CLARIFICATION OF HIGH STRENGTH WASTEWATER USING DISSOLVED AIR FLOTATION TECHNOLOGY

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ABSTRACT

Dissolved air flotation (DAF) systems are designed to remove suspended solids from water slurries. Clarification is achieved by the addition of pressurized air as fine bubbles. The microscopic bubbles attach to the solids reducing its specific gravity, allowing the material to float. SMBSC has tested several DAF units to clarify high strength water flows. The test results showed good removal of fine soil particles producing an effluent suitable for the wastewater treatment plant.

Introduction:

SMBSC uses a Biothane® up-flow anaerobic sludge blanket (UASB) process as the key component to treating wastewater generated from the processing of sugarbeets. The effectiveness of the UASB can be negatively impacted by the introduction of excessive quantities of suspended solids into the reactor. First, some of the heavier solids can settle to the bottom of the tank, decreasing the effective treatment capacity in the UASB. Second, solids that remain in suspension through the anaerobic process and exit the tank with the effluent will carry viable biomass out of the process.

Anaerobic digestion of wastewater is a complex biochemical treatment process that can be generally described as a two-step process. Initially, the wastes are converted by acid forming bacteria into volatile fatty acids. The acid forming bacteria are relatively robust, thriving over a wide range of both pH and temperature and capable of reproducing every few minutes. In the second step, methane forming bacteria convert the volatile fatty acids into methane and carbon dioxide. These methane formers are much more sensitive to their environment and only reproduce every 3 to 5 days. This slow growth characteristic makes it critical to contain the biomass within the UASB tank.

Historically, SMBSC has used one of the wastewater storage ponds to reduce the total suspended solids (TSS) prior to treatment through the wastewater treatment facility. Typically, the solids in the wastewater spend approximately 7 to 10 days settling in the 30-acre pond before the wastewater is treated. Even after several days of settling significant levels of TSS remain.

In other unrelated trials, settling aids have been used to try to improve the removal of the TSS in the pond. These approaches have proven to be unreliable and/or economically unfeasible. DAF technology was evaluated as a possible alternative to the more typical settling techniques in a brief pilot test performed during May 2010.

The full-scale evaluation of DAF as a viable pre-treatment option included the use of two Multifloat units designed and built by Krofta™ Technologies, LLC. Each unit was designed to handle approximately 750 gpm, depending on the solids loading. At the TSS concentrations that can be experienced at SMBSC the estimated throughput was

approximately 500 gpm at 2,500 to 3,000 mg/l TSS. Several chemistries were explored to aid in the estimation of the effluent quality attainable with the DAF unit and to allow treatment costs to be projected.

System Layout and Equipment Description:

The equipment used in the evaluation is installed in a temporary fashion using flexible connections whenever possible. Figure 1 (see Appendix A) depicts the general arrangement in a block diagram format. The wastewater destined for DAF treatment is taken from one of the 30-acre ponds used to store excess beet wash water, centrate from the Broadbent® horizontal bowl decanters (used to remove mud from the wash water) and a collection of various wastewaters that enter through the main factory drain.

A small DAF feed tank is installed to provide a convenient means of splitting the flow between the two DAF units. Located between the DAF feed tank and the DAF feed pumps, Keckley® basket strainers containing screens with 1/8-inch openings are used to prevent foreign materials from entering the DAF units.

The flow of wastewater to and from the DAF unit is controlled with an Allen-Bradley™ programmable logic controller (PLC) and Vertiflo centrifugal pumps with the process variable feedback coming from a Foxboro® flow meter.

The dissolved air flotation (DAF) equipment selected for the evaluation was designed and constructed by Krofta™ Engineering (see Figure 2). According to Krofta™[1], the Multifloat rectangular unit, model MFH-750 has a capacity of 750 gallons per minute (gpm) at a total suspended solids (TSS) concentration of 2,000 ppm. The design includes the use of parallel plates (lamellas) to enhance separation and flotation of the solids.

Figure 2. Krofta™ MFH-750 DAF

Chemical conditioning of the solids to improve the separation is accomplished by adding a coagulant and a polymer. The liquid coagulant, Ecolab® WCS 7888 is fed into the wastewater stream just ahead of the DAF feed pumps using an Alldos 48 l/hr diaphragm chemical dosing pump. The polymer, Midland PC S3000 is received dry and is prepared into a working solution using an Excell® polymer feeder and eductor. Alldos diaphragm dosing pumps are also used to deliver the polymer into the DAF unit. Chemical feed pumps are proportionally controlled based on flow into the DAF unit.

Air is supplied to the air dissolving tube (ADT) of the DAF unit at a working pressure of approximately 90 pounds per square inch (psi) using an Ingersol Rand® compressor, rated at 35 cubic feet per minute at 40 psi. Recycled clarified water is pumped through the ADT and into the base of the DAF unit. When the air saturated recycle enters the DAF unit and the pressure is released microscopic air bubbles are released and attach to the solids floating the solids to the top of

Figure 2. Float rake system.

[1] Krofta™ website, February 2011; www.kroftaenginee

the DAF unit. Research has shown that bubbles in the 30-70 μm range provide the best flotation[2]. The separated solids, known as the float, that rise to the surface of the DAF unit are removed with a rake system (see Figure 2) and are initially pumped to a small collection tank using an Ingersoll Rand® 2-inch diaphragm pump (see Figure 3). The float is transferred to the wastewater treatment facilities biomass storage tank using a 3-inch Sandpiper® diaphragm pump. The DAF float is then land applied along with the aerobic biomass at an agronomic rate, based on the nitrogen content. The clarified wastewater is pumped from the DAF units to an equalization tank prior being fed to the anaerobic and aerobic portions of the wastewater treatment system.

Discussion:

Figure 3. Air Compressor Skid.

The wet conditions that occurred during the 2009 harvest resulted in mud handling problems throughout the washhouse and wastewater treatment system. The total suspended solids (TSS) from the storage ponds were at levels that did impact the effectiveness of the Biothane® up-flow anaerobic sludge blanket (UASB) reactor that is depended upon as the primary treatment process for the removal of the organic loading in the wastewater. The Biothane® operating manual recommends that the TSS in the influent be no more than 20% of the total chemical oxygen demand (COD) being treated. In subsequent documents Biothane® has recommended that SMBSC limit the TSS loading to 10% of the total COD, in an attempt to facilitate the accumulation of biomass. Wastewater pumped from the ponds has had levels of TSS as high as 35% of the total COD.

The full-scale trial and evaluation of a dissolved air flotation (DAF) system as a possible pre-treatment process that could be used to help control TSS to the wastewater treatment plant was an interesting and unique opportunity. SMBSC collaborated with Ecolab® to select the Krofta™ DAF equipment as well as the Ecolab® and Midland Research® solids conditioning chemistries.

The evaluation began in January 2011 and is planned to continue through the end of the 2010-2011 beet slicing campaign. During the first month, flow rates through the DAF equipment varied from a high of about 450 gallons per minute (gpm) per DAF unit to a low of about 180 gpm per DAF unit. TSS concentration in the influent during the same time frame varied from 500 mg/l to 4,000 mg/l. Tables 1 and 2 (see Appendix B) contain the daily data and Figure 4 (see Appendix C) compares the TSS concentrations in and out of the DAF units with the flow through the system.

Of the 330,000 pounds (lbs) of TSS entering the DAF treatment system with the 31 million gallons of wastewater fed to the wastewater treatment system, over 199,000 lbs of TSS were removed by the DAF process prior to entering the wastewater treatment facility. The average TSS concentration in the influent was 1,285 mg/l and was reduced to an average concentration in the effluent of 510 mg/l.

[2] Krofta™ website, February 2011; www.kroftaengineering.com.

Both Krofta™ and Ecolab® have communicated on several different occasions that removal efficiencies of 80 to 90% should be attainable. This has not been the case in practice. Removal efficiency of the entire DAF system averaged just over 60%.

Initial jar testing of various solids conditioning chemistries led to the selection of an anionic polymer from Midland Research®, PCS 3000 and an anionic coagulant from Ecolab®, WCS 7888. The average dosage rate on untreated wastewater for PCS 3000 was 0.6 ppm and 126 ppm for the WCS 7888. The cost of the chemical conditioning averaged about $1,200 per million gallons treated.

The up time of the equipment has generally been very good. There have been several interruptions due to motors tripping electrically. Both DAF feed pumps have tripped 3 times, the north DAF compressor motor has tripped once and the north clear water recycle pump has tripped once. The motors have been restarted successfully each time without significant disruption to the treatment process.

The controller for the original gear pump included in the Excell® dry polymer station failed and down time was kept to a minimum by using Alldos diaphragm chemical dosing pumps to deliver the polymer working solution to the DAF units.

The most significant downtime occurred when the level sensor and transmitter on the north DAF unit failed on February 3rd and it took approximately 5 days to obtain a replacement. Fortunately this occurred during a time when the total flow rate of approximately 500 gpm could be treated successfully with the south DAF unit.

Conclusion:

Dissolved air flotation (DAF) can be used successfully to significantly reduce the total suspended solids concentration in the wastewater generated from the processing of sugarbeets.

DAF applications in other industries have achieved clarification rates as high as 97%[3]. SMBSC's experience would indicate a clarification rate of just over 60% was achieved with the chosen chemistries and equipment.

During the 2010-2011 operating season, approximately 225 million gallons will be treated through the anaerobic reactor. With the chemical cost at approximately $1,200 per million gallons, the total chemical cost for a campaign could be on the order of $270,000.

The total pounds of chemical oxygen demand (COD) treated will top 9,250,000 through the anaerobic reactor for the 2010-2011 campaign, which compares very favorably to the 4,600,000 pounds of COD and 91 million gallons treated in 2009-2010. The decision on how to proceed in future years will depend to a great extent on the quantity and condition of the solids in the anaerobic reactor, when it is opened for cleaning in May of 2011.

[3] Pan America Environmental website, February 2011; www.dissolved-air-flotation.com

Future Work:

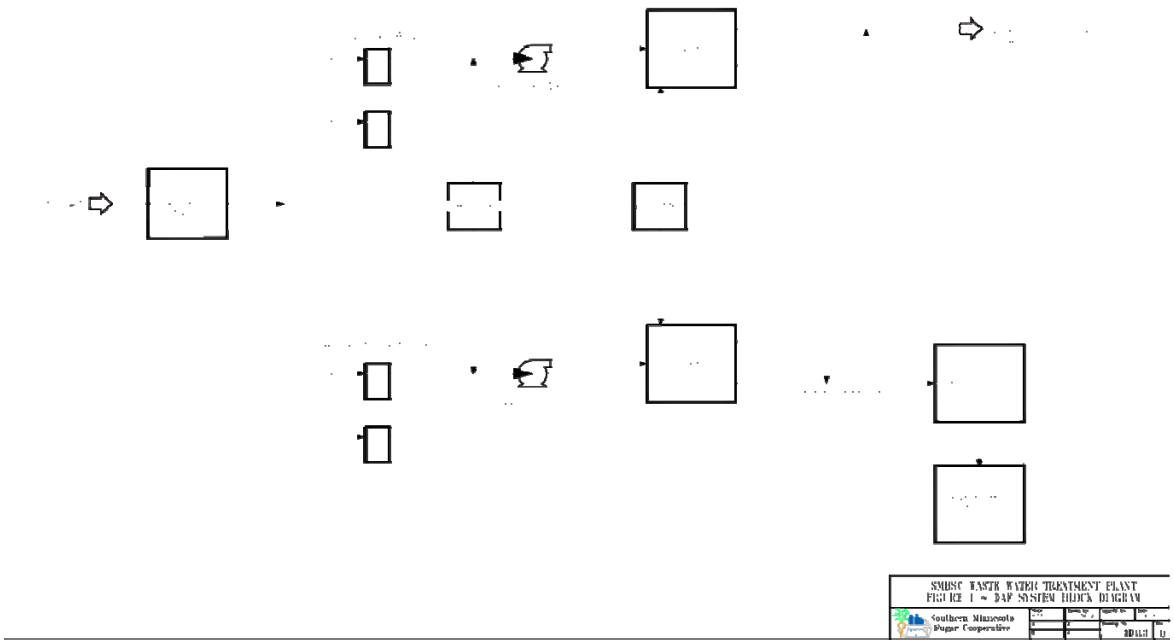
During the remainder of the 2011 evaluation of DAF, much of the focus will be on optimizing the treatment by maximizing the efficiency and minimizing the costs of treatment, as well as trying to reduce the variability in the treatment process.

Additional jar testing has shown that with adequate mixing at the coagulant addition point and slightly longer retention times prior to polymer addition, the separation of solids can be improved. This requires evaluation on the field equipment to determine if the removal efficiency can be improved or the chemical dosage rates reduced or perhaps both.

Particle size analysis indicates that the TSS left in the clarified water is smaller than 2 μm. Additional work will be required to see if adjustments can be made to capture a larger percentage of the solids.

APPENDIX A

Figure 1. DAF System Block Diagram



APPENDIX B

Table 1. Dissolved Air Flotation Data for January 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted% Removal
January 4, 2011	1.190	DAF Influent	0.4237	75	0.511	0.4816	1,164	392						
		DAF Effluent	0.4253	100	0.4452	0.4350	199	102	82.90	73.98				
		DAF Influent	0.4257	50	0.4586		658							
		DAF Effluent	0.4236	100	0.4346		110		83.28		9,041	1,533	7,508	83.04
January 5, 2011	1.204	DAF Influent	0.4254	50	0.4628	0.4482	748	292						
		DAF Effluent	0.4257	100	0.4733	0.4493	476	240	36.36	17.81	7,511	4,780	2,731	36.36
January 6, 2011	1.256	DAF Influent	0.4255	50	0.4626	0.4471	742	310						
		DAF Effluent	0.4275	100	0.4638	0.444	363	198	51.08	36.13	7,772	3,802	3,970	51.08
January 13, 2011	1.254	North DAF Influent	0.4196	25	0.4363	0.4281	668	328						
		North DAF Effluent	0.4233	25	0.4366	0.4286	532	320	20.36	2.44				
		South DAF Influent	0.4199	25	0.4432	0.4297	932	540						
		South DAF Effluent	0.4198	25	0.4262	0.4222	256	160	72.53	70.37	8,367	4,121	4,246	50.75
January 14, 2011	1.254	North DAF Influent	0.4187	25	0.4375	0.4280	752	380						
		North DAF Effluent	0.4203	25	0.4327	0.4248	496	316	34.04	16.84				
		South DAF Influent	0.4202	25	0.4386	0.4287	736	396						
		South DAF Effluent	0.4187	25	0.4247	0.4208	240	156	67.39	60.61				
		North DAF Influent	0.4216	50	0.4556	0.4386	680	340						
		North DAF Effluent	0.4209	50	0.4456	0.4307	494	298	27.35	12.35				
		South DAF Influent	0.4204	50	0.4548	0.4376	688	344						
		South DAF Effluent	0.4216	50	0.4303	0.4250	174	106	74.71	69.19	7,467	3,671	3,796	50.84
January 15, 2011	1.254	North DAF Influent	0.4215	25	0.4416	0.4313	804	412						
		North DAF Effluent	0.4206	25	0.4362	0.4269	624	372	22.39	9.71				
		South DAF Influent	0.4192	25	0.4398	0.4291	824	428						
		South DAF Effluent	0.4212	25	0.4279	0.4236	268	172	67.48	59.81				
		North DAF Influent	0.4228	50	0.4583	0.4403	710	360						
		North DAF Effluent	0.4233	50	0.4500	0.4332	534	336	24.79	6.67				
		South DAF Influent	0.4263	50	0.4661	0.4456	796	410						
		South DAF Effluent	0.4232	50	0.4318	0.4259	172	118	78.39	71.22	8,194	4,178	4,016	49.01
January 16, 2011	1.242	North DAF Influent	0.4188	25	0.4401	0.4292	852	436						
		North DAF Effluent	0.4211	25	0.4374	0.4276	652	392	23.47	10.09				
		South DAF Influent	0.4207	25	0.442	0.4311	852	436						
		South DAF Effluent	0.4204	25	0.4264	0.4223	240	164	71.83	62.39				
		North DAF Influent	0.4218	50	0.4705	0.4463	974	484						
		North DAF Effluent	0.4224	50	0.4528	0.4345	608	366	37.58	24.38				
		South DAF Influent	0.4232	50	0.4702	0.4457	940	490						
		South DAF Effluent	0.4250	50	0.4408	0.4315	316	186	66.38	62.04	9,369	4,703	4,666	49.81

Table 1. (continued) Dissolved Air Flotation Data for January 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted% Removal
January 17, 2011	1.127	North DAF Influent	0.4281	25	0.4531	0.4392	1,000	556						
		North DAF Effluent	0.4276	25	0.4425	0.4331	596	376	40.40	32.37				
		South DAF Influent	0.4249	25	0.4491	0.4356	968	540						
		South DAF Effluent	0.4245	25	0.4299	0.4255	216	176	77.69	67.41				
		North DAF Influent	0.4234	50	0.4817	0.4507	1,166	620						
		North DAF Effluent	0.4191	25	0.4301	0.4220	440	324	62.26	47.74				
		South DAF Influent	0.4196	25	0.4460	0.4313	1,056	588						
		South DAF Effluent	0.4216	25	0.4314	0.4250	392	256	62.88	56.46	9,846	3,863	5,983	60.76
January 18, 2011	0.941	North DAF Influent	0.4236	25	0.4434	0.4332	792	408						
		North DAF Effluent	0.4216	25	0.4297	0.4226	324	284	59.09	30.39				
		South DAF Influent	0.4213	25	0.4419	0.4311	824	432						
		South DAF Effluent	0.4223	25	0.4295	0.4237	288	232	65.05	46.30				
		North DAF Influent	0.4247	25	0.4530	0.4387	1,132	572						
		North DAF Effluent	0.4264	25	0.4415	0.4319	604	384	46.64	32.87				
		South DAF Influent	0.4265	25	0.4671	0.4453	1,624	872						
		South DAF Effluent	0.4228	25	0.4337	0.4270	436	268	73.15	69.27	8,578	3,241	5,337	62.21
January 19, 2011	0.935	North DAF Influent	0.4282	25	0.4527	0.4383	980	576						
		North DAF Effluent	0.4278	25	0.4468	0.4325	760	572	22.45	0.69				
		South DAF Influent	0.4271	25	0.4546	0.4394	1,100	608						
		South DAF Effluent	0.4245	25	0.4350	0.4288	420	248	61.82	59.21				
		North DAF Influent	0.4271	25	0.4630	0.4428	1,436	808						
		North DAF Effluent	0.4255	25	0.4408	0.4307	612	404	57.38	50.00				
		South DAF Influent	0.4299	25	0.4757	0.4513	1,832	976						
		South DAF Effluent	0.4283	25	0.4420	0.4334	548	344	70.09	64.75	10,426	4,562	5,864	56.25
January 20, 2011	0.796	North DAF Influent	0.4240	25	0.4511	0.4368	1,084	572						
		North DAF Effluent	0.4268	25	0.4362	0.4287	376	300	65.31	47.55				
		South DAF Influent	0.4252	25	0.4512	0.4367	1,040	580						
		South DAF Effluent	0.4277	25	0.4373	0.4295	384	312	63.08	46.21				
		North DAF Influent	0.4259	25	0.4659	0.4433	1,600	904						
		North DAF Effluent	0.4275	25	0.4468	0.4340	772	512	51.75	43.36				
		South DAF Influent	0.4252	25	0.4569	0.4397	1,268	688						
		South DAF Effluent	0.4264	25	0.4433	0.4323	676	440	46.69	36.05	8,285	3,665	4,620	55.77

Table 1. (continued) Dissolved Air Flotation Data for January 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted % Removal
January 21, 2011	0.726	North DAF Influent	0.4243	25	0.4600	0.4396	1,428	816						
		North DAF Effluent	0.4268	25	0.4412	0.4303	576	436	59.66	46.57				
		South DAF Influent	0.4280	25	0.4565	0.4405	1,140	640						
		South DAF Effluent	0.4236	25	0.4390	0.4284	616	424	45.96	33.75				
		North DAF Influent	0.4216	25	0.4546	0.4374	1,320	688						
		North DAF Effluent	0.4291	25	0.4479	0.4359	752	480	43.03	30.23				
		South DAF Influent	0.4244	25	0.4583	0.4409	1,356	696						
		South DAF Effluent	0.4257	25	0.4413	0.4311	624	408	53.98	41.38	7,938	3,887	4,051	51.03
January 22, 2011	0.659	North DAF Influent	0.4186	25	0.4564	0.4356	1,512	832						
		North DAF Effluent	0.4200	25	0.4340	0.4240	560	400	62.96	51.92				
		South DAF Influent	0.4208	25	0.4493	0.4342	1,140	604						
		South DAF Effluent	0.4209	25	0.4357	0.4251	592	424	48.07	29.80				
		North DAF Influent	0.4258	25	0.4586	0.4426	1,312	640						
		North DAF Effluent	0.4281	25	0.4428	0.4337	588	364	55.18	43.12				
		South DAF Influent	0.4205	25	0.4600	0.4402	1,580	792						
		South DAF Effluent	0.4210	25	0.4347	0.4259	548	352	65.32	55.56	7,618	3,144	4,474	58.73
January 23, 2011	0.651	North DAF Influent	0.4182	25	0.4656	0.4445	1,896	844						
		North DAF Effluent	0.4187	25	0.4456	0.4317	1,076	556	43.25	34.12				
		South DAF Influent	0.4199	25	0.4709	0.4468	2,040	964						
		South DAF Effluent	0.4205	25	0.4466	0.4331	1,044	540	48.82	43.98				
		North DAF Influent	0.4255	25	0.4951	0.4645	2,784	1,224						
		North DAF Effluent	0.4211	25	0.4483	0.4351	1,088	528	60.92	56.86				
		South DAF Influent	0.4220	25	0.4902	0.4620	2,728	1,128						
		South DAF Effluent*	0.4209	25	0.5083	0.4731	3,496	1,408	-28.15	-24.82	12,824	5,806	7,018	54.73
January 25, 2011	0.698	North DAF Influent	0.4209	25	0.5275	0.4790	4,264	1,940						
		North DAF Effluent	0.4209	25	0.4314	0.4238	420	304	90.15	84.33				
		South DAF Influent	0.4224	25	0.4760	0.4460	2,144	1,200						
		South DAF Effluent	0.4221	25	0.4406	0.4273	740	532	65.49	55.67				
		North DAF Influent	0.4195	25	0.4746	0.4442	2,204	1,216						
		North DAF Effluent	0.4191	25	0.4332	0.4228	564	416	74.41	65.79				
		South DAF Influent	0.4225	25	0.4708	0.443	1,932	1,112						
		South DAF Effluent	0.4258	25	0.4368	0.4294	440	296	77.23	73.38	15,345	3,149	12,196	79.48

Table 1. (continued) Dissolved Air Flotation Data for January 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted % Removal
January 26, 2011	0.707	North DAF Influent	0.4158	25	0.4719	0.4403	2,244	1,264						
		North DAF Effluent	0.4108	25	0.4319	0.4174	844	580	62.39	54.11				
		South DAF Influent	0.4139	25	0.4697	0.4385	2,232	1,248						
		South DAF Effluent	0.4165	25	0.4315	0.4212	600	412	73.12	66.99				
		North DAF Influent	0.4153	25	0.4622	0.4361	1,876	1,044						
		North DAF Effluent	0.4120	25	0.4274	0.4168	616	424	67.16	59.39				
		South DAF Influent	0.4103	25	0.4548	0.4296	1,780	1,008						
		South DAF Effluent	0.4159	25	0.4273	0.4188	456	340	74.38	66.27	11,987	3,709	8,279	69.06
January 27, 2011	0.744	North DAF Influent	0.4138	25	0.4795	0.4458	2,628	1,348						
		North DAF Effluent	0.4152	25	0.4435	0.4263	1,132	688	56.93	48.96				
		South DAF Influent	0.4177	25	0.4782	0.4462	2,420	1,280						
		South DAF Effluent	0.4157	25	0.4306	0.4211	596	380	75.37	70.31				
		North DAF Influent	0.4244	25	0.4736	0.4473	1,968	1,052						
		North DAF Effluent	0.4138	25	0.4331	0.4201	772	520	60.77	50.57				
		South DAF Influent	0.4120	25	0.4649	0.4363	2,116	1,144						
		South DAF Effluent	0.4135	25	0.4288	0.4189	612	396	71.08	65.38	14,166	4,827	9,338	65.92
January 28, 2011	0.811	North DAF Influent	0.4197	25	0.4757	0.4448	2,240	1,236						
		North DAF Effluent	0.4209	25	0.4378	0.4260	676	472	69.82	61.81				
		South DAF Influent	0.4195	25	0.4665	0.4443	1,880	888						
		South DAF Effluent	0.4225	25	0.4449	0.4296	896	612	52.34	31.08				
		North DAF Influent	0.4208	25	0.4697	0.4449	1,956	992						
		North DAF Effluent	0.4189	25	0.4407	0.4257	872	600	55.42	39.52				
		South DAF Influent	0.4180	25	0.4764	0.4460	2,336	1,216						
		South DAF Effluent	0.4181	25	0.4327	0.4215	584	448	75.00	63.16	14,224	5,120	9,104	64.00
January 29, 2011	0.767	North DAF Influent	0.4106	25	0.4653	0.4371	2,188	1,128						
		North DAF Effluent	0.416	25	0.4365	0.4221	820	576	62.52	48.94				
		South DAF Influent	0.4138	25	0.4705	0.4397	2,268	1,232						
		South DAF Effluent	0.4133	25	0.4261	0.4172	512	356	77.43	71.10				
		North DAF Influent	0.4192	20	0.4689	0.4418	2,485	1,355						
		North DAF Effluent	0.4156	21	0.4359	0.4226	967	633	61.10	53.26				
		South DAF Influent	0.4161	20	0.4609	0.4369	2,240	1,200						
		South DAF Effluent	0.4130	20	0.4270	0.4175	700	475	68.75	60.42	14,682	4,795	9,887	67.34

Table 1. (continued) Dissolved Air Flotation Data for January 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted% Removal
January 30, 2011	0.725	North DAF Influent	0.4118	25	0.4595	0.4330	1,908	1,060						
		North DAF Effluent	0.4132	25	0.4374	0.4205	968	676	49.27	36.23				
		South DAF Influent	0.4126	25	0.4635	0.4344	2,036	1,164						
		South DAF Effluent	0.4117	25	0.4295	0.4162	712	532	65.03	54.30				
		North DAF Influent	0.4109	25	0.4591	0.4311	1,928	1,120						
		North DAF Effluent	0.4123	25	0.4260	0.4172	548	352	71.58	68.57				
		South DAF Influent	0.4133	25	0.4522	0.4291	1,556	924						
		South DAF Effluent	0.4222	25	0.4354	0.425	528	416	66.07	54.98	11,228	4,166	7,062	62.90
January 31, 2011	0.725	North DAF Influent	0.4257	25	0.4652	0.4457	1,580	780						
		North DAF Effluent	0.4206	25	0.4364	0.4247	632	468	60.00	40.00				
		South DAF Influent	0.4215	25	0.4648	0.4415	1,732	932						
		South DAF Effluent	0.4229	25	0.4407	0.4278	712	516	58.89	44.64				
		North DAF Influent	0.4244	20	0.4543	0.4379	1,495	820						
		North DAF Effluent	0.4207	20	0.4313	0.4231	530	410	64.55	50.00				
		South DAF Influent	0.4223	20	0.4595	0.4390	1,860	1,025						
		South DAF Effluent	0.4197	20	0.4311	0.4224	570	435	69.35	57.56	10,078	3,694	6,384	63.34
	19.67						Total Lbs Removed and Average Removal for the month of January:				214,947	84,417	130,530	60.73

* - January 28, 2011, South DAF Effluent results eliminated in evaluation

Table 2. (continued) Dissolved Air Flotation Data for February 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted% Removal
February 13, 2011	0.550	North DAF Influent	0.4206	25	0.4364	0.4272	632	368						
		North DAF Effluent	0.4208	25	0.4265	0.4213	228	208	63.92	43.48				
		South DAF Influent	0.4230	25	0.4377	0.4291	588	344						
		South DAF Effluent	0.4215	25	0.4307	0.4228	368	316	37.41	8.14				
		North DAF Influent	0.4187	25	0.4357	0.4262	680	380						
		North DAF Effluent	0.4196	25	0.4270	0.4212	296	232	56.47	38.95				
		South DAF Influent	0.4217	25	0.4388	0.4292	684	384						
		South DAF Effluent	0.4211	25	0.4319	0.4246	432	292	36.84	23.96	2,963	1,518	1,445	48.76
February 14, 2011	0.514	North DAF Influent	0.4191	25	0.4316	0.4239	500	308						
		North DAF Effluent	0.4200	25	0.4248	0.4200	192	192	61.60	37.66				
		South DAF Influent	0.4218	25	0.4362	0.4268	576	376						
		South DAF Effluent	0.4231	25	0.4304	0.4239	292	260	49.31	30.85				
		North DAF Influent	0.4177	25	0.4508	0.4315	1,324	772						
		North DAF Effluent	0.4208	25	0.4357	0.4241	596	464	54.98	39.90				
		South DAF Influent	0.4206	25	0.4494	0.4323	1,152	684						
		South DAF Effluent	0.4222	25	0.4365	0.4256	572	436	50.35	36.26	3,807	1,770	2,036	53.49
February 15, 2011	0.514	North DAF Influent	0.4236	25	0.4444	0.4333	832	444						
		North DAF Effluent	0.4222	25	0.4316	0.4238	376	312	54.81	29.73				
		South DAF Influent	0.4214	25	0.4450	0.4321	944	516						
		South DAF Effluent	0.4197	25	0.4289	0.4209	368	320	61.02	37.98				
		North DAF Influent	0.4212	25	0.4490	0.4344	1,112	584						
		North DAF Effluent	0.4201	25	0.4357	0.4252	624	420	43.88	28.08				
		South DAF Influent	0.4234	25	0.4503	0.4359	1,076	576						
		South DAF Effluent	0.4226	25	0.4362	0.4268	544	376	49.44	34.72	4,248	2,049	2,199	51.77
February 16, 2011	0.514	North DAF Influent	0.4174	25	0.4393	0.4272	876	484						
		North DAF Effluent	0.4167	25	0.4249	0.4180	328	276	62.56	42.98				
		South DAF Influent	0.4190	25	0.4416	0.4289	904	508						
		South DAF Effluent	0.4194	25	0.4265	0.4207	284	232	68.58	54.33				
		North DAF Influent	0.4194	25	0.4463	0.4324	1,076	556						
		North DAF Effluent	0.4211	25	0.4354	0.4256	572	392	46.84	29.50				
		South DAF Influent	0.4241	25	0.4522	0.4370	1,124	608						
		South DAF Effluent	0.4233	25	0.4372	0.4277	556	380	50.53	37.50	4,265	1,865	2,401	56.28

Table 2. Dissolved Air Flotation Data for February 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted% Removal
February 1, 2011	0.750	North DAF Influent	0.4198	25	0.4574	0.4390	1,504	736						
		North DAF Effluent	0.4238	25	0.4427	0.4293	756	536	49.73	27.17				
		South DAF Influent	0.4219	25	0.4624	0.4406	1,620	872						
		South DAF Effluent	0.4197	25	0.4391	0.4255	776	544	52.10	37.61				
		North DAF Influent	0.4202	25	0.4664	0.4409	1,848	1,020						
		North DAF Effluent	0.4197	25	0.4386	0.4257	756	516	59.09	49.41				
		South DAF Influent	0.4218	25	0.4709	0.4442	1,964	1,068						
		South DAF Effluent	0.4205	25	0.4413	0.4274	832	556	57.64	47.94	10,846	4,879	5,967	55.02
February 2, 2011	0.753	North DAF Influent	0.4218	25	0.4543	0.4372	1,300	684						
		North DAF Effluent	0.4183	25	0.431	0.4213	508	388	60.92	43.27				
		South DAF Influent	0.4205	25	0.4513	0.4343	1,232	680						
		South DAF Effluent	0.4215	25	0.4392	0.4264	708	512	42.53	24.71				
		North DAF Influent	0.4229	25	0.4693	0.4433	1,856	1,040						
		North DAF Effluent	0.4219	25	0.4400	0.4265	724	540	60.99	48.08				
		South DAF Influent	0.4213	25	0.4688	0.4414	1,900	1,096						
		South DAF Effluent	0.4215	25	0.4443	0.4283	912	640	52.00	41.61	9,872	4,478	5,395	54.64
February 3, 2011	0.726	North DAF Influent	Down											
		North DAF Effluent	Down											
		South DAF Influent	0.4233	25	0.4674	0.4428	1,764	984						
		South DAF Effluent	0.4225	25	0.4448	0.4293	892	620	49.43	36.99	5,340	2,700	2,640	49.43
February 4, 2011	0.717	North DAF Influent	Down											
		North DAF Effluent	Down											
		South DAF Influent	0.4235	20	0.4569	0.4383	1,670	930						
		South DAF Effluent	0.4244	20	0.4422	0.4294	890	640	46.71	31.18				
		North DAF Influent	Down											
		North DAF Effluent	Down											
		South DAF Influent	0.4221	25	0.4691	0.4443	1,880	992						
		South DAF Effluent	0.4214	25	0.4390	0.4273	704	468	62.55	52.82	5,307	2,383	2,924	55.10

Table 2. (continued) Dissolved Air Flotation Data for February 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted% Removal
February 5, 2011	0.699	North DAF Influent	Down											
		North DAF Effluent	Down											
		South DAF Influent	0.4257	25	0.4708	0.4446	1,804	1,048						
		South DAF Effluent	0.4230	25	0.4418	0.4284	752	536	58.31	48.85				
		North DAF Influent	Down											
		North DAF Effluent	Down											
		South DAF Influent	Down											
		South DAF Effluent	Down								2,629	1,096	1,533	58.31
February 6, 2011	0.684	North DAF Influent	Down											
		North DAF Effluent	Down											
		South DAF Influent	0.4196	25	0.4570	0.4374	1,496	784						
		South DAF Effluent	0.4211	25	0.4390	0.4273	716	468	52.14	40.31	4,267	2,042	2,225	52.14
February 7, 2011	0.660	North DAF Influent	0.4264	25	0.4704	0.4472	1,760	928						
		North DAF Effluent	0.4257	25	0.4696	0.4467	1,756	916	0.23	1.29				
		South DAF Influent	0.4266	25	0.4629	0.4422	1,452	828						
		South DAF Effluent	0.4246	25	0.4432	0.4301	744	524	48.76	36.71				
		North DAF Influent	Down											
		North DAF Effluent	Down											
		South DAF Influent	0.4244	25	0.4658	0.4444	1,656	856						
		South DAF Effluent	0.4265	25	0.4441	0.4325	704	464	57.49	45.79	6,699	4,409	2,290	34.18
February 8, 2011	0.675	North DAF Influent	0.4243	25	0.4658	0.4423	1,660	940						
		North DAF Effluent	0.4288	25	0.4432	0.4324	576	432	65.30	54.04				
		South DAF Influent	0.4273	25	0.4666	0.4443	1,572	892						
		South DAF Effluent	0.4262	25	0.4446	0.4319	736	508	53.18	43.05				
		North DAF Influent	0.4249	25	0.4564	0.4296	1,260	1,072						
		North DAF Effluent	0.4260	25	0.4394	0.4397	536	-12	57.46	101.12				
		South DAF Influent	0.4254	25	0.4573	0.4404	1,276	676						
		South DAF Effluent	0.4245	25	0.4401	0.4285	624	464	51.10	31.36	8,118	3,479	4,639	57.14

Table 2. (continued) Dissolved Air Flotation Data for February 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted% Removal
February 9, 2011	0.644	North DAF Influent	0.4260	25	0.4642	0.4428	1,528	856						
		North DAF Effluent	0.4239	25	0.4394	0.4277	620	468	59.42	45.33				
		South DAF Influent	0.4260	25	0.4650	0.4422	1,560	912						
		South DAF Effluent	0.4228	25	0.4376	0.4265	592	444	62.05	51.32				
		North DAF Influent	0.4279	25	0.4550	0.4413	1,084	548						
		North DAF Effluent	0.4237	25	0.4342	0.4259	420	332	61.25	39.42				
		South DAF Influent	0.4218	25	0.4566	0.4376	1,392	760						
		South DAF Effluent	0.4233	25	0.4335	0.4260	408	300	70.69	60.53	7,471	2,739	4,732	63.34
February 10, 2011	0.572	North DAF Influent	0.4253	25	0.5038	0.4716	3,140	1,288						
		North DAF Effluent	0.4235	25	0.4398	0.4276	652	488	79.24	62.11				
		South DAF Influent	0.4248	25	0.5016	0.4686	3,072	1,320						
		South DAF Effluent	0.4245	25	0.4474	0.4314	916	640	70.18	51.52				
		North DAF Influent	0.4257	25	0.5086	0.4731	3,316	1,420						
		North DAF Effluent	0.4255	25	0.4324	0.4268	276	224	91.68	84.23				
		South DAF Influent	0.4259	25	0.4990	0.4690	2,924	1,200						
		South DAF Effluent	0.4272	25	0.4447	0.4350	700	388	76.06	67.67	14,851	3,034	11,816	79.57
Februery 11, 2011	0.541	North DAF Influent	0.4253	25	0.4704	0.4498	1,804	824						
		North DAF Effluent	0.4260	25	0.4382	0.4292	488	360	72.95	56.31				
		South DAF Influent	0.4261	25	0.4673	0.4480	1,648	772						
		South DAF Effluent	0.4236	25	0.4390	0.4280	616	440	62.62	43.01				
		North DAF Influent	0.4272	25	0.4497	0.4363	900	536						
		North DAF Effluent	0.4274	25	0.4343	0.4282	276	244	69.33	54.48				
		South DAF Influent	0.4224	25	0.4421	0.4312	788	436						
		South DAF Effluent	0.4244	25	0.4309	0.4280	260	116	67.01	73.39	5,798	1,850	3,948	68.09
February 12, 2011	0.550	North DAF Influent	0.4233	25	0.4459	0.4328	904	524						
		North DAF Effluent	0.4199	25	0.4304	0.4224	420	320	53.54	38.93				
		South DAF Influent	0.4233	25	0.4447	0.4328	856	476						
		South DAF Effluent	0.4242	25	0.4366	0.427	496	384	42.06	19.33				
		North DAF Influent	0.4177	25	0.4384	0.4262	828	488						
		North DAF Effluent	0.4236	25	0.4306	0.4240	280	264	66.18	45.90				
		South DAF Influent	0.4247	25	0.4423	0.4320	704	412						
		South DAF Effluent	0.4200	25	0.4300	0.4227	400	292	43.18	29.13	3,775	1,830	1,945	51.52

Table 2. (continued) Dissolved Air Flotation Data for February 2011

Sample Date	Flow MGD	Sample Description	Filter Weight g	Sample Size ml	Dry Weight g	Ash Weight g	Total Suspended Solids mg/L	Volatile Suspended Solids mg/L	% Removal TSS	% Removal VSS	Influent TSS Lbs	Effluent TSS Lbs	TSS Removed Lbs	Flow Weighted% Removal
February 17, 2011	0.544	North DAF Influent	0.4218	25	0.4396	0.4305	712	364						
		North DAF Effluent	0.4183	25	0.4248	0.4192	260	224	63.48	38.46				
		South DAF Influent	0.4249	25	0.4465	0.4350	864	460						
		South DAF Effluent	0.4244	25	0.4315	0.4251	284	256	67.13	44.35				
		North DAF Influent	0.4215	25	0.5129	0.4803	3,656	1,304						
		North DAF Effluent	0.4193	25	0.4410	0.4297	868	452	76.26	65.34				
		South DAF Influent	0.4210	25	0.5131	0.4812	3,684	1,276						
		South DAF Effluent	0.4202	25	0.4332	0.4253	520	316	85.88	75.24	10,113	2,191	7,922	78.33
February 18, 2011	0.541	North DAF Influent	0.4200	25	0.4448	0.4321	992	508						
		North DAF Effluent	0.4247	25	0.4335	0.4260	352	300	64.52	40.94				
		South DAF Influent	0.4267	25	0.4490	0.4366	892	496						
		South DAF Effluent	0.4216	25	0.4304	0.4238	352	264	60.54	46.77				
		North DAF Influent	0.4253	25	0.4581	0.4411	1,312	680						
		North DAF Effluent	0.4223	25	0.4402	0.4286	716	464	45.43	31.76				
		South DAF Influent	0.4247	25	0.4587	0.4411	1,360	704						
		South DAF Effluent	0.4227	25	0.4360	0.4275	532	340	60.88	51.70	5,139	2,202	2,937	57.16
Feb	11.15										115,508	46,515	68,993	59.73
Jan	19.67										214,947	84,417	130,530	60.73
Total/average	30.81										330,455	130,932	199,523	60.38

APPENDIX C

Figure 4. TSS Concentrations compared to flow rate.