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Technical Memorandum

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Technical Memorandum

Subject: Upgrade Alternatives for the Air Flotation Tanks (AFT) at the Sunnyvale WPCP

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EXECUTIVE SUMMARY

This Technical Memorandum (TM) evaluates alternatives to remove algae from the effluent from the Sunnyvale Water Pollution Control Plant (WPCP). The following alternatives were evaluated to remove and thicken the algae from the oxidation ponds:

1. Maintain existing AFTs.
2. Upgrade existing AFTs.
3. Maintain flotation as the algae removal process, but replace system.
4. Replace flotation technology with sedimentation and separate thickening.
5. Replace flotation technology with ballasted sedimentation and separate thickening.
6. Replace flotation technology with membrane separation and separate thickening.

Of these alternatives, only two, alternatives 2 and 3 were maintained for further consideration. The other alternatives were rejected for the following reasons:

- Alternative 1 requires a similar investment for structural and electro-mechanical improvements, but without the benefit of the technology upgrades in Alternative 2.
- Alternative 4 requires deaeration of the oxygen supersaturation with uncertain results. It also requires additional thickening which is likely to be DAF thickening, with an area requirement similar to Alternatives 2 and 3.
- Alternative 5 has no known track record for algae removal and also requires the same additional thickening step as Alternative 4.
- Alternative 6 has no known track record for algae removal from oxidation ponds and also requires the same additional thickening step as Alternatives 4 and 5.

The analysis shows that for Alternative 2, only two of the four existing air flotation tanks (AFT) need be rehabilitated and upgraded. The expected float concentration is 4 to 6%.

Because very little of the existing AFT system is anticipated to be utilized, Alternative 3 abandons the existing equipment and infrastructure and replaces the AFTs with a new DAF system. This alternative uses rectangular dissolved air flotation (DAF) tanks. The required process area is approximately 33-percent the existing AFT area. Four DAF tanks 37 ft long and 25 ft wide would be required. A preliminary site layout would be with the new DAF tanks constructed over AFTs 3 and 4. AFT 4 would first be demolished and DAFs 1 and 2 constructed. Then AFT 3 would be demolished, and DAFs 3 and 4 constructed. AFTs 1 and 2 would be abandoned. The expected float concentration is 4 to 6%.

Selection of Alternative 3 may allow higher loading rates, with even smaller DAF process areas. However this would require on-site pilot tests.

The recommendation in this TM is to carry out cost evaluations of Alternatives 2 and 3 to decide which alternative should be carried through to final design and implementation.

1. INTRODUCTION

This Technical Memorandum (TM) evaluates alternatives to remove algae from the effluent from the Sunnyvale Water Pollution Control Plant (WPCP). There are four existing air flotation tanks (AFT) that use dissolved air flotation (DAF) to remove and recover the algae that grows in the oxidation ponds at the WPCP. Removal of the algae from the effluent is required to maintain effluent quality within permitted limits. The four AFTs were constructed in the mid-1970s and early 1980s and, therefore, are in need of extensive mechanical and electrical improvements to continue operation in the future. This TM examines the current system of dissolved air flotation, and compares this with other alternative approaches for algae removal from the effluent from the oxidation pond effluent.

2. ALTERNATIVES FOR ALGAE REMOVAL AT THE WPCP

The projected maximum month flow for the WPCP is 22.4 mgd in 2035. The corresponding peak week and peak hour flows are 24.3 and 50 mgd, respectively, although operation of the lagoon system allows attenuation of peak flows. Therefore, the algae removal system should be designed to receive up to the maximum month design flow, assuming that peak flows will be contained in the lagoon system.

The following list provides a number of approaches for removing algae at the WPCP. These alternatives have been short-listed from a wider spectrum of alternatives to consider only those that appear to be viable for the Sunnyvale WPCP. Each of the alternatives will be evaluated based on the projected flows.

Table 1. Algae Removal Alternatives

Alternative	Description
1 Maintain existing AFTs	Rehabilitate existing AFT equipment in kind. Process remains the same, but mechanical equipment replaced as needed. Maintain existing filtration system.
2 Upgrade existing AFTs	Upgrade AFTs to improve energy efficiency and provide enhanced thickening capability within the AFTs. Maintain existing filtration system.
3 Maintain flotation as the algae removal process, but replace system	Replace AFTs with newer technology. Maintain existing filtration system.
4 Replace flotation technology with sedimentation and separate thickening	Provide deaeration to relieve oxygen supersaturation, to allow sedimentation. Maintain existing filtration system.
5 Replace flotation technology with ballasted sedimentation and separate thickening	Deaeration is not required for sedimentation. Maintain existing filtration system.
6 Replace flotation technology with membrane separation and separate thickening	Coagulant may not be required; or at much reduced dosage. Existing filtration system not required.

2.1 Alternative 1 – Maintain Existing AFTs

Figure 1 shows a schematic of one of the AFTs in the existing system. The recent RMC Improvements Alternatives Technical Memorandum (December 29, 2008) pointed out that extensive structural, mechanical, electrical and I&C improvements are required with the existing installations to continue operation into the future.

There are four AFTs, each with a diameter of 60-feet. Based on historical performance, the float concentration expected is approximately 3 to 4 % under projected peak week loads.

Since this alternative requires extensive structural, mechanical, electrical and I&C improvements, as delineated in the December 2008 RMC TM, it appears obvious that Alternative 2, which builds on Alternative 1 to upgrade the system and incorporate the latest technology is the preferred alternative. Therefore, Alternative 1 is not considered further in this TM.

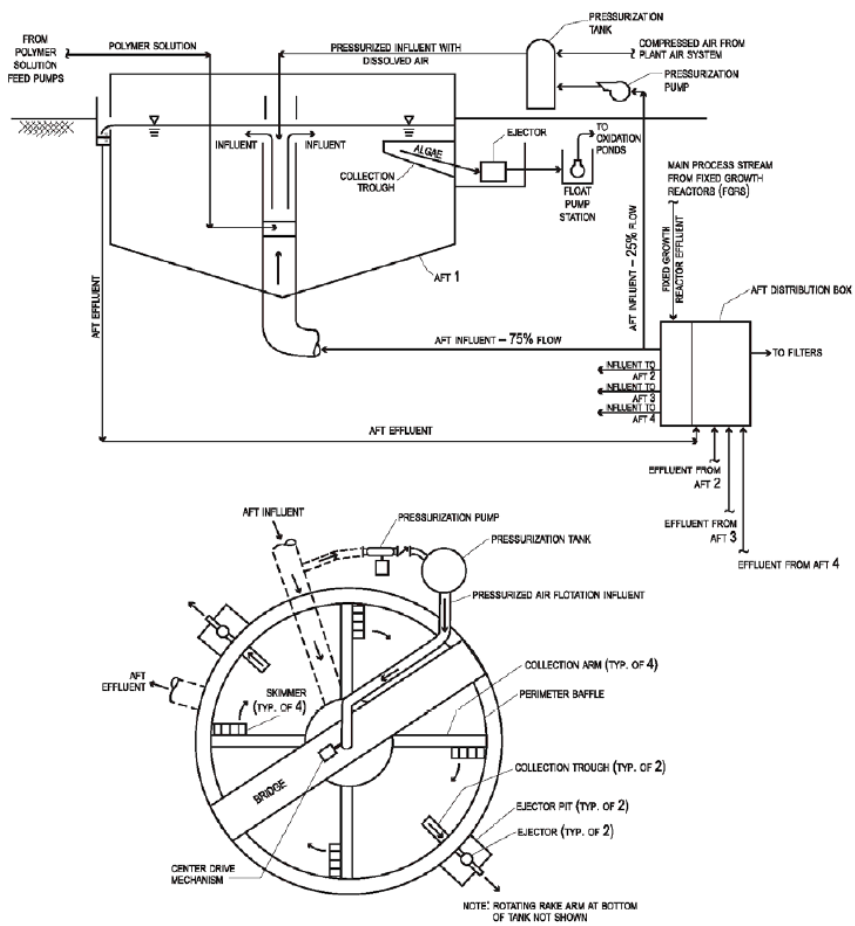

Figure 1. Process schematic of a single AFT

2.2 Alternative 2 – Upgrade Existing AFTs

The difference between this alternative and Alternative 1, is that in addition to the structural, mechanical, electrical and I&C upgrades required, design changes would be made to the existing system in terms of the saturators, chemical addition, the scrapers and float beach assemblies. In other words, there would be a re-

design and replacement of much of the basic equipment within the AFTs. Figure 2 shows some of the potential proposed improvements to the original AFT design. In addition to these improvements, changes to the way coagulating chemicals are fed to the AFTs, and the saturator design, would be proposed.

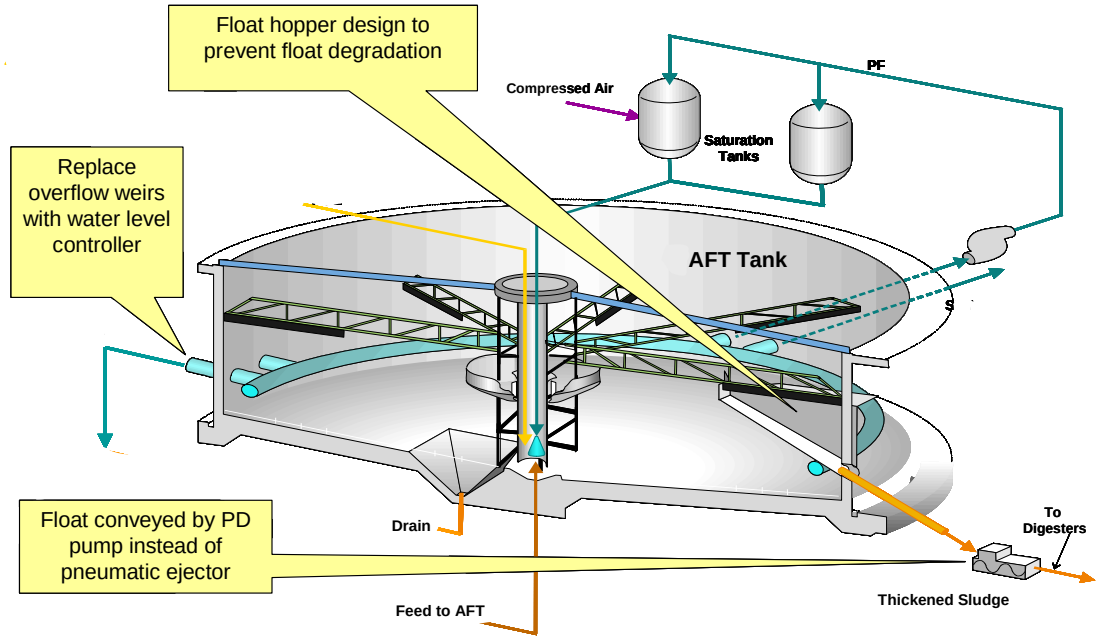

Figure 2. Process Schematic of AFT Improvements

In summary, the proposed improvements would be:

- Replace overflow weirs with submerged clarified water collection and water level controller. The benefit is that drainage and thickening of the float can be optimized.
- Replace float hopper with a design that prevents rotation of the float mass and encourages float dewatering. The benefit is that thickening of the float would be optimized.
- To resolve maintenance and operational issues with the existing pneumatic ejectors, these would be replaced with positive displacement pumps.
- Replace saturator system including pumps. The benefit here is that the existing system could have a saturation efficiency of approximately 65% based on measurements on other systems of this generation. More recent Brown and Caldwell designs have proven efficiencies of approximately 90%. This means that energy costs are significantly reduced for a given air/solids ratio.

The hydraulic and solids loadings to the AFTs would be the same as for Alternative 1. Because of improvements to the thickening function, the float concentration expected is approximately 4 to 6% under projected peak week loads.

2.3 Alternative 3 – Maintain Flotation as the Algae Removal Process, but Replace System

In this alternative, the existing AFT system would be abandoned, and replaced with a completely new system. The new system could take various forms:

- The first option could be the suspended air flotation (SAF) system marketed by Heron Innovators, shown schematically in Figure 3. In this system, the SAF system injects a chemical emulsion pre-saturated with compressed air into the center well of the AFT. The chemical used is proprietary but it appears that it may essentially comprise a cationic detergent. The cationic charge facilitates attachment of the detergent molecule to bubbles and algae particles, and stabilizes the air suspension. The SAF system does not utilize pressurization pumps and the compressed air utilized has a pressure of only approximately 20 psi. Polymer would likely still be used to optimize collection of the algae and maximize clarification of the effluent.

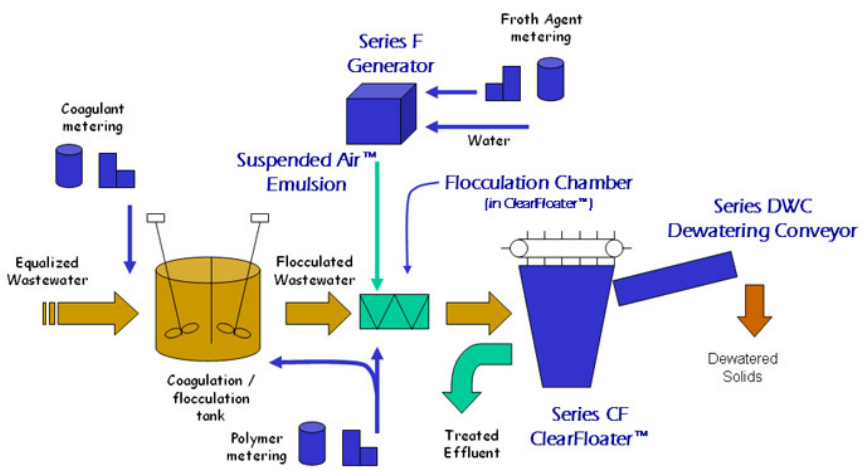

Figure 3. Heron's SAF Flotation System

Possible disadvantages with this system include:

- This system does require process proving. Therefore, before considering this option, pilot scale process trials should be conducted at the plant alongside the existing AFTs.
- Cationic detergents are generally toxic, and are often used for disinfection purposes. Therefore, there may be an undesirable effect on effluent WET tests, which needs to be demonstrated.
- It appears that this system has heretofore been used on relatively small systems. Therefore there may be issues with scale-up in the case of applying the technology to the WPCP.

Because of these disadvantages, this option is not considered further in this TM. If the City does conduct successful pilot trials then this option could be re-examined in the future if required.

- The second option is also a DAF process, but different to the existing system by the method of air dissolution. In this case special centrifugal pumps allow air to be injected to the suction side of the pump as shown in Figure 4. No saturation vessels are required. One manufacturer, World Water Works claims that the system is much simpler to control and operate than a DAF system that includes pressurization pumps, saturation vessels, compressors and level controls.

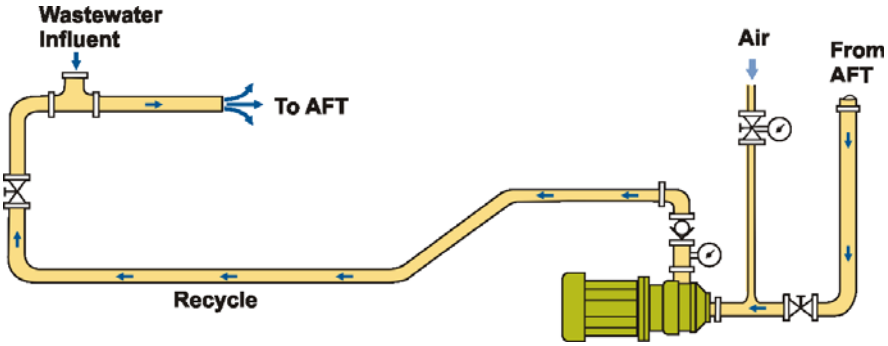

Figure 4. Pump Injection Dissolution System

There are potential capital cost savings with this alternative, since saturation vessels are not required. However, disadvantages are that there is a limit to the amount of air injection possible before air binding occurs, and higher energy is required because of the reduced pump efficiency. On-site measurements at existing full-scale installations are required to determine the actual amount of dissolved air produced by this system, and the energy expended in producing the dissolved air.

Because of the higher energy costs that would be associated with this system, it is not considered further in this TM.

- The third option could be the rectangular DAF process marketed by Infilco or ITT/Leopold. Such systems have been able to process water at rates of approximately 20 gpm/ft^2 in water treatment applications. An integral feature of this system is a full floor coverage of effluent drawoff by nozzles or collection headers, as shown in Figure 4.

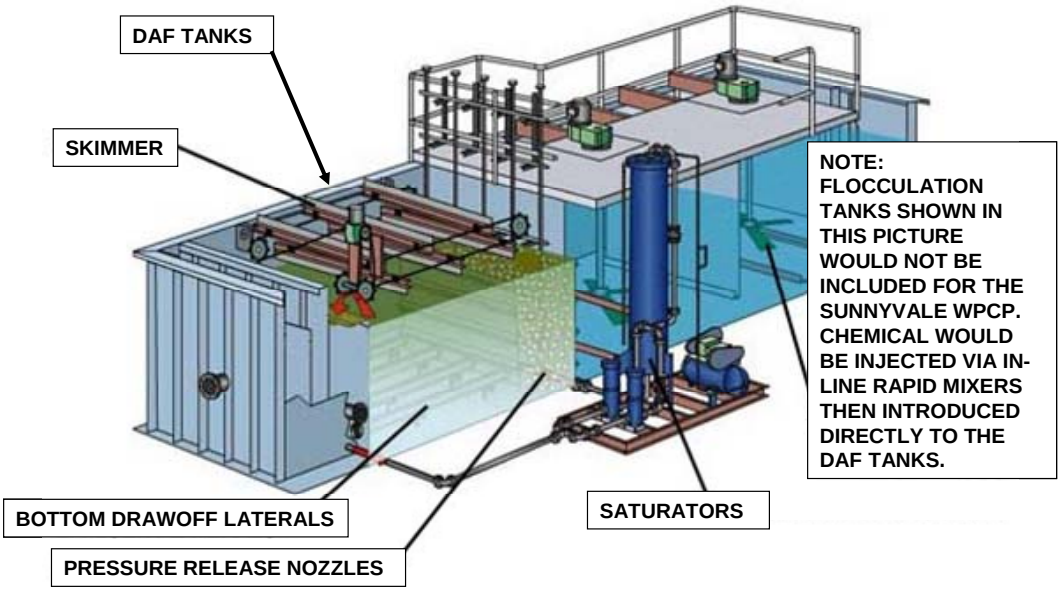

Figure 4. High Rate DAF System (ITT/Leopold® Clari-DAF™ System)

The benefit of the rectangular system is that area requirements would be significantly less, with overall space savings.

Since there is long-term experience with this type of flotation device, particularly applied to water treatment, backwash water treatment, secondary effluent polishing, and with algae recovery, this alternative should be considered further.

2.4 Alternative 4 – Replace Flotation Technology with Sedimentation and Separate Thickening

In this alternative, the existing AFTs would be abandoned and replaced with sedimentation tanks. The advantage would be that the sedimentation system would be simpler than the AFTs without pressurization pumps, saturation vessels, compressors or level controls. However, the main disadvantage is that the high degree of oxygen supersaturation developed in the ponds would seriously hinder settling. Therefore, before settling, a deaeration tank would be required to strip the supersaturated gases from the water. In addition, coagulation and flocculation tanks in series would be required before the sedimentation tanks. The required surface overflow rate for the sedimentation tanks, even after deaeration is estimated at approximately 0.5 gpm/ft2. The process area required, based on maximum month flow would be 31,100 ft^2, or almost 3-times the area of the existing AFTs.

It is expected that the thickened sludge concentration removed from the bottom of the sedimentation tanks would be approximately 1% or less. Therefore, an additional thickening step would be required before the anaerobic digesters. Potentially there are a number of thickening devices that could be used, including DAF thickeners and gravity belt thickeners. Of these, the proven track record is with DAF thickeners. The area requirement for the DAF thickeners is dependent on the applied solids loading rate to achieve the required degree of thickening. Since the solids loading rates in flotation alternatives 1 though 3 would be similar to that required in the thickener, the area for the DAF thickener would be similar to the AFT or DAF tank areas in Alternatives 1 through 3. Therefore, there appears to be little advantage in having a separate thickening stage, when both clarification and thickening can be carried out simultaneously in alternatives 1 through 3.

In addition to the low settled sludge concentration and the separate thickening issue, the large area required for the sedimentation tanks is a significant disadvantage. For these reasons, this alternative is not considered further in this TM.

2.5 Alternative 5 – Replace Flotation Technology with Ballasted Sedimentation and Separate Thickening

In this alternative, the need for deaeration is replaced by the addition of a weighting agent to the algae. This allows a higher sedimentation rate and consequently smaller tankage. Two alternative weighting agents are sand, used in the Actiflo process, and magnetite, used in the CoMag process, shown in Figure 5. There are some advantages to using magnetite, including the higher rate of sedimentation possible given the higher specific gravity of the magnetite, and the possibility of using either the existing filters, or a magnetic filter for final effluent polishing.

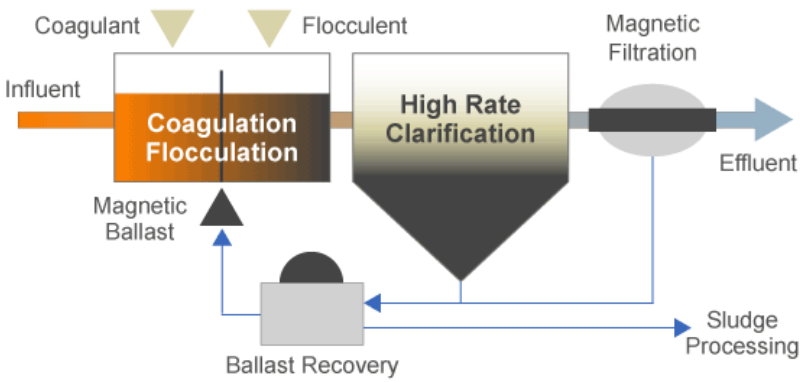

Figure 5. Schematic of the CoMag Process.

Assuming a surface overflow rate of approximately 7.5 gpm/ft² for this application, the process area requirement would be approximately 2,100 ft².

Despite the addition of the ballasting agent, the settled sludge concentration after magnetite recovery would still likely be approximately 2% or less. Therefore, similarly to Alternative 4 an additional thickening step would be required before digestion. Because of the issues identified with separate thickening, and that there is no known track record with this alternative for algae separation, this alternative is not considered further in this TM.

2.6 Alternative 6 – Replace Flotation Technology with Membrane Separation and Separate Thickening

This alternative would represent the most compact option for the WPCP. There are no known applications of microfiltration (MF) or ultrafiltration (UF) for separation of algae from oxidation ponds, although the application of membranes in water treatment with algae in the raw water has been reported. Generally membranes have experienced serious flux declines due to the presence of algae in the raw water, but at least one application using submerged aerated membranes (GE-Zenon UF membranes) was successful, although coagulation and sedimentation did precede the membranes in that application. Despite the possible application of UF for algae separation at the WPCP, a major disadvantage is that the algae concentration to be conveyed for further processing would be approximately 1% or less. This would require an additional thickening step – probably DAF thickening, as in Alternatives 4 and 5. For this reason, and the possible fouling and flux limiting conditions, this alternative is not considered further in this TM.

3. COMPARISON OF SHORT-LISTED ALTERNATIVES

The previous section considered six alternatives. Of these, Alternative 2 and a sub-alternative in Alternative 3 were shown to be worthy of further consideration. Specific features of these two short-listed alternatives are as follows:

3.1 Alternative 2 – Upgrade Existing AFTs

In this alternative, the existing AFTs would be essentially stripped and almost all of the electro-mechanical equipment replaced with updated equipment designed for process optimization in terms of both clarification and thickening. The main features of this alternative are as follows:

- Maintain existing AFT concrete structures

- Carry out recommended structural improvements to prevent rebar corrosion and leakage, and to bring the structure up to seismic and structural code requirements. The existing structure has been found to be compromised due to past seismic events, according to the December 2008 RMC TM.
- Replace most of existing electro-mechanical equipment, including:
    - Sludge pumps and check valves
    - Saturator system including pressure cylinders and pressurization pumps
    - Center drive mechanisms
    - Float scraper assemblies
    - Replace perimeter baffle with submerged launder
    - Float collection troughs
    - Replace MCC and other electrical equipment as needed
    - Replace and install instrumentation as needed

The plant layout for the AFT complex will remain essentially the same as the existing installations.

A key design criterion is the amount of air supplied for flotation. Design will be based on the greater of two parameters: an air/solids ratio of 0.03, and at least 8 mg air per liter pond effluent treated. The reason why the air/solids ratio is not considered a sufficient design parameter in this case, is the need to provide adequate contact opportunity between the cloud of precipitated bubbles, and the relatively low TSS exiting the ponds at the WPCP. From the EOA Memorandum (October 5, 2005) the monthly average pond effluent TSS, for the period 1990 through 2005 varies from a low of 59 mg/l (typically in January-February) to 130 mg/l (typically in July).

Table 2 presents the calculated air and required saturator recycle flow, based on 2035 flows. Assuming a saturator pressure of 70 psig, the total required saturator recycle flow is calculated to be 1.5 mgd. The amount of air supplied would be 8 mg air per liter pond effluent flow. The corresponding air/solids ratio under design maximum month conditions would be 6%.

Table 2. Air Calculations

Flow		a_s[1] basis	Assumed TSS[2]	Assumed Sat. Press.	Precipitated air	Required Saturator Recycle		Calc. air[3] on a_s basis	Required air[3]	Required recycle	Calc. air[3] on mg/l basis	Calc. a_s
Basis	mgd	g/g	mg/l	psig	mg/l	Ratio	mgd	mg/l	mg/l	mgd	mg/l	g/g
MMF	22.4	**0.03**	130	70	117	**0.033**	**0.75**	3.9	**8.0**	**1.5**	8.0	0.062

[1]a_s = air/solids ratio (mass/mass basis)

[2]From EOA Memo Oct.5, 2005 - Highest month average pond TSS in July = 129.6 mg/l

[3]Recommended 8-10 mg air/l wastewater flow for adequate contact at low TSS

Another key design criterion is the area provided for clarification and thickening in the AFTs. Figure 6 shows the results from pilot studies on DAF applied to separate algae from oxidation pond effluents. From these results, the maximum air/solids ratio applied to separate algae from the oxidation ponds in those studies was 0.026 g/g. The maximum limiting downflow rate at that air/solids ratio, before solids were drawn down to the effluent from the pilot DAF unit, was 7.4 gpm/ft². Therefore, this represents the maximum known hydraulic loading applied to algae separation from oxidation ponds. Applying a factor of 1.25 to this limiting loading, a maximum design hydraulic loading of approximately 6 gpm/ft² is determined. It is pertinent to note that this hydraulic loading may not be the maximum that could be applied successfully for algae separation – it merely represents the limit of past reported experience.

Figure 6 also presents results from the same pilot studies on DAF thickening of the separated algae. From these results, and assuming a design maximum month thickened float concentration of approximately 5%, the proposed maximum applied solids loading for design maximum month conditions is 10 lb/ft².d.

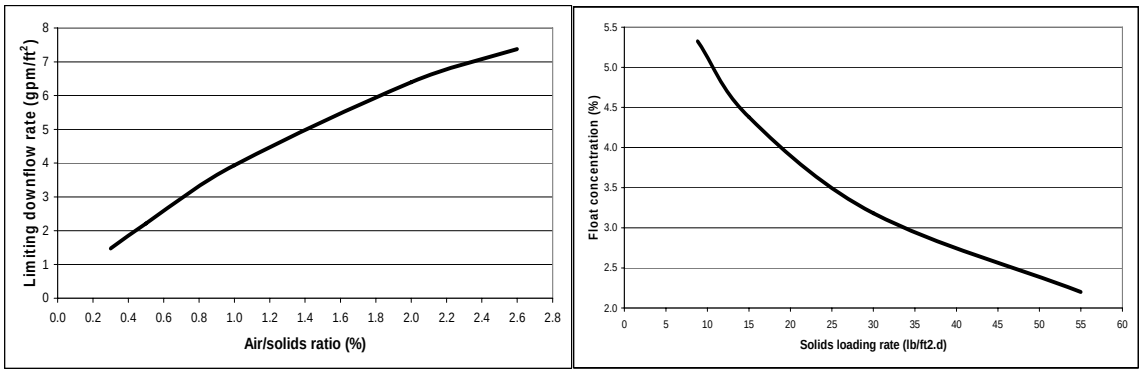

Figure 6. Oxidation Pond Algae Separation and Thickening Results – Using Ferric Chloride as Sole Coagulant at 50 mg/l as Fe. (From Bratby J., Filtration & Separation, Nov/Dec, 1974, pp.614-624)

Table 3 presents calculated hydraulic and solids loadings to the existing AFTs. Calculations are presented for all four, three, two or one AFTs in service. Based on the hydraulic and solids loading criteria presented above, projected design flows could be treated in one of the four existing AFTs. However, in terms of redundancy, at least two units would be required.

Therefore, only two of the existing four AFTs need to be upgraded.

Table 3. Hydraulic and Solids Loading Calculations

Flow		Assumed TSS[1]	Air/ solids ratio[2]	Saturator recycle[2]	Number of AFTs in service	Total AFT area	Calc. solids loading	Calc. hydraulic loading
Basis	mgd	mg/l	g/g	mgd	-	ft2	lb/ft^2.d	gpm/ft^2
MMF	22.4	130	0.062	1.5	4	11,310	2.1	1.5
MMF	22.4	130	0.062	1.5	3	8,482	2.9	2.0
MMF	22.4	130	0.062	1.5	2	5,655	4.3	2.9
MMF	22.4	130	0.062	1.5	1	2,827	8.6	5.9

[1]From EOA Memo Oct.5, 2005 - Highest month average pond TSS in July = 129.6 mg/l

[2]From air calculations

3.2 Alternative 3 – Maintain Flotation as the Algae Removal Process, but Replace System

Because very little of the existing AFT system is anticipated to be utilized in Alternative 2, this alternative of completely replacing the existing AFT system with a new DAF system is a viable alternative. The format proposed for the replacement system is rectangular. The new DAF tanks will be constructed with in-line rapid mix facilities and reciprocating or chain and flight float removal scrapers. Figure 6 shows examples of such systems.

Figure 6. Examples of Rectangular DAF Tanks

Table 4 presents calculated DAF area requirements to comply with the proposed design hydraulic and solids loading criteria.

Table 4. DAF Tank Area Calculations

Flow		Applied solids loading[1]	Assumed TSS[2]	Calc. area based on solids load	Saturator recycle[3]	Calc. hydraulic loading	Air/ solids ratio[3]	Maximum acceptable hydraulic loading[4]	Calc. area based on hydraulic load	Calc. solids loading[5]
Basis	mgd	lb/ft^2.d	mg/l	ft^2	mgd	gpm/ft^2	g/g	gpm/ft^2	ft^2	lb/ft^2.d
MMF	22.4	**10.0**	130	**2,429**	1.5	6.8	0.062	6.0	2,768	8.8

[1]estimated to achieve 5% thickened float

[2]From EOA Memo Oct.5, 2005 - Highest month average pond TSS in July = 129.6 mg/l

[3]From air calculations

[4]Maximum value from pilot work (Bratby, 1974) and 1.25 factor applied to limiting downflow rate.

[5]Based on largest calculated area

Table 4 shows that the required total area for the DAF tanks is principally dependent on the hydraulic loading limit of 6 gpm/ft^2. On this basis, the applied solids loading under 2035 design conditions is 8.8 lb/ft2.d under maximum month conditions.

Assuming a common length:width ratio of approximately 1.5:1 for this type of application, and a maximum area of each DAF tank of approximately 1,200 ft^2, then four DAF tanks, each with length 37 ft and width 25 ft would be required. The fourth tank would be provided for redundancy.

Figure 7 presents a preliminary suggestion of how the new rectangular DAF tanks could be implemented. In this case the construction sequence could be to:

1. Deactivate and demolish AFT-4;
2. Construct and put into service DAFs 1 and 2;
3. Deactivate and demolish AFT-3;
4. Construct and put into service DAFs 3 and 4;
5. Deactivate and abandon AFTs 1 and 2.

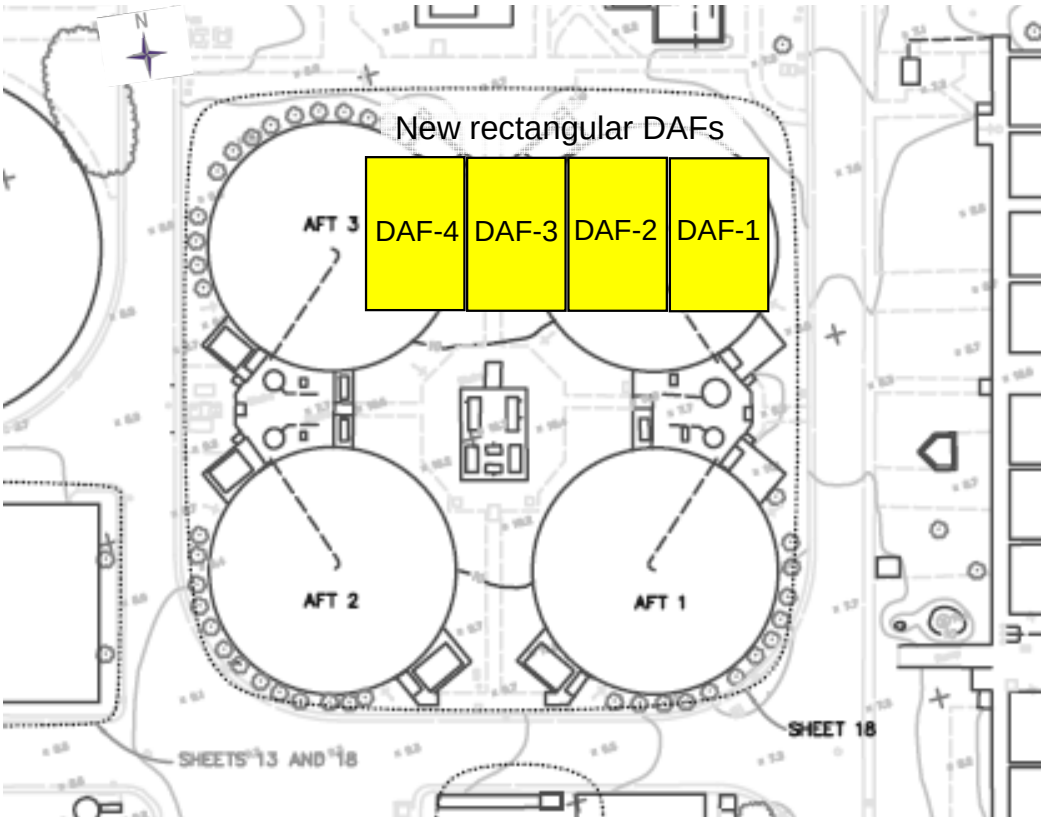

Figure 7. Preliminary Site Layout for New Rectangular DAF Tanks

It was noted previously that the maximum hydraulic loading adopted for design may not be the maximum that could be applied successfully for algae separation – it merely represents the limit of past reported experience. Therefore, this suggests that there would be a benefit to conducting pilot trials to test whether higher hydraulic and solids loadings can be applied for the design of the new facilities. One approach is to pre-select an equipment supplier and, as part of the pre-purchase agreement, conduct on-site pilot tests using the manufacturer's pilot equipment.

4. RECOMMENDATIONS

Two alternatives are recommended for further consideration:

Alternative 2 retains the existing AFT structure, but requires extensive structural rehabilitation and complete electro-mechanical equipment replacement.

Alternative 3 abandons the existing AFT system and installs a new DAF system in its place.

Cost estimates of Alternatives 2 and 3 should be developed to decide which alternative should be carried through to final design and implementation.

The new rectangular system proposed for Alternative 3 may allow higher loading rates than assumed in this TM. On-site pilot tests are recommended to establish this.