BROWN AND CALDWELL

Appendix G. Data for DAFT Experiments

BAF Phase II TM
Bench Scale DAFT Study

Source/Remark

OBJECTIVE

Calculate the A/S ratio at 50 percent of recycle ratio for DAF thickening of the mixed Biostyr and Biofor C backwash water

Formula

$$\frac{A}{S} = \frac{1.3 s_a (fP - 1)R}{S_a Q}$$

Metcalf & Eddy, Third edition, page 249

A/S = air to solids ratio, mL/mg
sa = air solubility, mL/L
f = fraction of air dissolved at pressure P
P= pressure , atm
Sa = wastewater TSS, mg/L
R/Q = recycle ratio

Assumptions

Temperature = 20 ^{o}C
sa = 18.7 mL/L at 20 ^{o}C — *Metcalf & Eddy, Third edition, page 249*
Air density = 1.204 mg/ml at 20 ^{o}C — *Metcalf & Eddy, Third edition*
f = 0.65

Data Obtained through DAFT Experiments

Sa = 640 mg/L
R/Q = 0.5
P = 4.4 atm

Calculations

$$A/S = \frac{1.3\ (18.7\text{mL/L})\ ((0.65*4.4\text{atm})-1) * (0.5)}{640\ \text{mg/L}}$$

A/S = 0.0395 mL/mg

A/S= (0.0395 mL/mg) (1.204 mg/mL)

A/S= 0.042

END OF CALCULATION

Source/Remark

OBJECTIVE

Calculate the A/S ratio at 150 percent of recycle ratio for co-thickening of the primary sludge and BAF backwash water

Formula

$$\frac{A}{S} = \frac{1.3 s_a (fP - 1)R}{S_a Q}$$

Metcalf & Eddy, Third edition, page 249

A/S = air to solids ratio, mL/mg
s_a = air solubility, mL/L
f = fraction of air dissolved at pressure P
P= pressure , atm
S_a = wastewater TSS, mg/L
R/Q = recycle ratio

Assumptions

Temperature = 20 ^oC
s_a = 18.7 mL/L at 20 ^oC — *Metcalf & Eddy, Third edition, page 249*
Air density = 1.204 mg/ml at 20 ^oC — *Metcalf & Eddy, Third edition*
f = 0.65 — *Assumed*

Data Obtained through DAFT Experiments

S_a = 1970 mg/L
R/Q = 1.5
P = 4.4 atm

Calculations

A/S = 1.3 (18.7mL/L) ((0.65*4.4atm)-1) * (1.5) / 1970 mg/L

A/S = 0.0344 mL/mg

A/S= (0.0344 mL/mg) (1.204 mg/mL)

A/S= 0.041

END OF CALCULATION

Source/Remark

OBJECTIVE

Calculate the solids content of the mixture of primary sludge with one percent solids content and BAF backwash water

Data available

Primary sludge = 479,000 ld/day

Primary sludge peaking factor = 1.27 — *Table 2.2 inTechnical Memorandum, June 2003*

BAF sludge = 172,000 lb/day

BAF sludge peaking factor = 1.36

Assumptions

Primary sludge solid content = 1% (10,000 mg/L)

BAF backwash water TSS = 760 mg/L — *mixed Biostyr and Biofor C backwash water average TSS concentration in Phase I*

Calculations

At peak loading conditions:

Primary sludge (M_{PS}) = (479,000) lb/day * 1.27
608,330 lb/day

Volume of primary sludge (V_{PS}) = (608,330 lb/day)*(1/10g/L)*(454.54 g/lb)
27,651,031 L/day

BAF sludge (M_{BAF}) = (172,000 lb/day) * 1.36
233,920 lb/day

Volume of BAF sludge (V_{BAF})= (233,920 lb/day)*(1/0.76g/L)*(454.54 g/lb)
139,904,306 L/day

Mass Balance:

M_{PS} +M_{BAF} = (V_{PS} + V_{BAF})* TSS of the mixture
842,250 lb/day = (167,555,337 L) * TSS of the mixture
TSS of the mixture = 2285 mg/L

END OF CALCULATION

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Bench Scale DAFT Testing

Test: DAFT → CO-THICKENING

Date: 12/9/04 **Time:** 17:00 **Batch #:** 1 **Analyst:** SS

INSTRUMENT READINGS – DAFT Unit		PORTABLE METER READINGS –DAFT-Inf	
Parameter	**Value**	**Parameter**	**Value**
Volume of CEPT sludge used, L	430 mL	pH	7.06
Solid content of CEPT sludge, %	4 %	Temperature, °C	19.6
Volume of BAF sludge used, L	10 L	Turbidity, NTU	Too high
Solid content of BAF sludge, %	640 mg/L		
Polymer usage, mg/L	3		
Pressure applied, psi	50		
Duration of pressure application, min	26	**PORTABLE METER READINGS –DAFT-Eff**	
Sludge blanket level, in	1.1 cm	pH	7.21
Recycle ration used, %	1.5 (150%)	Temperature, °C	20.7
How fast is floatability of the solids?	25 cm/ ~~3~~ 20 sec	Turbidity, NTU	99.1
Other observations: Settling time = 18 min.			

Nalco Optimer polymer (mg/L)	NTU
1	162
2	130
2.5	123
3	108 / 118
4	128

big flocs

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Bench Scale DAFT Testing

Test: DAFT → CO-THICKENING

Date: 12/9/04 Time: 18:00 Batch #: 2 Analyst: SS

INSTRUMENT READINGS – DAFT Unit		PORTABLE METER READINGS –DAFT-Inf	
Parameter	**Value**	**Parameter**	**Value**
Volume of CEPT sludge used, L	430	pH	7.06
Solid content of CEPT sludge, %	4	Temperature, °C	19.6
Volume of BAF sludge used, L	10	Turbidity, NTU	Too high
Solid content of BAF sludge, %	640 mg/L		
Polymer usage, mg/L	3		
Pressure applied, psi	50		
Duration of pressure application, min	24	**PORTABLE METER READINGS –DAFT-Eff**	
Sludge blanket level, in	1 cm	pH	7.19
Recycle ration used, %	150 %	Temperature, °C	20.6
How fast is floatability of the solids?	24.3 cm / 20 sec	Turbidity, NTU	104
Other observations:			some particles contributed to the subnatant!

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Bench Scale DAFT Testing

Test: DAFT → CO-THICKENING

Date: 12/9/04 **Time:** 6:35pm **Batch #:** 3 **Analyst:** SS

INSTRUMENT READINGS – DAFT Unit		PORTABLE METER READINGS –DAFT-Inf	
Parameter	**Value**	**Parameter**	**Value**
Volume of CEPT sludge used, L	480 mL	pH	7.06
Solid content of CEPT sludge, %	4%	Temperature, °C	19.6
Volume of BAF sludge used, L	10	Turbidity, NTU	Too high
Solid content of BAF sludge, %	640 mg/L		
Polymer usage, mg/L	3		
Pressure applied, psi	50		
Duration of pressure application, min	20	**PORTABLE METER READINGS –DAFT-Eff**	
Sludge blanket level, in	1cm	pH	7.11
Recycle ration used, %	150	Temperature, °C	20.7
How fast is floatability of the solids?	24.5 cm / 20sec	Turbidity, NTU	95.1
Other observations:			

1 L	6.5 cm
1.5 L	10 cm
2	13.3 cm
2.5	16.8 cm
3	20.3 cm
3.5	24 cm
3.7	25.5 cm

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Bench Scale DAFT Testing

Test: DAFT ➔ Mixed BIOSTYR and BIOFOR C BW

Date: 12/9/04 **Time:** 12:00 **Batch #:** 1 **Analyst:** SS

INSTRUMENT READINGS – DAFT Unit		**PORTABLE METER READINGS –DAFT-Inf**	
Parameter	**Value**	**Parameter**	**Value**
Volume of BW used, L	2	pH	7.16
Polymer usage, mg/L	1.5	Temperature, °C	19.6
Pressure applied, psi	50	Turbidity, NTU	400
Duration of pressure application, min	18	**PORTABLE METER READINGS –DAFT-Eff**	
Sludge blanket level, in	0.5 cm	pH	7.15
Recycle ration used, %	1L/2L = 50%	Temperature, °C	20.1
How fast is floatability of the solids?	in 20 sec	Turbidity, NTU	43.5
Other observations: Sludge rise was very fast. ~ 20.3 cm / 20 sec = 1 cm/sec Fine Air bubbles observed in subnatant after the ~~sett~~ settling time.			

Settling time = 20 min

Could not take sludge samples.

Nalco Optimer polymer (mg/L)	Turbidity (NTU)	
0.5	23	pin flocs
1	20	
1.5	18	good flocs
2	17	↓ large flocs
3	14.7	

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Bench Scale DAFT Testing

Test: DAFT → Mixed BIOSTYR and BIOFOR C BW

Date: 12/9/04 **Time:** 13:00 **Batch #:** 2 **Analyst:** SS

INSTRUMENT READINGS – DAFT Unit		PORTABLE METER READINGS –DAFT-Inf	
Parameter	**Value**	**Parameter**	**Value**
Volume of BW used, L	2	pH	7.16
Polymer usage, mg/L	1.5	Temperature, °C	19.6
Pressure applied, psi	50	Turbidity, NTU	400
Duration of pressure application, min	16	**PORTABLE METER READINGS –DAFT-Eff**	
Sludge blanket level, in	0.5 cm	pH	7.28
Recycle ration used, %	50%	Temperature, °C	20.4
How fast is floatability of the solids?	20.3 cm / 24 sec	Turbidity, NTU	34.5 / 36.1
Other observations: settling time = 22 min In 2 min all the sludge rised.			ave = 35.3

A/S = 0.04

City of San Diego MWWD BAF Pilot Study Sampling Program
Brown and Caldwell Project 24901
Bench Scale DAFT Testing

Test: DAFT ➔ Mixed BIOSTYR and BIOFOR C BW

Date: 12/9/04 Time: 14:00 Batch #: 3 Analyst: SS

INSTRUMENT READINGS – DAFT Unit		PORTABLE METER READINGS –DAFT-Inf	
Parameter	Value	Parameter	Value
Volume of BW used, L	2	pH	7.16
Polymer usage, mg/L	1.5	Temperature, °C	19.6
Pressure applied, psi	50	Turbidity, NTU	400
Duration of pressure application, min	20	PORTABLE METER READINGS –DAFT-Eff	
Sludge blanket level, in	0.5 cm	pH	7.26
Recycle ration used, %	50 %	Temperature, °C	20.6
How fast is floatability of the solids?	20 cm / 20 sec	Turbidity, NTU	39.1
Other observations: Sludge rises very fast.			

A/S = 0.04

BROWN AND CALDWELL

Appendix H. Estimate of Aeration Requirement

Problem Statement:

This worksheet calculates annual electrical power cost for full-scale Kurger Biostyr BAF based on full-scale design conditions and oxygen transfer efficiency measurements by Dr. Michael Stenstrom on December 13-14, 2004. User-entered information is highlighted yellow.

Calculate Full-Scale Oxygen Transfer Rate (OTR):

$Q := 264 \cdot mgd$

$BOD := 116 \cdot \frac{mg}{L}$ Maximum month design conditions from Kruger proposal (11/21/03)

$T := 22 \cdot degreeC$

$BOD_{load} := Q \cdot BOD$

$BOD_{load} = 255570 \frac{lb}{day}$

$OTR := BOD_{load} \cdot 1 \cdot \frac{lb}{lb}$ Assume 1 lb oxygen/lb BOD

$OTR = 10649 \frac{lb}{hr}$

Calculate Specific Airflow Rate:

$Q_{air} := 88000 \cdot \frac{ft^3}{min}$ Total airflow from Kruger proposal

$A := 2582 \cdot ft^2$ Cell area from Kruger proposal

$NoCells := 40$ 40 cells from Kruger proposal

$Q_{air\_specific} := \frac{Q_{air}}{A \cdot NoCells}$

$Q_{air\_specific} = 0.85 \frac{ft}{min}$

Define Other Parameters:

$D := 20 \cdot ft$

Kruger proposal states only media depth (11.48 ft), not diffuser submergence or SWD. Assume 20 ft diffuser submergence.

$P_B := 14.7 \cdot psia$

Ambient atmospheric pressure

$P_B = 101.353 kPa$

$C^*_{S20} := 9.07 \cdot \frac{mg}{liter}$

DO saturation concentration at 20 degrees C, standard atmospheric pressure (P(S)), and 100 percent relative humidity

$\beta := 0.95$

$C := 4.7 \cdot \frac{mg}{liter}$

BAF effluent DO concentration assuming average concentration measured during off-gas testing

$\theta := 1.024$

$\rho_W := 998.3 \cdot \frac{kg}{m^3}$

Density of water at 20 degrees C (from Vennard and Street, 5th ed)

Calculate Temperature Correction Factor:

$$TempCorrFactor := \theta^{(T - 20 \cdot degreeC) \cdot \frac{1}{degreeC}}$$

$TempCorrFactor = 1.049$

Calculate DO Gradient Correction Factor:

$$C^* := C^*_{S20} \cdot \frac{51.6 \cdot degreeC}{31.6 \cdot degreeC + T}$$

$C^* = 8.73 \frac{mg}{L}$

DO saturation concentration at temperature T using correlation from BioWin 2.1 User Manual (EnviroSim Associates)

$DOGradientCorrFactor := \frac{\beta \cdot C^* - C}{C^*}$

$DOGradientCorrFactor = 0.412$

Calculate Normalized OTE:

$OTE_{norm} := 28.72 \cdot \left(\frac{Q_{air\_specific}}{\frac{ft}{min}} \right)^{-0.71}$

Correlation from analysis of off-gas test data collected over a specific airflow range between 0.39 and 1.08 ft/min

$OTE_{norm} = 32.18$ percent

Calculate OTE:

$OTE := OTE_{norm} \cdot TempCorrFactor \cdot DOGradientCorrFactor$

$OTE = 13.89$

Full-scale OTE at maximum month field conditions

Calculate Aeration Air Requirement:

$Q_{air} := 100 \cdot \frac{ft^3}{min}$

Given

$OTR = Q_{air} \cdot 0.0745 \cdot \frac{lb}{ft^3} \cdot 0.23 \cdot \frac{OTE}{100}$

Assumed value for solve block

$Foo := Find(Q_{air})$

$Q_{air} := Foo$

$Q_{air} = 74560 \frac{ft^3}{min}$

Calculate Blower Adiabatic Power:

$p_1 := P_B - 0.3 \cdot psia$ Assume 0.3 psi inlet filter pressure loss

$p_1 = 14.4\,psia$

$p_2 := P_B + \left[\left[(D + 6 \cdot in) \cdot \rho_W \cdot g\right] + 2.0 \cdot psia\right]$ Assume 6 in diffuser dynamic wet pressure (DWP) plus 2.0 psi aeration air distribution piping pressure loss

$p_2 = 25.6\,psia$ Corresponds to gage discharge pressure of 10.9 psig (24.6 psia - 14.7 psia). Kruger proposal states that discharge pressures typically range from 11.0 to 13.0 psig.

$\frac{p_2}{p_1} = 1.78$

$k := 1.395$ Cp/Cv (ratio of specific heats) for air

$HP_{ad} := \frac{k}{k-1} \cdot Q_{air} \cdot p_1 \cdot \left[\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}} - 1\right]$ Eq 6-23b from Chemical Engineers' Handbook, 6th ed.

$HP_{ad} = 2921.63\,hp$

Calculate Peak Month Electrical Power Cost:

$BHP := \frac{HP_{ad}}{0.80}$ Assume 80% blower efficiency (e.g., centrifugal blower)

$BHP = 3652.04\,hp$

$HP_{elect} := \frac{BHP}{0.95}$ Assume 95% motor efficiency

$HP_{elect} = 3844.26\,hp$

$PeakMonthPower := HP_{elect} \cdot 30 \cdot day \cdot 24 \cdot \frac{hr}{day}$

$PeakMonthPower = 2 \times 10^{6} kW \cdot hr$

$ElectPowerCost := 0.10 \cdot \frac{1}{kW \cdot hr}$ Assume $0.10/kWh

$PeakMonthPowerCost := PeakMonthPower \cdot ElectPowerCost$

$PeakMonthPowerCost = 206400$ Expressed as $/month

Calculate Annual Average Power Cost:

$PeakFactor_{PeakMonth} := 1.3$ Ratio of peak month BOD loading (oxygen demand) to annual average BOD loading

$AnnualPowerCost := \frac{PeakMonthPowerCost \cdot 12}{PeakFactor_{PeakMonth}}$

$AnnualPowerCost = 1.91 \times 10^{6}$ Expressed as $/year

Problem Statement:

This worksheet calculates annual electrical power cost for full-scale Infilco Degremont (IDI) Biofor C BAF based on full-scale design conditions and oxygen transfer efficiency measurements by Dr. Michael Stenstrom on December 13-14, 2004. User-entered information is highlighted yellow.

Calculate Full-Scale Oxygen Transfer Rate (OTR):

$Q := 264 \cdot mgd$

$BOD := 116 \cdot \frac{mg}{L}$ Maximum month design conditions from IDI proposal (12/12/03)

$T := 21.8 \cdot degreeC$

$BOD_{load} := Q \cdot BOD$

$BOD_{load} = 255570 \frac{lb}{day}$

$OTR := BOD_{load} \cdot 1 \cdot \frac{lb}{lb}$ Assume 1 lb oxygen/lb BOD

$OTR = 10649 \frac{lb}{hr}$

Calculate Specific Airflow Rate (based on manufacturer proposal):

$Q_{air} := 53600 \cdot \frac{ft^3}{min}$ Total airflow from IDI proposal

$A := 1612.54 \cdot ft^2$ Cell area from IDI proposal

$NoCells := 64$ 64 cells from IDI proposal

$$Q_{air\_specific} := \frac{Q_{air}}{A \cdot NoCells}$$

$Q_{air\_specific} = 0.52 \frac{ft}{min}$

Define Other Parameters:

$D := 20 \cdot ft$ — IDI proposal states only media depth (12.1 ft) and gravel depth (1.67 ft), not diffuser submergence or SWD. Assume 20 ft diffuser submergence.

$P_B := 14.7 \cdot psia$ — Ambient atmospheric pressure

$P_B = 101.353 kPa$

$C^*_{S20} := 9.07 \cdot \frac{mg}{liter}$ — DO saturation concentration at 20 degrees C, standard atmospheric pressure (P(S)), and 100 percent relative humidity

$\beta := 0.95$

$C := 4.7 \cdot \frac{mg}{liter}$ — BAF effluent DO concentration assuming average concentration measured during off-gas testing

$\theta := 1.024$

$\rho_W := 998.3 \cdot \frac{kg}{m^3}$ — Density of water at 20 degrees C (from Vennard and Street, 5th ed)

Calculate Temperature Correction Factor:

$$TempCorrFactor := \theta^{(T-20 \cdot degreeC) \cdot \frac{1}{degreeC}}$$

$TempCorrFactor = 1.044$

Calculate DO Gradient Correction Factor:

$$C^* := C^*_{S20} \cdot \frac{51.6 \cdot degreeC}{31.6 \cdot degreeC + T}$$

$C^* = 8.76 \frac{mg}{L}$

DO saturation concentration at temperature T using correlation from BioWin 2.1 User Manual (EnviroSim Associates)

$DOGradientCorrFactor := \frac{\beta \cdot C^* - C}{C^*}$

$DOGradientCorrFactor = 0.414$

Calculate Normalized OTE:

$OTE_{norm} := 28.72 \cdot \left(\frac{Q_{air\_specific}}{\frac{ft}{min}} \right)^{-0.71}$

Correlation from analysis of off-gas test data collected over a specific airflow range between 0.39 and 1.08 ft/min

$OTE_{norm} = 45.73$ percent

Calculate OTE:

$OTE := OTE_{norm} \cdot TempCorrFactor \cdot DOGradientCorrFactor$

$OTE = 19.74$

Full-scale OTE at maximum month field conditions

Calculate Aeration Air Requirement:

$Q_{air} := 100 \cdot \frac{ft^3}{min}$

Assumed value for solve block

Given

$OTR = Q_{air} \cdot 0.0745 \cdot \frac{lb}{ft^3} \cdot 0.23 \cdot \frac{OTE}{100}$

$Foo := Find(Q_{air})$

$Q_{air} := Foo$

$Q_{air} = 52457 \frac{ft^3}{min}$

Calculate Blower Adiabatic Power:

$p_1 := P_B - 0.3 \cdot psia$ Assume 0.3 psi inlet filter pressure loss

$p_1 = 14.4\,psia$

$p_2 := P_B + \left[\left[(D + 6 \cdot in) \cdot \rho_W \cdot g\right] + 2.0 \cdot psia\right]$ Assume 6 in diffuser dynamic wet pressure (DWP) plus 2.0 psi aeration air distribution piping pressure loss

$p_2 = 25.6\,psia$ Corresponds to gage discharge pressure of 10.9 psig (24.6 psia - 14.7 psia). IDI proposal rates process air blowers at 11.5 psig

$\frac{p_2}{p_1} = 1.78$

$k := 1.395$ Cp/Cv (ratio of specific heats) for air

$HP_{ad} := \frac{k}{k-1} \cdot Q_{air} \cdot p_1 \cdot \left[\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}} - 1\right]$ Eq 6-23b from Chemical Engineers' Handbook, 6th ed.

$HP_{ad} = 2055.55\,hp$

Calculate Peak Month Electrical Power Cost:

$BHP := \frac{HP_{ad}}{0.80}$ Assume 80% blower efficiency (e.g., centrifugal blower)

$BHP = 2569.44\,hp$

$HP_{elect} := \frac{BHP}{0.95}$ Assume 95% motor efficiency

$HP_{elect} = 2704.67\,hp$

$$PeakMonthPower := HP_{elect} \cdot 30 \cdot day \cdot 24 \cdot \frac{hr}{day}$$

$$PeakMonthPower = 1 \times 10^{6}\, kW \cdot hr$$

$$ElectPowerCost := 0.10 \cdot \frac{1}{kW \cdot hr}$$ Assume $0.10/kWh

$$PeakMonthPowerCost := PeakMonthPower \cdot ElectPowerCost$$

$$PeakMonthPowerCost = 145215$$ Expressed as $/month

Calculate Annual Average Power Cost:

$$PeakFactor_{PeakMonth} := 1.3$$ Ratio of peak month BOD loading (oxygen demand) to annual average BOD loading

$$AnnualPowerCost := \frac{PeakMonthPowerCost \cdot 12}{PeakFactor_{PeakMonth}}$$

$$AnnualPowerCost = 1.34 \times 10^{6}$$ Expressed as $/year

BROWN AND CALDWELL

Appendix I. BAF Stress Testing Protocol

BAF Stress Test Protocol

The BAF stress testing protocol will cover the following 9 areas:

1. Goal
2. Startup
3. Establishment of operational set points
4. The stress test
5. Backwash cycle
6. Sampling and Analysis
7. Process Monitoring
8. Roles and Responsibilities
9. Schedule

<u>1. Goal</u>

The goal of this experiment is to determine the minimum number of units in service required to treat wastewater per 7 day organic and solids discharge limits under peak hydraulic condition. Peak hydraulic condition corresponds to the full-scale PLWTP design flow of 432 MGD.

<u>2. Startup</u>

The BAF units will be started from an operation condition at 2 gpm/sf. Stress testing will begin right after the backwash, i.e. with a clean column. In order to start stress testing for both BAF units at the same time, it is required to perform both backwashes at the same time.

<u>3. Establishment of Operational Set Points</u>

Operational set points (OSP) the BAF units were determined based on the following worst case scenarios:

- OSP1 - 10 percent of the cells are assumed to be out of service (proposed by the BAF vendors)
- OSP2 - 22 percent of the cells are assumed to be out of service (OOS)
- OSP3 - 33 percent of the cells are assumed to be OOS
- OSP4 - 42 percent of the cells are assumed to be OOS

The four operational set points are summarized below.

Item	**Biostyr**	**Biofor C**
Total number of cells proposed	40	64
Peak hourly flow, mgd	432	432
Size of a cell, sf	2582	1612.5
Operating Set Point	Hydraulic Loading Rate (HLR), gpm/sf	
OSP1	3.2 (4 cells OOS)	3.2 (6 cells OOS)
OSP2	3.8 (9 cells OOS)	3.7 (14 cells OOS)
OSP3	4.3 (12 cells OOS)	4.3 (21 cells OOS)

Item	Biostyr	Biofor C
OSP4	5.1 (17cells OOS)	5.0 (27cells OOS)

The idea behind the stress test is to increase the hydraulic loading rate (HLR) until the effluent TSS exceeds 45 mg/L for two consecutive bi-hourly composite samples (see section 6). When this occurs the stress test for that unit is complete and testing will be terminated for that unit.

4. Stress Testing

Each OPS will be conducted within a 24 hour period and testing will proceed as follows:

- Hour 1 – Aggressively backwash the column
- Hour 2 to 3 - Slowly ramp up HLR from 2.0 gpm/sf to target HLR noted above
- Hour 4 to 24 - Operate at target HLR while taking 2-hour composite samples (see Item 6 for details)

This process is repeated for each OPS. If at any time the effluent TSS value exceeds the target concentration noted in Item 3 for two consecutive bi-hourly composite samples, the testing for that particular cell will cease and the HLR at breakthrough will recorded as the maximum for that cell.

5. Backwash cycle

As the loading to the BAF columns increases, the backwash frequency is expected to increase. The Biostyr has an automated backwashing system that is activated when the pressure at the bottom of the column exceeds a certain set point. On the other hand, the Biofor-C has to be manually backwashed when the pressure below the plenum reaches a certain value. Therefore, backwashing must be handled differently for each.

Biostyr: Kruger will be asked to program the backwash cycle such that no mini backwash will be performed. Whenever the set maximum column pressure is reached, a normal backwash will be initiated automatically. The timed backwash will be disabled so that headloss is the only controlling parameter.

Biofor C: Based on the previous pressure data, a reasonable maximum column pressure of 10 psi was selected as the headloss trigger for initiating a backwash. Column pressure will be monitored every five hours, commencing at the starting of the stress test. The column pressure versus time relationship (typically linear) will be developed from the five hour reading(s). Field staff will estimate the amount of minutes required to reach 10 psi. This value will be entered into the PLC at the "Miscellaneous Timers" control screen.

6. Sampling and Analysis

The 13-Inf, 13-BSEff and 13-BFCEff samplers will be outfitted with 24-bottle carousels. For each completed carousel, the lab shall:

a. Combine each pair of consecutive 1-hour bottles to form 12, 2-hour composite samples
b. Analyze the 12 samples from (a) for TSS, CBOD, and TBOD

It is important that the lab perform the TSS analysis as soon as possible since the previous day's TSS value is needed for the stress test progression.

7. Monitoring

Hourly monitoring of the BAF units during the stress-test will consist of observing the following:

Influent turbidity
Effluent turbidity
Influent flow rate
Process air flow rate
Biofor C column pressure
Time between backwashes

The observations shall be logged on the attached form.

8. Roles and Responsibilities

Startup – IDI and Kruger
Establishing operational set-points – IDI and Kruger
Operating samplers and collecting samples – Point Loma Process Control
Preparing, managing and analyzing samples – Point Loma Laboratory
Monitoring – EPMD, BC

8. Schedule

The schedule for the stress testing is shown in Table 1.

Table 1. BAF Stress Test Schedule

Date	Activity	Start time	End Time
14-Dec	Begin stress testing day 1 with backwashing the BAF columns	7:00	8:00
	Start samplers for day1	8:00	NA
	Ramp hydraulic loading from 2.0 to 3.2 gpm/sf	8:00	10:00
	Run the BAF columns at 3.2 gpm/sf	10:00	23:59
	Estimate Biofor-C backwash timer setpoint and input value	15:00	16:00
15-Dec	Run the BAF columns at 3.2 gpm/sf	0:00	7:00
	Begin stress testing day 2 with backwashing the BAF columns	7:00	8:00
	Start samplers for day 2	8:00	NA
	Ramp hydraulic loading from 2.0 to 3.7 gpm/sf	8:00	10:00
	Run the BAF columns at 3.7 gpm/sf	10:00	23:59
	Estimate Biofor-C backwash timer setpoint and input value	15:00	16:00
16-Dec	Run the BAF columns at 3.7 gpm/sf	0:00	7:00
	Begin stress testing day 3 with backwashing the BAF columns	7:00	8:00
	Start samplers for day 3	8:00	NA
	Ramp hydraulic loading from 2.0 to 4.3 gpm/sf	8:00	10:00
	Run the BAF columns at 4.3 gpm/sf	10:00	23:59
	Estimate Biofor-C backwash timer setpoint and input value	15:00	16:00
17-Dec	Run the BAF columns at 4.3 gpm/sf	0:00	7:00
	Begin stress testing day 4 with backwashing the BAF columns	7:00	8:00
	Start samplers for day 4	8:00	NA
	Ramp hydraulic loading from 2.0 to 5.0 gpm/sf	8:00	10:00
	Run the BAF columns at 5.0 (or 5.1) gpm/sf	10:00	23:59
	Estimate Biofor-C backwash timer setpoint and input value	15:00	16:00
18-Dec	Run the BAF columns at 5.0 (or 5.1) gpm/sf	0:00	7:00
	Stop sampling for day 4	7:00	NA

BROWN AND CALDWELL

Appendix J. Bacteria and Virus Data

PHASE I BACTERIA AND VIRUS DATA

Run	Week	Date	Sample ID	Total Coliform CFU/100mL	Log Removal	Fecal Coliform CFU/100 mL	Log Removal	Enterococcus CFU/100mL	Log Removal	Coliphage PFU/100mL	Log Removal
2	4	16-Mar-04	Influent	35,000,000		2,000,000		<1,000,000		10,000	
			Biofor C Effluent	5,800,000	0.78	680,000	0.47	45,000	1.35	2,100	0.68
			Biofor N Effluent	NS		NS		NS		NS	
			Biostyr Effluent	NS		NS		NS		NS	
	4	18-Mar-04	Influent	49,000,000		4,200,000		80,000		28,000	
			Biofor C Effluent	3,800,000	1.11	450,000	0.97	20,000	0.60	6,000	0.67
			Biofor N Effluent	120,000	1.50	19,000	1.37	300	1.82	21,000	-0.54
			Biostyr Effluent	NS		NS		NS		NS	
	5	24-Mar-04	Influent	68,000,000		4,000,000		55,000		38,000	
			Biofor C Effluent	6,200,000	1.04	480,000	0.92	23,000	0.38	14,000	0.43
			Biofor N Effluent	55,000	2.05	14,000	1.54	400	1.76	16,000	-0.06
			Biostyr Effluent	2,000,000	1.53	180,000	1.35	4,300	1.11	35,000	0.04
	6	29-Mar-04	Influent	30,000,000		3,100,000		68,000		7,000	
			Biofor C Effluent	4,900,000	0.79	370,000	0.92	24,000	0.45	5,800	0.08
			Biofor N Effluent	2,700,000	0.26	200,000	0.27	11000	0.34	500	1.06
			Biostyr Effluent	64,000	2.67	3,000	3.01	400	2.23	4,200	0.22
	6	1-Apr-04	Influent	38,000,000		5,400,000		26,000		90,000	
			Biofor C Effluent	900,000	1.63	70,000	1.89	10,000	0.41	33,000	0.44
			Biofor N Effluent	4,900,000	-0.74	420,000	-0.78	6000	0.22	31,000	0.03
			Biostyr Effluent	76,000	2.70	12,000	2.65	400	1.81	12,000	0.88
3	7	5-Apr-04	Influent	46,000,000		3,800,000		190,000		26,000	
			Biofor C Effluent	510,000	1.96	160,000	1.38	8,000	1.38	8,000	0.51
			Biofor N Effluent	1,300,000	-0.41	330,000	-0.31	13000	-0.21	5,900	0.13
			Biostyr Effluent	64,000	2.86	10,000	2.58	800	2.38	3,100	0.92
	7	7-Apr-04	Influent	48,000,000		4,300,000		180,000		26,000	
			Biofor C Effluent	460,000	2.02	130,000	1.52	13,000	1.14	17,000	0.18
			Biofor N Effluent	2,700,000	-0.77	330,000	-0.40	9000	0.16	23,000	-0.13
			Biostyr Effluent	150,000	2.51	39,000	2.04	1,300	2.14	4,300	0.78
	8	13-Apr-04	Influent	48,000,000		4,500,000		78,000		13,000	
			Biofor C Effluent	6,000,000	0.90	1,200,000	0.57	62,000	0.10	8,000	0.21
			Biofor N Effluent	4,000,000	0.18	560,000	0.33	23,000	0.43	7,000	0.06
			Biostyr Effluent	40,000	3.08	6,000	2.88	500	2.19	1,000	1.11
	8	15-Apr-04	PLWTP Influent	60,000,000		13,000,000		440,000		74,000	
			Influent	39,000,000		5,300,000		130,000		18,000	
			Biofor C Effluent	3,000,000	0.11	1,900,000	0.45	4,900	1.42	14,000	0.11
			Biofor N Effluent	1,200,000	0.40	3,000,000	-0.20	5,700	-0.07	2,900	0.68
			Biostyr Effluent	NS	NS	NS	NS	NS	NS	NS	NS
	9	21-Apr-04	PLWTP Influent	170,000,000		23,000,000		4,600,000		30,000	
			Influent	49,000,000		5,600,000		52,000		12,000	
			Biofor C Effluent	21,000,000	0.37	3,000,000	0.27	70,000	-0.13	9,000	0.12
			Biofor N Effluent	1,900,000	1.04	90,000	1.52	2,900	1.38	1,100	0.91
			Biostyr Effluent	290,000	2.23	44,000	2.10	300	2.24	1,600	0.88
	9	23-Apr-04	PLWTP Influent	210,000,000		25,000,000		400,000		110,000	
			Influent	55,000,000		4,500,000		40,000		11,000	
			Biofor C Effluent	7,300,000	0.88	600,000	0.88	41,000	-0.01	3,000	0.56
			Biofor N Effluent	5,400,000	0.13	800,000	-0.12	16,000	0.41	3,600	-0.08
			Biostyr Effluent	100,000	2.74	18,000	2.40	300	2.12	3,900	0.45
	10	27-Apr-04	PLWTP Influent	70,000,000		14,000,000		900,000		73,000	
			Influent	30,000,000		3,300,000		190,000		7,000	
			Biofor C Effluent	6,200,000	0.68	600,000	0.74	50,000	0.58	9,000	-0.11
			Biofor N Effluent	5,500,000	0.05	590,000	0.01	46,000	0.04	3,400	0.42
			Biostyr Effluent	40,000	2.88	12,000	2.44	300	2.80	1,900	0.57
	10	29-Apr-04	PLWTP Influent	100,000,000		24,000,000		1,500,000		220,000	
			Influent	40,000,000		4,400,000		170,000		8,000	
			Biofor C Effluent	5,100,000	0.89	770,000	0.76	80,000	0.33	11,000	-0.14
			Biofor N Effluent	4,000,000	0.11	400,000	0.28	30,000	0.43	6,000	0.26
			Biostyr Effluent	<10000	3.60	2,200	3.30	200	2.93	1,800	0.65
	11	3-May-04	PLWTP Influent	150,000,000		21,000,000		470,000		53,000	
			Influent	25,000,000		12,000,000		180,000		3,900	
			Biofor C Effluent	10,000,000	0.40	1,000,000	1.08	41,000	0.64	4,000	-0.01
			Biofor N Effluent	7,400,000	0.13	700,000	0.15	45,000	-0.04	3,300	0.08
			Biostyr Effluent	80,000	2.49	1,800	3.82	600	2.48	1,200	0.51
	11	5-May-04	PLWTP Influent	140,000,000		14,000,000		70,000		32,000	
			Influent	72,000,000		5,400,000		150,000		8,000	
			Biofor C Effluent	5,500,000	1.12	800,000	0.83	5,000	1.48	9,000	-0.05
			Biofor N Effluent	6,700,000	-0.09	1,400,000	-0.24	29,000	-0.76	6,000	0.18
			Biostyr Effluent	120,000	2.78	13,000	2.62	1,000	2.18	1,600	0.70
	12	11-May-04	PLWTP Influent	280,000,000		39,000,000		2,400,000		19,000	
			Influent	39,000,000		4,700,000		57,000		12,000	
			Biofor C Effluent	27,000,000	0.16	3,800,000	0.09	100,000	-0.24	11,000	0.04
			Biofor N Effluent	>8000000	0.53	2,300,000	0.22	41,000	0.39	3,000	0.56
			Biostyr Effluent	240,000	2.21	100,000	1.67	1,100	1.71	900	1.12
	12	13-May-04	PLWTP Influent	300,000,000		46,000,000		1,100,000		27,000	
			Influent	74,000,000		3,900,000		150,000		16,000	
			Biofor C Effluent	7,700,000	0.98	800,000	0.69	120,000	0.10	3,000	0.73
			Biofor N Effluent	7,200,000	0.03	900,000	-0.05	35,000	0.54	2,600	0.06
			Biostyr Effluent	11,000	3.83	21,000	2.27	700	2.33	900	1.25
	13	19-May-04	PLWTP Influent	320,000,000		50,000,000		3,000,000		240,000	
			Influent	50,000,000		5,300,000		40,000		58,000	
			Biofor C Effluent	8,000,000	0.80	560,000	0.98	29,000	0.14	13,000	0.65
			Biofor N Effluent	15,000,000	-0.27	3,800,000	-0.83	51,000	-0.25	6,000	0.34
			Biostyr Effluent	4,000,000	1.10	530,000	1.00	9,000	0.65	1,700	1.53
	14	25-May-04	Influent	28,000,000		2,500,000		62,000		14,000	
			Biofor C Effluent	5,400,000	0.71	590,000	0.63	58,000	0.03	3,300	0.63
			Biofor N Effluent	9,000,000	-0.22	1,100,000	-0.27	67,000	-0.06	2,500	0.12
			Biostyr Effluent	480,000	1.77	85,000	1.47	2,300	1.43	600	1.37

NS Not sampled

PHASE II-BACTERIA AND VIRUS DATA

Week	Date	Sample ID	Total Coliform CFU/100mL	Fecal Coliform CFU/100 mL	Enterococcus CFU/100mL	Coliphage PFU/100mL
29	7-Sep-04	Raw Wastewater	130,000,000	10,000,000	440,000	300,000
		Densadeg Effluent	51,000,000	4,700,000	24,000	4,300
		Biostyr Effluent	3,400,000	240,000	5,000	4,100
		Biofor C Effluent	NS	NS	NS	NS
29	8-Sep-04	Raw Wastewater	260,000,000	23,000,000	210,000	56,000
		Densadeg Effluent	53,000,000	5,100,000	13,000	2,100
		Biostyr Effluent	1,600,000	350,000	8,000	2,600
		Biofor C Effluent	NS	NS	NS	NS
32	27-Sep-04	Raw Wastewater	140,000,000	7,000,000	310,000	63,000
		Densadeg Effluent	84,000,000	12,000,000	240,000	20,000
		Biostyr Effluent	NS	NS	NS	NS
		Biofor C Effluent	LA	LA	LA	32,000
33	7-Oct-04	Raw Wastewater	280,000,000	18,000,000	600,000	44,000
		Densadeg Effluent	12,000,000	900,000	5,000	3,500
		Biostyr Effluent	2,500,000	380,000	**20,000**	1,700
		Biofor C Effluent	400,000	6,000	300	300
35	19-Oct-04	Raw Wastewater	59,000,000	8,000,000	2,000,000	80,000
		Densadeg Effluent	28,000,000	3,200,000	60,000	18,000
		Biostyr Effluent	18,000,000	1,300,000	33,000	37,000
		Biofor C Effluent	4,000,000	900,000	22,000	32,000
35	21-Oct-04	Raw Wastewater	80,000,000	8,300,000	350,000	350,000
		Densadeg Effluent	40,000,000	4,300,000	2,000	80,000
		Biostyr Effluent	5,200,000	1,000,000	**41,000**	32,000
		Biofor C Effluent	530,000	80,000	4,700	56,000
36	25-Oct-04	Raw Wastewater	70,000,000	5,000,000	200,000	60,000
		Densadeg Effluent	20,000,000	3,700,000	4,000	35,000
		Biostyr Effluent	4,100,000	410,000	**18,000**	25,000
		Biofor C Effluent	4,000,000	1,300,000	23,000	20,000
36	27-Oct-04	Raw Wastewater	61,000,000	5,400,000	1,900,000	45,000
		Densadeg Effluent	7,700,000	610,000	<1000	14,000
		Biostyr Effluent	3,200,000	440,000	**20,000**	17,000
		Biofor C Effluent	1,300,000	280,000	800	4,900
37	2-Nov-04	Raw Wastewater	90,000,000	9,000,000	220,000	100,000
		Densadeg Effluent	31,000,000	1,800,000	12,000	23,000
		Biostyr Effluent	1,200,000	150,000	**17,000**	11,000
		Biofor C Effluent	41,000	19,000	200	4,400
37	4-Nov-04	Raw Wastewater	130,000,000	16,000,000	440,000	160,000
		Densadeg Effluent	54,000,000	5,200,000	36,000	46,000
		Biostyr Effluent	900,000	150,000	16,000	5,000
		Biofor C Effluent	340,000	60,000	11,000	15,000
37	8-Nov-04	Raw Wastewater	15,000,000	6,000,000	380,000	140,000
		Densadeg Effluent	78,000,000	13,000,000	27,000	100,000
		Biostyr Effluent	1,200,000	160,000	10,000	23,000
		Biofor C Effluent	320,000	55,000	1,800	28,000
38	10-Nov-04	Raw Wastewater	130,000,000	16,000,000	280,000	390,000
		Densadeg Effluent	38,000,000	10,000,000	8,000	140,000
		Biostyr Effluent	630,000	71,000	5,900	14,000
		Biofor C Effluent	120,000	27,000	150	13,000
38	16-Nov-04	Raw Wastewater	150,000,000	8,000,000	400,000	110,000
		Densadeg Effluent	31,000,000	5,600,000	17,000	28,000
		Biostyr Effluent	3,600,000	310,000	11,000	10,000
		Biofor C Effluent	2,100,000	330,000	2,100	14,000
39	18-Nov-04	Raw Wastewater	140,000,000	11,000,000	100,000	430,000
		Densadeg Effluent	37,000,000	3,500,000	1,700	170,000
		Biostyr Effluent	3,400,000	530,000	**140,000**	80,000
		Biofor C Effluent	2,100,000	250,000	4,400	90,000
39	22-Nov-04	Raw Wastewater	90,000,000	11,000,000	200,000	24,000
		Densadeg Effluent	80,000,000	3,600,000	4,000	2,000
		Biostyr Effluent	NS	NS	NS	NS
		Biofor C Effluent	2,000,000	310,000	10,000	5,000

NS: Not Sampled
LA: Lab Accident
PLR: Point Loma Raw Wastewater
13-DDEGEff: Densadeg Efluent
13-BSEff: Biostyr Effluent
13-BFCEff: Biofor C Effluent

BACTERIA AND VIRUS DATA DURING WEEK 42 (PHASE I CONDITIONS)

Week	Date	Sample ID	Total Coliform	Fecal Coliform	Enterococcus	Coliphage
			CFU/100mL	CFU/100 mL	CFU/100mL	PFU/100mL
42	7-Dec-04	BAF Influent	68,000,000	10,000,000	60,000	29,000
		Biostyr Effluent	3,600,000	500,000	54,000	20,000
		Biofor C Effluent	12,000	3,000	80	16,000
42	9-Dec-04	BAF Influent	56,000,000	4,200,000	190,000	24,000
		Biostyr Effluent	420,000	220,000	12,000	8,000
		Biofor C Effluent	2,100,000	260,000	36,000	19,000
42	13-Dec-04	BAF Influent	45,000,000	3,500,000	30,000	22,000
		Biostyr Effluent	7,400,000	900,000	**43,000**	19,000
		Biofor C Effluent	200,000	34,000	480	15,000

NS: Not Sampled
PLR: Point Loma Raw Wastewater
13-Inf: BAF Influent Efluent
13-BSEff: Biostyr Effluent
13-BFCEff: Biofor C Effluent

BROWN AND CALDWELL

Appendix K. Media Solids Measurement Protocol

City of San Diego MWWD / Brown and Caldwell
BAF Pilot Study

Media Solids Measurement Procedure

Biostyr: Biostry media is floating Styrofoam media, which cannot be burned at 550 ^oC muffle furnace for the biomass measurement. Therefore, a different approach is needed. The following procedure will be used for the evaluation of the biomass:

TSS Determination:

Part I:

1. Weigh an empty clean pan (weight 1).
2. Take about 15 pieces of media into a container.
3. Wash the media with distilled water three times to remove any suspended particulate matter.
4. Put the media sample into the pan, and put the pan into an oven at 101 degree C for two hours.
5. After two hours, take out the pan, and put it into a desiccator for 20 minutes.
6. Re-weigh the pan (weight 2).
7. The difference in weight 1 and weight 2 gives the weight of BIOMASS+MEDIA.

Part II:

1. Take the dried media samples in Part I into a 40-mL glass vial.
2. Add concentrated bleach. Shake the media and bleach solution on a consistent basis for 15 minutes.
3. Rinse the media with copious amount of distilled water 3 times.
4. Add sulfuric acid to the media and shake the media and solution for additional 10 minutes.
5. Rinse the media with distilled water again, and inspect the media to be sure that the majority of the biomass is stripped of the media.
6. Weigh an empty clean pan (weight 3).
7. Put the clean media into the pan; place it into an oven at 105 degrees C for two hours.
8. After two hours, take out the pan, and put it into a desiccator for 20 minutes.
9. Re-weigh the pan (weight 4).
10. The difference between weight 3 and weight 4 gives the weight of MEDIA.
11. Subtract "BIOMASS+MEDIA" weight from "MEDIA" weight to find the weight of BIOMASS.
12. Report the result as gram biomass /gram media (or gram TSS/gram media).

VSS Determination:

1. Take about 30 pieces of media into a container.
2. Wash the media with distilled water three times to remove any suspended particulate matter.
3. Place the media sample into a 40-mL glass vial.
4. Add ethyl alcohol to the media and shake the media and solution for 20 minutes. Inspect the media to be sure that the majority of the biomass is stripped of the media.
5. Remove the beads from the ethyl alcohol solution containing scraped biomass.
6. Weigh an empty clean pan (weight 5).
7. Put the ethyl alcohol solution into the pan. Place the pan in an oven at 101 degrees C.
8. After two hours, take out the pan from the oven, and put into a desiccator for 20 minutes.
9. Weigh the pan (weight 6).
10. Place the pan in an oven at 550 decrees C for 30 minutes to burn the content of it.
11. After keeping in a desiccator for 20 minutes, weigh the pan (weight 7).
12. Calculate the total solids from the difference in weight 5 and weight 6 mentioned above.
13. Calculate the VSS content from the difference in weight 6 and weight 7.
14. Calculate the percent VSS content of the biomass based on the weights obtained in Step 12 and 13.

Final result to report:

Multiply the result found in gram TSS per gram media (TSS Determination, Part II, Step 12) by the percent VSS content (VSS Determination, Step 14) to report the final result as gram VSS per gram media.

BROWN AND CALDWELL

Appendix L. Data for Co-settling Experiments

Table J1.Combined Spent Backwash Water Quality

Parameter	Unit	Co-settling Test No. (Date)	
		1 (16-Nov)	2 (18-Nov)
TBOD	**mg/L**	**340**	---
SBOD	mg/L	20.5	---
COD	mg/L	636	---
SETS	mL/L	54	64
TS	mg/L	2360	2910
TVS	mg/L	816	1120
TSS	**mg/L**	**719**	**732**
VSS	mg/L	507	543

Table J2. Densadeg Influent and Effluent Wastewater and Sludge Quality during Co-settling Experiments

Date	Sampling Time	Raw Wastewater		Densadeg Effluent		Densadeg Sludge	
		CBOD	TSS	CBOD	TSS	TS (%)	VS (%)
16-Nov	9:00	107	208	47.5	53.2		
	10:00	103	270	44.4	55.7		
	11:00	126	333	45.8	48.7		
	12:00	127	329	45.7	39.9		
	13:00	127	326	42.7	50.8		
	14:00	237	326	78.3	53.6	8.9	75.7
	15:00	183	398	170	64.0		
18-Nov	9:00	105	168	44.4	44.9		
	10:00	139	205	44.2	32.4		
	11:00	132	253	51.3	31.7		
	12:00	132	278	55.1	33.6		
	13:00	132	338	60.6	40.1		
	13:45	170	342	62.5	44.3	7.5	75.2
	14:45	169	347	76.1	45.6		

Note: Bold numbers indicate the duration of co-settling experiment