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TECHNICAL MEMORANDUM

TO: Ms. Louanna Cruz, CDPHE - WQ Finance

FROM: Phillip Sack, P.E.

SUBJECT: Green Project Reserves - Business Case Requirements

On behalf of the City of Fruita (City), we are submitting this Technical Memorandum regarding Green Project Reserves – Business Case Requirements. The City's new Wastewater Reclamation Facility (WWRF) utilizes the activated sludge process to achieve biological reduction of biochemical oxygen demand and nutrient constituents. The aeration system for the activated sludge process is the most energy intensive system of a WWRF, requiring in excess of 55 percent of the facilities total power consumption[1]. This new facility incorporates several pieces of energy efficient equipment and has been designed with operational flexibility that allows the aeration system to operate continuously and in the most efficient way possible. The following discussion demonstrates the energy efficiency of this WWRF's aeration system and is worthy of consideration for Green Project Reserves.

AERATION SYSTEM

The aeration system is made up of several pieces of equipment that together with operational flexibility contributes to its overall efficiency. The major components are blowers, diffusers, motors, drives and most importantly controls.

Blowers

- The blower system consists of four blowers that are manifolded to a common discharge header to provide process air for the entire facility. Three of the four blowers are of the same capacity and the fourth has a reduced capacity. This combination of blowers allows them to operate at their most efficient condition and accommodates the full range of air demand that is anticipated without blowing off air.
- Multistage centrifugal blowers and High Speed Turbo (HST) blowers were evaluated as a part of the Secondary Treatment Process Design Technical Memorandum[2] in an effort to focus the project objectives on specific types of equipment. Multistage centrifugal

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blowers have been used for the past several decades as the primary means of aeration for WWRF facilities. Recently HST blowers have been introduced in the wastewater market and are revolutionizing the blower market. These blowers use high speed motors with frictionless bearing that are designed for minimal energy consumption.

- In order to evaluate the overall efficiency of the blower system, six different design points at varying atmospheric and operational conditions were considered. Blower manufacturers were given these conditions and were asked to optimize their blower system at the design points to provide the lowest total shaft horsepower possible with their equipment. Once the horsepower was determined, it was converted to a shaft electrical demand. A time weighted factor to approximate the duration that the blower system is anticipated to operate at each design point was applied to the shaft electrical demand and an evaluated electrical demand for each design condition was determined. The evaluated electrical demand for each design point was then summed to estimate the total system electrical demand for each manufacturer's blower system, see Tables 1 and 2 that follows.

Table 1: Multistage Centrifugal Blowers

Design Point	SCFM	Temp (°F)	RH (%)	Total Shaft HP per Blower Online	Number of Blowers Online	Total Shaft HP	Shaft Electrical Demand (KW)	Time Weighting Factor	Evaluated Electrical Demand (KW)
1	4100	94	0.36	98	3	294	219.2	0.1	21.9
2	1480	67	0.36	95.3	1	95.3	71.1	0.6	42.6
3	830	7	0.36	53	1	53	39.5	0.3	11.9
4	6200	94	0.36	110	4	440	328.1	0.1	32.8
5	1765	67	0.36	113.7	1	113.7	84.8	0.6	50.9
6	1480	7	0.36	84	1	84.0	62.6	0.3	18.8
Total System Electrical Demand kW = 178.9									

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Table 2: High Speed Turbo Blowers

Design Point	SCFM	Temp (°F)	RH (%)	Total Shaft HP per Blower Online	Number of Blowers Online	Total Shaft HP	Shaft Electrical Demand (KW)	Time Weighting Factor	Evaluated Electrical Demand (KW)
1	4100	94	0.36	116.7	2	233.4	174.0	0.1	17.4
2	1480	67	0.36	76.9	1	76.9	57.3	0.6	34.4
3	830	7	0.36	43.5	1	43.5	32.4	0.3	9.7
4	6200	94	0.36	116.7	3	350.1	261.1	0.1	26.1
5	1765	67	0.36	45.9	2	91.8	68.5	0.6	41.1
6	1480	7	0.36	67.8	1	67.8	50.6	0.3	15.2
Total System Electrical Demand kW = 143.9									

The results of this analysis show that the HST blowers are able to operate across all of the design conditions with fewer blowers than the multistage centrifugals. Additionally, they operate more efficiently at each design condition as demonstrated by the lower total shaft horsepower as compared to the multistage centrifugal blowers. The high efficiency results in a 19.6 percent decrease in the total aeration system electrical demand compared to the conventional use of multi-stage blowers.

During the bidding phase of this project, multiple HST blower manufacturers were requested to complete a performance evaluation worksheet that was used to evaluate the efficiency of the various HST blower manufacturers. The selected manufacturer is K-Turbo, Tables 3 and 4 below are portions of their worksheet.

Table 3: Annual Power Consumption Evaluation

Design Condition	Flow Rate (SCFM)	Discharge Pressure (psig)	Temp. (°F)	Relative Humidity (%)
1	6300	10	94	0.36
2	2250	8.5	94	0.36
3	830	8.3	94	0.36
4	6300	10	67	0.5
5	2250	8.5	67	0.5
6	830	8.3	67	0.5
7	6300	10	7	0.65
8	2250	8.5	7	0.65
9	830	8.3	7	0.65

Table 4: K-Turbo Performance Evaluation Worksheet

Design Condition	Blower 1			Blower 2			Blower 3		
	Blower Output (ICFM)	Shaft HP	Motor Efficiency (%)	Blower Output (ICFM)	Shaft HP	Motor Efficiency (%)	Blower Output (ICFM)	Shaft HP	Motor Efficiency (%)
1	1388.5	68.8	72.9%	3281.8	159.5	74.3%	3281.8	159.5	74.3%
2	0	0		2840	118.4	76.1%	0	0	
3	1047.7	46.6	70.1%	0	0		0	0	
4	1307.7	65	72.8%	3090.9	149.2	74.9%	3090.9	149.2	74.9%
5	0	0		2674.8	111.4	76.2%	0	0	
6	986.7	44	69.8%	0	0		0	0	
7	1145.2	57.5	71.9%	2706.9	128.5	76.1%	2706.9	128.5	76.1%
8	0	0		2342.5	97.2	76.5%	0	0	
9	864.1	39	68.8%	0	0		0	0	

The overall blower evaluation determined that HST blowers were the most efficient type of blower for the aeration system. These blowers exhibit efficiencies greater than 70 percent over the majority of the operational range and exhibit a lower horsepower requirement. The combination of the efficiency and low horsepower requirement results in the lowest life cycle cost of alternative blower equipment.

Diffusers

- The WWRF is designed to achieve a high Actual Oxygen Transfer Efficiency (AOTE) which is a percentage of the amount of oxygen supplied by the blowers to the amount of oxygen dissolved into the wastewater. During the design, an analysis was performed that found that fine bubble diffusers had the highest AOTE. Efficient oxygen transfer is important to overall energy efficiency because the more oxygen you can transfer to the water for use by the biomass means less air needs to be provided by the blower system.

Aeration Controls

- A properly designed aeration control system is critical to energy efficient aeration. While the efficiency of the blowers and diffusers are important, the control system is more important because it first monitors the actual air demand for the system which is needed to control the supply of air from the blowers.
- The aeration control system for the WWRF uses 4 aeration control zones per oxidation ditch to monitor the local air demand and distributes the right amount of air to each zone. For example, the air demand for the first zone after influent enters the ditch will have a

higher air demand than the last zone in the ditch; therefore, the air control system needs to distribute more air to the first zone than the last zone.

- Each air control zone is equipped with a dissolved oxygen (DO) and an oxidation reduction potential (ORP) meter to monitor the air demand in each zone. The aeration control monitors the DO and ORP in each zone and automatically adjusts the air delivered to the zone to maintain the meter reading close to the operator setpoint. The air control system also adjusts the speed of the blowers to supply the right amount of total air in the system to meet all of the air demands.

Motors

- In addition to the energy efficient aeration system, pumps and other pieces of equipment throughout the WWRF use premium efficiency motors resulting in lower electrical demand, lower heat output and reduced overall operation and maintenance cost. These motors are listed in the Department of Energy's Federal Energy Management Program as being among the highest 25 percent of equivalent products for energy efficiency.

VFDs

- In addition to premium efficiency motors, all pumps and blowers are equipped with variable frequency drives (VFDs). The use of VFD allows motors to run at the horsepower needed for operation rather than at full load, thus resulting in energy savings.

OPERATIONAL EVALUATION

Three different Oxidation Ditch configurations were evaluated as a part of the Secondary Treatment Process Design Technical Memorandum[2] to determine which operational alternative is the most energy efficient. The configurations that were considered are LANDOX Mixers with Diffused Aeration, Jet Aeration, and LANDOX Mixers with Simultaneous Nitrification and Denitrification (SNDN).

SNDN can be accomplished by operating the system at a very low DO concentration (less than 0.25 mg/L). During SNDN operation, there is enough oxygen present on the outside of the bacterial floc to allow nitrification to occur; however, there is not enough oxygen present to penetrate to the center of the floc. Denitrification occurs in the center of the floc due to the lack of oxygen, but the presence of nitrate from the outer floc bacteria.

While SNDN operation is possible with both jet aeration and fine bubble diffused aeration, it is more efficient with diffused aeration due to the increased control of the aeration system that is intrinsic to fine bubble aeration and therefore is not considered as an operational alternative for jet aeration. The results of the evaluation are as follows.

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Table 5: Operational Evaluation

Parameter	LANDOX Mixer w/ Diffused Air		Jet Aeration
	Design Average Without Denit Credit	Design Average SNDN With Denit Credit & Low DO	Design Average SNDN With Denit Credit
Flow (MGD)	2.48	2.48	2.48
BOD_5 Removed (mg/L)	246	246	246
NH_3 Removed (mg/L)	40.4	40.4	40.4
NO_3 Removed (mg/L)	35	35	35
Wasting Credit (lb O_2/day)	-2728	-2728	-2728
AOR (lb O_2/day)	6687	6687	6687
SOR (lb O_2/day)	21550	15750	13296
Process Air Req'd SCFM	2771	2025	2673
Process Air Req'd ACFM	3951	2888	3059
Process Air Req'd ICFM	4014	2934	3103
Estimated Horsepower Requirements with Multi Stage Centrifugal Blowers			
Summer Blower HP	233	170	178
Winter Blower HP	276	202	211
Mixer HP	30	30	192
Avg HP Req'd	284	216	387
Estimated Horsepower Requirements with High Speed Turbo Blowers			
Summer Blower HP	194	142	149
Winter Blower HP	231	168	177
Mixer HP	30	30	192
Avg HP Req'd	243	185	355

As can be seen from the operational evaluation, the LANDOX Mixer w/ Diffused Air when operating under average design conditions with SNDN has the lowest process air requirement. To determine the annual power required for this process, the horsepower requirement for both the Multi Stage Centrifugal Blower and the High Speed Turbo Blowers were determined for both summer and winter conditions. The yearly horsepower required estimates that the Summer Blower HP is required for half of the year, Mixer HP is required year round and the Winter Blower HP is required for the other half of the year. These results show that LANDOX mixers with SNDN Operation utilizing High Speed Turbo Blowers result in the lowest yearly horsepower requirement.

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COST SAVINGS

Cost savings were estimated by performing a net present value analysis for the three Aeration systems identified in the Operational Evaluation. The analysis is based on the capital cost of the equipment as well as the annual electrical costs over a 20 year life cycle. The following is a summary of the results.

Table 6: Present Value Evaluation

Equipment and Operational Alternative	Capital Cost	Annual Operation Cost	Annual Operation Net Present Value	Total Net Present Value
Multistage Centrifugal Blowers				
Landox Mixers w/ Diffused Air	$1,265,785	$174,149	$2,590,894	$3,856,679
Jet Aeration	$1,433,685	$237,308	$3,530,550	$4,964,235
Landox Mixers w/ SNDN and Low DO	$1,385,685	$132,451	$1,970,539	$3,356,224
HST Blowers				
Landox Mixers w/ Diffused Air	$1,278,100	$149,000	$2,216,856	$3,494,956
Jet Aeration	$1,446,000	$217,686	$3,238,618	$4,684,618
Landox Mixers w/ SNDN and Low DO	$1,398,000	$113,442	$1,687,730	$3,085,730

The selected alternative for the WWRF was the LANDOX Mixers w/ SNDN utilizing HST blowers. As shown from the above results, the selected alternative is not the most economical from a capital cost perspective. However, it does have the lowest annual operating cost and the lowest total net present value over a period of twenty years. If the City would have selected the LANDOX Mixers w/ Diffused Air utilizing Multistage Centrifugal Blowers, they would have incurred the lowest capital cost, however, this alternative also had a higher operation cost due to extra diffusers and air control equipment. Comparing the total net present value for Multistage Centrifugal Blowers with Jet Aeration to the installed alternative, the City saved $1,878,505.

SUSTAINABILITY

In addition to the energy efficiency presented above, the Fruita WWRF includes other Green aspects such as production of a sustainable biosolids product. The Fruita WWRF uses an Autothermal Thermophilic Aerobic Digestion (ATAD) process to produce a Class A biosolids product. The end product is dry, odorless, and can be land applied as fertilizer. The City plans to land apply the biosolids on parks, golf courses, and other municipal areas. This provides a far more sustainable biosolids application practice than using landfills or dedicated land disposal sites that are required for lesser quality biosolids.

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In the design of new treatment facilities, it is Tetra Tech's opinion that incorporating Green aspects into the design such as those described herein for the Fruita WWRF that protect public interests and the environment should be the responsibility of the utility owner and design engineers. Please contact us at (303) 825-5999 if you have any questions regarding this information

END

PWS/lgs

cc: Michael Beck
Tom Huston

[1] Wastewater Engineering Treatment and Reuse; Fourth Edition (2003), Metcalf and Eddy, Figure 15-24, pg 1704
[2] Secondary Treatment Process Design Technical Memorandum for the City of Fruita (March 2008), Rothberg, Tamburini and Windsor, Inc.