate the existing air flow at the LVSRRF.

3.3. Off-Gas Testing and Diffuser Replacement

The oxygen transfer efficiency (OTE) and diffuser performance of the facility significantly impacts the overall aeration system requirements. To characterize the oxygen uptake rate (OTR) and standardized oxygen transfer efficiency (SOTE), an Off-Gas Test was conducted on two of the aeration basins; Basin 3 which was configured as MLE and Basin 4 which was configured as A2O. The findings from this testing suggests that overall the system suffers from excessively high dissolved oxygen (DO) in the aeration basin which drives down the OTE. This does not necessarily indicate oversized blower capacity, but does indicate limitations with the current aeration process controls. Based on the off-gas testing results, there are opportunities for improved oxygen transfer efficiency with control modifications and diffuser replacement which could reduce the overall aeration requirements of the system by limiting overaeration in certain areas of the basin.

In Basin 3 (MLE), the oxygen uptake rate (OUR) is highest at the upfront portion of the system and then tapers down quickly across the length of the basin (Figure 5). The CSU does not have separate control valves on the aeration system, therefore the system is limited to a single setpoint for controlling the DO highly dependent on where the probe is located in the basin. This limits the control of optimizing aeration to the system resulting in excessive air on the front end of the basin corresponding to a high OUR.

In Basin 4 (A2O), a different OUR profile is observed (Figure 6). With the A2O conversion improvements, a baffle wall is constructed half way down the aeration basin dividing the aeration basin into two different zones and there is the ability for the aeration system to the basin to be adjusted based on a cascading DO setpoint referencing two meters. However, a single control valve controls the airflow to both zones of the basin therefore they both still receive the same airflow supply. With construction of the baffle wall, a delayed and more uniform OUR is observed in the upstream zone of the aeration basin, and a more uniform lower OUR is observed in the downstream zone of the aeration basin. This indicates that the upstream basin does more of the work in terms of BOD removal and nitrification. Again, this highlights that there is opportunity for improved aeration controls particularly by installing control valves to independently supply air to the upstream and downstream zones in the aeration basin.

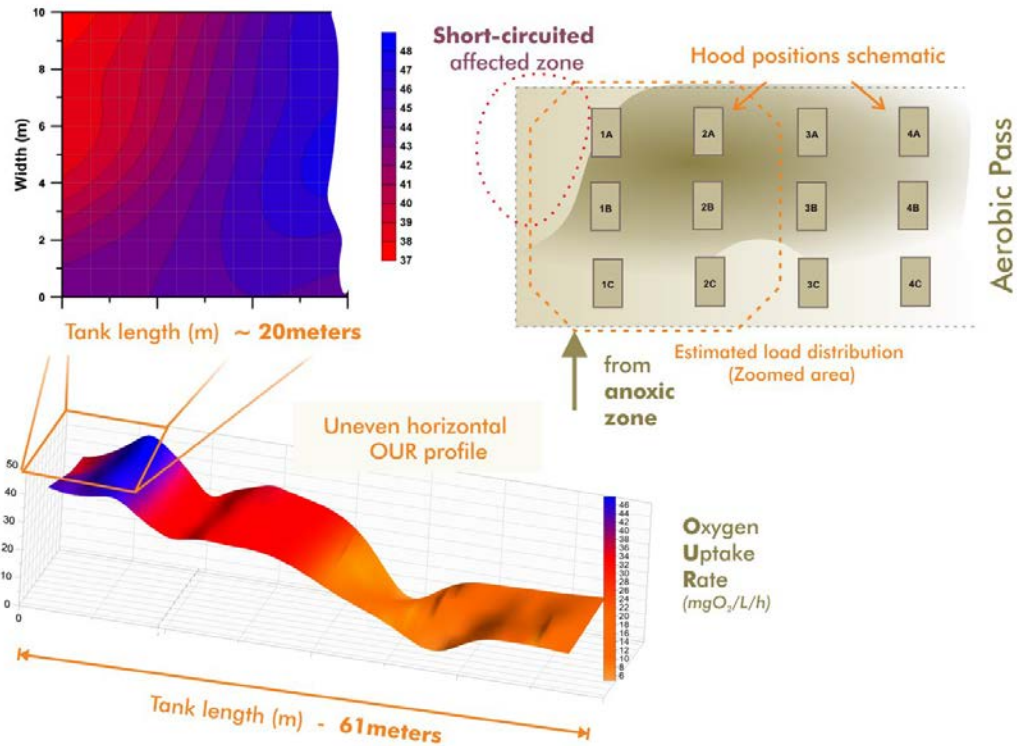


Figure 5. Basin 3 (MLE) Oxygen Uptake Rate based on Off-Gas Testing (Developed by M. Garrido-Baserba)

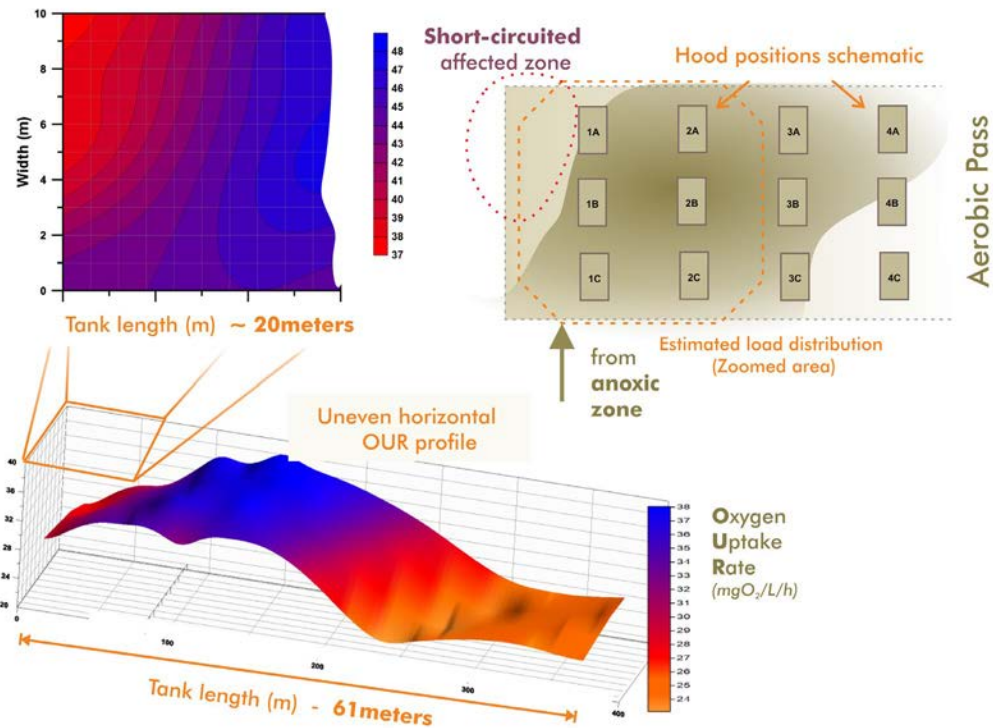


Figure 6. Basin 4 (A2O) Oxygen Uptake Rate based on Off-Gas Testing (Developed by M. Garrido-Baserba)

3.4. Process Modeling

Air Flow Ranges based on Process Configuration

Using the alpha factors developed as part of the off gas testing, various process configurations were developed to characterize the typical range of existing process air requirements under nitrite shunt, ABAC, A2O and 5-Stage Bardenpho process configurations. A typical week of the process model results under the alternative configurations for summer conditions is shown in Figure 7.

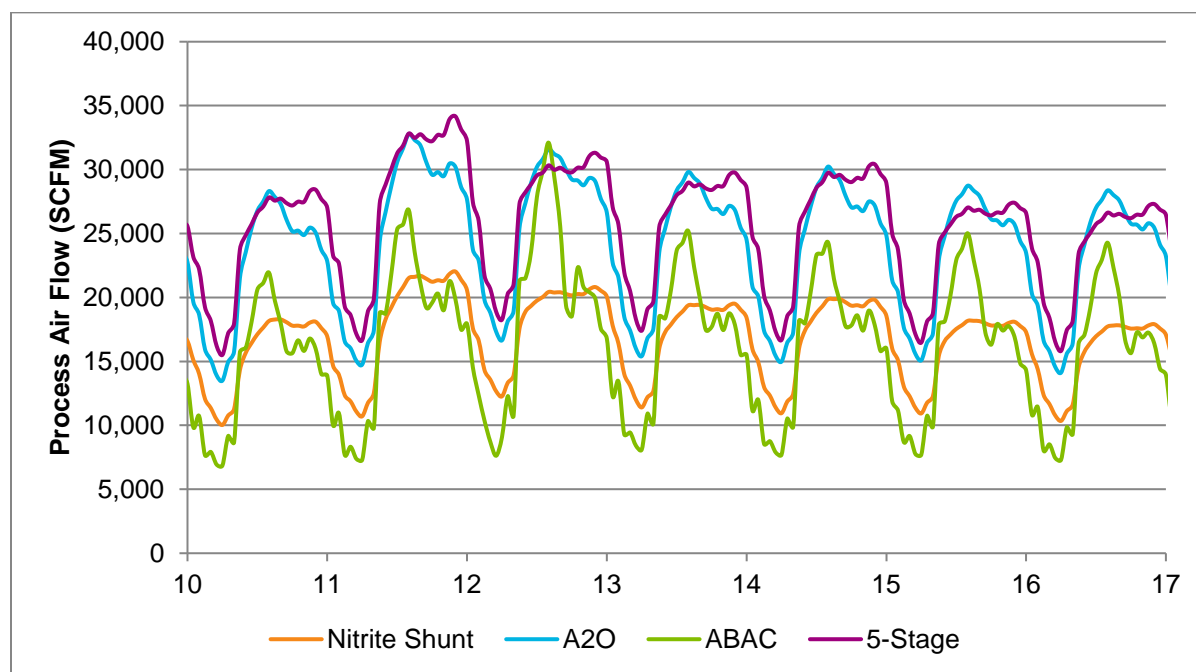


Figure 7. Process Air Flow Comparison

The identified range for each of the evaluated processes is presented in Figure 8. The results indicate that there is, understandably, little impact to the aeration system requirements under the 5-Stage and A2O configurations. This is because the LVSWRRF currently achieves complete nitrification so the majority of the process benefit for changing to 5-Stage Bardenpho would be improved denitrification which occurs under anoxic conditions, and biological P removal. The most significant process modification for reducing the aeration system requirement would be adopting ABAC or nitrite shunt which can reduce the average aeration system requirements by 35% or 30% respectively. Note that overall, the total airflow range for nitrite shunt is significantly less than that for ABAC. This is due to the fact that nitrite shunt short-cuts the conventional nitrification/denitrification process by utilizing the nitritation/denitrification process, eliminating the aeration requirements to convert nitrite to nitrate.

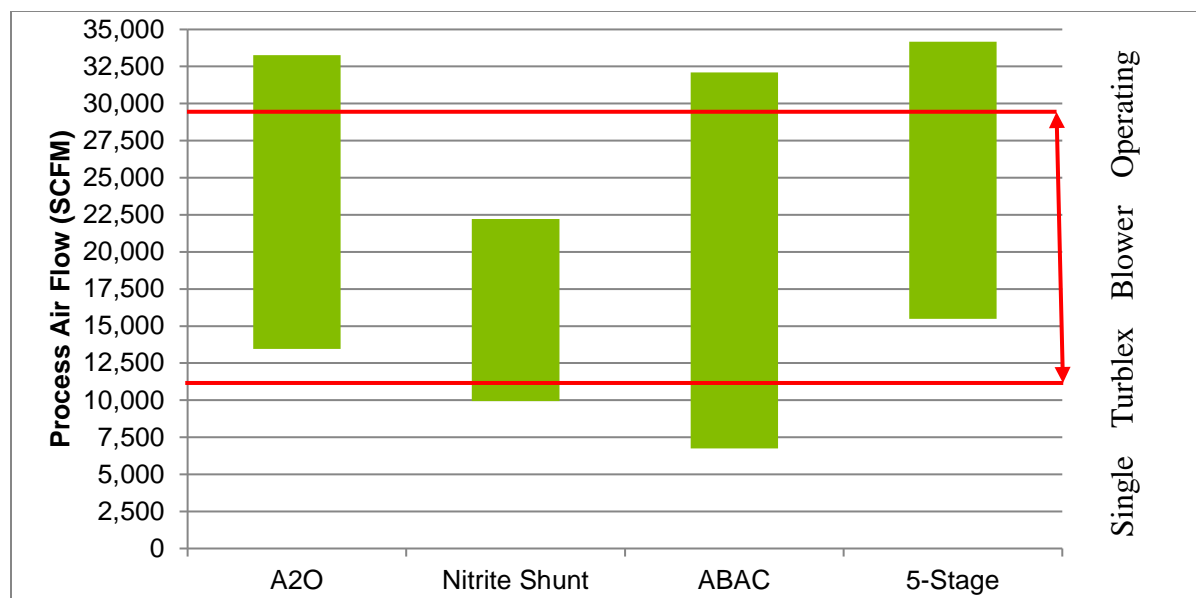


Figure 8. Process Air Flow Ranges

Potential Air Flow Ranges based on Diffuser Replacement

In addition to process controls, diffuser replacement would improve the oxygen transfer efficiency at the aeration basins and reduce the system aeration requirements. Based on the condition assessment and off-gas testing, the existing diffusers are nearing end of life and warrant replacement. For this evaluation, three scenarios for diffuser replacement were considered which included replacing the existing disc diffusers in-kind, installing new tube diffusers, or installing new panel diffusers. The estimated impacts based on the different types of diffusers are shown in Table 1.

Table 1. Estimated Alpha and SOTE for Replacement Diffusers

	Disc	Tube	Panel
Example Manufacturer	Sanitaire	Flexair	Aerostrip
Air Flow Rate (scfm / sqft)	2.0	4.0	0.25
Alpha	No Change	No Change	+0.05
SOTE (%)	+3%	+6%	+9%

The A2O model with DO control was revised to reflect the alpha and SOTE improvements estimated with diffuser replacement identified in Table 1. The diffusers above will have different air flow rates and panel diffusers would also have a different pressure drop; therefore, any upgrades or replacements to blower equipment should be performed concurrently with considerations on diffuser replacement particularly given the age and condition of the existing diffusers.

Process Air Requirements

For purposes of this analysis, the process air requirements were evaluated based on the historical air flow rates that range from 10,956-29,909 SCFM. Scenarios were developed for summer, winter, and spring/fall to evaluate alternative blower configurations for better meeting the low end process air flow requirements while providing overlap with the existing blower airflow range

(10,500-21,000 SCFM). As discussed above there are opportunities through advanced process control or diffuser replacement to potentially reduce the low-end airflow requirement by as much as 30% depending on the improvements and controls adopted by CSU. Therefore blower replacement was also assessed assuming that the aeration system is optimized through replacement of diffusers and implementation of nitrite shunt or ABAC process control reducing the existing aeration system requirements by 30% to a range of 7,669-20,936 SCFM.

To determine the annual power consumption for each alternative, the 2017 historical air flow data was used to select a “typical month” per season which was then used to determine the seasonal power consumption. These values were then combined to calculate the total annual power consumption. Overall there is little variation in aeration requirements based on the information provided by CSU. The alternatives were evaluated against two process air flow conditions: (1) the existing process requirements based on historical air flow meter data, and (2) optimized air flow requirements which are estimated to be a 30% reduction from existing aeration system needs. This reduction could be achieved with diffuser replacement in combination with implementing process control improvements like ABAC or nitrite shunt. The identified typical aeration requirements used for each season are shown in Table 2.

Table 2. Process Air Requirements used for determining Payback

	Existing Process (SCFM)	Optimized Process (SCFM)
Winter	10,479-28,700	7,335-20,090
Summer	10,558-28,518	7,040-19,962
Spring/Fall	9,509-28,742	6,656-20,120

3.5. Aeration System Process Equipment and EI&C Improvements

Potential improvements were identified to the process equipment and EI&C system based on known process issues or in the event that CSU considers different improvements to the process control philosophy or aeration system. These improvements are discussed for the major aeration system process equipment and EI&C components below.

Instrumentation

Given the uncertainty in air flow meter accuracy and age of the existing air flow meters it is recommended that the air flow meters be replaced or recalibrated at the factory to verify meter accuracy. It is important to have an accurate estimate of process air flow requirements to identify optimal aeration system improvements, to allow accurate quantification of payback for alternatives that improve the aeration system performance, and to create functional and accurate process controls.

Field Control Valves

Field control valves should continue to be replaced based on the age and condition. The existing control valve configuration is adequate for DO and nitrite shunt process control. In the event that CSU were to adopt ABAC, the existing control valves should be reconfigured to provide additional control to the B-Pass. To accomplish this, the aeration piping on the B-pass should be replaced to separate the air flow to the front end of the B-Pass and mid-point of the B-Pass with

independent control valves installed on each line and controlled based on the ammonia readings in the front end and mid-point, respectively. Modifications would not be necessary to the C-Pass as DO control would be implemented to ensure that there is complete nitrification prior to the ML channel.

Plant operations staff has also noted that, in addition to replacing or calibrating the air flow meters, replacing the existing valves and valve actuators with models that are designed for air flow control and modulating operation, respectively, would benefit the aeration system process controls.

Blow-Off Instrumentation and Control

The existing blow-off valve should be reprogrammed to only open when the aeration system requirements are below the minimum blower capacity. The reconfiguration should be performed in conjunction with the air flow meter replacement/recalibration to provide CSU with the information necessary to accurately control the blow-off valve operation. Should the existing blowoff valve not operate correctly under the adjusted control scheme, replacement of the valve with a modulating actuator should be considered so that optimal configuration scheme can be implemented.

3.6. Developed Alternatives

Alternatives were developed based on viable considerations working with CSU staff. Primarily, these alternatives include replacing the blow-off valve, modifying one of the existing blowers, or installing new low-end blowers. Modifying or installing a new low-end capacity blower also assumed that the blow-off valve is replaced in order to account for the lower blower capacities that will be achieved. The alternatives were developed by working with manufacturers to obtain recommended blower type and configuration for meeting the LVSWRRF aeration requirements. The developed alternatives are as follows:

Alternative 1 - Blow-Off Valve Replacement

This alternative evaluated replacement of the existing blow-off valve and reprogramming of the control philosophy to prevent the unnecessary wasting of air when the process air requirements are greater than the minimum blower capacity. The current valve installed in the common blow-off manifold has historically failed causing surges to the aeration system and tripping the existing blowers. To prevent surge events in case the valve fails, CSU programed the valve to never fully close. Therefore, the valve is open at all times. Energy consumption reduction can be achieved by replacing the valve and controls to allow the valve to be closed during low flow rate conditions. The blow-off valve will need to fail open as a safety feature to prevent over-pressurization of the discharge manifold.

Alternative 2 – Modify One Existing Blower

This alternative considered modifying one existing Turblex blower by replacing the impeller and contour ring which decreases the blower capacity, lowering the minimum airflow of the existing blower without reducing the energy efficiency at lower aeration operations. The modified blower would have a lower capacity and the two existing blowers would be maintained to meet the high end process requirements. The modified blower would be capable of supplying 10,605-25,250 SCFM.

Alternative 3-7 – New Low End Blower(s)

Alternative 3-7 evaluated installation of new low end capacity blowers that could meet the low end process aeration requirements. The low end blower aeration requirements were estimated to be 10,500-21,000 SCFM. Aeration patterns were developed for these ranges using the previously discussed process models and provided to the different manufacturers to provide a recommendation on their equipment configuration for best meeting this process range, while providing overlap with the existing high end blowers which are to remain in service to meet the high end process aeration demands.

AECOM contacted two integrally geared blower manufacturers and three direct-drive blower manufacturers for recommendations. Based on this information, the following low end capacity blower alternatives were developed:

- **Alternative 3:** Adding one (1) single-stage integrally geared blower
- **Alternative 4:** Adding two (2) single-stage integrally geared blowers
- **Alternative 5:** Adding six (6) single-stage direct-drive blowers
- **Alternative 6:** Adding two (2) multi-stage centrifugal blowers
- **Alternative 7:** Adding four (4) single-stage direct-drive blowers

3.7. Blower Configuration

To determine the power consumption of each alternative, it was assumed that the new blowers will operate within a specific low airflow range provided by the blower manufacturers, and the existing blowers would operate to serve the high end aeration requirements. Given the operating ranges above, overlap between the low end blower and high end blowers is required to allow smooth transitions during normal process conditions is shown in Figure 9.

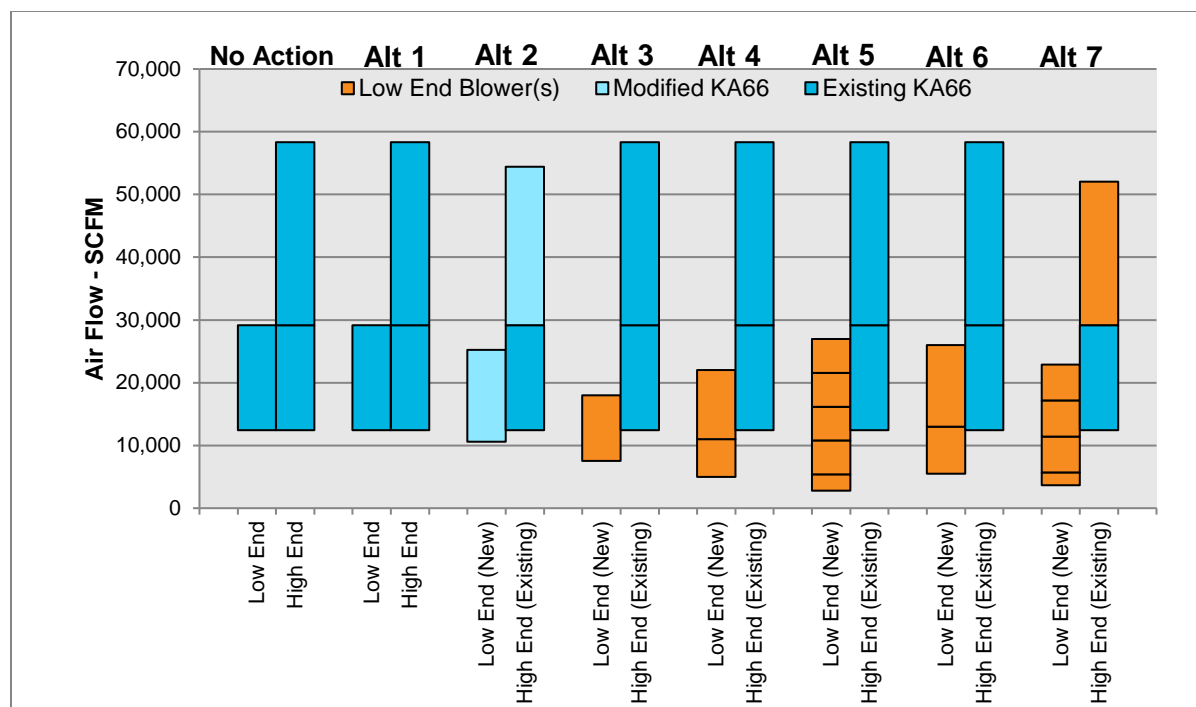


Figure 9. Alternative Blower Configuration Low End and High End Capacity

3.8. Alternatives Evaluation

The above alternatives were evaluated to identify the expected energy savings and payback associated with implementation. To accomplish this, a net present value (NPV) analysis was performed subtracting the initial investment (capital costs) from the present value of the future cash flows calculated for a return rate up to 50 years. For this exercise, the operation and maintenance (O&M) costs savings between the evaluated alternative and the current system were utilized as the future cash flows. Assumptions to perform the NPV analysis were:

- 20 year payback
- 2.25% discount rate
- Electricity costs of \$0.06/kWh or \$0.07/kWh
- 2% annual inflation rate for maintenance costs
- 3% annual inflation rate for electricity costs

The alternatives evaluation was performed under existing and optimized conditions where the optimized condition reflects a 30% energy reduction given control improvements and diffuser replacement. The payback of the alternatives is driven by the energy savings that is achieved. Therefore, the power consumption for each alternative based on the process air requirements and developed linear regression relationships for power consumption and process air requirements. It's important to note for the optimized scenario, at a 30% reduction in energy the maximum anticipated process aeration requirements are less than 21,000 SCFM and therefore would be met completely by the low end blowers for Alternative 4-7.

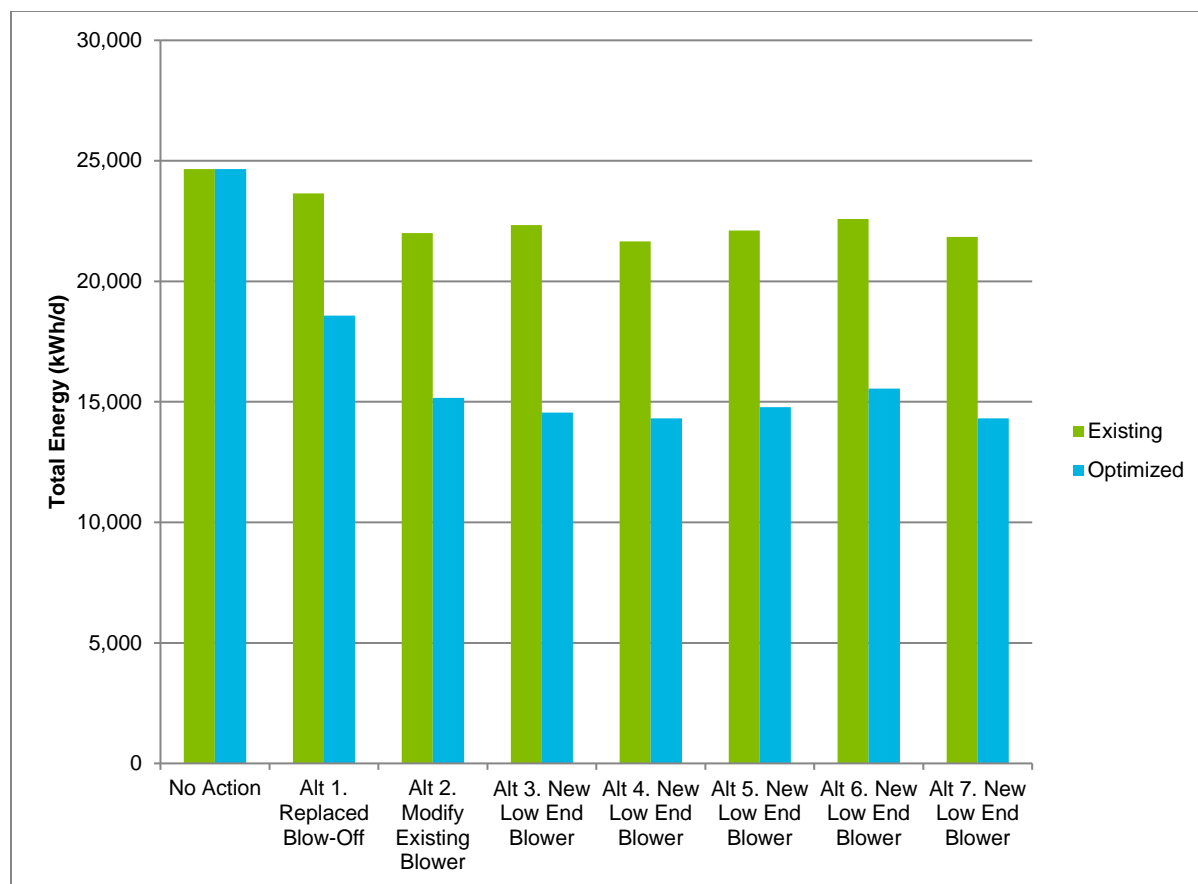


Figure 10. Alternative Comparison of Blower Energy Consumption

Based on these energy rates, the Net Present Cost (NPC) analysis was performed to determine the 20 year cost for each alternative at \$0.06/kWh and \$0.07/kWh. Based on the existing conditions, the NPV and payback for each alternative is presented in Figure 11. Alternatives 1 and 2 are the most cost beneficial with a payback period less than 10 years, while the other evaluated alternatives show a payback period greater than 20 years. As can be seen in Figure 11, the payback period is only slightly shorter at a higher price of electricity. While replacing the existing blowers with lower end capacity blowers will provide the most significant cost savings by reducing the wasted energy and optimizing energy operations, the capital cost for replacing these blowers will exceed the beneficial return that would be achieved over the desired 20 year payback period.

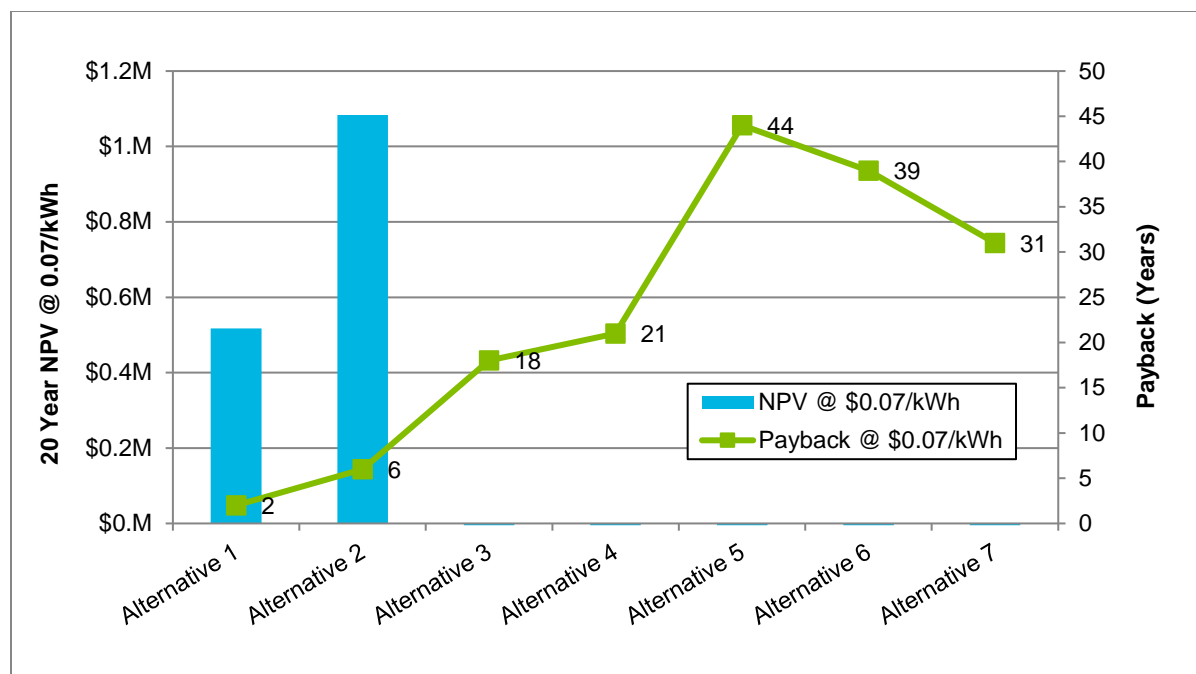


Figure 11. NPV and Payback Period based on Existing Process Requirements

As previously discussed, there are potential opportunities for CSU to optimize the aeration system demand by implementing a different process control philosophy (ABAC or Nitrite Shunt) and replacing the diffusers to achieve an estimated optimized reduction of existing aeration requirements by 30%. Some capital investment would be necessary, primarily for ABAC, to include necessary control valves and infrastructure to aerate based on measured ammonia levels. Additionally, depending on the type of diffuser selected, diffuser replacement may impact the operational pressure of the blowers requiring replacement or modifications. Neglecting these costs, the payback period for the identified alternatives was evaluated at \$0.06/kWh and \$0.07/kWh as indicated in Figure 12. If CSU is able to achieve a 30% reduction in aeration requirements, there will be significant cost savings and shorter payback periods for all of the evaluated alternatives. The most beneficial alternatives would be to modify one of the existing blowers (Alternative 2) or consider replacing with a low end blower where Alternative 3 or Alternative 4 were the most favorable in terms of cost and payback. As previously discussed, there will be some additional capital investment necessary for CSU to achieve a 30% reduction in aeration requirements and it will be important to consider the implementation of these improvements with blower improvements.

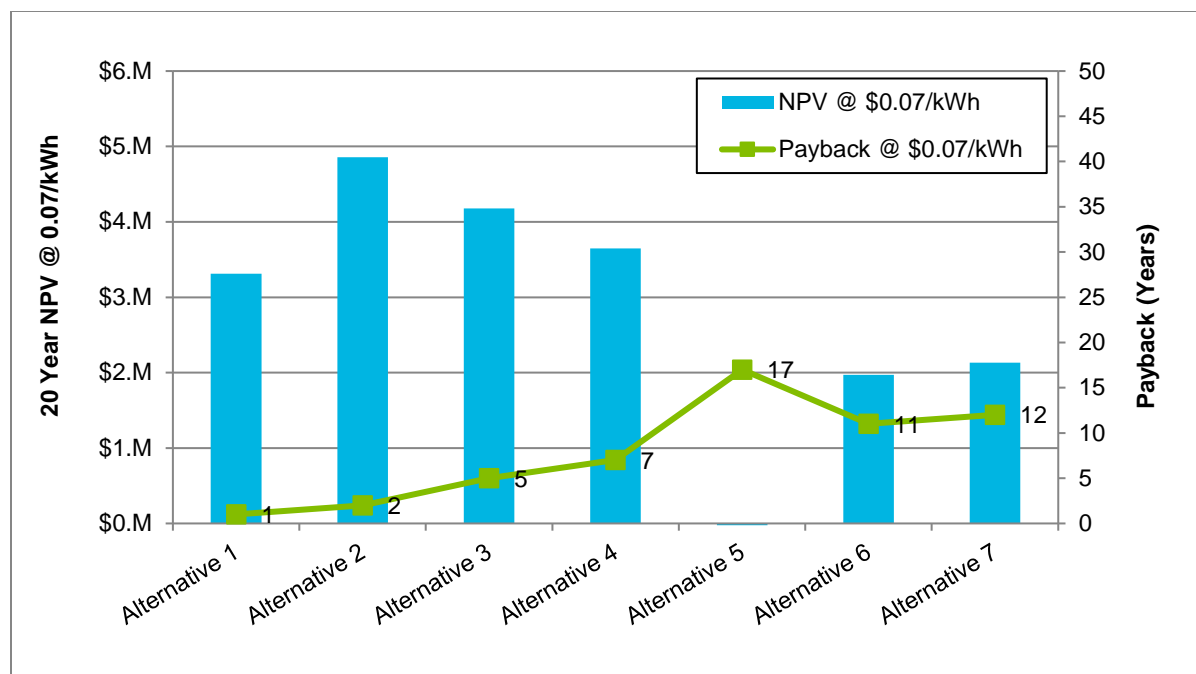


Figure 12. NPV and Payback Period based on Optimized Process Requirements

3.9. Alternatives Monetary/Non-monetary Evaluation

A monetary and non-monetary analysis was performed for each alternative by establishing weights and a scoring matrix of key criteria. This matrix analysis provides an objective evaluation and decision analysis of multiple criteria including both monetary considerations like capital cost, operational cost, and payback, and non-monetary considerations like frequency of maintenance, ease of installation, and operational impacts. Weights were prescribed for each of the identified evaluation criteria, and the individual alternatives were scored based off of the performance of that alternative to the evaluation criteria. The individual scores were then multiplied against the identified weights to generate an aggregate score for each alternative where the higher scores reflect a more preferred alternative. The score scale used for the evaluation criteria ranges from 1 – 5, with 5 being the highest value.

The Monetary/Non-Monetary evaluation was performed based on the existing system operations and optimized process configuration (Figure 13). The existing process configuration shows the total score results for each alternative where Alternative 1 and Alternative 2 score the highest. These two alternatives have the lowest capital costs and payback periods and at the same time do not require major updates to existing operations. Alternatives 4 thru 7 scored the lowest. Even though some of these alternatives resulted in O&M cost savings, the capital investment required to implement them is high. Also, the implementation of these alternatives will require significant changes and capital investment to the current system compared to Alternatives 1 and 2.

Under the optimized process configuration, Alternative 2 is still identified as the preferred alternative with Alternative 3 identified as the most preferable of the blower replacement alternatives.

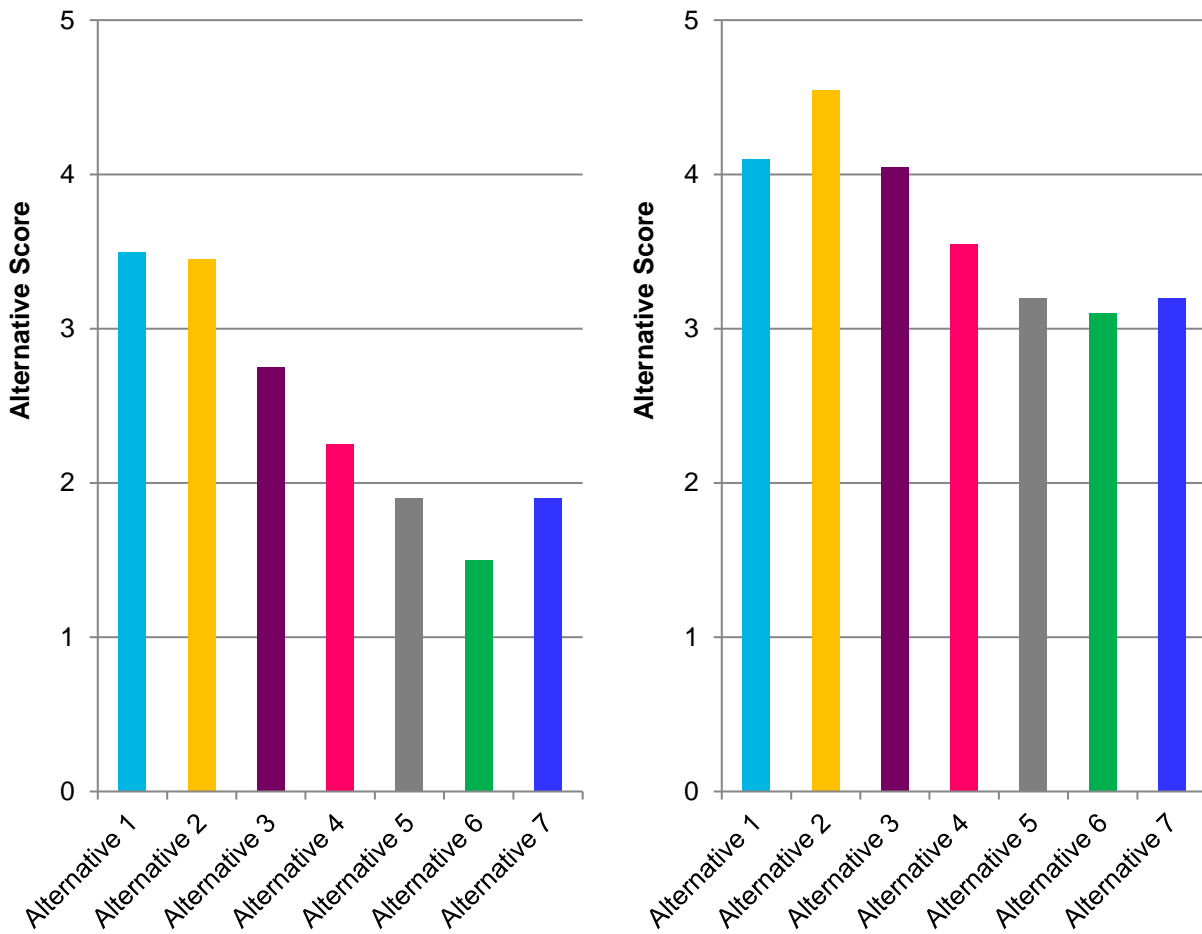


Figure 13. Alternatives Matrix Scoring Results based on Existing Process Configuration (Left) and Optimized Process Configuration (Right)

4. Conclusion

At WWTFs, the blowers and aeration system is the highest operational cost therefore there is significant motivation in optimizing this process. With CSU system improvements including completion of a new WWTF and conversion to the A2O process arrangement, there were concerns with the efficiency of the aeration system largely resulting from the size of the blowers. The evaluation considered blower replacement under the existing operations and a variety of scenarios for improving the aeration process at the LVSRRF. Through off-gas testing and process modeling, it was estimated that as much as 30% reduction in the aeration requirements could be obtained with diffuser replacement and process control improvements including installation of additional control valves on the aeration lines and implementing a more sophisticated DO or ABAC control system.

The payback period for the blower replacement was assessed under two scenarios, existing aeration system requirements and 30% improvement to the aeration system. Under the existing aeration system, there is a 6 year payback to modify one of the existing blowers, but it is not a favorable to install new low end capacity blowers to better meet the low end aeration requirements (>18 years). If the aeration system is optimized through diffuser replacement and process control improvements, then the payback period for modifying an existing blower reduces to 2 years, and installing new low end capacity blowers is greatly improved (5-17 years). The preferred improvement in both cases is modifying an existing blower which resulted in the highest NPV and lowest payback (2-6 years). Installing new low end capacity blowers was also favorable only under the optimized scenario with a payback as low as 5 years.

The case study identified that there is a potential benefit for blower replacement, however there is a need to optimize the aeration system before this investment should be considered. With this understanding the following approach was developed working with CSU for the LVSRRF aeration system.

1. Blow-Off Reconfiguration – reconfigure the existing blow-off to close when process aeration demands are above the minimum blower capacity. This is believed to primarily be a reprogramming exercise and no fatal flaws were identified with the existing blow-off valve location or control valve configuration. Successful reconfiguration of the blow-off is necessary in order to make any blower modification or low end capacity blower replacement cost beneficial. Without reconfiguring the blow-off, there is no payback to blower modifications or replacement due to the constant wasting of air.
2. Diffuser Testing – due to the age, condition, and performance of the existing diffusers, AECOM recommended on-site testing of diffusers to identify the preferred diffuser for replacement at LVSRRF. Considerations for diffuser replacement should be made prior to significant modification to the blower system to ensure adequate sizing of all blower equipment. It is recommended that this be done prior to modifications to one of the existing blowers because diffuser selection may impact the blower modifications. For example, the preferred diffuser may require a different differential pressure.

3. EI&C Improvements – recalibrate and/or replace process air flow meters to allow for precise control and better understanding of the existing aeration system needs to allow for clear quantification of the payback period associated with process improvements and/or blower replacement. Accurately maintaining the air flow meters will provide a better understanding for optimizing the energy use in the aeration system, and also allow for better process controls which can improve treatment reliability and treatment efficiency (avoiding excess aeration returned to anoxic zone and maintaining carbon availability for denitrification).
4. Process Control Improvements – CSU should seek to optimize the process efficiency prior to reconfiguring or installing low end capacity blowers. AECOM recommends adoption of an ABAC process control philosophy similar to the existing JDPWRRF that would decrease the aeration system requirements at LVSWRRF. Nitrite shunt also provides a significant reduction in aeration requirements, but has only been implemented at limited warm weather facilities and therefore poses greater operational risks. Successful implementation of either ABAC or nitrite shunt would reduce the payback period of reconfiguring or installing one of the low end capacity blower replacements.
5. Review proposed alternatives based on the above improvements and re-assess the benefits of blower improvements. This study identified reconfiguring one of the existing blowers, Alternative 2, to be a cost effective option for reducing the aeration system energy use with a payback period between 2-6 years depending on the estimated process air demands after the proposed improvements.

It is recommended that CSU implements recommendations 1-4 prior to significant blower modifications/improvements to optimize the aeration system to ensure that investments in the blowers can best meet the future system needs. After implementing the above recommendations, in particular, an advanced aeration control method, CSU should revisit the process aeration system requirements to reassess opportunities for improving the blower operations. The findings in this study suggest that reconfiguring one or more of the existing Turblex blowers will likely be the most cost-effective and preferred alternative for improving the aeration system performance (Alternative 2). If process demands are driven down by 30% of the existing process requirements through improved control, modifying the existing Turblex blower would have a payback of ~2 years. Even based on the existing aeration system demands, Alternative 2 provides a favorable payback period of less than 6 years.