
**COMPARISON OF THE 1D IDEALISED FLUX THEORY AND
A 2D HYDRODYNAMIC MODEL WITH FULL
SCALE SECONDARY SETTLING TANK
PERFORMANCE DATA**

P Marais

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I DEDICATE THIS THESIS TO THE FOLLOWING PEOPLE

Danette and Danté for their personal support and sacrifices during the course of my studies

My whole family for their support through a decade of studying and for their everlasting love

**COMPARISON OF THE 1D IDEALISED FLUX THEORY AND
A 2D HYDRODYNAMIC MODEL WITH FULL
SCALE SECONDARY SETTLING TANK
PERFORMANCE DATA**

by

Pierre Marais

A thesis submitted in partial fulfilment of the
requirements for the Degree of Master of Science
in the Faculty of Engineering, University of
Cape Town

DECLARATION BY CANDIDATE

I, Pierre Marais, hereby declare that this thesis is my own work and that it has not been submitted for a degree at another university

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PIERRE MARAIS

June 2001

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SYNOPSIS

Objectives

In this research, the two dimensional (2D) hydrodynamic model SettlerCAD (Zhou *et al.* 1998) was applied to full-scale circular secondary settling tanks (SSTs) with the principle aim to:

- 1) establish whether or not it “automatically” reproduces a flux rating < 1.0 with respect to the steady state 1D idealized flux theory (1DFT) and;
- 2) determine what factors influence this flux rating.

To do this, SST solids loading rate (SLR) stress tests reported in the literature were simulated. These are:

- 1) the 4 tests done by de Haas *et al.* (1998) on 4 similar 35 m diameter SSTs (2 new and 2 old) of the Darvill wastewater treatment plant (WWTP), Pietermaritzburg, South Africa;
- 2) the 15 tests done by Watts *et al.* (1996) on a single 3.66 m side water depth (SWD), 28.96 m, diameter circular SST with centre feed, peripheral and radial effluent overflow and rotating multiple suction pipe sludge collection system at the Kanapaha WWTP (Florida, USA), and;
- 3) 12 of the 47 tests done by STOWa (1981) (Stopkoper and Trentelman, 1982) on two of the 25 different SSTs with 30 to 46 m diameter, 1.5 to 2.5 m SWD and 1:12 sloping bottoms with scraped sludge collection.

Finding the maximum SLR and SOR of SettlerCAD

From the measured V_0 , n , feed concentration (X_F) and recycle flow (Q_R) of a particular SLR stress test, the maximum surface overflow rate (SOR) and sludge loading rate (SLR) was calculated from the 1DFT

The data listed in the literature for the particular SST and SLR stress test to be simulated, was given as input to SettlerCAD. Keeping the recycle flow (Q_R) and feed concentration (X_F) constant at the test values, the influent flow (Q_I), calculated as a % of the 1DFT limit value, was increased for successive simulation runs from a low value to a high value, first in 2 % of 1DFT limit increments, and then in 0.25 % of 1DFT limit increments between consecutive safe and fail runs. SST failure was accepted to be an average effluent suspended solid (ESS) $> 50 \text{ mg/}\ell$ over the final 2 actual hydraulic retention times (R_{na}) of the run. In this way the steady state influent flow rate (Q_I) for ESS $> 50 \text{ mg/l}$ was determined for SettlerCAD at an accuracy of 0.25 % of the 1DFT limit and the first run with ESS $> 50 \text{ mg/}\ell$ was accepted as the SettlerCAD predicted maximum influent flow rate limit. The SettlerCAD SLR limit was calculated from the predicted influent flow limit and the test Q_R and X_F values. The predicted ESS and RAS concentrations over the complete run were imported into a spreadsheet program, in which were calculated (i) the average ESS and return activated sludge (RAS) concentrations over the final 2 actual hydraulic retention times ($2 \times R_{na}$) and (ii) the % solids mass balance as the run proceeded. The outcome (fail or safe) of each simulation run was recorded by checking sludge blanket height in SettlerCAD at the end of each simulation and whether the average ESS concentration over the final $2 \times R_{na}$ was greater (fail), or less (safe) than $50 \text{ mg/}\ell$.

Because an ESS value of $> 50 \text{ mg/}\ell$ was chosen as a failure value for the SST, the concern was raised that a "failed" simulation could be the result of poor hydraulics in a SST and not the result of a propagating sludge blanket. To address this concern, the K_2 value in the double exponential equation of Takacs (which is used in SettlerCAD to define the sludge settling velocity) was made very high, more than a 1 000 times larger than realistic values.

This then reduces the double exponential to the usual single exponential of $V_s = V_o \exp(-nXt)$ where SettlerCAD's $K_1 = n$. With the single exponential, the settling velocity of low concentrations ($< 100 \text{ mg}/\ell$) are very high and close to and up to V_o . This means that the settling velocities of the low concentrations are much higher than the overflow rates on the SSTs. So the low concentrations always settle much faster than the overflow rate ($> 10x$) and hence low concentrations would not be able to be dragged out with the effluent even with serious hydraulic disturbances at the effluent launders. High ESS $> 50 \text{ mg}/\ell$ therefore could only be obtained with a high sludge blanket near the effluent launders. A view of the ESS versus simulation time show that the ESS was $1 \text{ mg}/\ell$ right up to the time the sludge blanket approached the effluent weirs which is what one expects from the single exponential equation.

The SettlerCAD model does not allow the modeling of an activated sludge (AS) reactor prior to the SST. This however do not affect the % of the 1DFT predicted SLR or SOR that SettlerCAD predicts because the recycle flow (Q_R), feed concentration (X_i) and influent flow (Q_i) were kept constant for each simulation. In doing so the effect of the AS reactor was eliminated.

The % mass balance was calculated as the sum of the masses of sludge in the return and effluent flows as a % of the mass of sludge entering the SST with the influent and recycle flows.

Validation of SettlerCAD prediction accuracy

From the 15 Watts SLR tests, SettlerCAD correctly predicted the results of 12 tests, i.e. Tests 1, 2 and 4 to 10 (safe) and 11 to 13 (fail) but incorrectly predicted the results for 3 tests, i.e. Tests 3 (actual test safe, SettlerCAD fail) and 14 and 15 (actual test fail, SettlerCAD safe). Of these 3 tests, only Tests 3 and 15 plot far from the SettlerCAD predicted limit and therefore are definitely incorrectly predicted. However, Tests 4, 14, 13, 7, 9 and 12 all plot very close to the SettlerCAD predicted limits and are correctly predicted.

This narrow range, indicates that apart from Tests 3 and 15, SettlerCAD accurately identifies the SOR and SLR capacity of the Watts SST. The SettlerCAD results of the Watts tests gives a good indication that the SettlerCAD predictions are valid for the simulation of full scale stress tests.

Determination of solids mass balance

In setting up the simulation runs, a simulation time was selected which was more than 25 times the actual hydraulic retention time ($25 \times R_{na}$) for all the runs. These run times were sufficiently long to establish a final steady state condition, which was checked with a solids mass balance at the end of each run. In the solids mass balance, the mass of solids exiting the SST via the underflow and overflow is calculated as a % of the inflow mass of sludge.

The final ESS (X_E) and RAS (X_R) concentrations for each run were the averages of the predicted values over the last $2 \times R_{na}$. Provided the run ended safe (ESS $< 50 \text{ mg}/\ell$), the final concentrations yielded a solids mass balance ranging from 99.5 % to 100.5 %. In contrast, runs that ended in failure (ESS $> 50 \text{ mg}/\ell$) yielded a lower than 99.5 % solids mass balance and the greater the SST overload (i.e. higher the ESS concentration) the lower the solids mass balance below 99.5 %, even as low as 86 % of the 1DFT limit influent flow. Halving the simulation time steps and/or doubling the number of iterations per time step yielded identical simulation results and no improvement in % mass balance at the end of the run.

As the simulations proceeded it was seen that (i) the simulation runs were long enough to reach a steady state because the mass balance remained constant, and (ii) for the runs which ended in fail the mass balance remained below 99 %. It is suspected that a 100 % mass balance for the failed runs is not achieved due to a simple logical error in SettlerCAD. It seems that the RAS concentration is “corrected” by subtracting from it the ESS concentration, because the higher the ESS concentration (or overload) the lower the RAS concentration. This is not consistent with the flux theory. Theoretically for increasing Q_i and constant Q_R and q_R the RAS concentration should remain constant (at $X_r = j_i/q_R$) once the SLR capacity (failure) has been reached.

This error does not influence the SettlerCAD predicted SOR and SLR limits. The same low solids mass balance for the failed runs ($ESS > 50 \text{ mg/l}$) was observed for all the SSTs simulated.

Simulating the Darvill SSTs

For the Darvill SSTs three different cases were simulated with SettlerCAD, and for each case the percentage (%) of the 1DFT maximum influent flow (Q_i) was determined. The three cases were as follows:

Case 1: The Darvill new and old SSTs as built, i.e. with Stamford baffles extending from the side wall and the actual side water depths i.e. old SST 2.5 m and new SST 4.1 m.

Case 2: The Darvill new and old SSTs without Stamford baffles and the actual SWDs.

Case 3: The Darvill new and old SSTs with Stamford baffles, but with interchanged SWDs i.e. old SST with 4.1 m SWD and new SST with 2.5 m SWD.

For Case 1, SettlerCAD consistently predicts that the new tank fails at a higher percentage (%) of the 1DFT maximum SOR and SLR (flux rating) than that of the old SSTs. At the lower HLRs i.e. Tests 1, 2 and 3, the flux rating of the new and old tanks are close to one another, but at high HLR i.e. Test 4, the new tank has a much higher flux rating than the old tank. The better performance of the new tank compared with the old tank is most probably due to the greater depth of the new tank.

For the Darvill SSTs both the new and the old tanks perform marginally better without a Stamford baffle for all the tests, with the exception of Test 2 which has the lowest HLR. For the new SSTs the flux ratings without baffles are 1.7 to 2.6 % (SLR) higher than with baffles and for the old SSTs the flux ratings without baffles are 1.4 to 1.8 % (SLR) higher than with baffles.

Because the difference between the flux rating increased from Test 2 through Test 1, Test 3 to Test 4, which is the order of increasing HLR, it was noticed that the Stamford baffle set-up a large vertical circular current extending the full clear water depth and radius of the SST, which is absent when the baffles are removed.

However, it must be remembered that the difference in flux rating is very small. Because the difference varies consistently with HLR, it seems that this difference is real and not artificial, due to variation in predicted results of the simulation model.

In Case 3, where the new and old SSTs had interchanged SWD i.e the new SST 2.1 m and the old SST 4.1 m, the SSTs performance also reversed in that now the old SSTs had higher flux ratings for all the tests than the new SSTs. This is due to the SSTs volume difference in that now the old SSTs have a greater volume than the new SSTs. These Case 3 runs clearly demonstrate the significant influence of the SSTs depth on the flux rating – the deeper the tank the closer the flux rating to the theoretical maximum of 1.0.

The old shallow SSTs had a much greater sensitivity to the HLR compared with the deeper new SST. As the HLR increases the difference between the percentage (%) of the 1DFT limits of the new and old tanks increase, with the deeper new tank always performing better (higher flux rating). This indicates that for the shallow old SSTs, the lower the HLR, i.e. for poor settling sludges and/or high X_F , the greater the SST capacity as a percentage (%) of the 1DFT limit. The higher the HLR, i.e. good settling sludges and/or low X_F , the lower the capacity of the SST as a percentage (%) of the 1DFT limit. The new deep SSTs do not show this sensitivity to HLR.

Simulating the Watts SST

For the Kanapaha SST tested by Watts *et al.* (1996), three different cases were simulated with SettlerCAD and for each case the maximum influent flow as a percentage (%) of the 1DFT maximum influent flow (Q_i), was determined. The three cases were as follows:

Case 1: Simulation of the 15 stress tests on the SST as built, i.e. without Stamford baffle and actual side water depth of 3.66 m.

Case 2: Simulation of Tests, 4, 7, 9, 12, 13 and 14 on the SST including a Stamford baffle extending 1.2 m from the side-wall at a height of 3.16 m above the bottom of the side wall, and actual SWD.

Case 3¹⁾: Simulation of Tests 4, 7, 9, 12, 13 and 14 on the SST without Stamford baffle and with a SWD of 6.0 m.

The average flux rating (SLR) for Case 1 – no Stamford baffle (Tests 4, 7, 9, 12, 13 and 14) is 79.2 %. For Case 2 – with Stamford baffles the average flux rating is 81.7 % and for Case 3 – 6 m SWD the average flux rating is 83.6 %. This shows that SettlerCAD predicts a 2 % increase in SST capacity with Stamford baffles. This is contrary to the results of the Darvill SST simulations where the SSTs without Stamford baffles performed about 2 % better than with Stamford baffles.

Comparing the solids flow pattern, a conclusion was made that the Stamford baffles can improve the effluent concentration, but is unlikely to have a strong effect on the sludge blanket level in the SST. Because the objective was reaching a final steady state for fixed loading conditions, which caused the sludge blanket for the failed cases to rise to the effluent launder, it seemed reasonable to conclude that the Stamford baffle does not increase the capacity (or flux rating) of the SST much; however for the safe loading conditions, the Stamford baffle helped to keep the ESS concentration low.

Considering that with respect to external SST geometry, the Watts SST (3.66 m SWD and 1:15.4 sloping bottom) is closer in likeness to the new Darvill SST (4.1 m SWD and 1:10 sloping bottom) than to the old Darvill SST (2.5 m SWD and flat bottom), the expectation was that the Watts results should fall closer to the new Darvill SST results than those of the old SST, but this did not happen.

¹⁾ Case 3 is an additional simulation that was done after the main objectives have been achieved and is only discussed in the Synopsis and Conclusion

However, a relatively consistent pattern seemed to be emerging because at least the Watts SST results fell between the Darvill new and old SST results and showed a similar decreasing trend in flux rating or capacity as the flux load factor increased.

Simulating the STOWa Rijen and Oss SSTs

For the Rijen and Oss SSTs only one set of simulations, resembling the as-built configuration, was conducted. In each instance 6 tests were selected for simulation i.e. the 6 data sets that spanned over the widest range of the flux load factor.

The SettlerCAD predicted flux rating (SLR) of the Rijen SST ranged between 70.7 % (Test 3) to 76.0 % (Test 8). For the Oss SST the flux rating (SLR) ranged between 68.1 % (Test 4) to 83.2 % (Test 8).

Placing the Rijen and Oss SettlerCAD simulations in context of the Darvill and Watts simulations, the following emerged. Considering that with respect to external SST geometry, the Rijen SST (2.25 m SWD and 1:12 sloping bottom), and Oss SST (2.0 m SWD and 1:12 sloping bottom) are closer in likeness to the old Darvill SST (2.5 m SWD and flat bottom), the expectation was that the average flux rating (SLR) of the Rijen results (74.08 %) and Oss results (75.15 %) should fall below the average flux rating of the Darvill old SST result (80.2 %), and this did indeed happen.

Conclusions

The simulations of the full-scale SST SLR stress tests with the 2D hydrodynamic model SettlerCAD indicate, as would be expected, that the SST hydraulic non-idealities are intrinsically part of the model and that appropriate flux rating for the full scale SSTs is reproduced “automatically” in the model. Moreover, the simulations provide further evidence that the 1D idealized flux theory (1DFT) cannot be applied to the design of full-scale SSTs without an appropriate flux rating.

The SettlerCAD simulations of the Darvill SSTs indicated that the *capacity*, or flux rating, of the old flat bottom shallow (2.5 m SWD) SST decreased as the hydraulic loading increased due to an improvement in sludge settleability and/or decrease in feed concentration. The new sloping bottom, deep (4.1 m SWD) SST did not show this sensitivity of capacity (flux rating) to hydraulic loading rate.

The magnitude of the flux rating therefore is not a constant value, and is shown to be dependent on SST depth and hydraulic loading; the deeper the SST and the lower the hydraulic loading the closer the flux rating is to 1.0. Simulations of the sloping bottom shallow (1.5 to 2.5 m SWD) Dutch SSTs tested by STOWa (1981) and the Darvill new and old SSTs with inter-changed depths, confirmed this sensitivity of the flux rating to depth and hydraulic loading. It would appear from the simulations so far that the flux rating of 0.80 of the 1DFT maximum SLR recommendation by Ekama and Marais (1986) remains a reasonable value to apply in the design of full scale SSTs – for deep SSTs (4 m SWD) the flux rating could be increased to 0.85 and for shallow SSTs (2.5 m SWD) decreased to 0.75.

From the simulations, some answers for the two crucial questions raised by Ekama *et al.* (1997), viz. (i) are the SST failures observed in this and other studies specific for the particular SSTs investigated and (ii) can the 1DFT be applied to full scale SSTs without correction, are emerging. While the failures observed on the Darvill and other SSTs mentioned may be specific for the particular SSTs, a consistent pattern is appearing i.e. that the 1DFT can be used for design but its predicted maximum SLR needs to be reduced by an appropriate flux rating, the magnitude of which depends on SST depth and hydraulic loading. It is accepted that the magnitude of the flux rating depends also on the design of the internal features built into the external shell of the SST such as (i) inlet arrangement; (ii) tank configuration; (iii) effluent launder position; (iv) control of hydraulic flow patterns, short circuiting and turbulence with baffling; (v) flocculation chambers and (vi) sufficient sludge transport and collection capacity, but such detail cannot be modelled with SettlerCAD, which offers quick and easy data input, no grid-mesh specification and fast run times at the cost of greater tank geometry specification flexibility.

While further SLR stress tests will make an important contribution to the full-scale SST performance data base, evaluation of the results with 1D flux models will not provide answers to these questions. These questions will find answers with further 2D hydrodynamic modelling studies on SSTs because these models allow the internal features of the SST to be simulated.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	(i)
SYNOPSIS	(ii)
TABLE OF CONTENTS	(xii)
LIST OF FIGURES	(xv)
LIST OF TABLES	(xxi)
LIST OF ABBREVIATIONS	(xxii)
LIST OF SYMBOLS	(xxiv)

ITEM	DESCRIPTION	PAGE
------	-------------	------

CHAPTER ONE : INTRODUCTION

1.1	Introduction	1 - 1
-----	--------------------	-------

CHAPTER TWO : LITERATURE REVIEW

2.1	General	2 - 1
2.2	Steady state one dimensional flux theory (1DFT)	2 - 4
2.3	Two dimensional hydrodynamic models	2 - 13
2.4	Prospects for 3D modelling	2 - 14

CHAPTER THREE : THE 2D HYDRODYNAMIC MODEL SettlerCAD

3.1	Introduction	3 - 1
3.2	Input information required	3 - 1
3.3	SettlerCAD dialog boxes	3 - 2
3.4	Finding the maximum loading rate with SettlerCAD	3 - 8
3.5	The flux load factor	3 - 11

ITEM	DESCRIPTION	PAGE
CHAPTER FOUR : SIMULATION OF THE DARVILL SSTs SettlerCAD		
4.1	The Darvill SLR stress tests	4 - 1
4.2	Results of full-scale actual stress tests	4 - 3
4.3	Find the cad maximum SOR and SLR for the Darvill SSTs ...	4 - 3
4.4	Evaluating the output results of SettlerCAD	4 - 11
4.5	Conclusion from the Darvill SST simulations	4 - 16
CHAPTER FIVE : SIMULATION OF THE WATTS SSTs WITH SettlerCAD		
5.1	The Watts stress tests	5 - 1
5.2	results of the full-scale actual stress tests	5 - 4
5.3	Finding the SettlerCAD maximum SOR and SLR for the Watts SSTs	5 - 4
5.4	Evaluating the output results of SettlerCAD	5 - 12
5.5	Conclusions from the Watts SST simulations	5 - 17
CHAPTER SIX : SIMULATION THE DUTCH STOWa SSTs WITH SettlerCAD		
6.1	The Rijen SST SLR stress tests	6 - 1
6.2	Results of the Rijen full-scale SST actual stress tests	6 - 3
6.3	Finding the SettlerCAD maximum SOR and SLR for the Rijen SSTs	6 - 6
6.4	Evaluating the output results of SettlerCAD	6 - 12
6.5	Results of the Oss full-scale SST actual stress tests	6 - 17
6.6	Find the SettlerCAD maximum SOR and SLR for the Oss SSTs	6 - 19
6.7.	Evaluating the output results of SettlerCAD	6 - 26
6.8	Conclusion from the Rijen and Oss SSTs simulations	6 - 31

ITEM	DESCRIPTION	PAGE
CHAPTER SEVEN : CONCLUSION		
7.1	Finding the maximum SOR and SLR OF SettlerCAD	7 - 2
7.2	Validation of SettlerCAD prediction accuracy	7 - 4
7.3	Find the SettlerCAD maximum SOR and SLR for the Davill, Watts, Rijen and Oss SSTs	7 - 6
7.4	Simulating the Darvill SSTs	7 - 7
7.5	Simulating the Watts SST	7 - 11
7.6	Simulating the Rjien and Oss SSTs	7 - 15
7.7	Summary of the SettlerCAD maximum OSR and SLR for the Davill, Watts, Rijen and Oss SSTs	7 - 18
7.8	Effect of HLR and R_{ha} on flux rating	7 - 21
7.9	Conclusion	7 - 22

REFERENCES

LIST OF APPENDICES

- Appendix A : Darvill Results
- Appendix B : Watts Results
- Appendix C : STOWa Results (Rijen)
- Appendix D : STOWa Results (Oss)

LIST OF FIGURES

		Page
Fig 2.1	Design and operating chart of Ekama <i>et al.</i> , (1984) for SSTs based on the flux procedure and the semi-log expression linking the SZSV and solids concentration.	2 - 10
Fig 2.2	Settling flux curves with settling tank operating state point diagrams for the points A, B, C and D in the four operating regions A, B, C and D respectively of the flux design and operating chart. Regions A and D (top) overloaded; regions B and C (bottom) underloaded. Flux $V_O = 5.93$ m/h; $n = 0.43$ m ³ /kg; feed concentration = 3.5 kgTSS/m ³ .	2 - 13
Fig 3.1 & 3.2	D&O charts demonstrating the calculation method of the 1DFT (Fig. 3.1, left) and SettlerCAD (Fig. 3.2, right) SOR and SLR limit values. Fig. 3.2 is for Test 3 on the old Darvill SSTs and the safe, fail and actual test position are indicated.	3 - 10
Fig 3.3	Design overflow (SOR, q_A , m/h) and underflow (q_A , m/h) and hydraulic loading (HLR, $q_A + q_R$, m/h) rates versus the flux load factor [$(V_O/(n.X_F))$, m/h] calculated from the 1DFT for the design point A in Fig. 3.1 for SSVI 40 to 160 m ^l /g (yielding V_O from 10.34 to 3.18 m/h and n from 0.31 to 0.61 ^l /g), and X_F from 2.5 to 4.5 g/ ^l . Note that an increase in the flux load factor leads to a consistent increase in SOR and HLR.	3 - 11
Fig 4.1a & 4.1b	Calculated 1DFT maximum SLR versus test applied SLR (Fig. 4.1a, left) and test applied to 1DFT calculated maximum SLR ratios (Fig. 4.1b, right) for the four Darvill SLR stress tests on the new and old SSTs.	4 - 3
Fig 4.2a & 4.2b	Case 1 : SSTs as-built – Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR (Fig. 4.2a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 4.2b, right) for the four Darvill old and new SSTs.	4 - 4
Fig 4.3a & 4.3b	Case 2 : Without Stamford baffles – Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR (Fig. 4.3a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 4.3b, right) for the four Darvill old and new SSTs.	4 - 5

Fig 4.4a & 4.4b	Case 3 : New and old SSTs with interchanged depths – Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR (Fig. 4.4a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 4.4b, right) for the four Darvill old and new SSTs.	4 - 5
Fig 4.5a to 4.5h	1DFT D&O charts showing the SST operating positions and result (safe O, fail X) of the SettlerCAD runs and actual tests for Tests 1 to 4 on the Darvill new and old SSTs	4 - 9 to 4 -10
Fig 4.6a to 4.6d	Final ESS and RAS concentrations (Fig. 4.6a, top left and Fig. 4.6b, top right) and percentage (%) mass balance (Fig. 4.6c, bottom left) versus influent flow as % of 1DFT limit showing runs ended safe (♦) and fail □) and % mass balance versus simulation time (Fig. 4.6d, bottom right) for Test 1 SettlerCAD simulations on the old Darvill SST.	4 - 12
Fig 4.7a & 4.7b	SettlerCAD predicted ESS concentration versus influent flow (as a percentage (%) of 1DFT limit) for Test 1 to 4 on the Darvill new (Fig. 4.7a, left) and old (Fig. 4.7b, right) SSTs.	4 - 13
Fig 4.8a & 4.8f	SettlerCAD predicted capacity as percentage (%) of the 1DFT maximum SOR and SLR limits versus the flux load factor for the Darvill new and old SSTs for Case 1, 2 and 3. The actual test positions and results are also shown.	4 - 15
Fig 5.1a & 5.1b	Calculated 1DFT maximum SLR versus test applied SLR (Fig. 5.1a, left) and test applied to 1DFT calculated maximum SLR ratios (Fig. 5.1b, right) for the 15 Watts SLR stress test on the Kanapaha SSTs.	5 - 4
Fig 5.2a & 5.2b	Case 1 : Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR (Fig. 5.2a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 5.2b, right) for the 15 Watts test .	5 - 5
Fig 5.3a & 5.3b	Case 2 – Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR (Fig. 5.3a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig 5.3b, right) for 6 of the 15 Watts tests.	5 - 6
Fig 5.4a to 5.4g	1DFT D&O charts showing the SST operating positions and result of the SettlerCAD runs and actual tests (safe O or fail x) for tests 1, 3, 4, 9, 11, 13 and 15 on the Watts SST.	5 – 10 to 5 - 11

		Page
Fig 5.5a & 5.5d	Final ESS and RAS concentrations (Fig. 5.5a, top left and Fig. 5.5b, top right) and percentage (%) mass balance (Fig. 5.5c, bottom left) versus influent flow as % 1DFT limit showing runs ended (safe \blacklozenge and fail \square) and % mass balance versus simulation time (Fig. 5.5d, bottom right) for Test 11 on SettlerCAD runs of the Watts SST.	5 - 13
Fig 5.6a & 5.6b	SettlerCAD predicted steady state ESS concentration versus influent flow (as percentage (%) of 1DFT limit) showing the whole field (Fig. 5.6a, left) and zoomed in detail (Fig. 5.6b, right).	5 - 14
Fig 5.7a & 5.7b	SettlerCAD predicted maximum SOR (Fig. 5.7a, left) and SLR (\square) (Fig. 5.7b, right), as a percentage (%) of 1DFT limit values versus flux factor $V_o/(nX_F)$. Also shown are the 15 actual test points safe (\bullet), fail (\blacktriangle) identified by number.	5 - 15
Fig 5.8a & 5.8b	SettlerCAD predicted SOR (Fig. 5.8a, left) and SLR (Fig. 5.8b, right), as a percentage (%) of 1DFT maximum limits versus flux load factor for the Watts (3.66 m SWD), and Darvill new (4.1 m SWD) and old (2.5 m SWD) SSTs.	5 - 16
Fig 6.1a & 6.1b	1DFT maximum SLR versus test applied SLR (Fig. 6.1a, left) and Test applied/1DFT predicted maximum SLR ratio (Fig. 6.1b, right) for the 14 Stress tests reported by STOWa (1981) on the Rijen SST.	6 - 4
Fig 6.2a & 6.2b	1DFT calculated maximum SLR versus SettlerCAD predicted SLR (Fig. 6.2a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 6.2b, right) for SLR Stress Tests 1, 2, 3, 4, 8 and 11 on the Rijen SST.	6 - 5
Fig 6.3a & 6.3b	1DFT D&O chart showing the SST operating positions and results (safe O, fail x) of the SettlerCAD runs and actual tests (safe and fail) for Tests 1, 2, 3, 4, 8 and 11 of the Rijen SST.	6 - 10 to 6 - 11
Fig 6.4a & 6.4b	Final ESS and RAS concentration (Fig. 6.4a, top left and Fig. 6.4b, top right) and percentage (%) mass balance (Fig. 6.4c, bottom left) versus influent flow as % 1DFT limit showing runs ended safe (\blacklozenge) and fail (\square) and percentage (%) mass balance versus simulation time (Fig. 6.4d, bottom right) for the SettlerCAD runs on the Rijen SST Test 2.	6 - 12 to 6 - 13
Fig 6.5a & 6.5b	Final steady state ESS concentration versus influent flow as a percentage (%) of the 1DFT limit for the 6 Rijen SST tests simulated.	6 - 14

		Page
Fig 6.6a & 6.6b	SettlerCAD predicted maximum SOR (Fig. 6.6a, left) and SLR (Fig. 6.6b, right), as a percentage (%) of the 1DFT limit values versus flux factor $V_o/(n.X_f)$. Also shown are the 14 actual test points (safe ●, fail ▲ or No Equilibrium) identified by test number.	6 - 14
Fig 6.7a & 6.7b	SettlerCAD predicted maximum SOR (Fig. 6.7a, left) and SLR (Fig. 6.7b, right), as a percentage (%) of the 1DFT limit values versus flux factor $V_o/(n.X_f)$ for the six test simulated with SettlerCAD identified by test number.	6 - 15
Fig 6.8a & 6.8b	SettlerCAD predicted maximum SOR (Fig. 6.8a, left) and SLR (Fig. 6.8b, right), as a percentage (%) of the 1DFT limit values, versus flux factor V_o/nX_f for the 4 tests on the Darvill new (■) and old (●) SSTs, 15 tests on the Watts' SST (▲) and 6 of the 14 tests on the Rijen SST (▼).	6 - 16
Fig 6.9a & 6.9b	1DFT maximum SLR versus test applied SLR (Fig. 6.9a, left) and Test applied /1DFT predicted maximum SLR ratio (Fig. 6.9b, right) for the 10 Stress tests reported by STOWa (1981) on the Oss SST.	6 - 19
Fig 6.10a & 6.10b	1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Fig. 6.10a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 6.10b, right) for STOWa SLR Stress Tests 15 to 19 and 22 on the Oss SST.	6 - 20
Fig 6.11a to 6.11f	1DFT D&O charts showing the SST operating positions and result (safe O, fail X) of the SettlerCAD runs and actual tests for STOWa Test 15 to 19 and 22 on the Oss SST.	6 - 24 to 6 - 25
Fig 6.12a to 6.12d	Final ESS and RAS concentrations (Fig. 6.12a, top left and Fig. 6.12b, top right) and percentage (%) mass balance (Fig. 6.12c, bottom left) versus influent flow as % 1DFT limit showing runs ended safe (◆) and fail (□) and percentage (%) mass balance versus simulation time (Fig. 6.12d, bottom right) for the SettlerCAD runs on the STOWa Test 16 on the Oss SST.	6 - 27
Fig 6.13a & 6.13b	Final steady state ESS concentration versus influent flow as a percentage (%) of the 1DFT limit for the 6 Oss SST tests simulated.	6 - 28

		Page
Fig 6.14a & 6.14b	SettlerCAD predicted maximum SOR (\square) (Fig. 6.14a, left) and SLR (\square) (Fig. 6.14b, right), as a percentage (%) of the 1DFT limit values versus flux load factor $V_o/(nX_F)$. Also shown are the 10 actual test points safe (\bullet), fail (\blacktriangle) identified by test number.	6 - 29
Fig 6.15a & 6.15b	SettlerCAD predicted maximum SOR (Fig. 6.15a, left) and SLR (Fig. 6.15b, right), as a percentage (%) of the 1DFT limit values versus flux load factor $V_o/(nX_F)$ for the six Oss SST tests simulated with SettlerCAD identified by test number.	6 - 30
Fig 6.16a & 6.16b	SettlerCAD predicted maximum SOR (Fig. 7.8a, left) and SLR (Fig. 7.8b, right), as a percentage (%) of the 1DFT limit values, versus flux factor V_o/nX_F for the 4 tests on the Darvill new (\blacksquare) and old (\bullet) SSTs, the 15 tests on the Watts' SST (\blacktriangle) and 6 of the 14 tests on the Rijen SST (\blacklozenge) and 6 of the 10 tests on the Oss SST (O).	6 - 32
Fig 7.1a & 7.1b	SettlerCAD predicted maximum SOR (\square) (Fig 7.1a, left) and SLR (\square) (Fig 7.1b, right) as a % of the 1DFT limit values versus flux load factor ($V_o/(nX_F)$). Also shown are the 15 actual test points (safe \bullet , fail \blacktriangle) identified by the number	7 - 4
Fig 7.2a to 7.2f	SettlerCAD predicted capacity as % of the 1DFT maximum HLR (Figures on left) and SLR (Figures on the right) limits versus the flux load factor for the Darvill new and old SSTs. The actual test position and outcome are also shown. The first two figures is for Case 1, the middle two figures are for Case 1 and 2 super-imposed upon each other. The last two figures is for Case 3 – reversed depth.	7 - 9 to 7 - 10
Fig 7.3a & 7.3b	SettlerCAD predicted SOR (Fig. 7.3a, left) and SLR (Fig. 7.3b, right), as a percentage (%) of 1DFT maximum limits versus flux load factor for the Watts simulation of Case 1, 2 and 3	7 - 14
Fig 7.4a & 7.4b	SettlerCAD predicted SOR (Fig 7.4a, left) and SLR (Fig 7.4b, right), as a percentage (%) of 1DFT maximum limits versus flux load factor for the Watts (3.66 m SWD), and Darvill new (4.1 m SWD) and old (2.5 m SWD) SSTs.	7 - 15
Fig 7.5a & 7.5b	SettlerCAD predicted maximum SOR (Fig 7.5a, left) and SLR (Fig 7.5b, right) as a % of the 1DFT limit values versus flux load factor for Darvill new, Darvill old, Watts, Rijen and Oss SSTs.	7 - 17

Fig 7.6a to 7.6d

SettlerCAD predicted % of 1DFT SLR (Fig 7.6a, left) and predicted % of 1DFT SOR (Fig 7.6b, right) versus HLR and SettlerCAD predicted % of 1DFT SLR (Fig 7.6c, left) and predicted % of 1DFT SOR (Fig 7.6d, right) versus R_{na}

LIST OF TABLES

		Page
Table 4.1	Description of Darvill old and new SSTs.	4 - 2
Table 4.2	Summary of the four SLR stress test results on the Darvill WWTP SSTs.	4 - 2
Table 4.3	Summary of the SettlerCAD predicted to 1DFT calculated maximum SLR ratios (i.e. flux ratings) for Case 1, 2 and 3.	4 - 6
Table 4.4	Summary of the SettlerCAD simulations results for the actual tests 1 to 4 on the new and old Darvill SSTs.	4 - 7
Table 5.1	Summary of the 15 SLR stress test results conducted by Watts et al. (1996).	5 - 3
Table 5.2	Summary of the SettlerCAD predicted to 1DFT calculated maximum SLR ratios for Case 1 and Case 2	5 - 6
Table 5.3	Summary of the SettlerCAD simulations results for the actual Test 1 to 15.	5 - 8
Table 5.4	Comparison Of Settlercad predicted result with the actual tests 1 To 15 on the Watts SSTs.	5 - 8
Table 6.1	Geometry details of Rijen and Oss SST of the STOWa (1981) data set.	6 - 3
Table 6.2	Summary Of The 14 SLR stress test results on the STOWa Rijen WWTP SST.	6 - 5
Table 6.3	Summary of the SettlerCAD simulation results for the SettlerCAD influent flow limit for the 14 SLR tests on STOWa Rijen SST.	6 - 7
Table 6.4	Summary of the SettlerCAD simulations results for the Rijen full-scale SST actual test.	6 - 9
Table 6.5	Summary of the 10 SLR stress test results on the STOWa Oss SST.	6 - 18
Table 6.6	Summary of the SettlerCAD simulations results for the Oss full-scale SST actual test.	6 - 21
Table 7.1	Summary of the SettlerCAD predicted to 1DFT calculated maximum SOR and SLR ratios (i.e flux ratings) for Cases 1, 2 and 3.	7 - 7
Table 7.2	Summary of the SettlerCAD predicted to 1DFT calculated maximum SOR and SLR (flux rating) ratios for Case 1, 2 and Case 3.	7 - 12
Table 7.3	Summary of the SettlerCAD predicted to 1DFT calculated maximum SOR and SLR (flux rating) ratios for the Rijen and Oss SSTs.	7 - 16
Table 7.4	Summary of SettlerCAD predicted limits for each data set for lowest and highest flux factor.	

LIST OF ABBREVIATIONS

BOD ₅	Biochemical Oxygen Demand at 5 days
CFD	Compaction Fluid Dynamic
COD	Chemical Oxygen Demand
diam	Diameter
D&O	Design and Operating chart
DSVI	Diluted Sludge Volume Index
Eq	Equation
ESS	Effluent Suspended Solids
<i>et al.</i>	and others
exp	exponent
F	Fail
Fig	Figure
F _{LF}	Flux Load Factor
g	gram
g/l	grams/litre
h	hour
HLR	Hydraulic Loading Rate
i.e.	<i>id est</i>
kg	kilogram
l	litres
l/g	litre/gram
log	logarithm to the base 10
m	metre
mg/l	milligrams per litre
min	minutes
M l/D	Megalitres per day (= 0.264 mgd)
m/h	metre/hour
MLSS	Mixed Liquor Suspended Solids
NE	No equilibrium
N	Nitrogen
P	Phosphate

PWWF	Peak Wet Weather Flow
RAS	Return Activated Sludge
S	Safe
SBH	Sludge Blanket Height
SHC	Solids Handling Criteria
SLR	Solids Loading Rate
SOR	Surface Overflow Rate
SS	Suspended Solids concentration
SST	Secondary Settling Tank
SSV _{13.5}	Stirred Specific Volume Index at 3.5 g/ℓ
SWD	Side Water Depth of secondary settling tank
SZSV	Stirred Zone Settling Velocity
TN	Nitrogen
TP	Total Phosphate
TSS	Total Suspended Solids
USA	United States of America
vs	versus
viz.	namely
WA	Washington
WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plant
1D	One Dimensional
2D	Two Dimensional
3D	Three Dimensional
1DFT	One Dimensional Flux Theory

LIST OF SYMBOLS

Δt	Change in time	T
A_{ST}	Surface area of SST	L ²
e	Base number of the natural logarithm scale (e = 2.713..)	-
Φ_{FS}	Feed-well skirt diameter	L
h_{FS}	Feed-well skirt depth	L
Φ_{IF}	Inlet feed-well diameter	L
h_{IF}	Inlet feed-well diameter	L
Φ_{ST}	SST diameter	L
h_{ST}	Feed-well skirt radius	L
H_{ave}	Average water depth	L
\dot{J}_B	Flux due to the movement of water with respect to the SST wall (bulk flux)	M/(L ² T)
\dot{J}_L	Limiting flux	M/(L ² T)
\dot{J}_{QF}	Flux (solids loading rate) of the SST feed flow rate (= applied flux)	M/(L ² T)
\dot{J}_s	Flux of the settling SS with respect to the water (gravity settling flux)	M/(L ² T)
\dot{J}_T	Total flux of SS with respect to SST wall (gravity flux + bulk flux)	M/(L ² T)
K_1, K_2	Constants in Takács double exponential settleability equation	L ³ /M
L	Length of SST	L
n	Flux theory constant in semi-log $V_{zs} - X$ relationship	L ³ /M
N_{TS}	Total time steps	T
Q_I	Influent flow rate to wastewater treatment plant	L ³ /T
Q_R	Return activated sludge (RAS) flow-rate (before underflow WAS abstraction)	L ³ /T
q_A	Surface overflow rate (Q_I/A_{ST} , m/h)	L/T
q_R	Underflow rate (Q_R/A_{ST} , m/h)	L/T
$q_{R,cont}$	Critical underflow rate in flux theory (i.e. $q_R = V_o/e^2$ m/h)	L/T
R_{min}	Minimum recycle ratio	-
R_{ha}	Actual retention time	h
R	Underflow recycle ratio (= Q_R / Q_I)	-
T_{sim}	Total simulation time	min °C

V_0	Flux theory constant in semi-log $V_{zs} - X$ relationship	L/T
V_s	Settling velocity of sludge particles	L/T
V_{zs}	Stirred zone settling velocity of the sludge	L/T
X	Suspended solids concentration (mgSSl)	M/L ³
X_{AT}	Reactor suspended solids concentration	M/L ³
X_E	Effluent suspended solids concentration	M/L ³
X_F	Feed SS concentration to SST	M/L ³
X_L	Limiting solids concentration of the flux theory	M/L ³
X_R	Underflow sludge concentration	M/L ³
X_W	Waste activated sludge concentration	M/L ³

CHAPTER 1

INTRODUCTION

In the past, design of secondary settling tanks (SSTs) has progressed along two parallel but distinct paths. One path mostly used in practice, has focussed on empirical design procedures. Empirical design rules such as the surface overflow rate (SOR) < 1 m/h at peak wet weather flow (PWWF) are being used (e.g. IWPC, 1973). Also, the design of the internal features has been very subjective and their effectiveness depends largely on the design engineer's experience. The other path has focussed on developing mathematical theories and incorporating these into models. Most of these models centred around the flux theory. Until recently, not much integration between the two paths has taken place, with the result that theoretical developments in SST modelling have not been well integrated into design and operation procedures. The idealized 1D flux theory presumes that the solids sedimentation processes through the SST dominate the behaviour and hence performance of the SST and that these processes alone give an adequate description of the behaviour of the SST. Other processes, such as hydraulic effects, turbulence and density currents, mixing, flocculation, and influences of inlet and outlet configurations and baffling, are not taken into consideration by the flux approach. In principle the 1D flux theory is simple, but it loses its attraction because it requires the solids zone settling velocity (V_s) to be known. This V_s varies with suspended solids concentration (X_t), so a relationship linking V_s to X_t needs to be established. The form of this relationship has been a point of debate over the years (Smollen and Ekama 1984), but nowadays the semi-log form seems to be the generally accepted and the superior form because it gives (i) a theoretically consistent description of the observed gravity flux curve with defined turning and inflection points; (ii) more internally consistent SST model with a continuous transfer between the two criteria that govern the loading conditions on the SST and; (iii) a better correlation coefficient for several extensive data sets accumulated over a number of years from full-scale plants.

With regard to the measurement of the V_s-X_t settlement data, this requires multiple batch zone settling tests over a concentration range which extends at least over the concentration range expected during SST operation. This is a time consuming and tedious undertaking, so much so that the V_s-X_t measurement has never been accepted in practice and therefore has been restricted mainly to research circles. This is the underlying cause for the flux theory *per se* not having been widely accepted for design and operation of SSTs.

Nevertheless, Ekama and Marais (1986) undertook to validate the steady state 1D flux theory (1DFT) with the aid of the data generated from the solid loading rate (SLR) stress tests from full-scale SSTs performance evaluations conducted by STOWa (1981), to assess the applicability of the 1D idealized flux theory to the design of full-scale SSTs. They found that the actual SLR to cause solid overload was about 80 % of that predicted by the 1D flux theory. Hence the permissible SLR predicted by the flux theory must be reduced by 25 % (1/0,80) in order to satisfactorily distinguish between the observed over and underloaded cases of the STOWa (1981) SLR data set, which comprised 47 SLR stress tests on 22 different circular SSTs from 30 to 48 m diameter, 1,5 to 3,5 m side water depths, 1:12 sloping bottoms with scraped sludge collection to the centre, and peripheral effluent overflow. They speculated that the 25 % reduction might be a consequence of hydraulic effects not taken into account in the idealised flux theory such as turbulence, density currents, inlet and outlet arrangements and baffling. If this is correct, then it is quite possible that the 25 % reduction is specific to the type of tank tested. Differently shaped and configured tanks may have produced a different percentage (%) reduction. Checking of the 1D flux theory against these particular SST performance data sets therefore may reflect local conventions embodied in the settling tank design and constitute a calibration to the specific SST rather than a validation of the flux theory.

Accepting that the internal features of the SST such as baffling, placement and type of effluent launder, inlet arrangement and type of sludge collection system affect tank performance, it would be valuable to determine with the aid of 2D hydrodynamic models how the arrangement of some of these features influences the SLR of the SST in relation to the maximum SLR calculated from the one dimensional flux theory 1DFT.

By this means, a flux rating could be established which is a measure of how well the design of the internal features have been optimised. In this respect the flux rating of the Dutch SSTs tested by STOWa would be 0.80 or 80 % of the 1DFT predicted SLR. With deeper tanks and with carefully designed and placed baffles determined from studies with the newly developed hydrodynamic models, the flux rating could possibly be increased to perhaps 90 % or 95 %, but the theoretical limit is 100 %, because this is the idealized SST. In this way the 2D models could become the means for optimising the internal features designed into the shell of the SST obtained from the 1DFT design procedure. This approach is similar to the suggestion of Wahlberg *et al.* (1998) who state that idealised 1DFT design "should be considered a theoretical limit, and hydrodynamic models give us the tools to develop better secondary clarifier designs that can operate closer to this limit."

In this research the 2D computational fluid dynamic (CFD) hydrodynamic computer programme SettlerCAD (Zhou *et al.*, 1998) was applied to full-scale circular SSTs with the principle aim to establish whether or not the 2D model automatically reproduces a flux rating < 1.0 with respect to the 1DFT and to determine what factors influence the flux rating. To do this the SLR stress tests reported by de Haas *et al.* (1998), Watts *et al.* (1996) and STOWa (1981) are simulated with the SettlerCAD programme.

CHAPTER 2

LITERATURE REVIEW

2.1 : GENERAL

Models are tools that are used to represent the physical, chemical and biological processes of natural and engineered systems. Engineers are usually concerned with mathematical or physical models. The simplest models consist of mathematical functions that are statistically fitted to known inputs and outputs; such models are sometimes referred to as a 'black box' or empirical model because they give very little insight into the controlling processes of the system. The application of such a model is limited to the calibration conditions used in setting the model in the first place.

Models can also be classified by their spatial resolution. There are very simple two cell models and complex multi-cell, three dimensional models. In addition, the models may simulate steady state or unsteady conditions. In their most complex form, models attempt to represent all of the important actions by solving the differential equations of continuity, momentum, energy and mass transport subject to realistic boundary conditions; these models may be called deterministic or 'glass box' models since they reveal the role of natural laws in determining the system's performance. These models can be applied outside of the range of calibration, albeit with caution.

Physical-scale models fill a similar role to 'glass box' models in that they attempt to represent the physical processes; however, true similarity is never achieved since all small-scale physical models are subject to some scale up effects.

Until a few years ago, SST models based on the idealized 1D approach were the only ones available for simulation of cyclic flow and load conditions on SSTs. In these models, the suspended solids (SS) and the water are assumed to move in the vertical direction only, which is clearly an idealisation of the flow regime in real SSTs with large diameter/depth ratios in which vertical and horizontal flows of solids and water take place.

Dynamic 1D idealized models for SSTs have been done before. The earlier models (pre 1980) were shown to be deficient and gave invalid predictions because they used a sequential approach to solve the continuity equations. Anderson and Edwards (1981) showed that the solution algorithm that correctly predicts the SS concentration with depth profiles and the movement of the sludge blanket must solve the continuity equations simultaneously. The dynamic 1D model developed by Ozinsky *et al.* (1994) is based on that of Anderson and Edwards (1981) because this was the best and most refined application at the time. Since then a number of other 1D models have been developed (i.e. Härtel and Pöpel, 1992; Ottéropohl and Freund, 1992; Hamilton *et al.*, 1992, and more recently Grijspeerdt *et al.*, 1995 and Watts *et al.*, 1996). These models vary principally in the way they deal with the boundary conditions, but a common feature in all of them is that they include a turbulent diffusion or dispersion coefficient in the partial differential equation that represents the movement of the solids. The effect of this coefficient is to introduce mixing between the elemental layers that make up the depth of the SST. Values for this coefficient must be determined by calibration against full-scale SST performance data. Calibration is a complex and tedious process because the value of the coefficient has been found to vary with depth, influent and recycle flow rate, geometry, baffling and other internal features of the SST (Ozinsky *et al.*, 1994, Watts *et al.*, 1996). These coefficients therefore incorporate the effect of the internal features of the SST and hydrodynamics in a single lumped parameter. The values found are specific for the particular SST simulated and have the effect of reducing the maximum SLR from that calculated by the steady state 1DFT, i.e. the coefficients are calibrated to conform the model predictions to the observed flux rating of the particular SST.

SettlerCAD is a computer program that models the 2D behaviour of a circular SST. Accordingly unlike in the non-steady state 1D flux SST simulation models, in SettlerCAD there are no model “constants” that influence tank hydrodynamics that can be adjusted to improve the correlation between experimental and simulated results¹⁾. Therefore, the outcome of a stress simulation (fail – raised sludge blanket and high ESS, or safe – stable sludge blanket and low ESS) can be compared with observed full-scale SST performance without needing to do a major calibration exercise first. In this research project the maximum SLR predicted by the SettlerCAD is compared with that predicted by the 1D idealized flux theory using the de Haas *et al.* (1998), Watts *et al.* (1996) and STOWa (1981) SLR stress tests on the different SSTs as a basis.

All the SST models mentioned above, i.e. the idealized steady state 1DFT, the dynamic non-steady state 1D models and the 2D hydrodynamic model SettlerCAD, have in common the specification of the sludge settleability. In all of them, this is the conventional way of relating the solids vertical settling velocity, with respect to the water due to gravity, (V_s , m/h) to the local solids concentration (X_t , kg/m³) with the empirical exponential equation

$$V_s = V_0 e^{-nX_t} \quad \text{m/h} \quad (1.1)$$

This, in fact, forms the unified basis between the different models and allows them to be compared. It is only the modelling of the hydraulic field in which solids settle that is modelled differently in the different models from the very simple to the very complex. In the steady state idealized 1DFT this is in the vertical direction only, in the dynamic non-steady state 1D models, this is also in the vertical direction only, but turbulent diffusion creates mixing in the SST to represent the non-idealities, and in the 2D hydrodynamic models such as SettlerCAD, this is modelled hydrodynamically in the more realistic vertical and horizontal directions.

¹⁾ There are, of course, many model “constants” in 2D hydrodynamic models for SSTs which would significantly change the simulation results if changed. (see Ekama *et al.*, 1997 for a review of 2D models). However, in SettlerCAD, except for those mentioned below, all the constants are in fact constant and cannot be changed by the user.

An understanding of the steady state 1D flux theory (1DFT) is therefore the foundation to all SST models. This theory is therefore briefly reviewed below to demonstrate how the 1DFT is used to determine the critical surface overflow rate (SOR, m/h), SLR and hydraulic loading rate (HLR, m/h).

2.2 : STEADY STATE ONE DIMENSIONAL FLUX THEORY (1DFT)

The sludge flocculation, settling and thickening characteristics can vary considerably not only from plant to plant but also at different times at the same plant. For reliable functioning of the settling tank, these variations need to be taken into account both in design and operation. In so far as continued functioning of the activated sludge - settling tank system is concerned, the settling and thickening characteristics are more important than clarification because the system relies on an adequate supply of return of activated sludge to the bio-reactor; the small amount of solids that may escape with the effluent if the flocculation characteristics are not good are inconsequential to the successful *operation* of the system. However, the flocculation characteristics of the sludge are very important for the performance of the system because the escaping effluent suspended solids (ESS) of solids which directly affects the effluent quality in terms of BOD₅, COD, Total N (TN) and Total P (TP) concentrations.

Currently, the design of secondary settling tanks (SSTs) is usually done in two stages; in the first, zone settling and thickening considerations are applied which lead to the specification of a surface area and depth. With the proper incorporation of design features for clarification, zone settling and thickening criteria will govern the specification of the area of the SST. Specification of depth will accommodate a provision for both sludge accumulation and thickening as well as for maximising clarification efficiency.

After specifying surface area and depth, the clarification efficiency of the tank is optimised by considering detail design of the internal features of the tank such as -

- (i) inlet arrangement;
- (ii) tank configuration;

- (iii) control of hydraulic flow patterns, short circuiting and turbulence with baffling;
- (iv) flocculation chambers; and
- (v) sufficient sludge transport and collection capacity. These features make the difference between achieving a low or high ESS concentration for the overflow rate and depth.

In the English speaking countries, such as the USA, UK, Australia and South Africa, the surface area of the SST is calculated with the aid of the 1DFT, which is briefly reviewed below.

2.2.1 : The stirred zone settling velocity (SZSV) test and the flux procedure

Since originally conceived by Coe and Clevenger (1916), the flux theory has received considerable research attention particularly since 1970. Contributions towards its development have been by Kynch (1952), Yoshioka *et al.* (1957), Dick and Ewing (1967), Vesilind (1968a), Dick (1970, 1972), Dick and Young (1972), Alkema (1971), Tracy and Keinath (1974), Keinath *et al.* (1977), Keinath and Laquidara (1982), Wilson and Lee (1982), Pitman (1980, 1984), Riddell *et al.* (1983), Ekama *et al.* (1984), Daigger and Roper (1985), Ekama and Marais (1986), Wahlberg and Keinath (1988), Keinath (1990), Daigger (1995) and Ekama *et al.* (1997). To facilitate analytical solutions (as opposed to the graphical solutions developed by Yoshioka *et al.* (1957), Vesilind (1968b) and Dick and Young (1972) proposed mathematical expressions linking the SZSV (V_{zs} , m/h) and the solids concentration (X , kg/m³); the former proposed a semi-log one, i.e. $V_{zs} = V_o \exp(-nX)$, the latter a log-log one, i.e. $V_{zs} = V_o(X)^{-n}$. From a survey of the literature (Smollen and Ekama, 1984; Ozinsky and Ekama, 1995b) the semi-log expression appears to be more generally accepted today.

Although the value and usefulness of the flux theory are well attested in the quoted references, it has not been widely adopted for design and operation, principally for three reasons:

- (i) the labour intensive effort required to obtain SZSV-X data, with the result that,
- (ii) measurement of SZSV-X data is uncommon in routine practice so that no data base relating this measure to full-scale SST performance has been developed; and
- iii) a lack of confidence in the predictive power of the flux theory because its applicability to full-scale design and operation has not been definitively demonstrated.

These problems with the flux theory, in particular the tedious SZSV-X measurement, were the stimuli for the development of not only the simpler settleability measures, $SSVI_{3.5}$ and $DSVI$, but also of the alternative design procedures based on them.

2.2.2 : Theoretical principles of the steady state idealized flux theory

In essence the flux theory, as it is generally known, is a 1D model which states that solids entering the SST are carried to the bottom via gravity settling flux (j_s) which results from the sludge settling downwards through the water, and bulk flux (j_B) which results from the water moving downwards in the SST due to the underflow sludge recycle pump. The total flux (j_T), i.e. the movement of solids with respect to the wall, is the sum of the settling and bulk fluxes, and expressing the former in terms of the semi-log model, yields -

$$\begin{aligned}
 j_T &= j_s + j_B \\
 &= X V_o e^{-nX} + X q_R \quad \quad \quad [\text{kg}/(\text{m}^2\text{h})] \quad \quad \quad (2.1)
 \end{aligned}$$

where

X = suspended solids concentration (kgTSS/m³)

q_R = underflow rate (m/h)

$$= Q_R / A_{ST}$$

Q_R = volumetric recycle flow rate (before waste sludge abstraction) (m³/h)

A_{ST} = SST surface area (m²)

In the ideal SST (which the idealized 1D flux theory assumes) movement of sludge and water is in the vertical direction only (i.e. 1D) and the mixed liquor flow entering the SST separates at the point of entry into the recycle flow (Q_R) moving downwards and the overflow (Q) moving upwards at underflow and overflow rates of q_R and q_A (m/h), respectively.

With the proviso that no solids are lost in the effluent so that a sludge mass balance is conserved, the recycle flow concentration (X_R) is related to the feed concentration (X_F) via the recycle ratio (R), viz.:

Solids withdrawn = solids applied

$$X_R Q_R = X_F (Q_i + Q_R) \quad (\text{kgSS/h}) \quad (2.2a)$$

$$X_R q_R = X_F (q_A + q_R) \quad [\text{kgSS}/(\text{m}^2\text{h})] \quad (2.2b)$$

$$R X_R = X_F (1+R) \quad (\text{kgSS}/\text{m}^3) \quad (2.2c)$$

$$R = Q_R / Q$$

The equation above for R is generally accepted as the definition for R .

For some selected underflow rate less than the critical ($q_R < q_{R,crit}$, see below), a particular value of X in Eq 2.1 less than X_R makes j_T a minimum; this X concentration and its associated flux are called the limiting concentration (X_L) and flux (j_L), respectively. This limiting flux is the limiting rate at which solids can reach the bottom of the SST, and therefore the applied solids loading rate or flux (j_{QF}) must not exceed this limiting flux for safe operation of the SST. This is called the solids capacity Criterion I, viz.:

$$j_{QF} \leq j_L$$

$$q_A \leq j_L / [X_F (1+R)] \text{ or } j_L / (R X_R) \quad (\text{m/h}) \quad (2.3)$$

The shape of the gravity flux curve (j_s in Eq 2.1) in terms of the semi-log model is such that once the underflow rate reaches a critical value ($q_{R,crit}$) then a limiting concentration (X_L) and flux (j_L) cannot any longer be found. When this happens Eq 2.3 no longer provides a valid solution.

However, White (1975) and Merkel (1971a,b) independently concluded that under these conditions the limiting flux on the SST is the flux of the feed concentration (X_F).

This is called the solids capacity Criterion II (see also Wilson and Lee, 1982), viz.:

$$j_L = (V_o e^{-nX_f} + q_R) X_F \leq j_{QF} = X_F (q_R + q_A)$$

which reduces to

$$q_A \leq V_o e^{-nX_f} \quad (\text{m/h}) \quad (2.4)$$

i.e. the overflow rate must not exceed the SZSV of the solids at the feed concentration. From Eqs 2.3 and 2.4, Ekama *et al.* (1984) and Daigger and Roper (1985) developed two kinds of design and operation (D&O) charts, which are both explained in Ekama *et al.* (1997). Because the Ekama D&O chart, is used in this research, this is discussed briefly below.

2.2.3 : The Ekama D&O chart - Fig. 2.1

The hyperbola in the D&O chart of Ekama *et al.* (1984) (see Fig. 2.1) represents the critical underflow rate $q_{R,crit}$ (equal to V_O/e^2) and distinguishes between the domains in which both the solids capacity criteria have to be met (area between axes and hyperbola) and in which the solids capacity Criterion II only has to be met (area above hyperbola). Criterion I is given by Eq 2.3 which, for different X_F values, is a family of curves from the origin to the hyperbola for increasing recycle ratio (R). These curves show that as the overflow rate (q_A) increases, R must increase also to satisfy Criterion I. Criterion II, given by Eq 2.4, is independent of R , and is a family of horizontal lines for different feed concentrations (X_F). In the region below the hyperbola, both criteria have to be met simultaneously.

In some instances in this region, the allowable overflow rate is higher for Criterion I than for Criterion II so that the latter is the governing one even though the tank is operating at a point below the hyperbola. Consequently for a specified feed concentration X_F , *failure* of the SST is represented by the overflow rate (q_A)-underflow recycle ratio (R) value pairs falling above the Criterion I and II lines for the specified reactor operating or feed concentration.

It is in the integration of Criterion I and Criterion II that the semi-log $V_S - X$ equation is superior to the log-log equation. With the semi-log model, the overflow rate for Criterion II is already equal to or slightly over the maximum overflow rate for Criterion I.

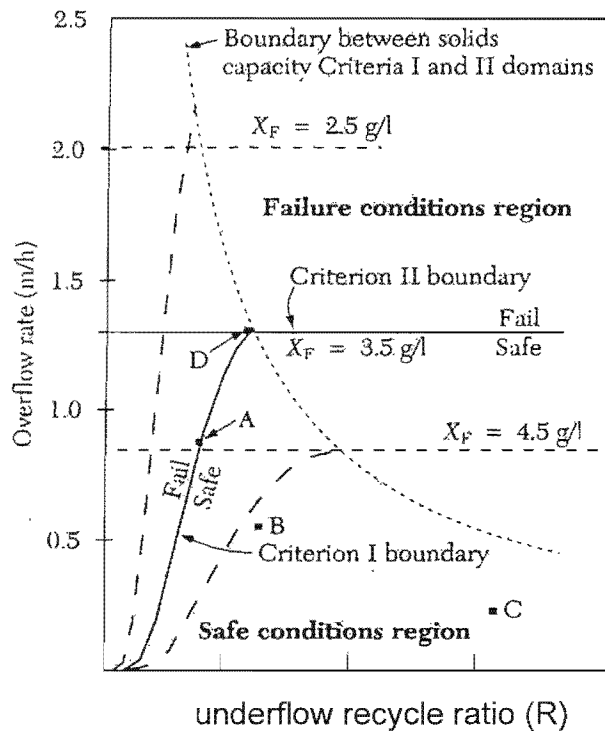


Fig. 2.1 : Design and operating chart of Ekama et al. (1984) for SSTs based on the flux procedure and the semi-log expression linking the SZSV and solids concentration.

The solids capacity Criteria I and II boundaries are shown for selected feed concentrations ($X_F = 2.5, 3.5$ and 4.5 g/l). For a feed concentration of 3.5 g/l , if the overflow rate (horizontal) and recycle ratio (vertical) lines intersect inside, on or outside the Criterion I and II bounded area, the operating conditions are safe, critical or overloaded respectively. The underflow rate q_R is the product of the recycle ratio (R) and overflow rate (q_A) operative at any particular point in the chart; constant q_R is represented by hyperbola in the chart of which $q_{R,crit} = V_0/e^2$ is one.

The D&O chart in Fig. 2.1 is valid also for daily cyclic conditions if it is accepted that no solids storage takes place in the tank or, alternatively, the peak flow is of long duration ($> 3\text{h}$) so that the storage capacity is fully utilised and the reactor concentration is not significantly reduced. Accepting zero storage capacity, for successful operation of the SST, the conditions prescribed by the D&O chart should be met at all times of the day.

For example, for a fixed SST area (A_{ST}) and constant recycle flow (Q_R), as the influent flow to the plant (Q_I) increases, so the overflow rate (q_A) increases and the recycle ratio (R) decreases, which moves the q_A - R intersection point upwards to the left in Fig. 2.1. At all times of the day, this intersection point should be below the two Criterion lines for safe operation.

This approach of dealing with cyclic flow conditions is generally conservative because SSTs can sustain a temporary overload due to reduction in reactor (or feed) concentration and sludge storage in the SST depending on the relative volumes of the biological reactor and SST (Keinath, 1985). Sludge storage capacity and SST volume, i.e. depth, are not considered in the flux design procedure. However, 1D models, based on the flux procedure, coupled to an activated sludge reactor can deal with sludge transfer to and from the SST.

The D&O chart in Fig. 2.1 is not the familiar way of presenting the flux procedure - settling flux curves with overflow rate (q_A), underflow rate (q_R) and feed concentration (X_F) lines intersecting at the state point is far more familiar. However, in the D&O chart, nothing has been added to or removed from the flux theory - it is merely a different way of presenting the same concepts. In order to assist interpretation of the D&O chart, the settling flux curves with state point for the four different regions of the D&O chart are shown in Fig. 2.2, viz.:

- **Region A:** overloaded - state point is *outside* settling flux curve and underflow rate (q_R) is low enough to make a tangent to the settling flux curve ($q_R \leq q_{R,crit} = V_O/e^2$).
- **Region B:** underloaded - state point is *inside* settling flux curve and $q_R \leq V_O/e^2$.
- The boundary line between regions A and B is solid capacity Criterion I and represents all combinations of overflow rate (q_A) and underflow rate (in terms of R i.e. $R=q_R/q_A$) such that the state point is on or within the settling flux curve and the underflow rate line intersects the settling flux curve tangentially.
- **Region C:** underloaded - state point is within the settling flux curve and $q_R > V_O/e^2$.

- **Region D:** overloaded - state point is outside the settling flux curve and $q_R > V_O/e^2$.
- The boundary line between regions C and D is solids capacity Criterion II and represents the state point on the settling flux curve at the intersection point of constant q_A and feed concentration X_F lines.
- The hyperbola boundary line between regions A and D and B and C distinguishes between q_R less (A and B) and greater (C and D) than the critical $q_{R,crit} = V_O/e^2$.

The D&O chart will be used extensively in this thesis. The SettlerCAD runs that were performed for the different SLR stress tests on the different SSTs will be plotted on D&O charts for the tests like points A, B, C and D on Fig. 2.2, so an usual assessment can be made were these runs fall in relation to the safe and criteria of the 1DFT.

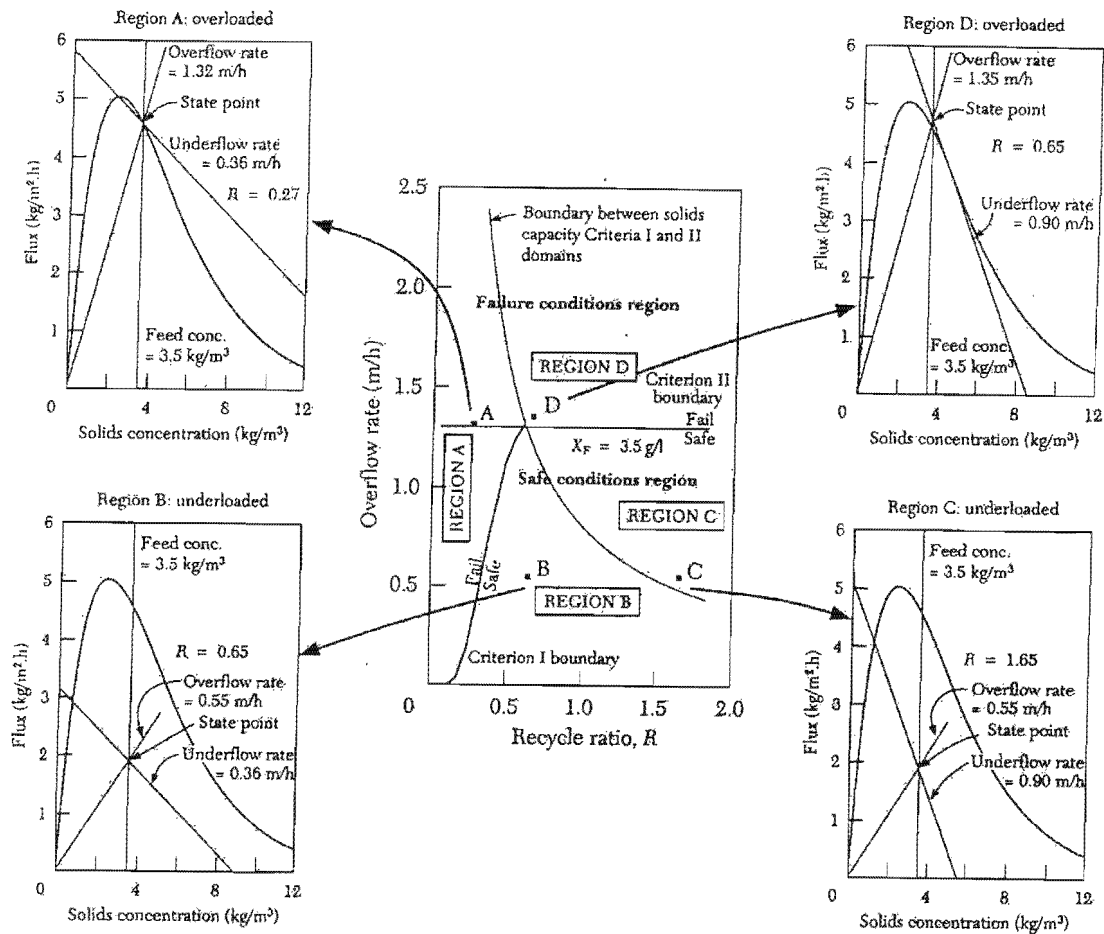


Fig. 2.2 : Settling flux curves with settling tank operating state point diagrams for the points A, B, C and D in the four operating regions A, B, C and D respectively of the flux design and operating chart. Regions A and D (top) overloaded; regions B and C (bottom) underloaded. Flux $V_o = 5.93 \text{ m/h}$; $n = 0.43 \text{ m}^3/\text{kg}$; feed concentration = 3.5 kgTSS/m^3 .

2.3 : TWO DIMENSIONAL HYDRODYNAMIC MODELS

Hydrodynamic models for SSTs allow design and optimization of the SSTs internal features such as geometry, side wall depth, baffling, inlet and sludge collection arrangements. A few such models of various complexity and sophistication have been developed for simulating circular and rectangular SSTs (see Krebs, 1995 or Chapter 5 in Ekama *et al.*, 1997 for a review of these models). Although application is limited at this stage, these models are being used successfully in research programmes and design for 2D and 3D simulation of full-scale SSTs.

While the description of the hydrodynamics of the SSTs has progressed dramatically with the advent of 2D and 3D hydrodynamic models, description of the sludge settling behaviour in these models has not progressed very much beyond that of the Y_{zs} - X as in the 1D flux theory models and remains the major weakness in these models, especially with respect to flocculation and breakup.

In this research the 2D hydrodynamic computer programme SettlerCAD, developed by Zhou *et al.* (1998) will be used. A more detailed description of this programme is given in Chapter 3.

2.4 : PROSPECTS FOR 3D MODELLING

As discussed earlier, the flow pattern in full-scale settling tanks is very complex. Although some success has been achieved through 2D models, several field conditions cannot be adequately represented by 2D models. Generally, circular tanks exhibit approximately axisymmetric flow and therefore can be adequately modelled by 2D models with the exception of the local field around the sludge collection and removal system. Rectangular and square tanks are prone to more complex flow and may require 3D models. Some examples of such tanks are: centre feed square tanks, peripheral feed square tanks, rectangular tanks with non-uniform lateral feed and any settling tank subject to strong wind effects.

Recent advances in numerical techniques and computational power make it possible to apply 3D modelling to SSTs. With 3D models it is hoped to simulate the effect of the sludge collection system i.e. scraper or hydraulic suction, and its associated structure on the hydraulic flows and the transport of solids.

CHAPTER 3

THE 2D HYDRODYNAMIC MODEL SettlerCAD

3.1 : INTRODUCTION

SettlerCAD is a 2D dynamic mathematical model in the form of a computer programme for the simulation of SSTs in wastewater treatment plants. SettlerCAD is structured around the steps that the user would be taking in order to perform simulations and analyse results. SettlerCAD is designed to only model circular SST's.

The simulations are usually conducted in four major steps as follows:

- Preparing the SettlerCAD programme input: During this step all the conditions and parameters for the simulation are defined;
- Execution of the SSTs programme: The computer programme performs calculations and generates results;
- Display and review of results: Simulation results are examined through several graphic views, such as concentration and velocity plots;
- Saving and retrieving model parameters and simulation results for archiving and inclusion in reports and studies.

3.2 : INPUT INFORMATION REQUIRED

The SettlerCAD complete programme requires 4 types of input:

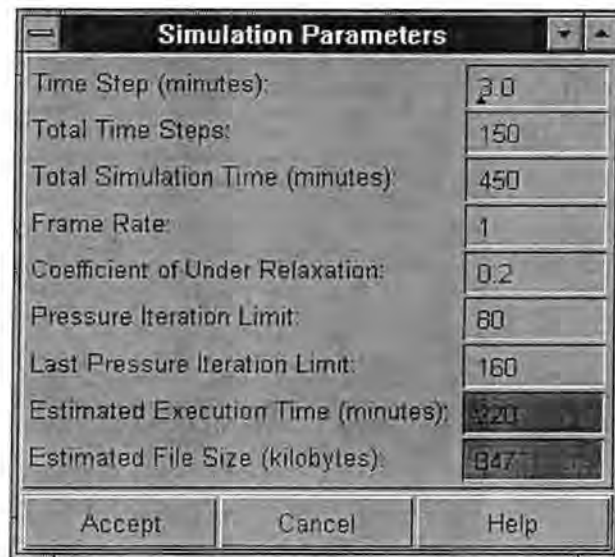
1. The SST loading comprises the feed concentration (X_F), recycle flow (Q_R) and the influent flow (Q_I) into the SST excluding the recycle flow. The recycle flow can be withdrawn uniformly over the tank bottom, thus simulating a flat or sloping bottom hydraulic suction sludge collection SST. Or it can be scraped to and withdrawn from the centre, simulating a sloping bottom scraper sludge collection SST. In SettlerCAD this is simulated as uniform sludge collection from the tank floor.

2. The SST geometry requires specification of the side wall radius, side water depth and bottom slope. For the inlet arrangement, the inlet feed well radius and depth and the feed well skirt radius and depth are required. The model makes provision for two types of baffles; As defined by SettlerCAD a Crosby baffle, which is a small circular vertical wall on the bottom of the tank, and a Stamford baffle, a horizontal wall extending inwards, immediately below the effluent launder. The definition of a Crosby baffle in SettlerCAD differs from that in Ekama *et al.*, 1997, where the Crosby baffle slopes inwards from the sidewall.
3. The sludge settleability which can be defined either in terms of the Stirred Specific Volume Index (SSVI) which is then converted internally to a V_0 and n value with the equations of Wahlberg and Keinath (1988) (see Ozinsky *et al.*, 1995 or Ekama *et al.*, 1997) or the V_0 and n values can be individually defined. The V_{zs} -X relationship for SettlerCAD includes an additional exponential term with an exponent K_2 proposed by Takacs *et al.* (1991). This term takes into account the slow settling particles at low concentration ($< 100 \text{ mg}/\ell$). In this research the value of K_2 was set very high (10). This eliminated the effect of the slow settling particles on the identification of the failure from a raised sludge blanket ESS concentration prediction.
4. The simulation parameters of which those relevant in this research were the length of time step (Δt_{\min}), total time steps (N_{TS}) and total simulation time (T_{sim}). To ensure a final steady state, was reached at the end of the simulation run, the T_{sim} had to be at least 15 times the hydraulic retention time (R_{ha}). Generally simulation times were 30 times R_{ha} , ensuring steady state, which was 10 times longer than the actual SLR stress test duration Zhou *et al.*, (1998).

3.3 : SettlerCAD DIALOG BOXES

Outlined below is a short layout of the steps required for the set up of a simulation SettlerCAD. For a detailed functionality of the program the tutorial guide accompanying the model can be consulted Zhou *et al.*, (1998).

3.3.1 : Simulation parameters dialog



- **Time Step:** The change in time for each time step. This value must be greater than 0. Values greater than 3 may cause inaccurate results.
- **Total Time Steps:** The number of time steps to execute. This value must be 1 or greater.
- **Total Simulation Time:** The total amount of time represented in the simulation. Simulations with a total simulation time less than 400 minutes may not reach equilibrium.
- **Frame Rate:** The number of time steps that will go by before data will be written to the results file. i.e. a value of 2 will roughly halve the size of the output file. This value must be 1 or greater and less than the total time steps.
- **Coefficient of Under Relaxation:** The higher this number, the faster the simulation will execute, and the greater the chance of causing instability. This value must be greater than 0.05 and less than 1.
- **Pressure Iteration Limit:** The larger this value the more accurate the model results will be, but will slow down execution. This value must be 60 or greater.

- **Last Pressure Iteration Limit:** Pressure iteration limit for the last time step enables the final results to be more accurate than the intermediate results. This value must be 60 or greater.
- **Estimated Execution Time:** This is an output only field. It is a rough estimate for how long execution will take on the particular computer being used. Changes in the total time steps and the speed of the computer will affect this value.
- **Estimated File Size:** This is an output only field. This is an estimate of the file resulting from execution of the simulation. Changes in the total time steps and the frame rate will affect this value.

3.3.2 : Circular clarifier geometry dialog

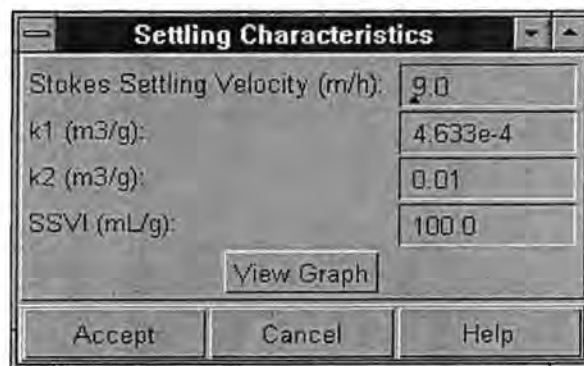
Clarifier Geometry	
Side Wall Radius (m):	22.0
Side Wall Depth (m):	5.0
Feed Well Skirt Radius (m):	2.7
Feed Well Skirt Depth (m):	2.4
Feed Well Inlet Radius (m):	1.0
Feed Well Inlet Depth (m):	1.0
Bottom Slope (%):	10.0
Crosby Baffle Distance (m):	0.0
Crosby Baffle Size (m):	0.0
Stanford Baffle Height (m):	0.0
Stanford Baffle Size (m):	0.0
<input type="button" value="Accept"/> <input type="button" value="Cancel"/> <input type="button" value="Help"/>	

- **Side Wall Radius:** The distance from the centre of the tank to the outer wall.
- **Side Wall Depth:** The depth of the tank at the outer wall.
- **Feed Well Skirt Radius:** The distance from the centre of the tank to the flocculating skirt.
- **Feed Well Skirt Depth:** The height of the flocculating skirt.
- **Feed Well Inlet Radius:** The distance from the centre of the tank to the inlet.

- **Feed Well Inlet Depth:** The height of the inlet opening.
- **Bottom Slope:** The percentage the tank floor slopes downward toward the centre of the tank.
- **Crosby Baffle:** A Crosby baffle is situated on the bottom of a tank extending upward. The distance is the radius at which the baffle will be placed and the size is the height that it extends upwards from the bottom of the tank.
- **Stamford Baffle:** A Stamford baffle is situated on the outer wall of a tank extending inward. The height is its position on the outer wall from the bottom of the tank and the size is the distance it extends toward the centre of the tank.



3.3.4 : Settling characteristics dialog



- **Stokes Setting Velocity (V_0):** This is the settling velocity of an average activated sludge particle at infinite dilution. It must be greater than 0 and normally is less than 20 m/h.

- **K_1 (n):** The first constant in the Takacs double exponential equation defining sludge settling velocity. This value must be greater than 0 and is usually between 0.00036 (SSVI of 40) and 0.000844 (SSVI of 130). Changes to this value will affect SSVI.
- **K_2 :** The second constant in the Takacs double exponential equation defining sludge settling velocity. This value must be greater than 0 and is usually between 0.005 and 0.3.

Because an ESS value of $> 50 \text{ mg}/\ell$ was chosen as a failure value for the SST, the concern was raised that a “failed” simulation could be the result of poor hydraulics in a SST and not the result of a propagating sludge blanket. To address this concern, the K_2 value in the double exponential equation of Takacs (which is used in SettlerCAD to define the sludge settling velocity) was made very high, more than a 1 000 times larger than realistic values.

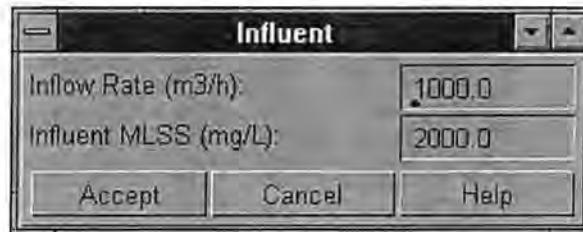
This then reduces the double exponential to the usual single exponential of $V_s = V_o \exp(-nXt)$ where SettlerCAD's $K_1 = n$. With the single exponential, the settling velocity of low concentrations ($< 100 \text{ mg}/\ell$) are very high and close to and up to V_o . This means that the settling velocities of the low concentrations are much higher than the overflow rates on the SSTs. So the low concentrations always settle much faster than the overflow rate ($> 10x$) and hence low concentrations would not be able to be dragged out with the effluent even with serious hydraulic disturbances at the effluent launders. High ESS $> 50 \text{ mg}/\ell$ therefore could only be obtained with a high sludge blanket near the effluent launders. A view of the ESS versus simulation time show that the ESS was $1 \text{ mg}/\ell$ right up to the time the sludge blanket approached the effluent weirs which is what one expects from the single exponential equation.

The SettlerCAD model does not allow the modeling of an activated sludge (AS) reactor prior to the SST. This however do not affect the % of the 1DFT predicted SLR or SOR that SettlerCAD predicts because the recycle flow (Q_R), feed concentration (X_i) and influent flow (Q_i) were kept constant for each simulation. In doing so the effect of the AS reactor was eliminated.

The % mass balance was calculated as the sum of the masses of sludge in the return and effluent flows as a % of the mass of sludge entering the SST with the influent and recycle flows.

- **SSVI:** This value cannot be less than 40; it is also recommended that the value should be less than 150, to ensure the simulations remain within the usual range for activated sludge. Changes to this value will affect K_1 .

3.3.5 : Constant inflow dialog



There are only two values to edit for this component:

- Inflow Rate:
- Influent MLSS:

The model has the function to input a diurnal influent flow. This was tested, but the model did not accept the input values. Subsequently only a constant influent flow was used.

3.3.6 : RAS geometry

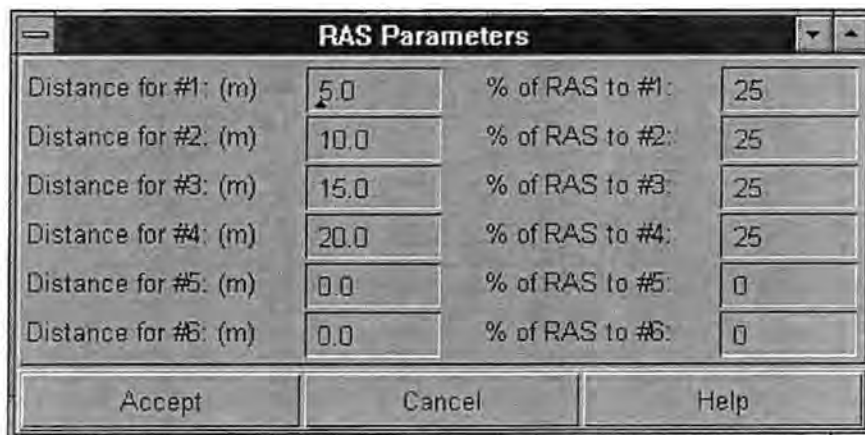
- **Uniform RAS withdrawal**

This object represents a RAS system that can withdrawal evenly from along the bottom of the tank. There are no values to edit for this object.



- **Pipe RAS Withdrawal**

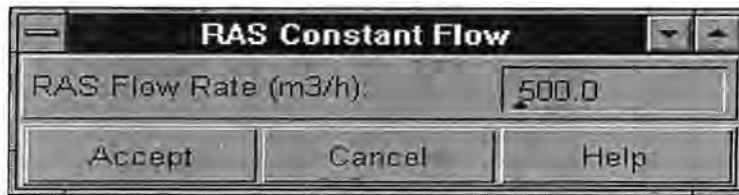
This object specifies the distance from the centre of the tank and the percentage of the total RAS flow for each pipe. The percentages should add up to 100 percent. A simulation without 100 percent withdrawal will halt and a warning message will be presented. All pipes including and beyond the first pipe with a zero percentage will be ignored by the interface.



A dialog box titled "RAS Parameters" with a table of values for six pipes. The table has two columns: "Distance for #X: (m)" and "% of RAS to #X:". The values are: Pipe #1: 5.0, 25%; Pipe #2: 10.0, 25%; Pipe #3: 15.0, 25%; Pipe #4: 20.0, 25%; Pipe #5: 0.0, 0%; Pipe #6: 0.0, 0%. Below the table are three buttons: "Accept", "Cancel", and "Help".

Distance for #X: (m)	% of RAS to #X:
5.0	25
10.0	25
15.0	25
20.0	25
0.0	0
0.0	0

3.3.7 : Constant RAS flow



This dialog box is for the return activated sludge (RAS) flow from the SST back to the reactor; no provision is made for WAS abstraction.

3.3.8 : Results contents

SettlerCAD gives output results on the following information:

- Concentration view
- Velocity view
- Contour view
- Timeline
- Computational grid
- Operation parameters

3.4 : FINDING THE MAXIMUM LOADING RATE FOR SettlerCAD

For a particular simulation of an actual test, the $V_{0, n}$ and feed concentration X_F was used and a D&O chart was drawn which defines the maximum surface overflow rate (SOR) and associated SLR at the test recycle flow (Q_R). Details of how to draw the D&O chart are discussed in Chapter 2. A typical D&O chart is shown in Fig. 3.1. The solids handling criterion (SHC) I and II lines and the hyperbola (which marks the boundary where the SHC I does and does not apply) are completely specified by the $V_{0, n}$ and X_F values that are used to find the 1DFT maximum SOR and SLR for a particular SST stress test.

First the minimum recycle ratio (R_{min}) for the maximum overflow rate ($q_A = Q_V/A_{ST}$, m/h) is determined (Point A in Fig. 3.1) by setting the equations for SHC I and II equal and solving for R which is R_{min} . This R_{min} is used as a reference recycle ratio to check whether SHC I or SHC II govern the maximum capacity of the SST for the particular underflow rate ($q_R = Q_R/A_{ST}$, m/h) of the SST test. For Test Y in Fig. 3.1, the locus of the SST operating point at the constant underflow rate (q_R , m/h) and increasing overflow rate (q_A , m/h) cuts the SHC I line at an R value (R_Y) $< R_{min}$ (at Point Y). This means that the SC I fixes the maximum SOR and SLR of the SST for the fixed q_R and X_F of the particular test and the maximum SOR and SLR capacities in terms of the 1DFT are defined by Point Y, viz. $SOR = q_{AY}$ m/h $HRL_{max} = q_{AY} (1 + R_Y)$ m/h and $SLR_{max} = (q_{AY} + q_{RY})X_F$ or $q_{AY} (1 + R_Y)X_F$ kg/(m².h). For Test Z in Fig. 3.1, the locus of the SST operating points at constant q_R and increasing q_A cuts the SHC I line at an R value (R_Z) $> R_{min}$ (at Point B). This means that the SCC II fixes the maximum SOR and SLR of the SST for the fixed q_R and X_F of the particular test and the maximum SOR and SLR capacities in terms of the 1DFT are defined by Point Z, viz. $SOR = q_{AZ}$ m/h, $HLR_{max} = q_{AZ}(1 + R_Z)$ m/h and $SLR_{max} = (q_{AZ} + q_{RZ})$ or $q_{AZ}(1 + R_Z)X_F$ kg/(m².h).

Once the 1DFT SOR is determined, the stress test is simulated on SettlerCAD. For each test, 16 SettlerCAD runs are set-up in which the recycle flow (Q_R) and feed concentration (X_F) are kept constant. The influent flow (Q_i) is varied as a percentage (%) of the 1DFT SOR limit value, as calculated above. First, in 2 % increments until SettlerCAD predicts failure and then in 0.25 % increments to refine the failure point between consecutive safe and fail runs. SST failure was accepted to be an average ESS > 50 mg/ℓ over the final 2 actual retention times (R_{ha}) of the run. In this manner the failure influent flow for SettlerCAD was determined with an accuracy of 0.25 % of the 1DFT limit. The SettlerCAD predicted maximum SOR and SLR are then converted to percentage (%) of the 1DFT maximum, where the percentages (%) are then the flux ratings of the SST simulated at the Test Q_R and X_F . As an example the operating points of the different simulations conducted for Test 3 on the old Darvill SST are indicated on the D&O chart of Fig. 3.2.

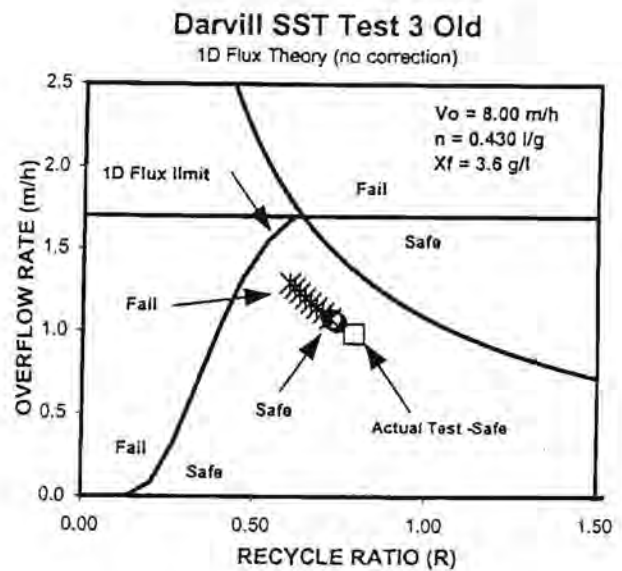
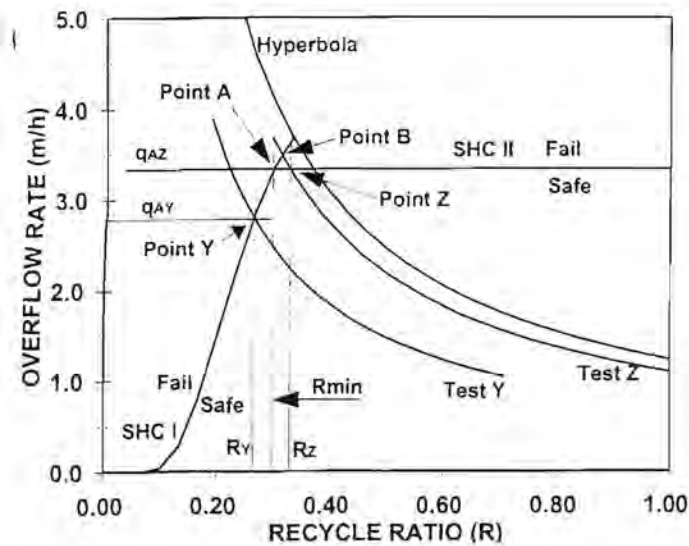


Fig. 3.1 and 3.2 : D&O charts demonstrating the calculation method of the 1DFT (Fig. 3.1, left) and SettlerCAD (Fig. 3.2, right) SOR and SLR limit values. Fig. 3.2 is for Test 3 on the old Darvill SSTs and the safe, fail and actual test positions are indicated.

Once the simulations have been completed the ESS and RAS concentrations over the total run for a particular stress test were imported into a spreadsheet and the following were calculated in the spreadsheet:

- (i) The average ESS and RAS concentrations over the final 2 actual hydraulic retention times;
- (ii) The percentage (%) solids mass balance as the run proceeded from start to finish, to ascertain whether SettlerCAD gives a solid mass balance.

3.5 : THE FLUX LOAD FACTOR

In general the better the sludge settles i.e. the higher the V_o and the lower the n , and the lower the X_F , the higher the maximum surface overflow rate (SOR) and hydraulic loading rate (HLR). Thus, the higher $(V_o/n.X_F)$ the higher the SOR and HLR.

Figure 3.3 shows the relationship between the flux load factor $(V_o/n.X_F)$ and the 1DFT predicted SOR and HLR for Point A in Fig. 3.1. In Fig. 3.3 the feed concentration X_F was varied from 2.5 to 4.5 g/l and the sludge settleability was varied from SSVI 40 to 160 m l/g, for which V_o ranged from 3.18 to 10.74 m/h and n from 0.3 to 0.6 l/g, resulting in a flux load factor that varied from 1.15 to 14.28 m/h.

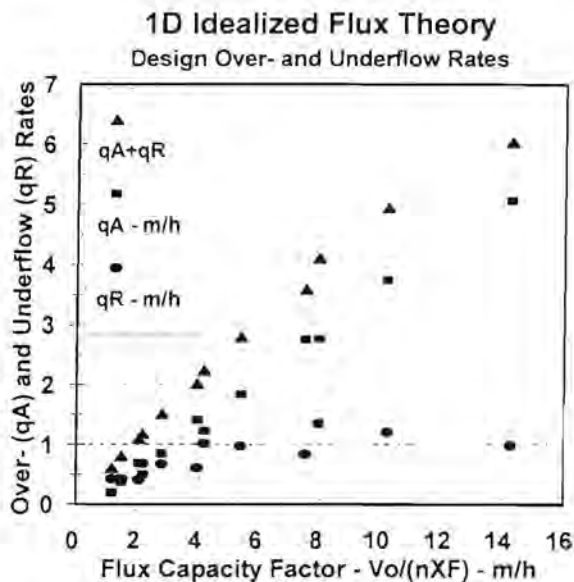


Fig. 3.3 : Design overflow (SOR, q_A , m/h) and underflow (q_R , m/h) and hydraulic loading (HLR, $q_A + q_R$, m/h) rates versus the flux load factor $[(V_o/n.X_F)$, m/h] calculated from the 1DFT for the design point A in Fig. 3.1 for SSVI 40 to 160 m l/g (yielding V_o from 10.34 to 3.18 m/h and n from 0.31 to 0.61 l/g), and X_F from 2.5 to 4.5 g/l. Note that an increase in the flux load factor leads to a consistent increase in SOR and HLR.

From Fig. 3.3, the following can be seen:

- The higher the flux load factor the higher the SOR and HLR.
- Different V_o , n and X_F values making up the same flux load factor, gives approximately the same SOR and HLR.

In this thesis the SOR_i and SLR flux ratings calculated from the SettlerCAD simulations runs will be plotted versus the flux load factor (F_{LF}). Because an increase in the HLR and SOR affects the hydraulic disturbance and non-idealities in the SST_i, it is expected that lower flux rating would be obtained at higher flux load factor.

CHAPTER 4

SIMULATION OF THE DARVILL SSTs WITH SettlerCAD

4.1 : THE DARVILL SLR STRESS TESTS

The Darvill WWTP has five 35 m diameter circular SSTs, 3 old and 2 new. Details of these SSTs are given in Table 4.1. The design capacity of the SSTs is $7.5 \text{ kgSS}/(\text{m}^2 \cdot \text{h})$ at a DSVI of around $80 \text{ m}^3/\text{g}$, MLSS concentration of $3.8 \text{ g}/\ell$, a PWWF of $162 \text{ M}^3/\text{d}$ and a recycle ratio of 0.406 viz. $(162 \text{ 000}/24) \times (1+0.406) \times 3.8 / (5 \times 962) = 7.5 \text{ kgSS}/(\text{m}^2 \cdot \text{h})$. Four solids loading rate (SLR) stress tests were conducted on these SSTs. The first three (Tests 1 to 3) with four SSTs in operation (2 old and 2 new) and the fourth (Test 4) with two SSTs (1 old and 1 new) in operation. The tests were conducted by setting the sludge recycle (RAS) and influent flows at rates that would cause critical loading conditions on the SSTs, i.e. at around 80 % of the maximum SLR estimated from the 1DFT, calculated from the V_0 and n values measured just prior to the stress test. However, during the stress tests, the reactor concentration declined significantly below the normal operating value due to sludge storage in the SSTs. This reduced the applied SLR during the tests and so also the applied SLR ratio below the target 80 % of the 1DFT maximum.

During the tests, which each lasted about 5 to 10 h, the reactor and underflow concentration, the influent and RAS flow rates, the sludge blanket height and the ESS concentration were measured at about 1 h intervals. The summary of the four tests is given in Table 4.2.

From the measured V_0 and n values and the feed concentration (X_f), the 1DFT predicted maximum SOR and SLR were calculated as set-out in Chapter 3, Section 3.4 and are listed in Table 4.2 (1DFT predicted limits).

Table 4.1: Description of Darvill old and new SSTs.

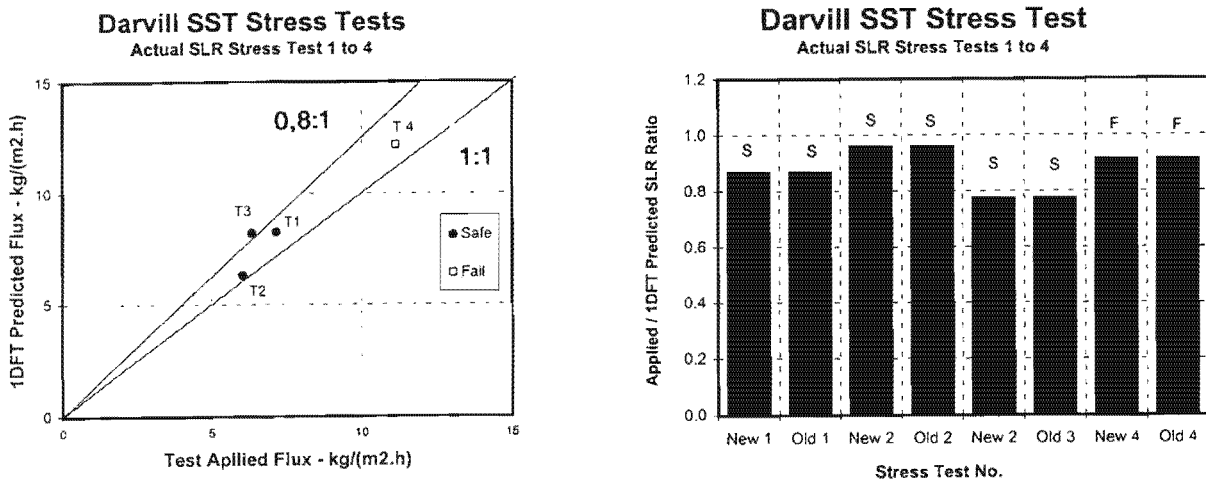
Parameter		Old SSTs (3 of) (Tanks A & E)	New SSTs (2 of) (Tanks B & C)
Diameter (m)		35	35
Side water depth (m)		2.5	4.1
Floor		Flat	Sloped (1:10)
Sludge collection		Suction lift with manually controlled valves (six per SST)	Scraped to central hopper
Recycle pumps and control		4 centrifugal of 11 M ℓ/d each Level control in sump into which suction lift siphons discharge	2 variable speed drive pumps of 19 M ℓ/d each computer controlled to a selected set point
Effluent launders		Single-sided peripheral	Single-sided peripheral
Inlet feed arrangement		1.0 m diam. centre feed well	1.0 m diam. centre feed well
Baffling	1.	No scum board	No scum board
	2.	6.0 m diameter skirt baffle acting as flocculator centre well to 1.8 m water depth. Gap to floor 0.70 m.	6.0 m diameter skirt baffle acting as flocculator centre well to 2.7 m water depth. Gap to floor 2.8 m.
	3.	Peripheral Stamford baffle extending 1.2 m from side wall	Peripheral Stamford baffle extending 1.7 m from side wall

Table 4.2 : Summary of the four SLR stress test results on the Darvill WWTP SSTs.

Parameter		Test 1	Test 2	Test 3	Test 4
SST	Number of SSTs	4	4	4	2
	Surface area (m ²)	4x 962	4x 962	4x 962	2x 962
Actual test loading conditions	Influent flow (M ℓ/d)	80	66	91	115
	Overflow rate (m/h)	0.866	0.715	0.985	2.49
	Recycle flow (M ℓ/d)	64	64	72	34
	Underflow rate (m/h)	0.693	0.693	0.780	0.736
	Recycle ratio	0.800	0.970	0.791	0.296
	Feed Concentration (g/ℓ)	4.60	4.30	3.60	3.45
	Applied SLR [kgSS/(m ² .h)]	7.17	6.05	6.35	11.13
	Weir loading rate [m ³ /(h.m)]	7.57	6.25	8.62	21.78
	Hydraulic loading [(q _A +q _R), m/h]	1.56	1.41	1.76	3.27
Sludge settleability	V ₀ (m/h)	7.71	7.83	8.00	9.08
	n (ℓ/g)	0.390	0.513	0.430	0.29
	DSVI (m ℓ/g)	78	104	62	49
1DFT predicted limits	Maximum SLR [kg/(m ² .h)]	8.26	6.31	8.22	12.19
	Overflow rate (m/h)	1.104	0.775	1.503	2.796
	Influent flow (excl. Q _R) : 1 SST (m ³ /h)	1 062	746	1 446	2 690
Loading ratios	Flux load factor [V ₀ /(nX _f), m/h]	4.30	3.55	5.17	9.08
	Test/ SLR ratio	0.87	0.96	0.77	0.91
	Test/ SOR ratio	0.79	0.92	0.66	0.89

4.2 : RESULTS OF FULL-SCALE ACTUAL STRESS TESTS

From Table 4.2 the 1DFT maximum and test applied SLRs are plotted against each other in Fig. 4.1a. Figure 4.1b shows the ratio of the test applied/1DFT predicted SLR for all four tests. From Fig. 4.1b the test applied/1DFT predicted SLR ratio, as a percentage (%), for the four tests are 87, 96, 77 and 91 % respectively. Of the four tests, only Test 4 on both the old and new SSTs ended in failure. From this it would appear that the flux ratings are somewhere between 77 % safe (Test 3) and 91 % fail (Test 4).



Figures 4.1a and 4.1b: Calculated 1DFT maximum SLR versus test applied SLR (Fig. 4.1a, left) and test applied to 1DFT calculated maximum SLR ratios (Fig. 4.1b, right) for the four Darvill SLR stress tests on the new and old SSTs.

4.3 : FINDING THE SettlerCAD MAXIMUM SOR AND SLR FOR THE DARVILL SSTs

4.3.1 : SettlerCAD predicted failure

To predict the SSTs failures by means of the 2D model SettlerCAD, the data from Table 4.2 and 4.3 were given as input to SettlerCAD. For each test, 16 SettlerCAD runs were set-up. For the new SST, runs 1 to 7 were at Q_i from 74 to 86 % of the predicted 1DFT SOR in 2 % increments and run 8 at 100 %. For the old SST the 7 runs ranged from 60 to 72 % of the predicted 1DFT SOR, also at 2 % increments with the 8th run at 100 %. Runs 9 to 15 were set-up between consecutive safe and fail runs at 0.25 % increments, and the 16th run was at the actual test influent flow.

The first run with $ESS > 50 \text{ mg}/\ell$ was accepted as the SettlerCAD predicted influent flow rate limit. With this SettlerCAD failure flow Q_i (or SOR) the SettlerCAD SLR limit could be calculated with the test Q_R and X_F values.

For the Darvill SST three different cases were simulated with SettlerCAD, and for each case the percentage (%) of the 1DFT maximum influent flow (Q_i) was determined. The three cases were as follows:

- Case 1:** The Darvill new and old SSTs as is, i.e. with Stamford baffles extending from the side-wall and the actual side water depths, i.e. old SST 2.5 m and new SST 4.1 m.
- Case 2:** The Darvill new and old SSTs without Stamford baffles, and the actual SWDs.
- Case 3:** The Darvill new and old SSTs with Stamford baffles, but with interchanged SWDs i.e. old SST with 4.1 m SWD and new SST with 2.5 m SWD.

A summary of the SettlerCAD results for the three different cases are given in Appendix A : Darvill Results. A graphical depiction of the results for cases 1 to 3 are given below in Fig. 4.2 to Fig. 4.4 respectively.

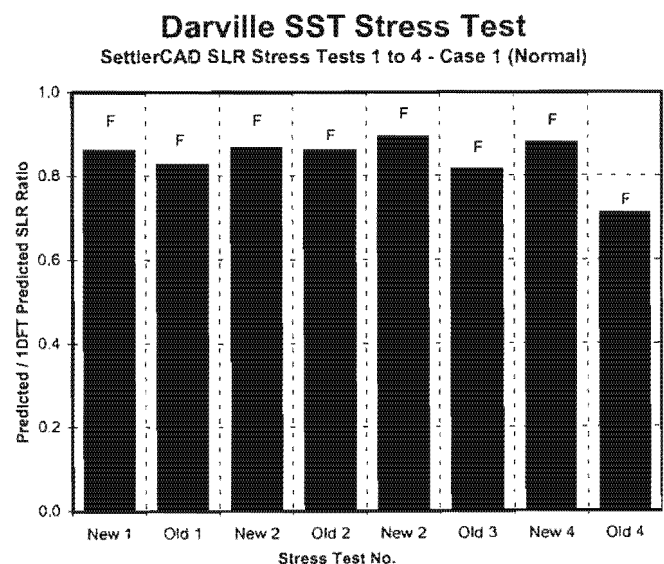
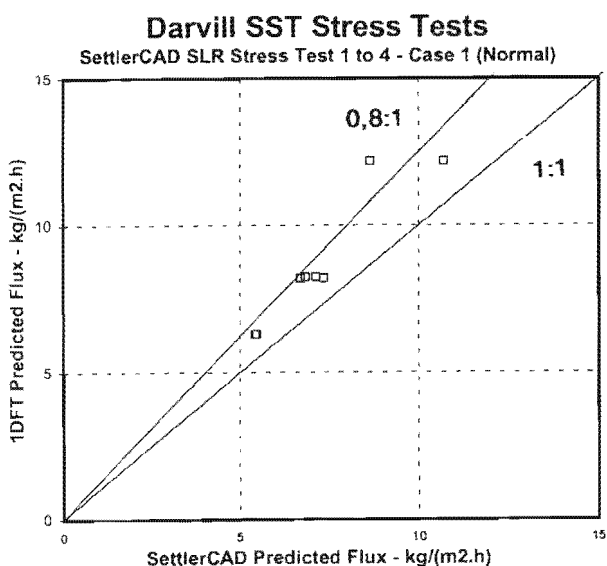


Fig. 4.2a and 4.2b: Case 1 : SSTs as-built – Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR including the 80 % of 1DFT maximum SLR line (Fig. 4.2a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 4.2b, right) for the four Darvill old and new SSTs.

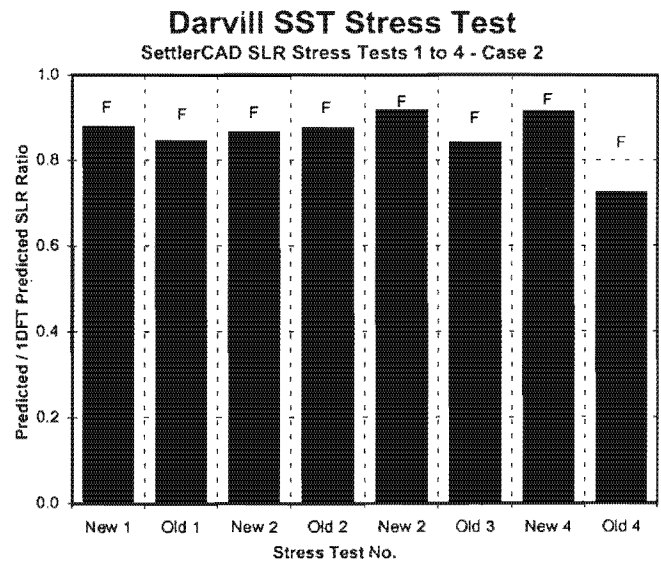
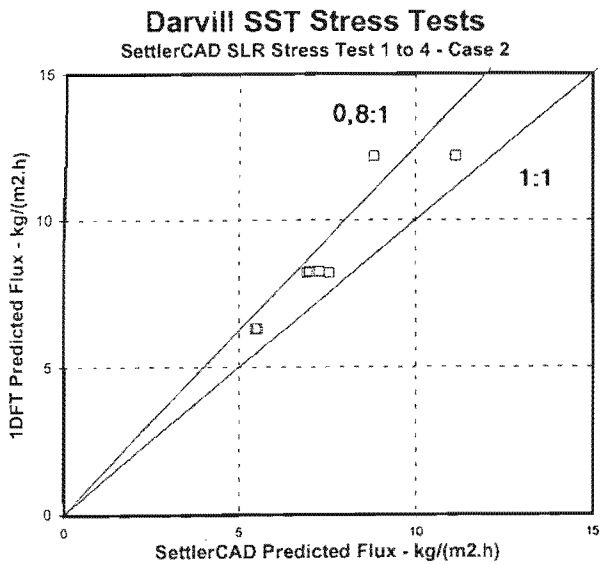


Fig. 4.3a and 4.3b: Case 2 : Without Stamford baffles – Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR (Fig. 4.3a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 4.3b, right) for the four Darvill old and new SSTs.

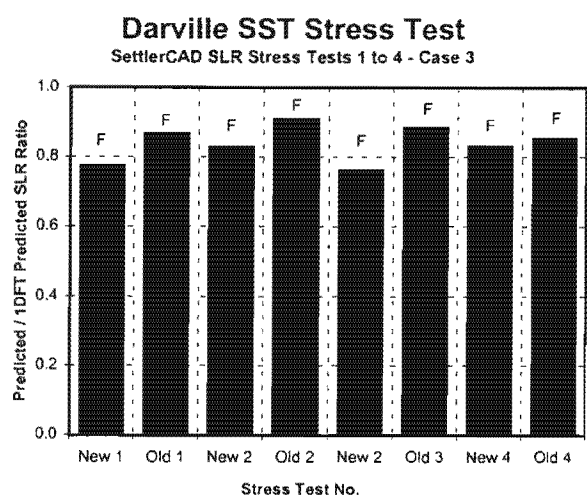
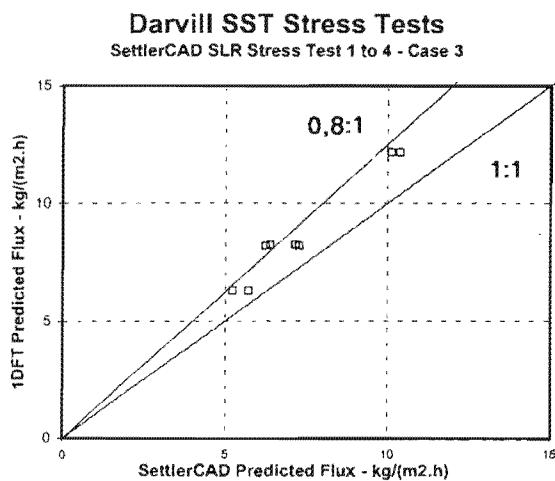


Fig. 4.4a and 4.4b: Case 3 : New and old SSTs with interchanged depths – Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR (Fig. 4.4a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 4.4b, right) for the four Darvill old and new SSTs.

Table 4.3 : Summary of the SettlerCAD predicted to 1DFT calculated maximum SLR ratios (i.e. flux ratings) for Cases 1, 2 and 3.

	Test 1		Test 2		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Case 1 : Normal	86.1	82.6	86.6	86.1	89.7	81.4	87.7	70.9
Case 2 : No baffles	87.8	84.4	86.5	87.5	91.6	84.0	91.3	72.3
Case 3 : Reverse depth	77.3	86.7	82.9	90.9	76.1	88.6	83	85.1

From Table 4.3 for Case 1, SettlerCAD predicts consistently that the new SSTs fail at a higher percentage (%) of the 1DFT maximum SLR than that of the old SSTs. At the lower HLRs i.e. Tests 1, 2 and 3, the flux rating of new and old tanks are similar but at high HLR i.e. Test 4, the new tank has a much higher flux rating than the old tank. The better performance of the new tanks compared with the old tanks is most probably due to the greater depth of the new tank.

The new tank has a much higher sludge storage capacity than the old tank due to its higher side wall depth and sloping bottom. The difference in flux rating between the new and old tanks is greater when the HLR is higher.

For the Darvill SSTs, both the new and the old tanks perform better without a Stamford baffle for all the tests, with the exception of Test 2 (which has the lowest HLR) on the new SST. For the new SSTs, the flux ratings without baffles are 1.7 to 2.6 % higher than with baffles and for the old SSTs, 1.4 to 1.8 % higher than with baffles. Because the difference between the flux rating increases from Test 2 through Test 1, 3 to Test 4, which is the order of increasing HLR, it was noted from the SettlerCAD output (defining velocity vectors) that the Stamford baffles set-up a large vertical circular current extending the full clear water depth and radius of the SST, which is absent when the baffles are removed. However, it must be remembered that the difference in flux rating is actually very small; however, because the difference varies consistently with HLR, it seems that this difference is real, and not an artefact of some simulation model variation in predicted results.

In Case 3, where the new and old SSTs had interchanged SWD i.e. the new SST 2.1 m and the old SST 4.1 m, the SST performance also reversed in that now the old SSTs had a higher flux rating for all the tests than the new SSTs. This is due to the SST volume difference in that now the old SSTs have a greater volume than the new SSTs. These Case 3 runs clearly demonstrate the significant influence of the SST depth on the flux rating – the deeper the tank, the closer the flux rating to the theoretical maximum of 1.0.

4.3.2 : SettlerCAD simulation of the full-scale actual stress test

The data given in Table 4.2 for the actual test loading condition was used to set up the 16th simulation run in SettlerCAD. The results of these simulations are summarised in Table 4.4.

Table 4.4: Summary of the SettlerCAD simulations results for the actual tests 1 to 4 on the new and old Darvill SSTs.

Parameter	Test 1		Test 2		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Flux load factor $V_O/(n.X_F)$ -m/h	4.30	4.30	3.55	3.55	5.17	5.17	9.08	9.08
Influent flow (m ³ /h) for 1 SST	833	833	688	6 88	948	948	2 396	2 396
% of 1DFT maximum Q_I	78.5	78.5	92.1	92.1	65.6	65.6	89.1	69.1
Overflow rate (m/h)	0.87	0.87	0.71	0.71	0.99	0.99	2.49	2.49
Recycle flow (m ³ /h)	667	667	667	667	750	750	708	708
Underflow rate (m/h)	0.693	0.693	0.693	0.693	0.779	0.779	0.736	0.736
Recycle ratio	0.80	0.80	0.97	0.97	0.79	0.79	0.296	0.296
Applied flux (kgSS)/m ² .h)	7.17	7.17	6.05	6.05	6.35	6.35	11.13	11.13
% of 1DFT maximum SLR	86.8	86.8	95.9	95.9	77.3	77.3	91.3	91.3
Actual retention time (h)	3.0	1.6	3.3	1.8	2.7	1.4	1.5	0.8
Duration of run (min)	6 000	3 600	6 000	3 600	6 000	3 600	3 600	1 800
Duration of run (# of R_{ha})	33.3	37.4	30.0	33.8	37.7	42.3	41.3	38.7
Sim time step (min)	2.5	2.5	2.5	2.5	2.5	2.5	1.25	1.25
Sim time step (% R_{ha})	1.39	2.60	1.25	2.35	1.57	2.94	1.44	2.69
Effluent SS (mg/ℓ)*	495	227	933	348	2.1	13.5	647	541
Recycle Conc (mg/ℓ)*	9 558	9 666	7 517	7 745	8 148	8 119	12 863	11 751
Mass balance (%)*	98.3	96.1	97.1	92.8	100.0	99.8	99.6	89.8
SettlerCAD Test result (ESS > 50 mg/ℓ)	Fail	Fail	Fail	Fail	Safe	Safe	Fail	Fail
Observed result	Safe	Safe	Safe	Safe	Safe	Safe	Fail	Fail

* Mean over the last 2 R_{ha} values.

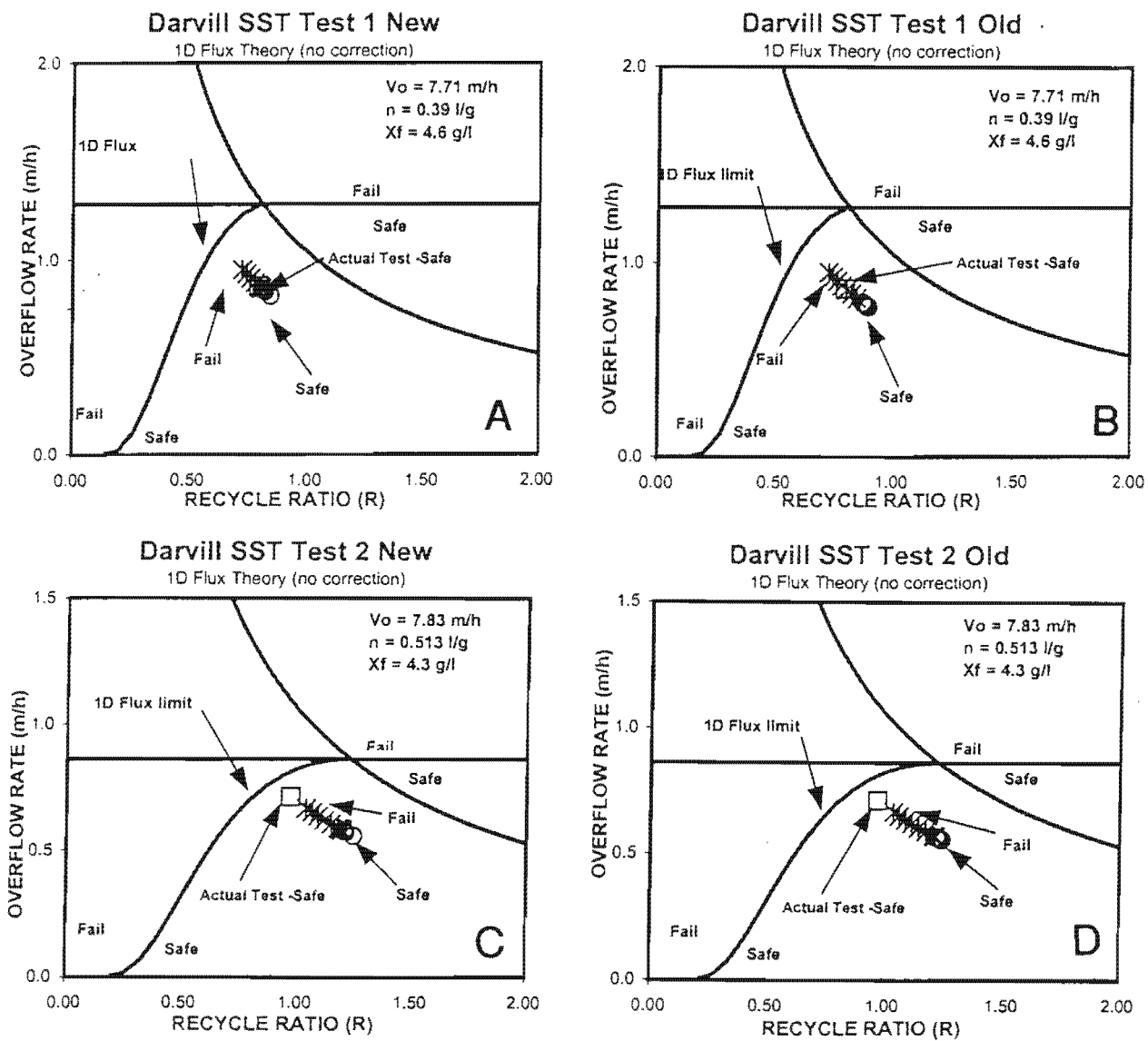
Table 4.4 shows that only Test 4 of the actual tests ended in failure. For the SettlerCAD simulations Test 1, Test 2 and Test 4 ended in failure. The reason why Test 3 did not fail, for the actual tests and the simulations, is that it was considerably under loaded. It was loaded to a value of only 65.6 % of the predicted 1DFT SLR.

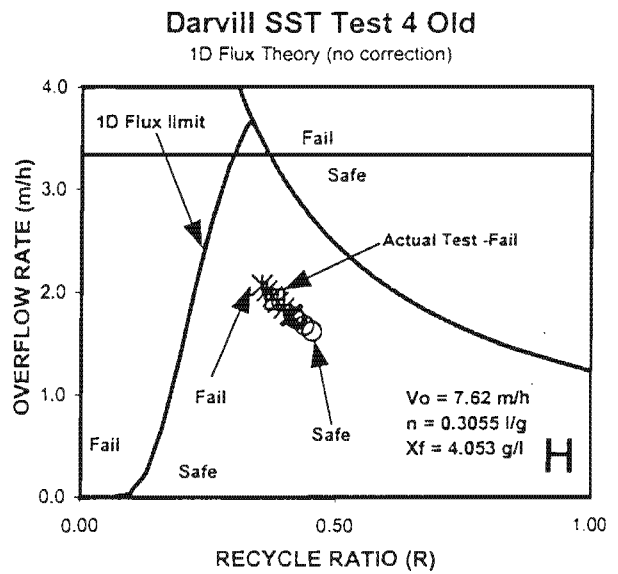
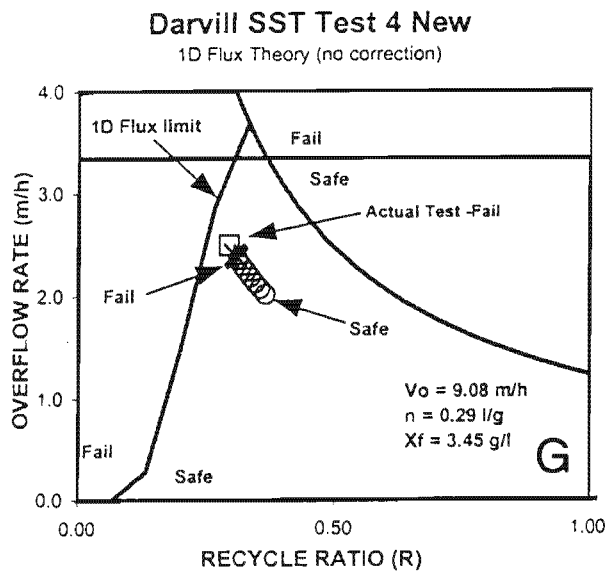
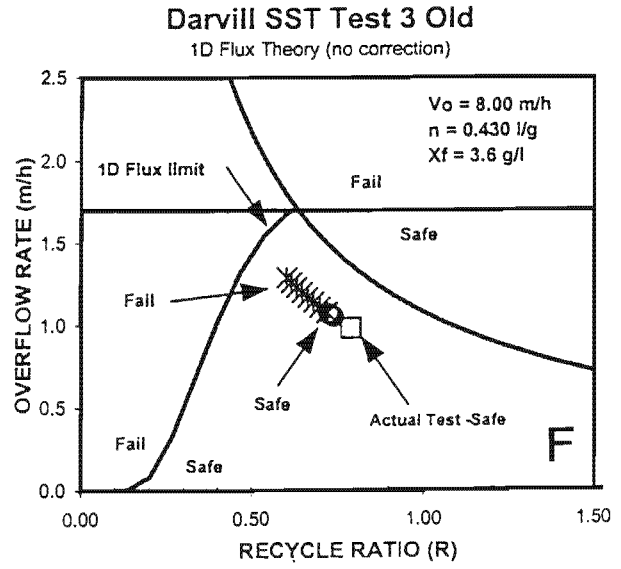
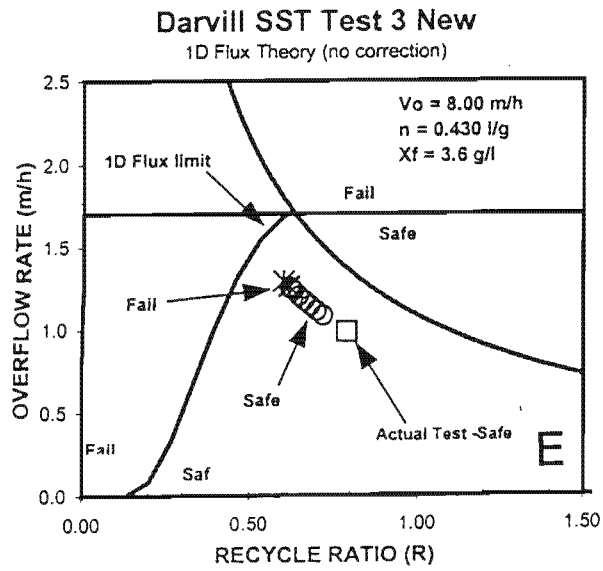
Comparing the 1DFT SLR of the SettlerCAD simulation of the actual test (Table 4.4) with that of the SettlerCAD predicted 1DFT maximum SLR (Table 4.3 – Case 1) the following can be seen:

Test 1's actual applied SLR is 86.8 %, which did not end in failure, and SettlerCAD predicted failure is at a SLR of 86.1 % and 82.6 %, respectively, for the new and old tank. Although the actual test did not end in failure and SettlerCAD simulation run failed at a lower 1DFT SLR maximum, the flux ratings from the simulation and actual test are very close. It is possible that had Test 1 been run for longer, it may have shown a failed result. Similarly Test 2's was run at a 95.9 % 1DFT SLR, and did not end in failure. SettlerCAD predicted failure at flux ratings of 86.6 % and 86.1 % for the new and old tanks, respectively. With such a high loading, in comparison with the SettlerCAD flux rating, it seems strange this test did not end in failure. Looking back into the literature of the work conducted by De Haas *et al.* (1998), it was noticed that Test 2 had to be abandoned due to a shortage in influent flow (Q). It is thus possible that had Test 2 run over a longer period of time it could have ended in failure.

Test 3 was run at such a low percentage (%) of the 1DFT maximum SLR (65.6 %) that it is not meaningful to compare it with the SettlerCAD prediction; both the actual test and the SettlerCAD simulation ended safe. In contrast, Test 4 was conducted at a very high percentage (%) 1DFT SLR (91.3 %), and at such a high percentage (%), it is expected that the test ended in failure, which it did. SettlerCAD also predicted a failure for test 4. The SettlerCAD predicted to 1DFT maximum SLR ratios for the new and old SSTs are 87.7 % and 70.9 % respectively.

The position and result (safe O, fail X) of the SettlerCAD simulation runs for each of the 4 tests on the new and old SSTs are shown in the 1DFT D&O chart in Figures 4.5a to 4.5h. The actual test position and results are also indicated. In the D&O charts, the SettlerCAD predicted HLR limit is given at the transition from the safe to the fail positions. If the actual test position is within the safe (O) runs, then the SettlerCAD would have predicted a safe result for the actual test and if the actual test position is within the fail (X) runs then SettlerCAD would have predicted a fail result for the actual test. From this it can be seen that SettlerCAD predicted that Tests 1, 2 and 4 for both the new and old ended in fail and Test 3 for both new and old SSTs ended safe. Because the observed test results were safe for Tests 1, 2 and 3 and fail for Test 4, SettlerCAD predicted the result of Test 3 and 4 correctly i.e. safe and fail respectively, but the result of Tests 1 and 2 incorrectly, i.e. fail for both when the observed result was safe for both.





Figures 4.5a and 4.5h: 1DFT D&O charts showing the SST operating positions and result (safe O, fail X) of the SettlerCAD runs and actual tests for Tests 1 to 4 on the Darvill new and old SSTs

4.4 : EVALUATING THE OUTPUT RESULTS OF SettlerCAD

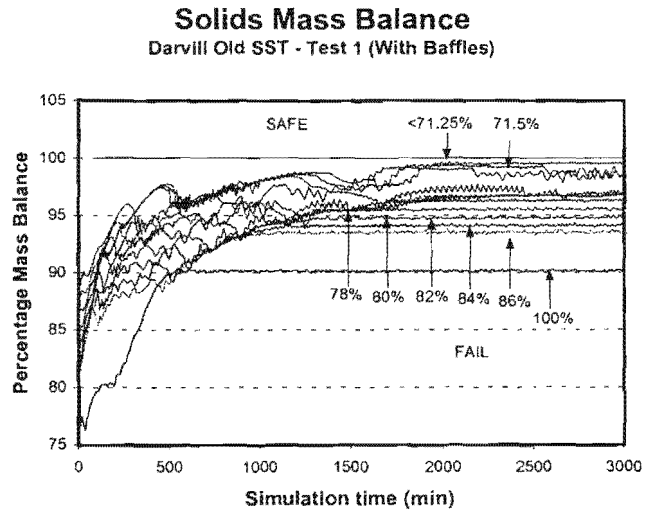
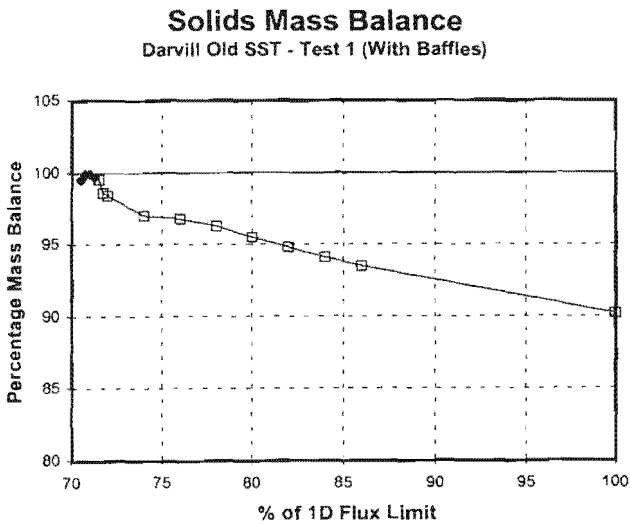
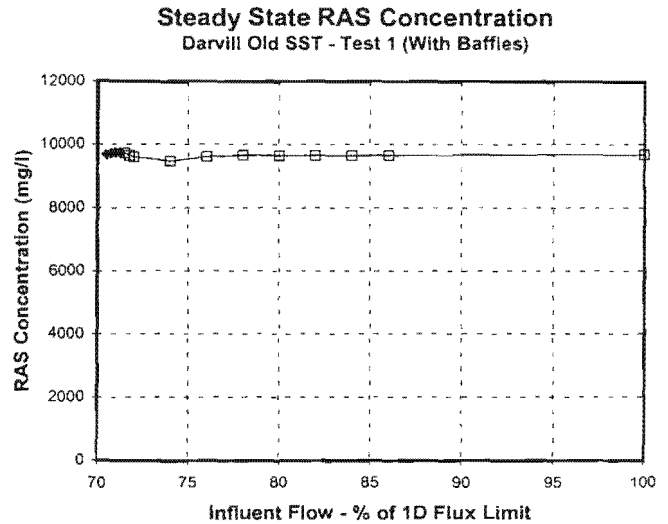
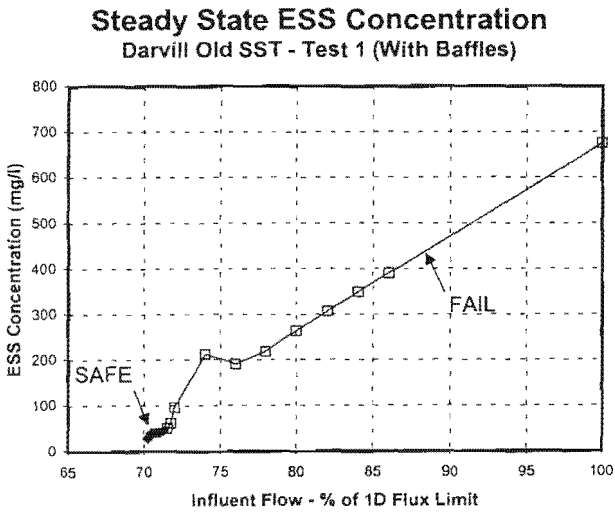
4.4.1 : Determination of solids mass balance

In the simulation runs, the simulation times of 6 000 and 3 600 min were selected for the new and old SSTs respectively, which is more than 25 times the actual hydraulic retention time ($25 \times R_{ha}$) for all the runs. These run times were sufficiently long to establish a final steady state condition, which was checked with a solids mass balance at the end of each run. In the solids mass balance, the mass of solids exiting the SST via the underflow and overflow was calculated as a percentage (%) of the inflow mass of sludge.

The final ESS (X_E) and RAS (X_R) concentrations used for the mass balance for each run were the averages of the predicted values over the last $2 \times R_{ha}$. Provided the run ended safe ($ESS < 50 \text{ mg}/\ell$), the final concentration yielded a solids mass balance within 0.5 %. In contrast, runs that ended in failure ($ESS > 50 \text{ mg}/\ell$) yielded a lower than 99.5 % solids mass balance and the more severe the SST failure (i.e. higher the ESS concentration) the lower the solids mass balance below 99.5 %, even as low as 86 % for Test 4 on the old SST at 100 % of the 1DFT limit influent flow. The ESS, RAS and percentage (%) mass balance versus influent flow (as % of the 1DFT limit Q_i) for Test 1 on the old SST are given in Figures 4.6a to 4.6c. Halving the simulation time step and/or doubling the number of iterations per time step yielded identical simulation results and no improvement in percentage (%) mass balance. Figure 4.6d shows the percentage (%) mass balance for the 8 runs at 74 to 86 % and 100 % of the 1DFT influent flow maximum, as the simulation proceeded. It can be seen that (i) the simulation runs were long enough to reach a steady state because from about the 2 500 min run time the mass balance remains constant, and (ii) for those runs which ended in fail the mass balance remains below 99 %. It is suspected that a 100 % mass balance for the failed runs is not achieved due to a simple logical error in SettlerCAD.

It seems that the RAS concentration is "corrected" by subtracting from it the ESS concentration, because the higher the ESS concentration (or overload), the lower the RAS concentration. This is not consistent with the flux theory.

Theoretically for increasing Q_I and constant Q_R and X_F , the RAS concentration should remain constant (at $X_r = j_L/q_R$) once the SLR capacity (failure) has been reached. This error does not influence the safe runs (because ESS concentration is low) and so does not influence the SettlerCAD predicted SOR and SLR limits.



Figures 4.6a to 4.6d : Final ESS and RAS concentrations (Fig. 4.6a, top left and Fig. 4.6b, top right) and percentage (%) mass balance (Fig. 4.6c, bottom left) versus influent flow as % of 1DFT limit showing runs ended safe (♦) and fail (□) and % mass balance versus simulation time (Fig. 4.6d, bottom right) for Test 1 SettlerCAD simulations on the old Darvill SST.

4.4.2 : ESS concentration versus influent flow (for Case 1)

Figure 4.7a shows the ESS concentration vs influent flow (as % of 1DFT limit) for the tests on the new tanks. The increase in ESS concentration from the point of failure is a little more gradual for Tests 1 and 2 at around 75 % of the 1DFT SOR than for Tests 3 and 4 at 83 % of the 1DFT SOR.

This is possibly due to the overflow velocity for Test 1 and 2 being below 1 m/h and that of Tests 3 and 4 being over 1 m/h. The higher overflow velocity may cause sludge to be dragged over the launder as soon as the sludge blanket reaches the top. Another possible reason is that the settling characteristics of the sludge for Tests 3 and 4 are better than that of Tests 1 and 2. This means that the top of the sludge blanket for Tests 3 and 4 is more concentrated and that failure occurs as soon as the top of the sludge blanket reaches the overflow launder. However, in all cases the relatively rapid increase in ESS concentration for increase influent flow from the onset of failure, indicates that the % of 1DFT limit that indicates failure can be accurately determined. Further, it also justifies the selection of ESS = 50 mg/l as the criteria to determine failure

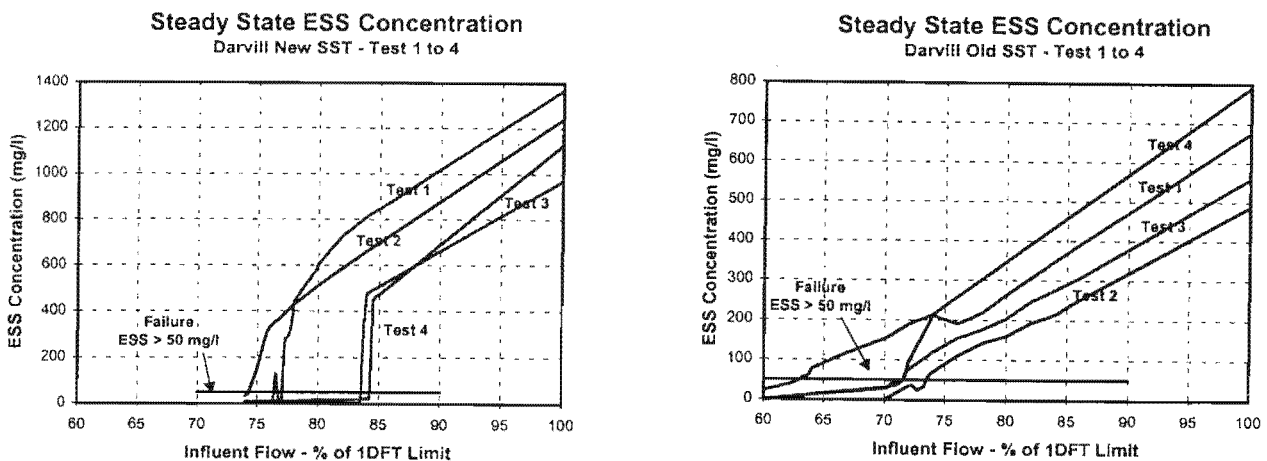


Fig. 4.7a and 4.7b : SettlerCAD predicted ESS concentration versus influent flow (as a percentage (%) of 1DFT limit) for Test 1 to 4 on the Darvill new (Fig. 4.7a, left) and old (Fig. 4.7b, right) SSTs.

The ESS versus influent flow (as a % of the 1DFT SOR) for the old SST is given in Fig. 4.7b and shows that Tests 1 and 2 have a much more gradual increase in ESS concentration than Tests 1 and 2 for the new tanks, and that failure takes place at a much lower influent flow rate i.e. at around 74% of the 1DFT SOR. For Test 4, which has the high HLR, failure takes place at 62 % of the 1DFT SOR, which is the lowest value found for the Darvill new and old SSTs. This shows that the shallow old SSTs have a far greater sensitivity to HLR than the new SSTs. This is due to the fact that the storage capacity in the old tanks are less than that of the new tanks and being much smaller in volume, would be more sensitive to hydraulic flows throughout the tank depth. For the old SSTs, the inflection in the ESS concentration line (indicating a more rapid increase in ESS with increase in influent flow) occurs at $ESS < 50 \text{ mg/l}$, again justifying selection of the value as an indication of failures.

4.4.3 : Flux load factor versus 1DFT limits

The SettlerCAD predicted maximum SOR and SLR, as a percentage (%) of the 1DFT limits, versus the flux load factor (F_{LF}) or equivalently HLR (see Fig. 3.3) for the new and old SSTs (as built) are plotted in Figures 4.8a and 4.8b. Also shown are the four actual test points. Both these figures clearly show the greater sensitivity to the HLR of the shallow old SST compared with the deeper new SST. As the HLR increases the difference between the percentage (%) of the 1DFT limits of the new and old tanks increased, with the deeper new tanks always performing better (higher flux rating). This indicates that for the shallow old SSTs, the lower the HLR, i.e. for poor settling sludges and/or high X_F , the greater the SST capacity as a percentage (%) of the 1DFT limit. The higher the HLR, i.e. good settling sludges and/or low X_F , the lower the capacity of the SST as a percentage (%) of the 1DFT limit. The new deep SSTs do not show this sensitivity to HLR.

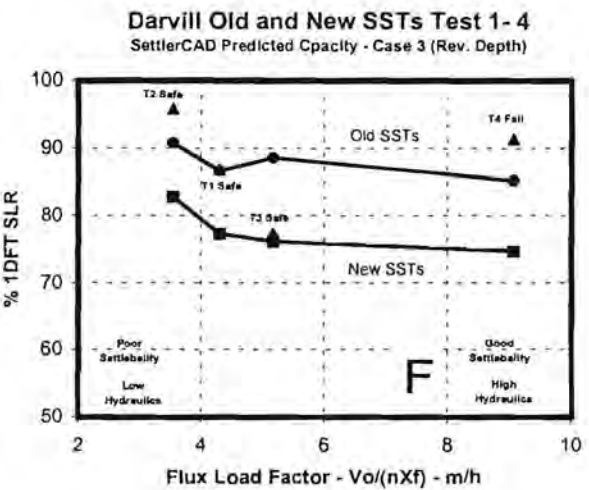
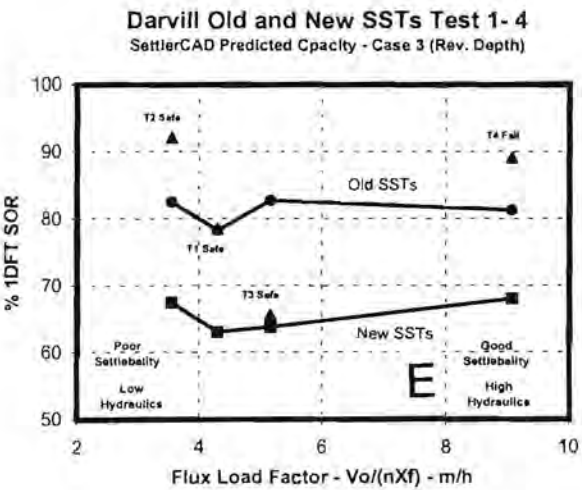
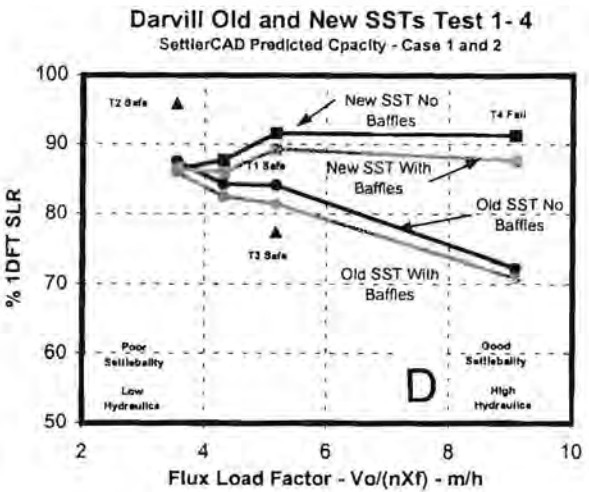
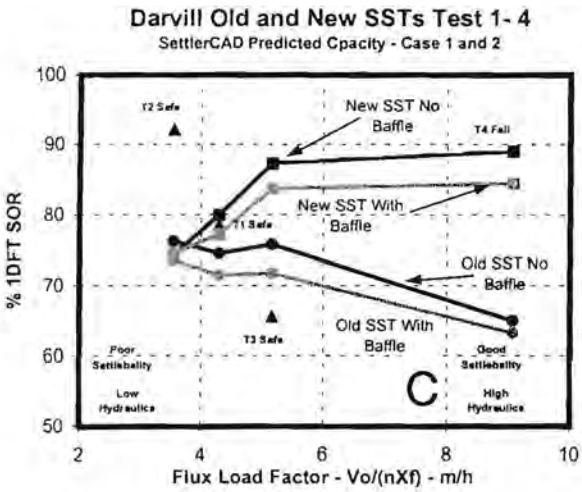
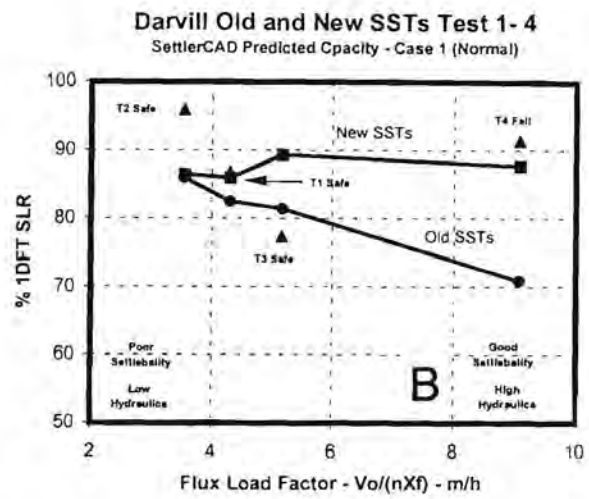
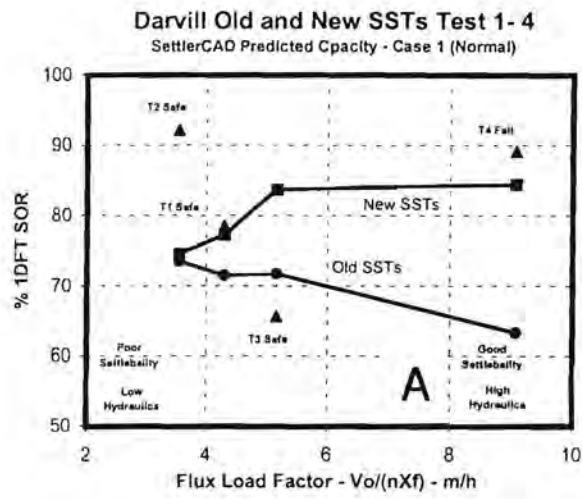


Fig. 4.8a and 4.8f: SettlerCAD predicted capacity as percentage (%) of the 1DFT maximum SOR and SLR limits versus the flux load factor for the Darvill new and old SSTs for Case 1, 2 and 3. The actual test positions and results are also shown.

In Figs. 4.8c and 4.8d, the flux rating versus flux load factor for the old and new SSTs with and without Stamford baffles are shown. The same performance pattern is observed with or without the Stamford baffles in the new and old tanks, but both new and old SSTs perform marginally better (i.e. are 1.5 to 2 % higher flux rating) without Stamford baffles.

In Figs. 4.8e and 4.8f shows the flux rating versus the flux load factor for the old and new SSTs with interchanged depths. Now the old SST (with 4.1 in SWD and flat bottom) show an insensitivity to HLR at around 80 % of the 1DFT SOR, which is below that of the new SST as built (4.1 m SWD and 1:10 sloping bottom) at around 87 %. The shallow new SST (with 2.5 m SWD and 1:10 sloping bottom) now also shows itself to be sensitive to HLR and performs significantly below the deep old SSTs. This comparison clearly shows the significant impact of SST depth on the flux rating.

4.5 : CONCLUSION FROM THE DARVILL SST SIMULATIONS

From evaluation of the SettlerCAD simulations on the Darvill new and old SSTs with diameter to average depth ratios (D/H_{ave}) of 7.47 and 14.0 respectively, the following conclusions can be made:

- The SST hydraulic non-idealities are intrinsically part of the 2D hydrodynamic model SettlerCAD and the SettlerCAD predicted maximum SOR and SLR were significantly below (at 70 to 85 %) those calculated from the 1DFT.
- The accuracy of the SettlerCAD predicted flux rating could not be validated with the actual Darvill SST tests because the results of only two of the four tests (Tests 3 safe and 4 fail) on the new and the old SSTs were predicted correctly.
- The simulations showed that the flux rating of the old flat bottom shallow SSTs decreased from 73 % to 62 % with increase in flux load factor from 3.5 to 9.0 m/h (or equivalent increase in HLR from 1.4 to 3.2 m/h). The new sloping bottom deep SSTs showed no sensitivity of the flux rating with the same increase in flux load factor, or HLR which remained approximately constant at 88 %.

This is an indication that the magnitude of the flux rating is not a constant value and is dependent on SST depth and HLR, the deeper the SST and the lower the HLR, the closer the flux rating is to 1.0.

- Curiously, the Darvill new and old SSTs had higher flux ratings without Stamford baffles than with Stamford baffles, but the difference is very small, only 1.4 to 2.1 of 1DFT SLR. It seemed that the Stamford baffle set-up a large circular current over the entire radius and depth of the SST; without the baffles, the currents did not reach as far as the side-wall.
- The Darvill simulation of the full-scale SST SLR stress tests provide further evidence that the 1D idealised flux theory cannot be applied to the design of full-scale SSTs without an appropriate reduction factor. The magnitude of this reduction factor is not a universal value; however, it would appear that the 0.80 value recommended by Ekama and Marais (1986) appears a reasonable value for SSTs of average depth (>3 m) and HLR (< 2.5 m/h).

CHAPTER 5

SIMULATION OF THE WATTS SSTs WITH SettlerCAD

5.1 : THE WATTS STRESS TESTS

Watts *et al.* (1996) conducted 15 SLR stress tests on one of the 4 SSTs at the Kanapaha Water Reclamation Facility (Florida, USA) over a 3 week period. The SSTs were 28.96 m in diameter with a 3.66 m and 4.60 m side wall and centre depths, respectively, giving a bottom slope of 1:15.4. The centre influent feed well was bounded by an annular skirt baffle 2.44 m deep and occupying 28 % of the SST surface area (i.e. 15.32 m diameter). Peripheral and radial effluent launders collected the surface overflow. Settled sludge was collected continuously via a rotating multiple pipe suction system with 4 draw offs at radial distances of 1.5, 5.2, 8.6 and 12.2 m from the centre. Waste sludge was pumped from the sludge return flow.

In the SLR tests, the influent and recycle flows were kept constant and each test lasted 8 to 10 hours (3 to 6 \times R_{na}). The feed (X_F), effluent (X_E , ESS), underflow (X_R , RAS) and waste (X_w , WAS) sludge concentrations were measured hourly. Sludge blanket height (SBH) measurements were taken at about 15 min intervals and the position and movement of the sludge blanket height (SBH) was used to determine the test result. Where the SBH remained constant, the test was continued for at least two hours longer into the steady state period and the test ended safe. Where the SBH continued increasing, the test was stopped just prior to the SBH reaching the effluent launders and the test failed.

During the three week testing period, the sludge settleability flux constants V_o and n were measured in 7 sets of 6 multiple batch settling tests at concentrations ranging from 2 to 14 g/l. After rejecting 2 sets, the remaining 5 were pooled and the average V_o and n determined for the 15 SLR tests, viz. $V_o = 7.62$ m/h and $n = 0.3055$ m³/kg. In the 15 tests, of which the first 10 ended safe and the last 5 ended failed, the overflow and underflow rates ranged from 0.72 to 1.66 m/h and 0.36 and 1.14 m/h respectively, and the feed concentration 3.44 to 4.13 kg/m³.

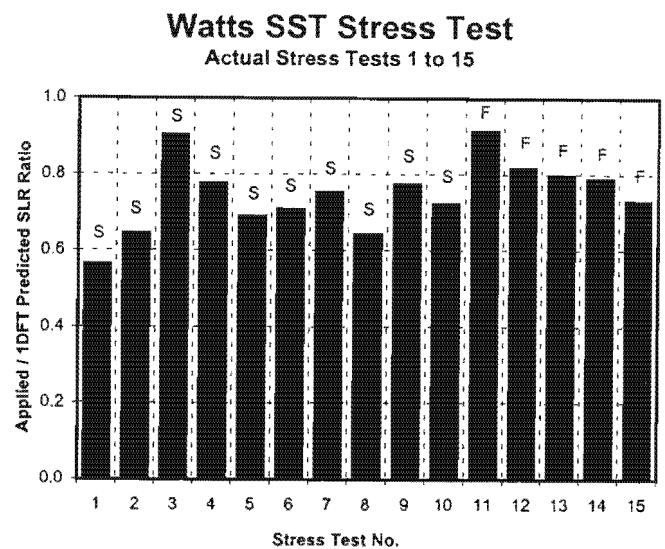
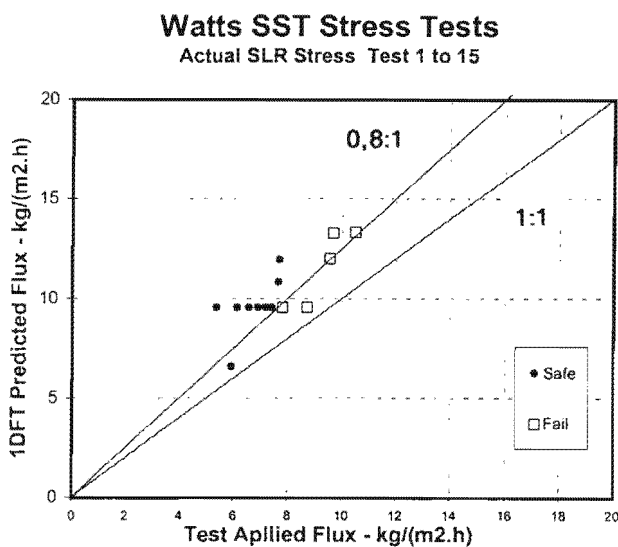
Because the V_0 and n were accepted to be the same for all 15 tests, the flux load factor $V_0/(nX_F)$ varied in a narrow range from 6.04 m/h for Test 4 to 7.24 m/h for Test 9 due to the small change in feed (X_F) concentration. Details of the 15 tests are listed in Table 5.1.

Table 5.1: Summary of the 15 SLR stress test results conducted by Watts et al. (1996).

Parameter		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	
SST	Number of SSTs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	Surface area (m ²)	659	659	659	659	659	659	659	659	659	659	659	659	659	659	659	
Actual test loading conditions	Influent flow (M ℓ/d)	11.4	14.9	18.9	18.8	18.8	18.8	22.4	18.8	24.4	18.6	24.5	26.3	24.5	24.5	24.2	
	Overflow rate (m/h)	0.72	0.95	1.20	1.19	1.19	1.19	1.42	1.19	1.54	1.17	1.55	1.66	1.55	1.55	1.53	
	Recycle flow (M ℓ/d)	9.5	9.6	5.8	9.5	9.5	11.4	9.5	13.3	9.5	9.5	9.5	9.5	9.5	13.3	17.1	18.1
	Underflow rate (m/h)	0.60	0.60	0.36	0.60	0.60	0.72	0.60	0.84	0.60	0.60	0.60	0.60	0.60	0.84	1.08	1.14
	Recycle ratio	0.837	0.639	0.304	0.508	0.507	0.606	0.426	0.706	0.391	0.514	0.389	0.363	0.543	0.698	0.746	
	Feed Concentration (g/ℓ)	4.053	3.972	3.801	4.130	3.664	3.994	3.560	3.787	3.444	3.885	4.044	3.444	3.987	3.983	3.618	
	Applied SLR [kgSS/(m ² .h)]	5.37	6.15	5.94	7.39	6.57	7.65	7.20	7.68	7.40	6.91	8.71	7.80	9.55	10.50	9.68	
	Weir loading rate [m ³ /(h.m)]	5.22	6.84	8.67	8.59	8.62	8.62	10.26	8.60	11.19	8.50	11.23	12.04	11.24	11.24	11.10	
HLR [(qA+qR), m/h]	1.32	1.55	1.56	1.79	1.79	1.91	2.02	2.03	2.15	1.78	2.15	2.27	2.40	2.64	2.68		
Sludge settleability	V ₀ (m/h)	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	
	n (ℓ/g)	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	
	DSVI (m ℓ/g)	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	
1DFT predicted limits	Maximum SLR [kg/(m ² .h)]	9.54	9.55	6.58	9.54	9.55	10.81	9.55	11.94	9.55	9.55	9.54	9.55	11.98	13.31	13.27	
	Overflow rate (m/h)	1.75	1.80	1.37	1.71	2.00	1.98	2.08	2.31	2.17	1.85	1.76	2.17	2.16	2.26	2.52	
	Influent flow Q _i (excl. Q _R): (m ³ /h)	1153.9	1186.5	899.9	1124.2	1319.4	1307.4	1369.1	1523.8	1428.6	1221.7	1156.9	1428.9	1423.6	1486.9	1662.3	
Loading ratios	Flux load factor [V ₀ /(nX _F), m/h]	6.15	6.28	6.56	6.04	6.81	6.25	7.01	6.59	7.24	6.42	6.17	7.24	6.26	6.26	6.89	
	Test/1DFT SLR ratio	56.2	64.4	90.3	77.5	68.8	70.7	75.4	64.3	77.5	72.3	91.3	81.7	79.7	78.9	73.0	
	Test/1DFT SOR ratio	41.2	52.5	87.7	69.5	59.4	60.1	68.2	51.4	71.2	63.3	88.3	76.7	71.8	68.8	60.7	

5.2 : RESULTS OF THE FULL-SCALE ACTUAL STRESS TESTS

From the measured V_O , n and X_F , the 1DFT predicted maximum SOR and SLR were calculated and are listed in Table 5.1. The 1DFT predicted SLR versus test applied SLRs and the test applied/1DFT predicted SLR ratios from Table 5.1 are plotted in Figures 5.1a and 5.1b. From Fig. 5.1b, the test applied/1DFT predicted maximum SLR ratio for the 15 tests are between 0.56 (Test 1) and 0.91 (Test 11) and tests 3, 4, 7 and 9, which ended safe, have higher test applied/1DFT predicted SLR ratios than Test 15, which was the test with the lowest SLR that failed. From Fig. 5.1a, the line that best separates the safe (●) and fail (□) tests is about 0.80.



Figures 5.1a and 5.1b: Calculated 1DFT maximum SLR versus test applied SLR (Fig. 5.1a, left) and test applied to 1DFT calculated maximum SLR ratios (Fig. 5.1b, right) for the 15 Watts SLR stress test on the Kanapaha SSTs.

5.3 : FINDING THE SettlerCAD MAXIMUM SOR AND SLR FOR THE WATTS SSTs

5.3.1 : SettlerCAD predicted failure

For each of the 15 tests, 16 SettlerCAD runs were set-up and executed. Runs 1 to 7 were at Q_i from 66 to 78 % of the 1DFT SOR in 2 % increments and an 8th run at 100 %. Runs 9 to 15 were set-up between consecutive safe and fail runs at 0.25 % increments. The first run with $ESS > 50 \text{ mg}/\ell$ was accepted as the SettlerCAD predicted influent flow rate limit. The 16th run was at the actual test influent flow.

For the Kanapaha SST tested by Watts *et al.* (1996), two different cases were simulated with SettlerCAD and for each case the maximum influent flow, as a percentage (%) of the 1DFT maximum influent flow (Q_1), was determined. The two cases were as follows:

Case 1: Simulation of the 15 stress tests on the SST as-built, i.e. without a Stamford baffle and actual side water depth (SWD) of 3.66 m.

Case 2: Simulation of Tests 4, 7, 9, 12, 13 and 14 on the SST including a Stamford baffle extending 1.2 m from the side-wall at a height of 3.16 m above the bottom of the side-wall, and actual SWD.

A summary of the SettlerCAD results for the two different cases can be seen in Appendix B : Watts Results. A graphical depiction for the two different cases are given below.

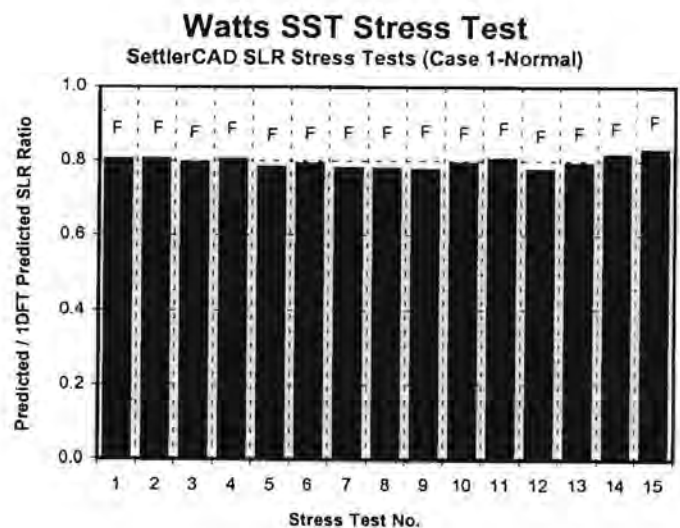
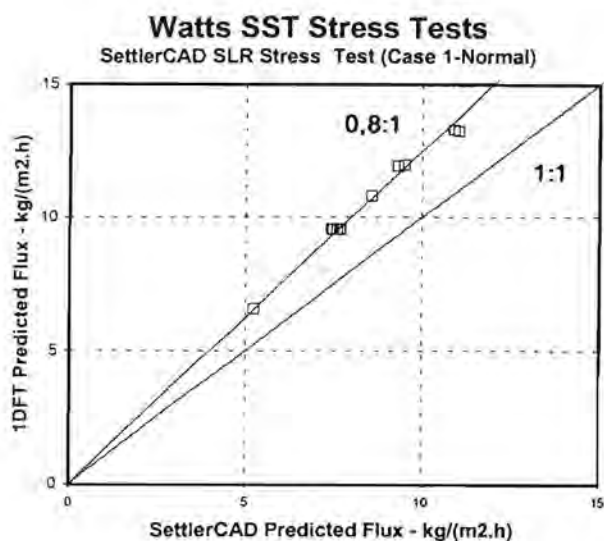


Fig. 5.2a and 5.2b: Case 1 – Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR (Fig. 5.2a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 5.2b, right) for the 15 Watts test.

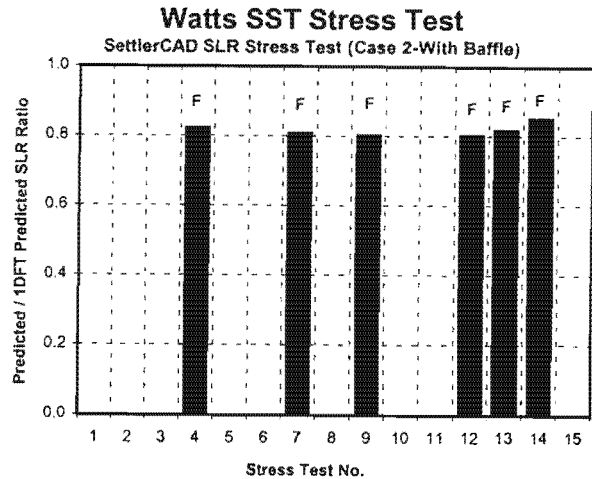
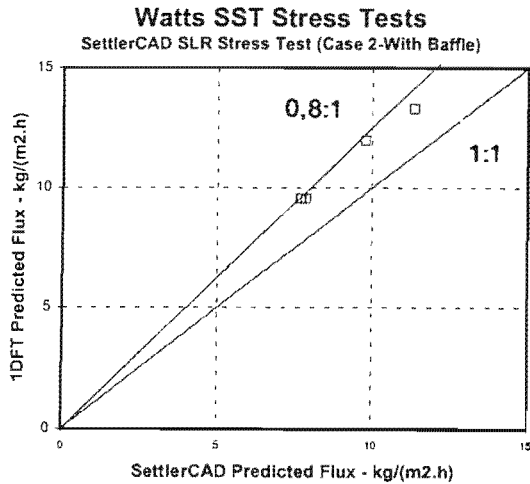


Fig. 5.3a and 5.3b: Case 2 – Calculated 1DFT maximum SLR versus SettlerCAD predicted SLR (Fig. 5.3a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig 5.3b, right) for 6 of the 15 Watts tests.

In Figures 5.2a and 5.2b, it can be seen that the SettlerCAD predicted flux rating of the Watts SST ranges between 77.7 % (Test 9) and 83.0 % (Test 15). Fig. 5.2a shows the SettlerCAD maximum predicted SLR (flux rating) of the 15 tests fall very close to the 0.80 flux rating line. The SettlerCAD predicted maximum SOR (as a % of the 1DFT maximum) ranged between 70.0 % (Test 8) and 75.3 % (Test 15).

Table 5.2 : Summary of the SettlerCAD predicted to 1DFT calculated maximum SLR ratios for Case 1 and Case 2.

Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Case 1 : (Normal)	80.3	80.3	79.5	80.4	78.3	79.3	78.1	78.0	77.7	79.4	80.5	77.7	79.3	81.8	83.0
Case 2 : (With baffles)	-	-	-	82.3	-	-	80.6	-	80.2	-	-	80.2	81.7	85.1	-

From Table 5.2, the average flux rating for Case 1 (no Stamford baffle) for Tests 4, 7, 9, 12, 13 and 14 is 79.2 %. For Case 2 (with Stamford baffle) for Tests 4, 7, 9, 12, 13 and 14 the average flux rating is 81.7 %, showing that SettlerCAD predicts a 2 % increase in SST capacity with Stamford baffles.

This is contrary to the results of the Darvill SST simulations where the SSTs without Stamford baffles performed ~2.0 % better than with Stamford baffles.

In the Tutorial literature made available with the SettlerCAD programme by the developers Zhou *et al.*, (1998), the impact of the Stamford baffle is investigated in an example. A comparison of the flow pattern in the different SSTs shows that the Stamford baffle does not have a strong impact on the overall flow field within the SST, an observation also made in this investigation. Comparing the solids flow pattern, a conclusion was made that the Stamford baffles can improve the effluent concentration, but is unlikely to have a strong effect on the sludge blanket level in the SST. Because a final steady state for fixed loading conditions, which causes the sludge blanket for the failed cases to rise to the effluent launders it seems reasonable to conclude that the Stamford baffle does not increase the capacity (or flux rating) of the SST much; however, for the safe loading conditions, the Stamford baffle helps to keep the ESS concentration low.

5.3.2 : SettlerCAD simulation of the full-scale actual stress test

The results of the simulations at the actual tests influent flow conditions for each test are summarised below in Table 5.3. From this table, it can be seen that SettlerCAD correctly predicted the observed test result for 12 of the 15 tests – only Tests 3, 14 and 15 were incorrectly predicted; Test 3 was observed to end safe, but predicted to end fail, and Tests 14 and 15 were observed to end fail, but predicted to end safe. These three tests had the lowest (Test 3) and highest (Tests 14 and 15) recycle flows. This indicates that the effect of the recycle flow in the flux theory (which is included in the SettlerCAD programme to model the solids movement with respect to the water) is greater than expected. The accuracy of the SettlerCAD prediction is discussed further below.

Table 5.3: Summary of the SettlerCAD simulations results for the actual Test 1 to 15.

ACTUAL TEST INFLUENT FLOW	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Influent flow (m ³ /h) for 1 SST	475.1	622.8	788.9	781.5	784.2	785.3	933.8	782.6	1017.8	733.5	1021.4	1095.2	1022.5	1022.8	1009.6
% of 1DFT maximum Q _i	41.2	52.5	87.7	69.5	59.5	60.1	68.2	51.4	71.2	63.3	88.3	76.7	71.8	68.8	60.7
Overflow rate (m/h)	0.72	0.95	1.20	1.19	1.19	1.19	1.42	1.19	1.54	1.17	1.55	1.66	1.55	1.55	1.53
Recycle flow (m ³ /h)	397.5	398.0	235.9	396.9	397.7	475.7	397.7	552.8	397.7	397.7	397.2	397.7	555.6	714.2	753.7
Underflow rate (m/h)	0.60	0.60	0.36	0.60	0.60	0.72	0.60	0.84	0.60	0.60	0.60	0.60	0.84	1.08	1.14
Recycle ratio	0.837	0.639	0.304	0.508	0.507	0.606	0.426	0.706	0.391	0.514	0.398	0.363	0.543	0.698	0.746
Applied flux [(kgSS)/(m ² .h)]	5.37	6.15	5.94	7.39	6.57	7.65	7.20	7.68	7.40	6.91	8.71	7.80	9.55	10.50	9.68
% of 1DFT SLR	56.2	64.4	90.3	77.5	68.8	70.7	75.4	64.3	77.5	72.3	91.3	81.7	79.7	78.9	73.0
Actual retention time (h)	3.0	2.6	2.5	2.2	2.2	2.1	2.0	2.0	1.8	2.2	1.8	1.8	1.7	1.5	1.5
Duration of run (min)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Duration of run (# of R _{ha})	33.3	39.0	39.3	45.0	45.2	48.2	50.9	51.0	54.1	44.7	54.2	57.0	60.3	66.3	67.4
Sim time step (min)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sim time step (% R _{ha})	1.39	1.62	1.64	1.88	1.88	2.01	2.12	2.13	2.25	1.86	2.26	2.38	2.51	2.76	2.81
Effluent SS (mg/ℓ)*	3.9	5.0	484.3	5.7	5.8	5.7	6.8	6.1	17.9	5.3	479.9	238.0	66.9	9.9	7.5
Recycle Conc (mg/ℓ)*	8891.9	10200.2	13268.3	12268.7	10879.7	10577.1	11900.8	9137.8	12205.3	11430.0	12150.5	11792.4	11078.1	9672.4	8452.7
Mass balance (%)*	100.0	100.2	91.2	99.9	100.0	100.0	100.0	100.0	100.0	100.0	92.7	96.3	98.9	100.0	100.0
Test result (ESS > 50 mg/ℓ)	Safe	Safe	Fail	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Fail	Fail	Fail	Safe	Safe
Observed result	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Fail	Fail	Fail	Fail	Fail

* Mean over the least 2 R_{ha} values.

Table 5.4: Comparison of SettlerCAD predicted result with the actual Tests 1 to 15 on the Watts SSTs

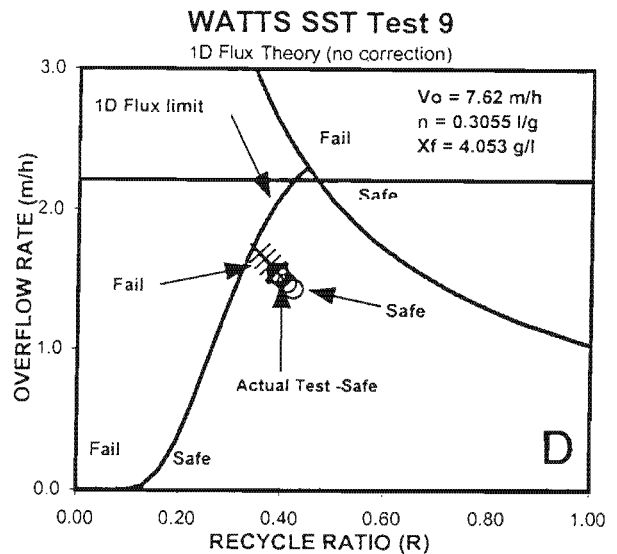
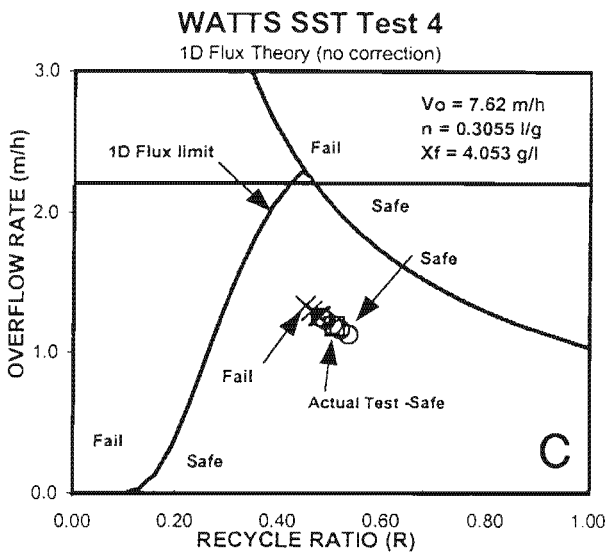
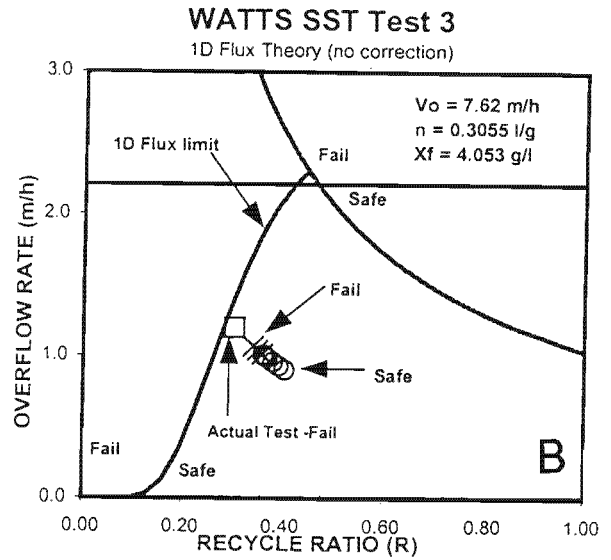
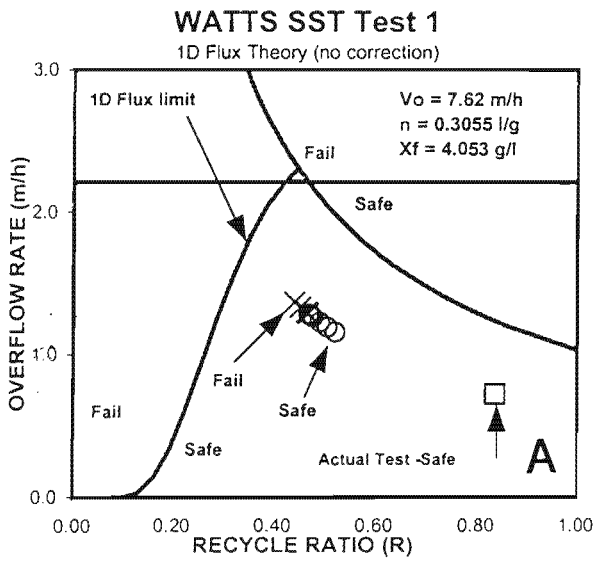
PARAMETER	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Test Q _i for 1 SST (m ³ /h)	475.1	622.8	788.9	781.5	784.2	785.3	933.8	782.6	1017.8	733.5	1021.4	1095.2	1022.5	1022.8	1009.6
% of 1DFT maximum Q _i	41.2	52.5	87.7	69.5	59.5	60.1	68.2	51.4	71.2	63.3	88.3	76.7	71.8	68.8	60.7
1DFT predicted outcome	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe
SettlerCAD predicted max. Q _i (m ³ /h)	848.1	875.1	665.9	826.3	946.7	938.0	982.3	1 066.6	1 021.4	888.8	853.2	1 021.4	1 014.3	1 085.5	1 238.4
% of SettlerCAD predicted max Q _i	56.0	71.2	118.5	94.6	82.8	83.7	95.1	73.4	99.6	87.0	119.7	107.2	100.8	94.2	81.5
SettlerCAD predicted outcome	Safe	Safe	Fail	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Fail	Fail	Fail	Safe	Safe
Observed test result	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Fail	Fail	Fail	Fail	Fail

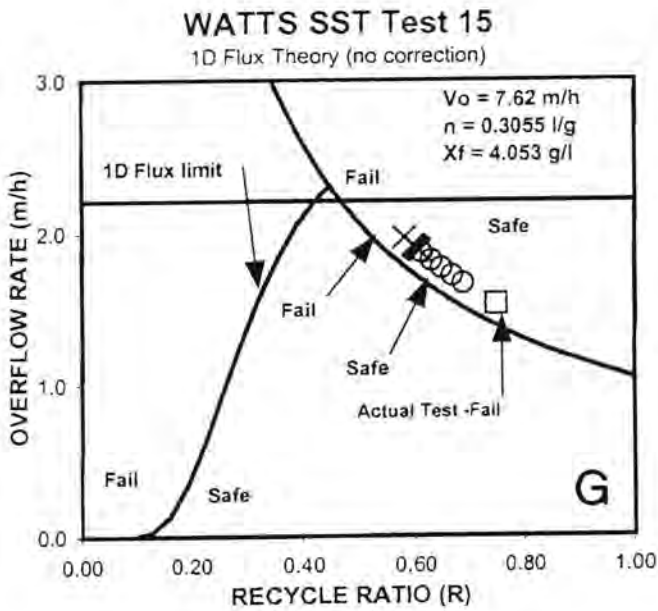
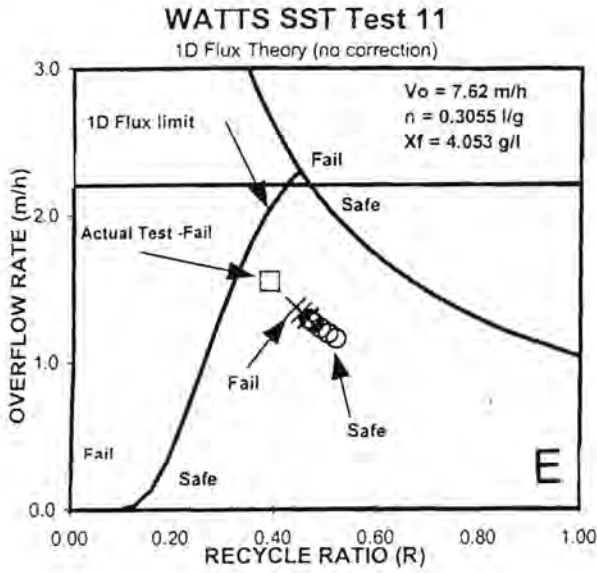
The position and result (safe O, fail X) of the SettlerCAD simulation runs for Tests 1, 3, 4, 9, 11, 13 and 15 are shown in the D&O charts in Figures 5.4a to 5.4g. The actual test position and result (safe, fail) are also indicated. In the charts, the SettlerCAD predicted SOR limit is given at the transition from the safe to the fail positions. For the tests ended safe (i.e. 1 to 10), if the actual test position is within the safe runs, then SettlerCAD correctly predicted a safe result for the actual test, and for the tests ended fail (i.e. 11 to 15), if the actual test position is within the failed runs, then SettlerCAD correctly predicted a fail result for the actual test. The 7 tests in Fig. 5.4a to 5.4g were selected to demonstrate the following:

- Test 1 :** Lowest test applied/1DFT maximum SOR (0.412) and SLR (0.562) ratios with SHC I governing capacity; Test ended safe and SettlerCAD predicted result correctly.
- Test 3:** Second highest test applied/1DFT maximum SOR (0.877) and SLR (0.903) ratios with SHC I governing capacity; test with lowest recycle flow; test ended safe but SettlerCAD predicted result incorrectly as fail.
- Test 4:** Lowest flux load factor $V_o/(nX_F) = 6.04$ m/h with SHC I governing capacity; test ended safe and SettlerCAD predicted result correctly.
- Test 9:** Highest flux load factor $V_o/(nX_F) = 7.24$ m/h with SHC I governing capacity; test ended safe and SettlerCAD predicted result correctly.
- Test 11:** Highest test applied/1DFT maximum SOR (0.883) and SLR (0.913) ratios with SHC I governing capacity; test ended fail and SettlerCAD predicted result correctly.
- Test 13:** Test applied/1DFT maximum SOR (0.718) and SLR (0.797) ratios very close to SettlerCAD predicted/1DFT maximum SOR (0.712) and SLR (0.793) ratios with SHC II governing capacity; test ended fail and SettlerCAD predicted result correctly.

Test 15: Low test applied/1DFT maximum SOR (0.607) and SLR (0.730) ratios with SHC II governing capacity; test ended fail but SettlerCAD predicted result incorrectly.

From all 15 D&O charts, SettlerCAD correctly predicted the result for 12 tests, i.e. Tests 1, 2 and 4 to 10 (safe) and 11 to 13 (fail), but incorrectly predicted the result for 3 tests, i.e. Tests 3 (actual test safe, SettlerCAD fail) and 14 and 15 (actual test fail, SettlerCAD safe).





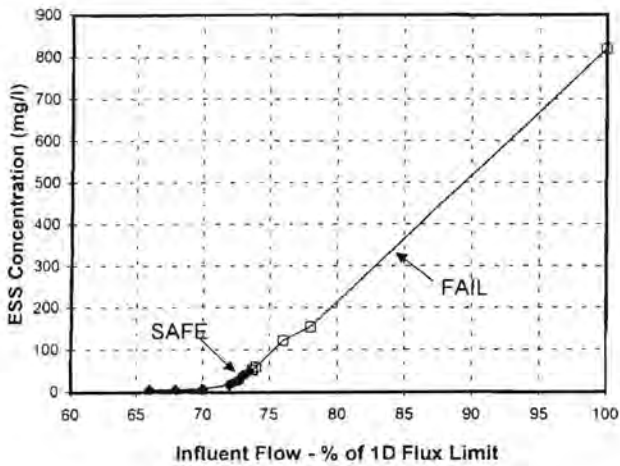
Figures 5.4a to 5.4g: 1DFT D&O charts showing the SST operating positions and result of the SettlerCAD runs and actual tests (safe O or fail X) for tests 1, 3, 4, 9, 11, 13 and 15 on the Watts SST.

5.4 : EVALUATING THE OUTPUT RESULTS OF SettlerCAD

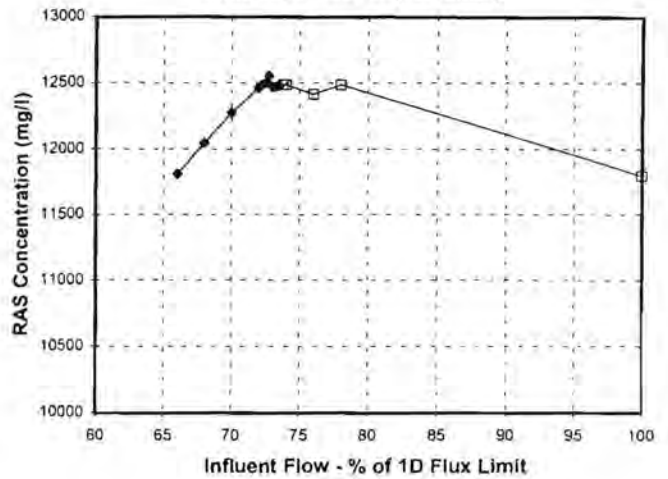
5.4.1 : Determination of solids mass balance

In the simulation runs, a simulation time of 6 000 min was selected which was more than 35 times the actual hydraulic retention time ($35 \times R_{ha}$) for all the runs. As for the Darvill SST runs, these run times were sufficiently long to establish a final steady state condition and the final ESS and RAS (X_R) concentrations accepted for each run were the averages of the predicted values over the last $2 \times R_{ha}$. The solids mass balance was based on these final average ESS and RAS concentrations (which are listed in Appendix B : Watts Results). The same pattern regarding the mass balance was observed as in the Darvill results – the safe runs ($ESS < 50 \text{ mg}/\ell$), yielded a solids mass balance within 0.5 % of 100 % and runs that ended in failure ($ESS > 50 \text{ mg}/\ell$) yielded a lower than 99.5 % solids mass balance; the greater the SST overload (i.e. the higher the ESS concentration), the lower the solids mass balance below 99.5 %. The ESS, RAS and percentage (%) mass balance versus influent flow (as % of the 1DFT limit Q_i) for Test 11, which had the highest test applied/1DFT maximum SOR ratio, are shown in Figures 5.5a to 5.5c. In Fig. 5.5d, the percentage (%) mass balance versus simulation time for simulation runs 1 to 8 (66 to 78 % and 100 %) of Test 11 are shown. It can be seen that for the failed runs, even though a final steady state is achieved, this steady state does not yield a mass balance.

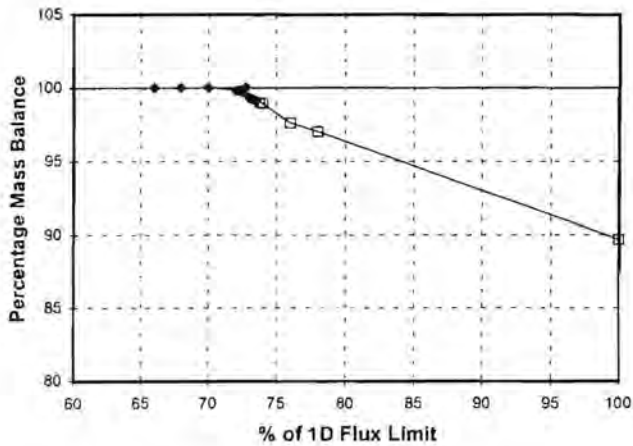
Steady State ESS Concentration
Watts SST - Test 11 (No Baffles)



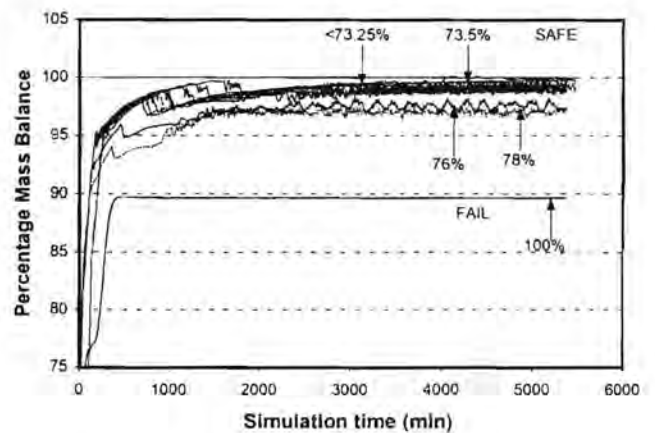
Steady State RAS Concentration
Watts SST - Test 11 (No Baffles)



Solids Mass Balance
Watts SST - Test 11 (No Baffles)



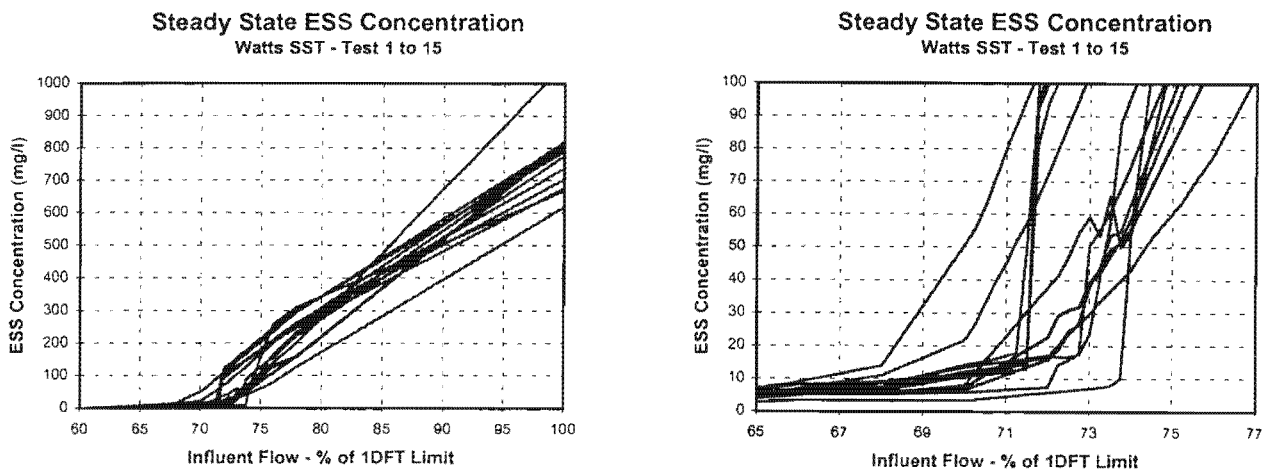
Solids Mass Balance
Watts SST - Test 11 (No Baffles)



Figures 5.5a to 5.5d: Final ESS and RAS concentrations (Fig. 5.5a, top left and Fig. 5.5b, top right) and percentage (%) mass balance (Fig. 5.5c, bottom left) versus influent flow as % 1DFT limit showing runs ended (safe \blacklozenge and fail \square) and % mass balance versus simulation time (Fig. 5.5d, bottom right) for Test 11 on SettlerCAD runs of the Watts SST.

5.4.2 : ESS concentration versus influent flow

The ESS concentrations, versus Q_i (as a % of the 1DFT limit) for all 15 tests are shown in Figs. 5.6a and 5.6b. It can be seen that the ESS concentration increases gradually above 50 mg/ℓ in the narrow range between 70 and 74 % of the 1DFT limit influent flow. The precipitous increase in ESS concentration observed with the new (deep) Darvill SST is not apparent. The increase in ESS of the Watts SST resembles more the gradual increase in ESS of the old (shallow) Darvill SST. However, the Watts SST geometry resembles more the new Darvill SST with a 3.66 m SWD and 1:15.4 sloping bottom.

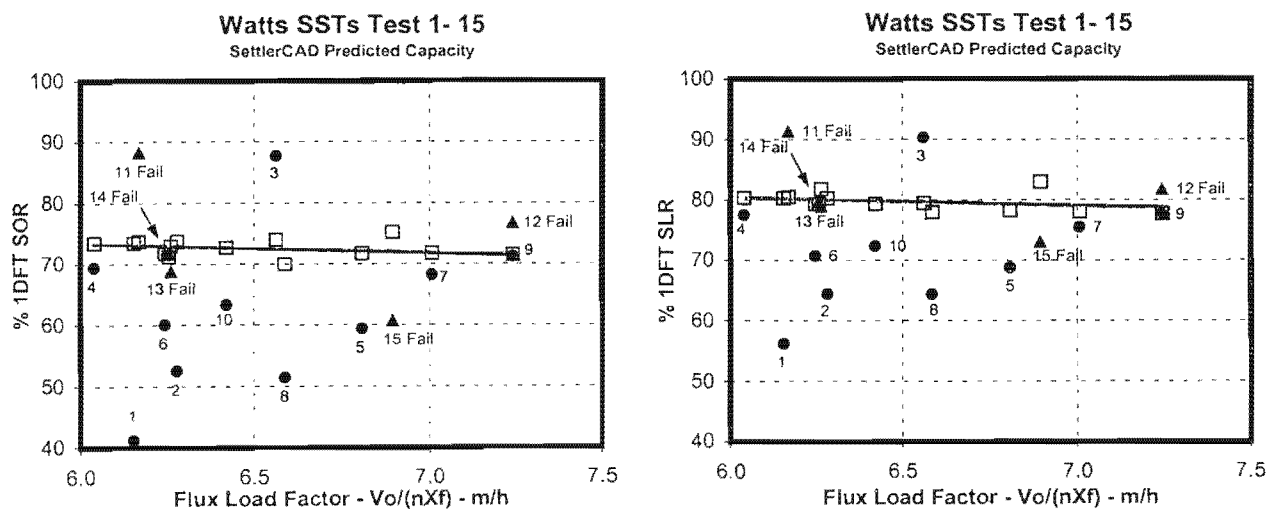


Figures 5.6a and 5.6b: *SettlerCAD predicted steady state ESS concentration versus influent flow (as percentage (%) of 1DFT limit) showing the whole field (Fig. 5.6a, left) and zoomed in detail (Fig. 5.6b, right).*

5.4.3 : Flux load factor versus 1DFT limits

The SettlerCAD predicted maximum SOR and SLR (\square), as a % of the 1DFT limits, are plotted versus the flux load factor $V_o/(nX_F)$ in Figures 5.7a and 5.7b. Also shown are the 15 actual test points (safe \bullet and fail \blacktriangle). In these figures, the actual tests that ended safe and fail which plot *below* and *above* the SettlerCAD predicted SOR and SLR limits, are tests the result of which SettlerCAD predicted correctly; the actual tests that ended safe and fail which plot *above* and *below* the SettlerCAD predicted SOR and SLR limits, are tests the result of which SettlerCAD predicted incorrectly. Table 5.4 gives more detail, listing the actual test SOR as a percentage (%) of the SettlerCAD predicted maximum SOR, and the SettlerCAD predicted and observed result of the tests.

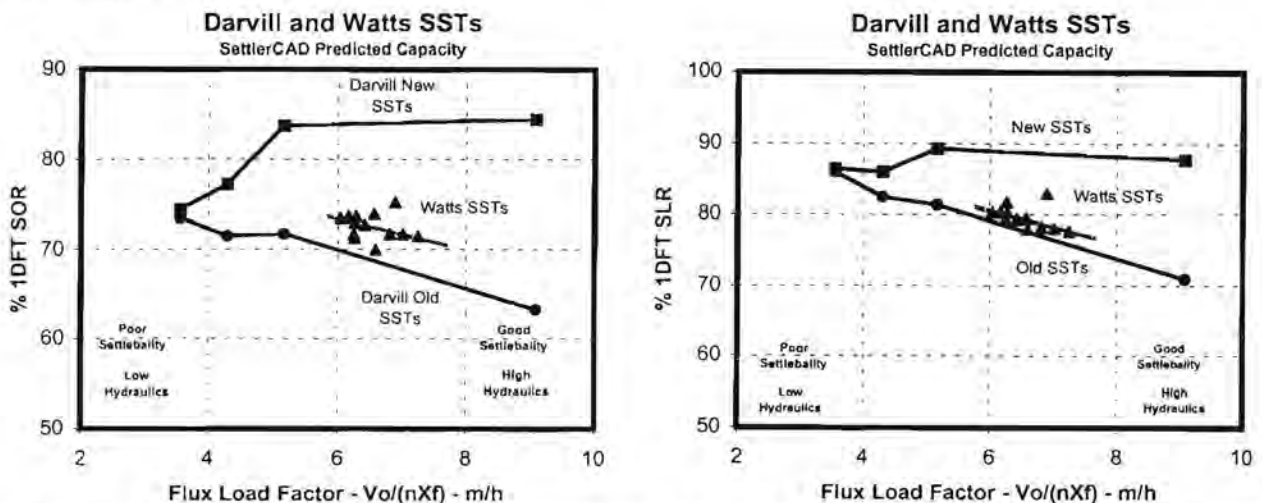
From this, the actual test results which SettlerCAD predicts incorrectly are Tests 3 (observed safe but SettlerCAD predicts fail) and 14 and 15 (observed fail but SettlerCAD predicts safe). Of these 3 tests, only Tests 3 and 15 plot far from the SettlerCAD predicted maximum SOR and SLR results and therefore are definitely incorrectly predicted. However, Tests 4, 14, 13, 7, 9 and 12, three of which are safe (4, 7 and 9) and three of which are fail (14, 13 and 12), all plot very close to the SettlerCAD predicted limits and are all correctly predicted. This indicates that apart from Test 3 and 15, SettlerCAD accurately identifies the SOR and SLR capacity of the Watts SST.



Figures 5.7a and 5.7b: SettlerCAD predicted maximum SOR (Fig. 5.7a, left) and SLR (Fig. 5.7b, right), as a percentage (%) of 1DFT limit values versus load flux factor $V_o/(nX_F)$. Also shown are the 15 actual test points safe (\bullet), fail (\blacktriangle) identified by number.

Figures 5.7a and 5.7b show a small decreasing trend in SettlerCAD predicted SOR and SLR as the flux load factor increases – for the SOR (Fig. 5.7a) from 74 % (Test 4) to 71 % (Test 9 and 12) and for the SLR (Fig. 5.7b) from 81 % (Test 4) to 79 % (Test 9 and 12). This seems to suggest that the Watts SST is as insensitive to HLR as the Darvill new SST. However, the flux load factor range for the Watts tests is very narrow – only from 6.0 to 7.2 m/h, whereas for the Darvill tests the flux load factor range was from 3.5 to 9.0 m/h, leading to a much greater range in 1DFT maximum SORs and SLRs. To place the Watts SettlerCAD predicted flux rating in perspective, they are plotted together with the Darvill flux ratings in Figures 5.8a and 5.8b. The Watts SettlerCAD predicted SOR and SLR limit results lie between the old and new Darvill SST lines, but closer to the old SST line.

Considering that with respect to external SST geometry, the Watts SST (3.66 m SWD and 1:15.4 sloping bottom) is closer in likeness to the new Darvill SST (4.1 m SWD and 1:10 sloping bottom) than to the old Darvill SST (2.5 m SWD and flat bottom), the expectation was that the Watts results should fall closer to the new Darvill SST results than those of the old SST, but this did not happen. However, a relatively consistent pattern does seem to be emerging because at least the Watts SST results fall between the Darvill new and old SST results and show a similar decreasing trend in flux rating or capacity as the flux load factor increases.



Figures 5.8a and 5.8b: SettlerCAD predicted SOR (Fig. 5.8a, left) and SLR (Fig. 5.8b, right), as a percentage (%) of 1DFT maximum limits versus flux load factor for the Watts (3.66 m SWD), and Darvill new (4.1 m SWD) and old (2.5 m SWD) SSTs.

5.5 : CONCLUSIONS FROM THE WATTS SST SIMULATIONS

From evaluation of the SettlerCAD simulation results on the Watts SST with a diameter to average depth rates (D/H_{ave}) of 7.29 the following conclusions can be made:

- The SettlerCAD model correctly predicted the result of 12 of the 15 actual stress tests; three tests (Tests 3, 14 and 15) were predicted incorrectly. Tests 4, 14, 13, 7, 9 and 12 all plot very close to the SettlerCAD predicted limits and are correctly predicted. This narrow range, indicates that apart from Test 3 and 15, SettlerCAD accurately identifies the SOR and SLR capacity of the Watts SST. The SettlerCAD results of the Watts test gives a good indication that the SettlerCAD predictions are valid for the simulation of full-scale stress tests.
- The 3 tests not predicted correctly had the lowest (Test 3) and highest (Test 14 and 15) recycle flows – this seems to indicate that the effect of the recycle flow in the flux theory (which models the movement of the solids with respect to the water) is greater than in real SSTs. However, a quantitative assessment of this cannot be made.
- The SST hydraulic non-idealities are implicitly included in the SettlerCAD model and the maximum predicted SLR of the 15 tests fall very close to a 80 % flux rating.
- The Watts simulation results of the full-scale SST SLR stress tests provide further evidence that the steady state 1DFT cannot be applied to the design of full-scale SSTs without an appropriate reduction factor.

CHAPTER 6

SIMULATION THE DUTCH STOWa SSTs WITH SettlerCAD

6.1 : THE RIJEN SST SLR STRESS TESTS

Stofkoper and Trentelmann (1982) conducted 47 SLR stress tests on 25 different circular SSTs, 30 to 46 m in diameter, 1.5 to 2.5 m SWD and 1:12 sloping bottoms with scraper sludge collection to a central hopper and peripheral overflow. Details of these tests are reported by STOWa (1981a, b, c). The larger SSTs had double sided inset ($< 1 \times \text{SWD}$ from side-wall) effluent launders, but the outer edge was blocked off so that effluent flowed only over the inner edge of the launder (see Ekama *et al.*, 1997, page 173). The first 14 STOWa tests were done on the 45.5 m diameter, 2.25 m SWD Rijen SST (Rijen Tests 1 to 6a, 6b and 7 to 13), the second 10 STOWa tests on the 41.8 m diameter, 2.0 m SWD Oss SST (Oss tests 1 to 10), and the final 23 tests on 23 different SSTs. In the tests, influent to the plant was shut-off and allowed to accumulated in the sewer. At the same time, the sludge return flow was set to the required rate to minimise the amount of sludge in the SST. The test was commenced when the influent pumps were started and set at the required rate to give a selected SOR. The influent and recycle flows were kept constant until a test led to (i) sludge loss with the effluent, in which case the test ended in fail (F), (ii) a steady state, in which the sludge blanket height (SBH) remained constant, in which case the test ended safe (S), or (iii) an inability to maintain the influent flow at the required rate due to insufficient sewage, in which case the test result was inferred from SBH measurements – if this was not possible with reasonable accuracy, the test was deemed inconclusive (NE, no equilibrium). During each test the following were measured at regular intervals (i) influent and recycle flows (ii) sludge settleability with the SSVI and DSVI tests, (iii) SBH, (iv) feed, RAS and ESS concentrations and (v) concentration – depth profiles at various radial distances from the centre. Multiple batch zone settling velocity tests, from which the V_0 and n values could be determined. However, these results could not be used for defining the sludge settleability because these tests were conducted over too narrow a concentration range (1.0 to 6.0 g/l).

Hence for this investigation, the V_o and n values for the different tests were calculated from the measured SSVI or DSVI with the relationships reported by Ekama and Marais (1986) (See Ozinsky and Ekama, 1995; Ekama *et al.*, 1997), i.e.

$$\begin{array}{lll}
 V_o/n & = 67.9 \exp (-0,016 \text{ SSVI}) & \text{kg}/(\text{m}^2 \cdot \text{h}) \\
 n & = 0,88 - 4\,393 \log (V_o/n) & \text{m}^3/\text{kgSS} \\
 V_o & = n (V_o/n) & \text{m}/\text{h} \\
 \text{SSVI} & = 0.67 \text{ DSVI} & \text{m} \ell / \text{g}
 \end{array}$$

Details of the internal features such as the the feed-well skirt diameter (\varnothing_{FS}) and depth (h_{FS}) and the inlet feed-well diameter (\varnothing_{IF}) and depth (h_{IF}), required as input by SettlerCAD, were not available for all the SSTs stress tested. The detailed reports of the SST evaluation project (STOWa, 1981a, b, c) cite some details of the internal features of 22 SSTs surveyed in Holland. However, only 7 of these 22 SSTs were among the 27 SSTs stress tested. From the information of the 22 SSTs surveyed, the feed-well skirt diameter (\varnothing_{FS}), as a fraction of the SST diameter (\varnothing_{ST}) i.e. $\varnothing_{FS}/\varnothing_{ST}$ varied from 0.05 to 0.16 with a mean of 0.10 and the feed-well skirt depth (h_{FS}), as a fraction of the SST depth at the radius of the feed-well skirt (h_{ST}), i.e. h_{FS}/h_{ST} varied from 0.27 to 0.55 with a mean of 0.42. So for the Rijen and Oss, the feed-well skirt diameter (\varnothing_{FS}) and depth (h_{FS}) were set at these mean values. No information was given on the inlet feed-well diameter (\varnothing_{IF}) and depth (h_{IF}) so these dimensions were fixed at a diameter of 1.0 m diameter and a depth of 0.3 m less than the feed-well skirt depth. To check the sensitivity of the simulations on the inlet dimensions, 16 SettlerCAD runs were set-up for the Rijen SST under Test 1 conditions. The first 8 runs had the same inlet arrangements as defined above, but had an increasing influent flow-rate to determine the SettlerCAD SOR and SLR capacity. The last 8 runs had a constant SOR and SLR of the first fail run, but different inlet dimensions, i.e. feed-well skirt diameters (\varnothing_{FS}) and depths (h_{FS}) (in m) of 2.8 and 1.1, 4.6 and 1.7, and 6.0 and 2.1 m in combination with inlet feed-well diameter (\varnothing_{IF}) and depths (h_{IF}) (in m) 1.0 and 1.0, 1.0 and 1.4, and 2.0 and 1.4. It was found that the runs with the large and deep inlet feed-well, in combination with the 4.6 m diameter ($\varnothing_{FS}/\varnothing_{St} = 0.10$) and 6.0 m diameter ($\varnothing_{FS}/\varnothing_{St} = 0.13$) and 1.7 deep ($h_{FS}/h_{ST} = 0.42$) feed-well skirt ended safe whereas the other runs ended fail.

This indicated the selection of feed-well skirt of $\phi_{FS}/\phi_{ST} = 0.10$ and $h_{FS}/h_{ST} = 0.42$ with fixed inlet feed-well diameter of 2.0 m and a depth 0.3 m less than the feed-well skirt.

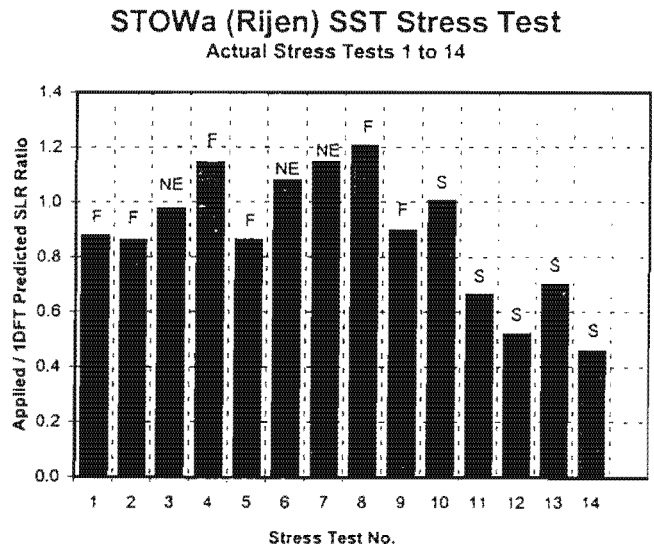
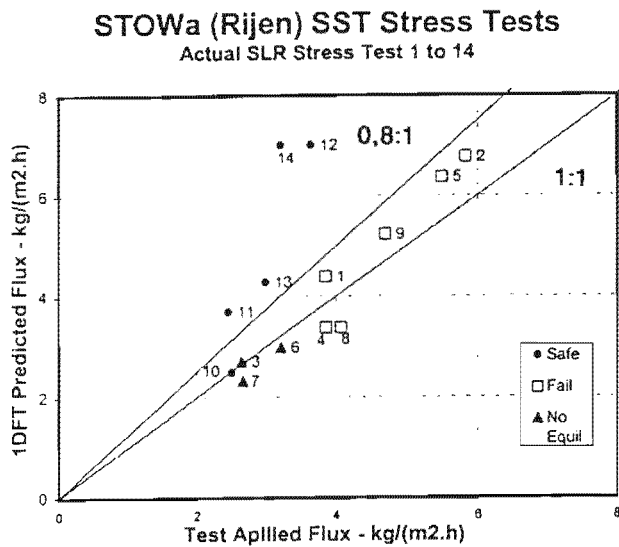
Table 6.1 : Geometry details of Rijen and Oss SST of the STOWa (1981) data set

Parameter		Rijen	Oss
Diameter D	(m)	45.5	41.8
Side water depth (SWD)	(m)	2.85	2.00
Bottom slope		1:12	1:12
Surface area	m ²	1 626	1 372
Volume	m ³	4 683	3 540
Feed-well diameter	(m)	2.0	1.88
Feed-well depth	(m)	1.4	2.56
Skirt baffle diameter	(m)	5.6	5.22
Skirt baffle depth	(m)	1.7	1.53
Average depth (H _{ave})	(m)	2.88	2.58
D/H _{ave}	(-)	15.79	16.20

6.2 : RESULTS OF THE RIJEN FULL-SCALE SST ACTUAL STRESS TESTS

From the V_o , n and X_f , the 1DFT predicted maximum SOR and SLR were calculated for the 14 Rijen SLR tests and are listed in Table 6.2. The 1DFT predicted and test applied SLRs and the test applied/1DFT predicted SLR ratio from Table 6.2 are plotted in Figures 6.1a and 6.1b. Of the 14 tests, 6 tests ended fail (F, □ i.e. Tests 1, 2, 4, 5, 8 and 9), 5 ended safe (S, ●, i.e. Tests 10 to 14) and 3 inconclusive (NE, ▲, i.e. Tests 3, 6 and 7). From Fig. 6.1b, the test applied/1DFT predicted maximum SLR ratio for the 14 tests are between 0.457 (Test 14) and 1.322 (Test 8). Tests 1 to 9 all have test applied/1DFT predicted SLR ratios > 0.80 and therefore can be expected to fail and do. It is quite likely that had the inconclusive tests 3, 6 and 7 been run for longer, that these would have ended fail because they have test applied/1DFT predicted maximum SLR ratios > 0.85.

Of the 5 safe tests, it is expected that the 4 tests 11 to 14 ended safe because they have low (< 0.65) test applied/1DFT predicted maximum SLR ratios. The only inconsistent test of the 14 is Test 10, which at a test applied/1DFT predicted maximum SLR ratio of 1.00 ended safe; in Fig. 6.1a it plots near the 3 inconclusive tests. In Fig. 6.1a, the 2 safe Tests 11 and 13 and the 4 fail Tests 1, 2, 5 and 9 define the measured capacity (flux rating) to be between 0.75 and 0.85 of the 1 DFT SLR maximum.



Figures 6.1a and 6.1b: 1DFT maximum SLR versus test applied SLR (Fig. 6.1a, left) and Test applied /1DFT predicted maximum SLR ratio (Fig. 6.1b, right) for the 14 stress tests reported by STOWa (1981) on the Rijen SST.

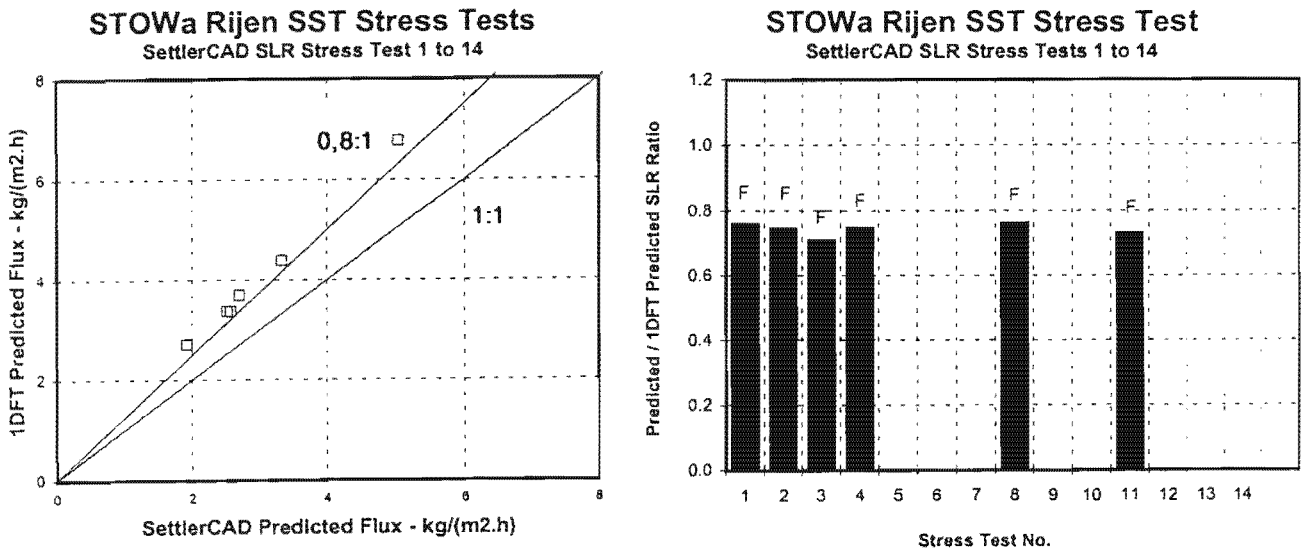
Table 6.2: Summary of the 14 SLR stress test results on the STOWA Rijen WWTP SST.

Parameter		STOWa Test #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14
		Rijen Test #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6a	Test 6b	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13
SST	Number of SSTs		1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Surface area (m ²)		1 626	1 626	1 626	1 626	1 626	1 626	1 626	1 626	1 626	1 626	1 626	1 626	1 626	1 626
Actual test loading conditions	Influent flow (M ℓ/d)		42.5	42.5	34.3	34.3	34.3	28.9	28.9	28.9	28.9	24.6	24.6	24.6	20.3	20.3
	Overflow rate SOR (m/h)		1.09	1.09	0.88	0.88	0.88	0.74	0.74	0.74	0.74	0.63	0.63	0.63	0.52	0.52
	Recycle flow (M ℓ/d)		12.8	24.2	6.9	12.7	24.4	6.9	6.9	12.7	24.3	6.9	12.8	24.4	12.8	24.4
	Underflow rate (m/h)		0.327	0.621	0.176	0.326	0.625	0.178	0.178	0.326	0.622	0.176	0.328	0.624	0.328	0.624
	Recycle ratio		0.300	0.570	0.200	0.370	0.710	0.241	0.241	0.441	0.841	0.279	0.521	0.990	0.631	1.200
	Feed Concentration (g/ℓ)		2.720	3.410	2.500	3.200	3.650	3.500	2.900	3.820	3.440	3.100	2.560	2.900	3.530	2.800
	Applied SLR [kgSS/(m ² .h)]		3.85	5.83	2.64	3.86	5.49	3.21	2.66	4.07	4.69	2.50	2.45	3.64	2.99	3.20
	Weir loading rate [m ³ /(h.m)]		12.40	12.40	10.01	10.01	10.01	8.42	8.42	8.42	8.42	7.17	7.17	7.17	5.92	5.92
HLR [(qA+qR), m/h]		1.417	1.711	1.056	1.206	1.505	0.918	0.918	1.066	1.362	0.806	0.958	1.254	0.848	1.144	
Sludge settleability	V ₀ (m/h)		6.53	6.33	6.53	4.86	5.94	7.15	5.38	4.86	4.86	5.94	5.38	6.53	6.33	6.53
	n (ℓ/g)		0.406	0.415	0.406	0.488	0.433	0.379	0.460	0.488	0.488	0.433	0.460	0.406	0.415	0.406
	SSVI (DSVI) (m ℓ/g)		90	(140)	90	120	100	80	110	120	120	100	110	90	(140)	90
1DFT predicted limits	Maximum SLR [kg/(m ² .h)]		4.39	6.77	2.71	3.38	6.37	2.98	2.32	3.38	5.23	2.49	3.70	7.01	4.28	7.01
	Overflow rate (m/h)		1.289	1.363	0.908	0.731	1.121	0.675	0.621	0.560	0.898	0.628	1.117	1.704	0.884	1.880
	Influent Q _i (excl. Q _R): (m ³ /h)		2095.8	2217.3	1476.5	1189.0	1822.2	1097.0	1009.4	910.3	1459.7	1021.0	1816.4	2917.8	1437.1	3057.9
Flux rating	Flux load factor [V ₀ /(nX _F), m/h]		5.91	4.47	6.43	3.11	3.76	5.39	4.03	2.61	2.89	4.42	4.56	5.55	4.32	5.75
	Test/1DFT SLR ratio		87.7	86.2	97.4	114.1	86.2	107.7	114.9	120.3	89.6	100.3	66.3	51.9	70.0	45.7
	Test/1DFT SOR ratio		84.6	79.9	96.9	120.4	78.5	109.7	119.2	132.2	82.4	100.3	56.4	35.1	58.8	27.7

6.3 : FINDING THE SettlerCAD MAXIMUM SOR AND SLR FOR THE RIJEN SSTs

6.3.1 : SettlerCAD predicted failure

The data given in Table 6.2 were used as input to SettlerCAD. For 6 of the 14 tests, 16 SettlerCAD runs per test were set-up. The 6 tests selected were the 2 tests with the highest flux load factor $V_o/(nX_F)$ (Tests 1 and 3), the 2 tests with the lowest flux load factor (Tests 4 and 8) and the 2 tests nearest the average flux load factor (Tests 2 and 11). SettlerCAD runs 1 to 7 for each of the 6 tests simulated were at Q_i from 60 to 72 % of the 1DFT SOR in 2 % increments and an 8th run at 100 %. Runs 9 to 15 were set-up between consecutive safe and fail runs at 0.25 % increments and the 16th run was at the actual test Q_i . The first run with $ESS > 50 \text{ mg/l}$ was accepted as the SettlerCAD predicted maximum influent rate limit. The SettlerCAD SLR limit was calculated from the Q_i limit and the test Q_R and X_F values. The SettlerCAD predicted results of the first failure runs are given in Table 6.3 and are shown plotted in Figures 6.2a and 6.2b as 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Fig. 6.2a) and SettlerCAD predicted/1DFT maximum SLR ratio (Fig. 6.2b).



Figures 6.2a and 6.2b: 1DFT calculated maximum SLR versus SettlerCAD predicted SLR (Fig. 6.2a, left) and SettlerCAD predicted to 1DFT calculated Rijen maximum SLR ratios (Fig. 6.2b, right) for SLR Stress Tests 1, 2, 3, 4, 8 and 11 on the Rijen SST.

Table 6.3 : Summary of the SettlerCAD simulation results for the SettlerCAD influent flow limit for the 14 SLR tests on STOWa Rijen SST.

SettlerCAD Q _i LIMIT	STOWa Test # Rijen Test #	Test 1 Test 1	Test 2 Test 2	Test 3 Test 3	Test 4 Test 4	Test 5 Test 5	Test 6 Test 6a	Test 7 Test 6b	Test 8 Test 7	Test 9 Test 8	Test 10 Test 9	Test 11 Test 10	Test 12 Test 11	Test 13 Test 12	Test 14 Test 13
Flux factor $V_o/(nX_F) - m/h$		5.91	4.47	6.43	3.11	3.76	5.39	4.03	2.61	2.89	4.42	4.56	5.55	4.32	5.75
Influent flow (m ³ /h) for 1 SST		1461.8	1396.9	959.7	749.1				564.4			1180.7			
% of 1DFT maximum Q _i		69.75	63.00	65.00	63.00				62.00			65.00			
Overflow rate (m/h)		0.90	0.86	0.59	0.46				0.35			0.73			
Recycle flow (m ³ /h)		531.8	1009.9	186.2	530.1				530.1			533.4			
Underflow rate (m/h)		0.327	0.621	0.176	0.326				0.326			0.328			
Recycle ratio		0.36	0.72	0.30	0.71				0.94			0.45			
Applied flux [(kgSS)/(m ² .h)]		3.33	5.05	1.92	2.52				2.57			2.70			
% of 1DFT maximum flux		75.9	74.6	70.7	74.4				76.0			72.9			
Actual retention time (h)		2.4	1.9	3.8	3.7				4.3			2.7			
Duration of run (min)		4000	4000	4000	4000				4000			4000			
Duration of run (# of R _{ha})		28.4	34.2	17.7	18.2				15.6			24.4			
Sim time step (min)		2.5	2.5	2.5	2.5				2.5			2.5			
Sim time step (% R _{ha})		1.77	2.14	1.11	1.14				0.97			1.52			
Effluent SS (mg/ℓ)*		63.8	50.9	52.7	50.7				85.8			54.7			
Recycle Conc (mg/ℓ)*		9494	8037	9942	7551				7672			7989.7			
Mass balance (%)*		94.8	99.8	93.0	98.7				98.4			98.6			
Test result (ESS > 50 mg/ℓ)		Fail	Fail	Fail	Fail				Fail			Fail			

* Mean over the last 2 R_{ha} values

In Figures 6.2a and 6.2b and Table 6.3 it can be seen that the SettlerCAD predicted flux rating of the Rijen SST ranges between 0.707 (Test 3) and 0.760 (Test 8). Fig. 6.2a shows the SettlerCAD maximum predicted SLR (flux rating) of the 6 tests all fall above the 0.80 flux rating line indicating that the SettlerCAD maximum SLR is less than 0.80, i.e. around 0.73 of the 1DFT maximum. The SettlerCAD predicted maximum SOR (as % of the 1DFT maximum) ranged between 0.620 % (Test 8) and 0.697 % (Test 1).

6.3.2 : SettlerCAD simulation of the full-scale actual stress test

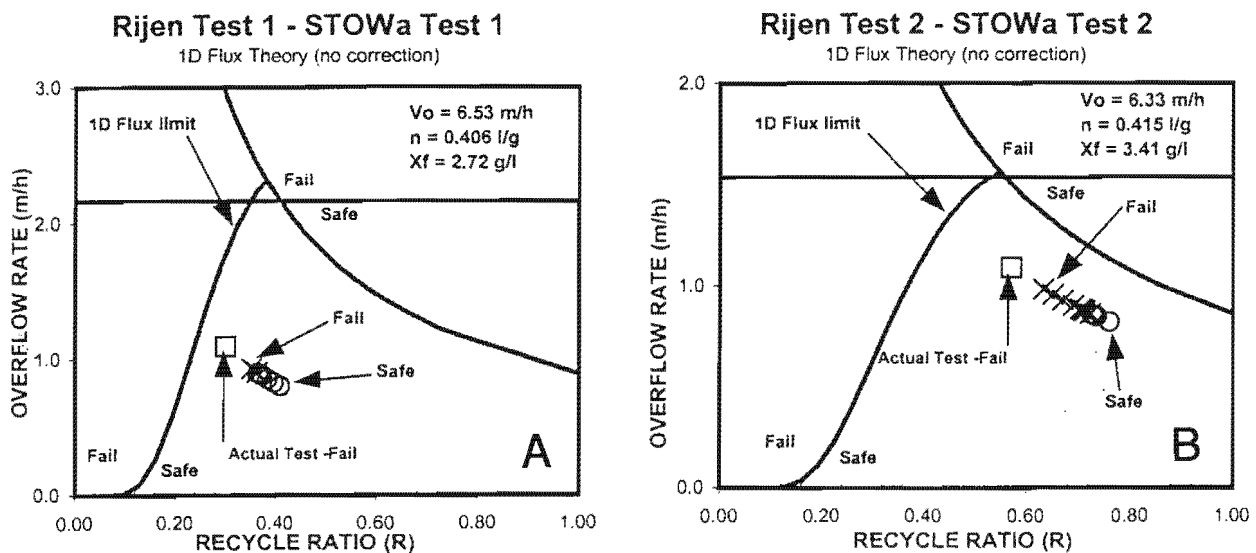
The results of the simulations of the 6 tests at the actual test influent flow rates are summarised below in Table 6.4.

Table 6.4 : Summary of the SettlerCAD simulations results for the Rijen full-scale SST actual test.

Actual test influent flow	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6a	Test 6b	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13
Influent flow (m ³ /h) for 1 SST	1772.5	1772.5	1431.0	1431.0	1431.0	1203.4	1203.4	1203.4	1203.4	1024.5	1024.5	1024.5	845.6	845.6
% of 1DFT maximum Q _i	84.6	79.9	96.9	120.4	78.5	109.7	119.2	132.2	82.4	100.3	56.4	35.1	58.8	27.7
Overflow rate (m/h)	1.09	1.09	0.88	0.88	0.88	0.74	0.74	0.74	0.74	0.63	0.63	0.63	0.52	0.52
Recycle flow (m ³ /h)	12.8	24.2	6.9	12.7	24.4	6.9	6.9	12.7	24.3	6.9	12.8	24.4	12.8	24.4
Underflow rate (m/h)	0.327	0.621	0.176	0.326	0.625	0.178	0.178	0.326	0.622	0.176	0.328	0.624	0.328	0.624
Recycle ratio	0.300	0.570	0.200	0.370	0.710	0.241	0.241	0.441	0.841	0.279	0.521	0.990	0.631	1.200
Applied flux [(kgSS)/(m ² .h)]	3.85	5.83	2.64	3.86	5.49	3.21	2.66	4.07	4.69	2.50	2.45	3.64	2.99	3.20
% of 1DFT maximum flux	87.7	86.2	97.4	114.1	86.2	107.7	114.9	120.3	89.6	100.3	66.3	51.9	70.0	45.7
Actual retention time (h)	2.0	1.7	2.7	2.4	1.9	3.1	3.1	2.7	2.1	3.6	3.0	2.3	3.4	2.5
Duration of run (min)	4000	4000	4000	4000				4000			4000			
Duration of run (# of R _{na})	32.8	39.6	24.4	27.9				24.7			22.2			
Sim time step (min)	2.5	2.5	2.5	2.5				2.5			2.5			
Sim time step (% R _{na})	2.05	2.47	1.53	1.74				1.54			1.39			
Effluent SS (mg/ℓ)*	503.5	399.0	581.4	1271.3				1761.2			1761.2			
Recycle Conc (mg/ℓ)*	9258.9	8317.2	10591.5	7369.1				7500.5			7501.0			
Mass balance (%)*	92.8	96.0	90.0	91.2				60.7			92.1			
Test result (ESS > 50 mg/ℓ)	Fail	Fail	Fail	Fail				Fail			Fail			
Observed result	Fail	Fail	No Equilibrium	Fail	Fail	No Equilibrium	No Equilibrium	Fail	Fail	Safe	Safe	Safe	Safe	Safe

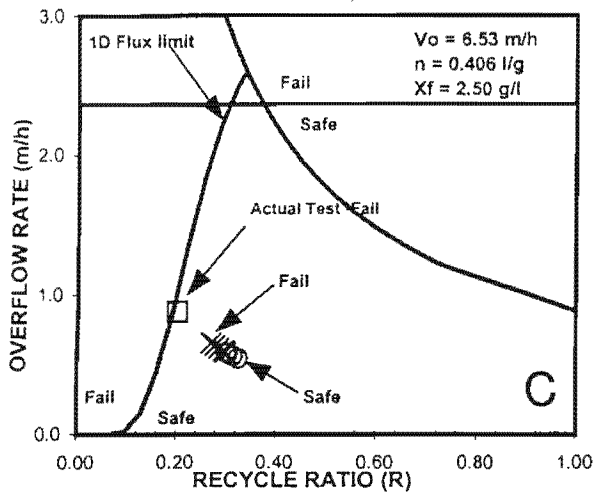
* Mean over the least 2 R_{na} values.

The position and result (safe O, fail X) of the SettlerCAD simulation runs for the simulated Tests 1, 2, 3, 4, 8 and 11 are shown in the D&O charts in Figures 6.3a to 6.3f. The actual test position and result are also indicated. In the D&O charts, the SettlerCAD predicted SOR limit is given at the transition from the safe to fail positions. If the actual test position of the safe tests (O) is within or below the safe runs, the SettlerCAD correctly predicted a safe result for the actual test. Similarly, if the actual test position of the fail (X) test is within or above the fail runs, then SettlerCAD correctly predicted a fail result for the actual test. From the six D&O charts, SettlerCAD correctly predicted the result for the 6 tests simulated if it is assumed that Test 4, which ended No Equilibrium (NE, (▲) in Fig. 6.1a), ended fail. From Fig. 6.1b, this is a reasonable assumption because it had test applied/1DFT predicted SLR ratio = 0.97. (This applies also to tests 6 and 7 which ended NE because these had test applied/1DFT predicted SLR ratios of 1.08 and 1.15 respectively). In fact, had all 14 Rijen tests been simulated, SettlerCAD would have predicted the test result correctly of all the tests except Test 10. This can be seen in Figures 6.6a and 6.6b in Section 6.4.3, which plot the SettlerCAD predicted maximum SOR and SLR versus the flux load factor.



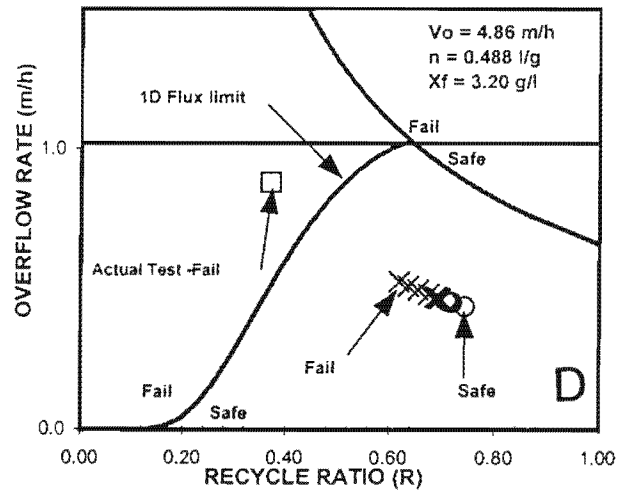
Rijen Test 3 - STOWa Test 3

1D Flux Theory (no correction)



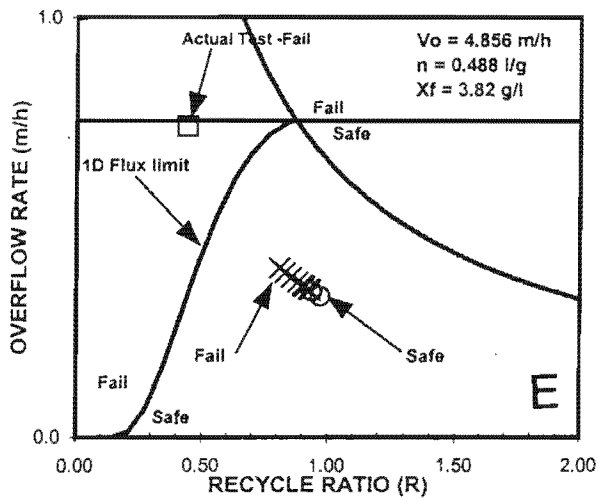
Rijen Test 4 - STOWa Test 4

1D Flux Theory (no correction)



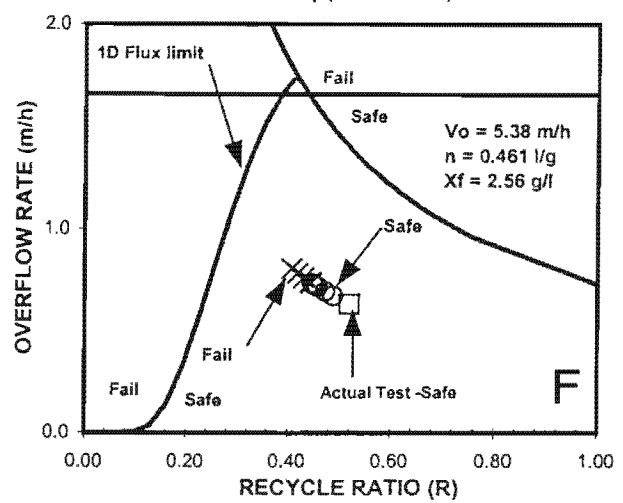
Rijen Test 7 - STOWa Test 8

1D Flux Theory (no correction)



Rijen Test 10 - STOWa Test 6

1D Flux Theory (no correction)



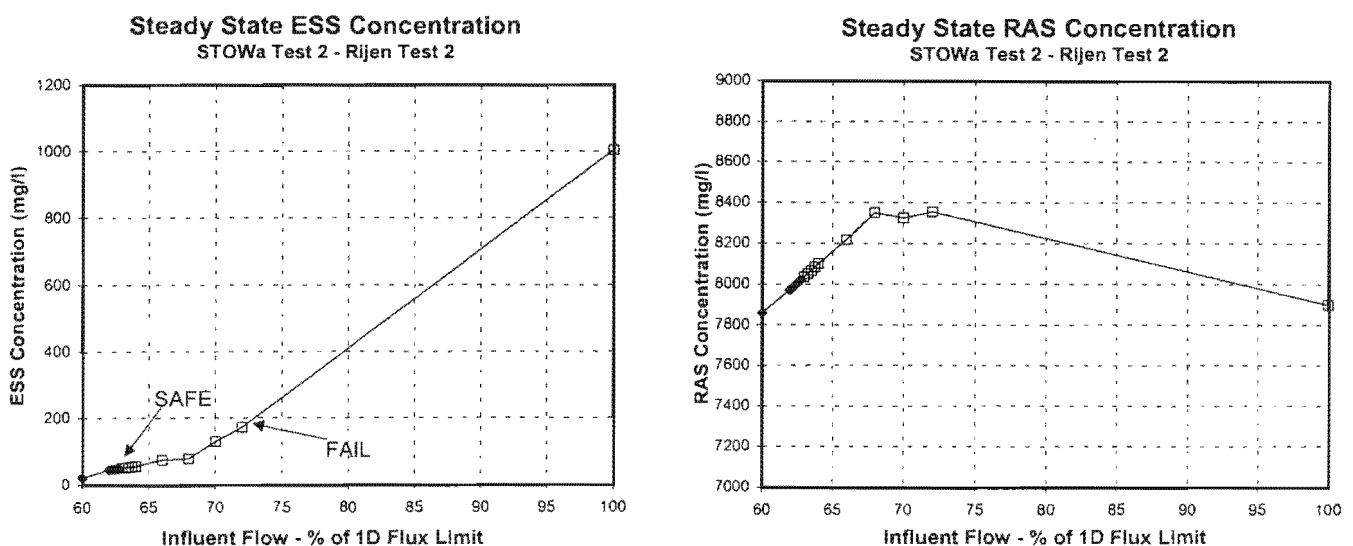
Figures 6.3a and 6.3f: 1DFT D&O chart showing the SST operating positions and results (safe O, fail x) of the SettlerCAD runs and actual tests (safe and fail) for Tests 1, 2, 3, 4, 8 and 11 of the Rijen SST.

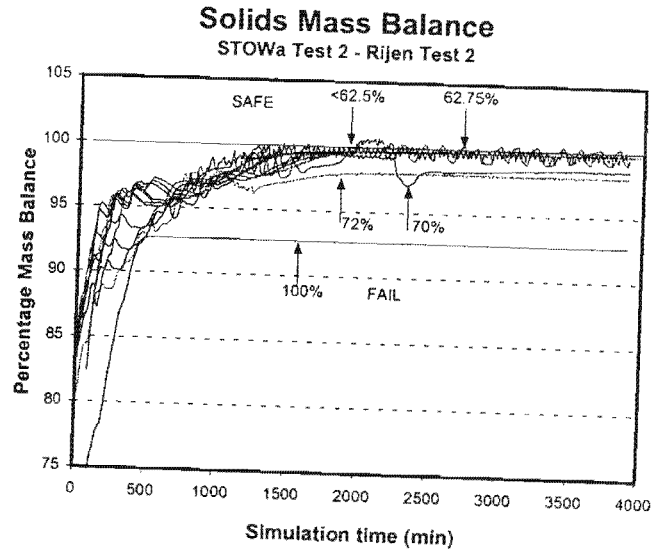
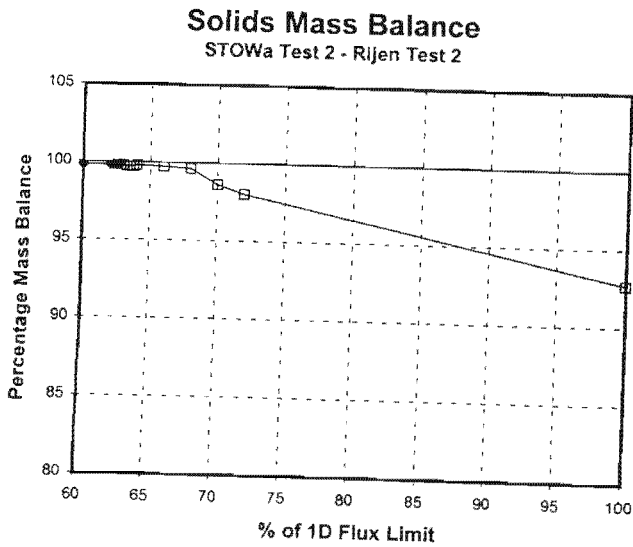
6.4 : EVALUATING THE OUTPUT RESULTS OF SettlerCAD

6.4.1 : Determination of solids mass balance

In the simulation runs, a simulation time of 4 000 min was selected which was 18 to 34 times the actual hydraulic retention time (R_{ha}) with respect to the SettlerCAD predicted SOR and SLR limits and 21 to 40 x R_{ha} of the actual test influent flows. As for Darvill and Watts SST runs, these run times were sufficiently long to establish a final steady state condition and the final ESS and RAS (X_R) concentrations accepted for each run were the averages of the predicted values over the last 2 x R_{ha} . The solid mass balance was based on these final average ESS and RAS concentrations, which are listed in Table 6.4. The same pattern regarding the mass balance was observed as previously – provided the run ended safe ($ESS < 50 \text{ mg}/\ell$), the run yielded a solids mass balance within 0.5 % of 100 % and runs that ended in failure ($ESS > 50 \text{ mg}/\ell$) yielded a lower than 99.5 % solids mass balance, the greater the SST overload (i.e. the higher the ESS concentration), the lower the solids mass balance below 99.5 %.

The ESS, RAS and percentage (%) mass balance versus influent flow (as % of the 1DFT limit Q_i) for the Rijen Test 2, which had the highest test applied SLR and SOR, are shown in Figures 6.4a to 6.4c. In Fig. 6.4d, the percentage (%) mass balance versus simulation time for runs 1 to 8 of Test 2 at 60 to 72 % and 100 % of the 1DFT maximum influent flow are shown – it can be seen that for the failed runs, a final steady state is achieved, but this steady state does not yield a mass balance.



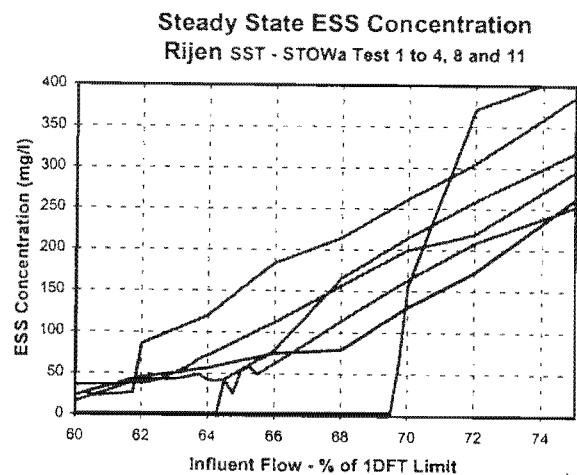
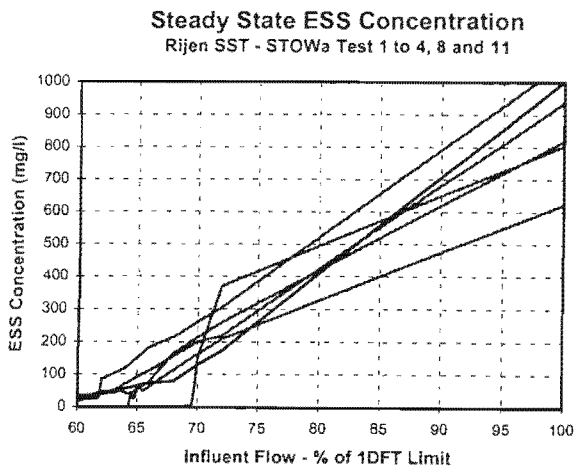


Figures 6.4a to 6.4d: Final ESS and RAS concentration (Fig. 6.4a, top left and Fig. 6.4b, top right) and percentage (%) mass balance (Fig. 6.4c, bottom left) versus influent flow as % 1DFT limit showing runs ended safe (♦) and fail (□) and percentage (%) mass balance versus simulation time (Fig. 6.4d, bottom right) for the SettlerCAD runs on the Rijen SST Test 2.

6.4.2 : ESS concentration versus influent flow

The final average ESS concentration versus Q_i (as a % of the 1DFT limit) for the 6 Rijen tests simulated are shown in Fig. 6.5. It can be seen that the ESS concentration increases gradually above 50 mg/ℓ in the range between 60 and 70 % of the 1DFT limit influent flow.

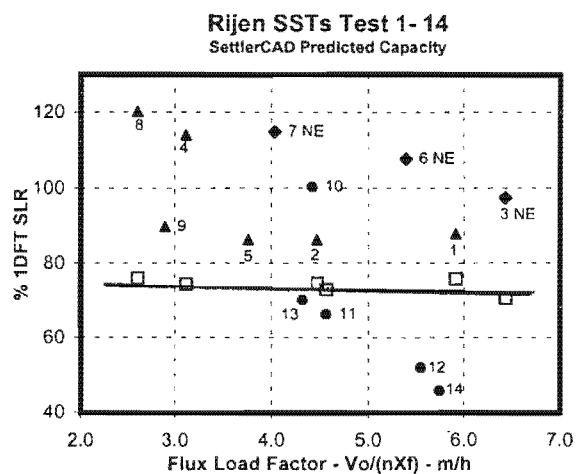
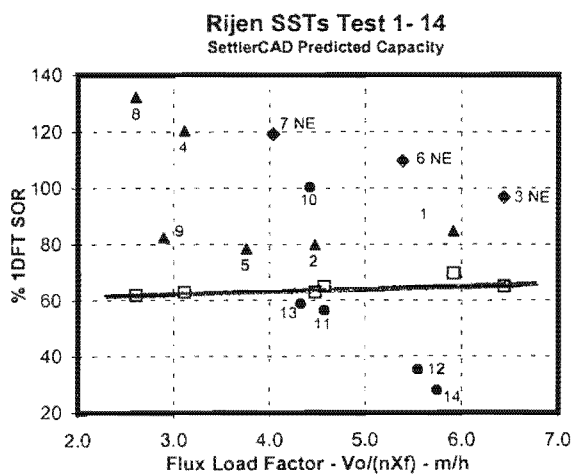
The gradual increase in ESS concentration of the shallow (2.25 m SWD) Rijen SST resembles the gradual increase in ESS of the old (2.5 m flat) Darvill SST.



Figures 6.5a and 6.5b: Final steady state ESS concentration versus influent flow as a percentage (%) of the 1DFT limit for the 6 Rijen SST tests simulated.

6.4.3 : Flux load factor versus 1DFT limits

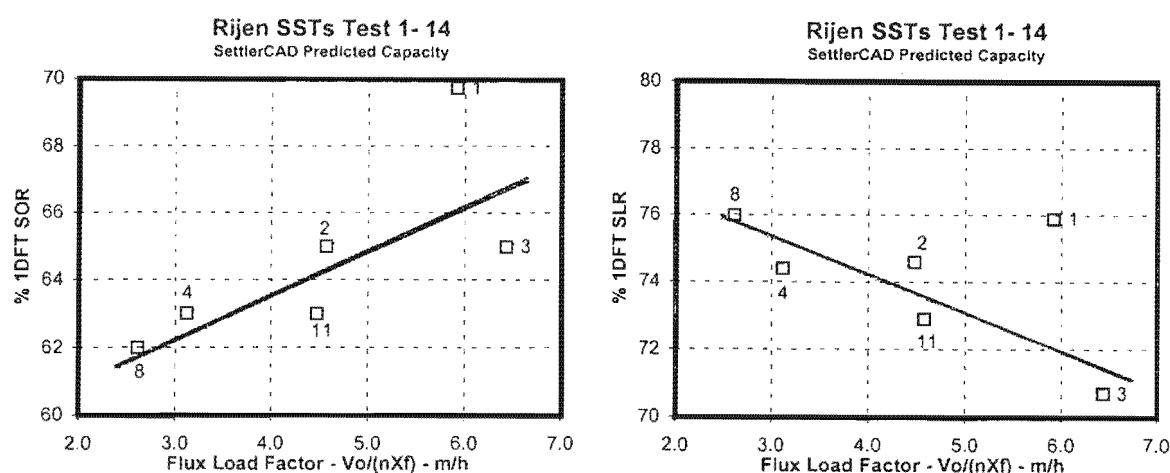
The SettlerCAD predicted maximum SOR and SLR, as a percentage (%) of the 1DFT limits, are plotted versus the flux load factor $V_o/(n.X_f)$ in Figures 6.6a and 6.6b.



Figures 6.6a and 6.6b: SettlerCAD predicted maximum SOR (\square) (Fig. 6.6a, left) and SLR (Fig. 6.6b, right), as a percentage (%) of the 1DFT limit values versus flux load factor $V_o/(n.X_f)$. Also shown are the 14 actual test points (safe \bullet , fail \blacktriangle or No Equilibrium \blacklozenge) identified by test number.

Also shown in Figures 6.6a and 6.6b are the 14 actual test points. In these figures, the actual tests that ended safe and fail which plot *below* and *above* the SettlerCAD predicted SOR and SLR limits (line through □), respectively, are the tests that SettlerCAD predicted correctly. Similarly, the actual tests that ended safe and fail which plot *above* and *below* the SettlerCAD predicted SOR and SLR limits (line through □), are tests which SettlerCAD predicted incorrectly. From this, the only test which SettlerCAD predicted incorrectly is Test 10 (observed safe but SettlerCAD predicted fail). In Figures 6.6a and 6.6b, Tests 9, 5, 2 and 1 (all fail) plot around 80 % and 88 % of the 1DFT SOR and SLR limits respectively, and Tests 13 and 11 plot around the 60 % and 65 % of the 1 DFT SOR and SLR limits. The gap between the safe and fail tests therefore is quite large, about 20 %.

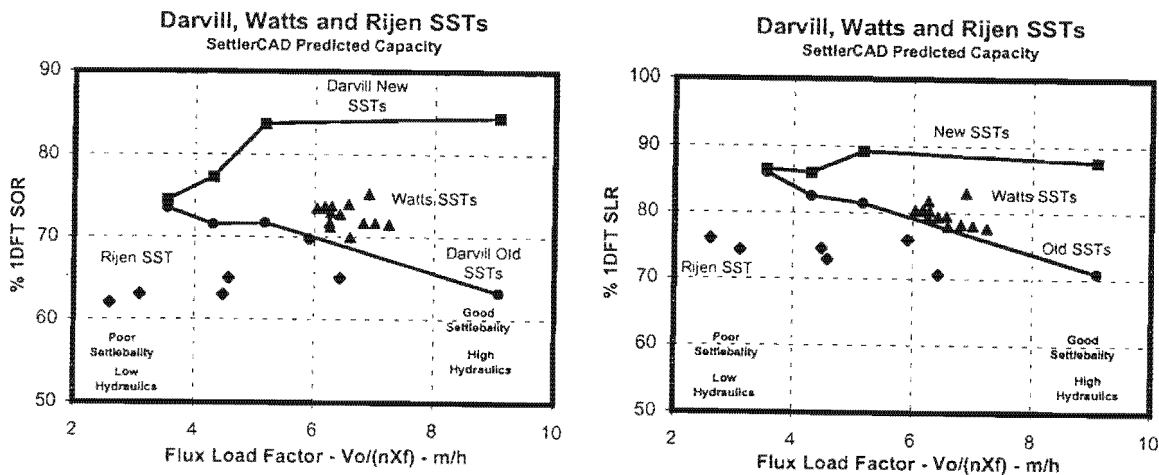
This means the SettlerCAD predicted SOR and SLR limits (flux rating) could plot in a 20 % range and still predict 13 out 14 test results correctly. Therefore unlike the Watts tests, the Rijen tests on their own are not very useful for checking the accuracy with which SettlerCAD predicts SST capacity.



Figures 6.7a and 6.7b: SettlerCAD predicted maximum SOR (Fig. 6.7a, left) and SLR (Fig. 6.7b, right), as a percentage (%) of the 1DFT limit values versus flux load factor $V_o/(nX_f)$ for the six test simulated with SettlerCAD identified by test number.

Figures 6.7a and 6.7b, which are the same as Figures 6.6a and 6.6b, shows a vertical scale range of only 10 % of 1DFT limit SOR and SLR. These figures show a small increasing and decreasing trend respectively in the SettlerCAD predicted SOR and SLR, as the flux load factor increases for the 6 tests simulated. For the SOR (Fig. 6.7a) from 62 % (Test 8) to 67 % (between Tests 1 and 3) and for the SLR (Fig. 6.7b) from 76 % (Test 8) to 74 % (between Tests 1 and 3). This indicates that the Rijen SST has a low hydraulic capacity of around 64 % of the 1DFT SOR limit (or 74 % of the 1DFT SLR limit) and is relatively insensitive to hydraulic loading variation arising from a wide range in flux load factors from 2.5 to 6.4 m/h.

To place the Rijen SettlerCAD simulation results in context of the Darvill and Watts simulation results, the results are plotted together in Figures 6.8a and 6.8b. The Rijen SettlerCAD predicted SOR and SLR limits (◆) lie below the Darvill old (●) and new (■) and Watts (▲) SST “lines”, but closer to the old SST line. Considering that with respect to external SST geometry, the Rijen SST (2.25 m SWD and 1:12 sloping bottom) is closer in likeness to the old Darvill SST (2.5 m SWD and flat bottom), the expectation is that the Rijen results should fall close to the old Darvill SST results, and this to some extent, did indeed happen.



Figures 6.8a and 6.8b: SettlerCAD predicted maximum SOR (Fig. 6.8a, left) and SLR (Fig. 6.8b, right), as a percentage (%) of the 1DFT limit values, versus flux load factor (V_o/nX_f) for the 4 tests on the Darvill new (■) and old (●) SSTs, 15 tests on the Watts' SST (▲) and 6 of the 14 tests on the Rijen SST (◆).

6.5 : RESULTS OF THE Oss FULL-SCALE SST ACTUAL STRESS TESTS

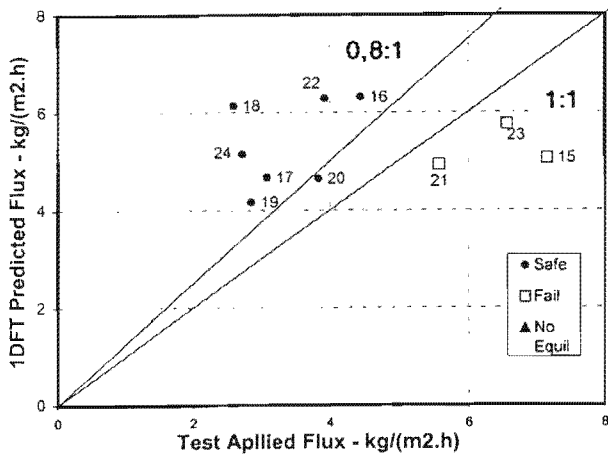
From the V_o , n and X_F the 1DFT predicted maximum SOR and SLR were calculated for the 10 Oss SLR tests and are listed in Table 6.5. The 1DFT predicted and test applied SLRs and the test applied/1DFT predicted SLR ratio from Table 6.5 are plotted in Figures 6.9a and 6.9b. Of the 10 tests, 3 tests ended fail (F, \square , i.e. Tests 15, 21 and 22), and 7 ended safe (S, \bullet , i.e. Tests 16 to 20, 22 and 23). From Fig. 6.9b, the test applied/1DFT predicted maximum SLR ratios for the 10 tests are between 0.422 (Test 18) and 1.417 (Test 15). Tests 15, 21 and 22 all have test applied/1DFT predicted SLR ratios > 1.10 which would be expected to fail and do. Of the 7 safe tests, it was expected that the 3 tests 18, 23 and 24 end safe because they have low (< 0.65) test applied/1DFT predicted maximum SLR ratios. The only possible odd test of the 10 is Test 20, which at a test/1DFT maximum SLR ratio of 0.83 ended safe, which is possibly close or slightly over the SettlerCAD predicted maximum SLR. The fail test with the lowest test applied/1DFT predicted SLR ratio is Test 21 at 1.13. This makes the range between the highest safe and lowest fail tests very large (30 %), with the result that the Oss tests are not useful to check the accuracy with which SettlerCAD predicts SST capacity. In hind sight, it would have been better to simulate some of the 23 other SLR stress tests on the 23 different SSTs in the STOWa (1981) data set, rather than the Oss SST tests because the Oss tests are unlikely to add more to the outcomes of this research.

At an average of about 8 h computation time per run (on a Pentium 500 MHz, PC) and at least 16 runs per test (if failure is found in one of the first 8 runs) computation time per test is 128 h, or 5 days. Because this amounts to 4 months computation for the 33 tests, these tests unfortunately could not be included in this study. However, they are being conducted and will be included in later reports on this work.

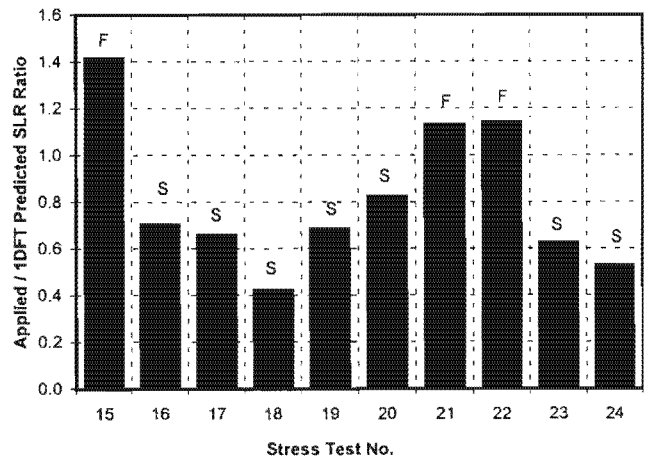
Table 6.5 : Summary of the 10 SLR stress test results on the STOWa Oss SST.

Parameter		STOWa Test # Oss Test #	Test 15 Test 1	Test 16 Test 2	Test 17 Test 3	Test 18 Test 4	Test 19 Test 5	Test 20 Test 6a	Test 21 Test 7	Test 22 Test 8	Test 23 Test 9	Test 24 Test 10
SST	Number of SSTs		1	1	1	1	1	1	1	1	1	1
	Surface area (m ²)		1 372	1 372	1 372	1 372	1 372	1 372	1 372	1 372	1 372	1 372
Actual test loading conditions	Influent flow (M ℓ /d)		27.0	27.0	24.4	24.4	22.4	22.4	21.1	21.1	16.8	15.2
	Overflow rate SOR (m/h)		0.82	0.82	0.74	0.74	0.68	0.68	0.64	0.64	0.51	0.46
	Recycle flow (M ℓ /d)		13.0	20.3	13.2	20.5	13.2	20.4	1.31	20.5	20.2	20.6
	Underflow rate (m/h)		0.394	0.615	0.400	0.622	0.401	0.619	0.397	0.621	0.612	0.626
	Recycle ratio		0.48	0.75	0.541	0.841	0.590	0.910	0.620	0.970	1.200	1.361
	Feed Concentration (g/ ℓ)		5.900	3.100	2.700	1.900	2.640	2.950	5.380	5.210	3.500	2.500
	Applied SLR [kgSS/(m ² .h)]		7.16	4.45	3.08	2.59	2.85	3.83	5.58	6.57	3.93	2.72
	Weir loading rate [m ³ /(h.m)]		8.57	8.57	7.73	7.73	7.11	7.11	6.69	6.69	5.33	4.81
HLR [(qA+qR), m/h]		1.214	1.435	1.140	1.362	1.081	1.299	1.037	1.261	1.122	1.086	
Sludge settleability	V ₀ (m/h)		6.53	5.94	5.94	5.94	5.20	4.37	6.33	5.38	5.94	4.86
	n (ℓ /g)		0.406	0.433	0.433	0.433	0.470	0.515	0.415	0.460	0.433	0.488
	SSVI (DSVI) (m ℓ /g)		90	100	100	100	(170)	130	(140)	110	100	120
1DFT predicted limits	Maximum SLR [kg/(m ² .h)]		5.06	6.31	4.67	6.14	4.16	4.65	4.93	5.76	6.28	5.15
	Overflow rate (m/h)		0.463	1.419	1.330	2.607	1.174	0.956	0.520	0.485	1.184	1.434
	Influent Q _i (excl. Q _R) : (m ³ /h)		653.3	1 947.4	1 825.5	3 578.7	1 611.5	1 312.2	713.4	665.3	1 624.5	1 968.6
Flux rating	Flux load factor [V ₀ /(nX _F), m/h]		2.73	4.42	5.08	7.22	4.20	2.88	2.83	2.24	3.92	3.98
	Test/1DFT SLR ratio		141.7	70.6	65.9	42.2	68.6	82.5	113.1	114.0	62.5	52.7
	Test/1DFT SOR ratio		177.2	57.8	55.6	28.4	57.9	71.1	123.1	132.0	43.1	32.1

STOWa (Oss) SST Stress Tests
Actual SLR Stress Test 15 to 24



STOWa (Oss) SST Stress Test
Actual Stress Tests 15 to 24



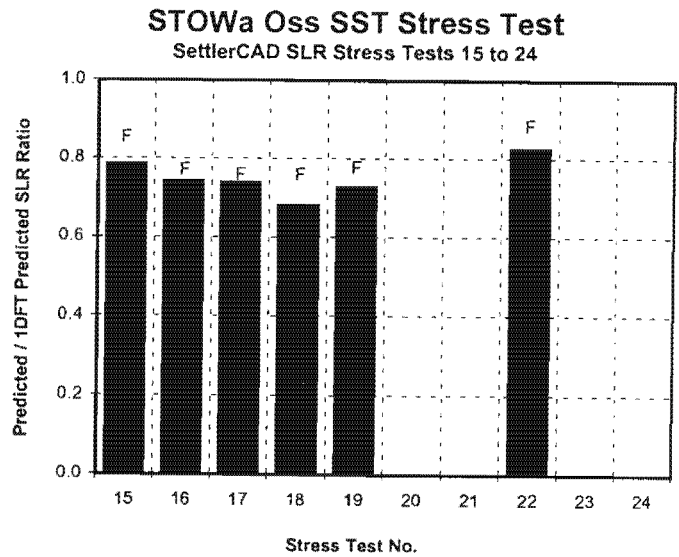
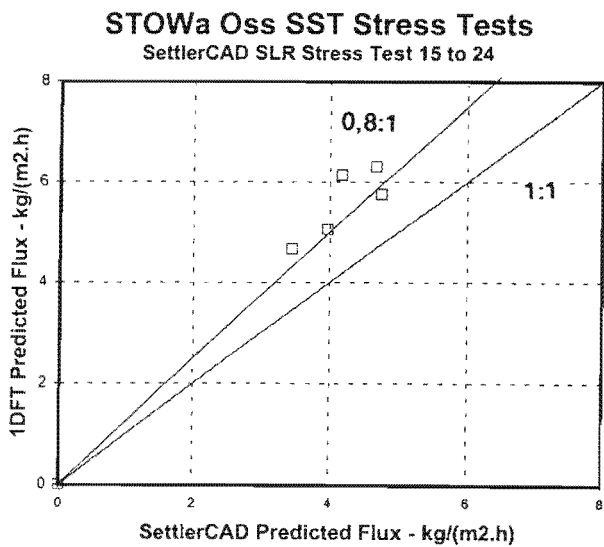
Figures 6.9a and 6.9b: 1DFT maximum SLR versus test applied SLR (Fig. 6.9a, left) and Test applied /1DFT predicted maximum SLR ratio (Fig. 6.9b, right) for the 10 Stress tests reported by STOWa (1981) on the Oss SST.

6.6 : FINDING THE SettlerCAD MAXIMUM SOR AND SLR FOR THE Oss SSTs

6.6.1 : SettlerCAD predicted failure

The data given in Table 6.5 were used as input to SettlerCAD. Like for the Rijen tests, for 6 of the 10 Oss tests, 16 SettlerCAD runs per test were set-up. The 6 tests selected were the 2 tests with the highest flux load factor (Tests 18 and 17), the 2 tests with the lowest flux load factor (Tests 22 and 15) and the 2 tests nearest the average flux load factor (Tests 16 and 19). SettlerCAD runs 1 to 7, for each of the 6 tests simulated, were at Q_i from 60 to 72 % of the 1DFT SOR in 2 % increments and an 8th run at 100 %. Runs 9 to 15 were set-up between consecutive safe and fail runs at 0.25 % increments and the 16th run was at the actual test Q_i . The first run with $ESS > 50 \text{ mg/l}$ was accepted as the SettlerCAD predicted maximum influent rate limit. The SettlerCAD SLR limit was calculated from the Q_i limit and the test Q_R and X_F values.

The SettlerCAD predicted results of the first failure runs are given in Table 6.6 and are shown plotted in Figures 6.10a and 6.10b. In Fig. 6.10a and 6.10b (or Table 6.6) it can be seen that the SettlerCAD predicted flux rating of the Oss SSTs ranges between 0.730 (Test 19) and 0.832 (Test 22).



Figures 6.10a and 6.10b: 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Fig. 6.10a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig. 6.10b, right) for STOWa SLR Stress Tests 15 to 19 and 22 on the Oss SST.

Fig 6.10a shows the SettlerCAD maximum predicted SLR (flux rating) of 5 of the 6 tests (not Test 22) fall above the 0.80 flux rating line indicating that the SettlerCAD maximum SLR is around 0.74 of the 1DFT maximum. The SettlerCAD predicted maximum SOR (as % of the 1DFT maximum) ranged between 60.2 % (Test 15) and 63.5 % (Test 19).

Table 6.6: Summary of the settlerCAD simulation results for the settlerCAD influent flow limit for the 10 SLR tests on STOWa Oss SSTs.

SettlerCAD Q _i LIMIT	STOWa Test # Oss Test #	Test 15 Test 1	Test 16 Test 2	Test 17 Test 3	Test 18 Test 4	Test 19 Test 5	Test 20 Test 6	Test 21 Test 7	Test 22 Test 8	Test 23 Test 9	Test 24 Test 10
Flux factor $V_o/(nX_F) - \text{m/h}$		2.73	4.42	5.08	7.22	4.20	2.88	2.83	2.24	3.92	3.98
Influent flow (m ³ /h) for 1 SST		3 82.7	1 226.9	1 204.8	2 165.1	1 027.3			410.8		
% of 1DFT maximum Q _i		60.25	63.00	66.00	60.50	63.75			61.75		
Overflow rate (m/h)		0.28	0.89	0.88	1.58	0.75			0.30		
Recycle flow (m ³ /h)		540.7	844.1	549.0	853.7	550.4			852.3		
Underflow rate (m/h)		0.395	0.615	0.400	0.622	0.401			0.621		
Recycle ratio		1.41	0.69	0.46	0.39	0.54			2.07		
Applied flux [(kgSS)/(m ² .h)]		3.97	4.68	3.45	4.18	3.03			4.79		
% of 1DFT maximum flux		78.5	74.2	73.9	68.1	73.0			83.2		
Actual retention time (h)		3.8	1.7	2.0	1.2	2.2			2.8		
Duration of run (min)		4 000	4 000	4 000	4 000	4 000			4 000		
Duration of run (# of R _{ha})		17.4	39.0	33.0	56.8	29.7			23.8		
Sim time step (min)		2.5	2.5	2.5	2.5	2.5			2.5		
Sim time step (% R _{ha})		1.09	2.44	2.06	3.55	1.86			1.49		
Effluent SS (mg/ℓ)*		64.8	54.9	63.6	50.1	50.9			52.1		
Recycle Conc (mg/ℓ)*		9 949	7 510	8 350	6 585	7 456			7 670		
Mass balance (%)*		99.2	99.8	98.4	99.9	99.8			99.7		
Test result (ESS > 50 mg/ℓ)		Fail	Fail	Fail	Fail	Fail			Fail		

* Mean over the last 2 R_{ha} values

6.6.2 : SettlerCAD simulation of the full-scale actual stress test

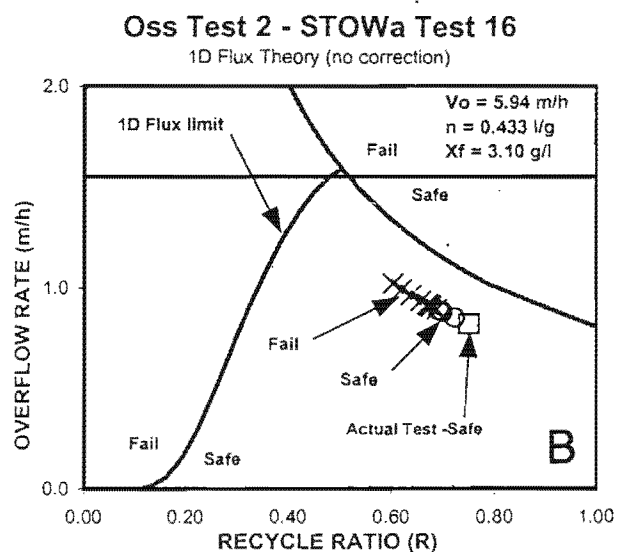
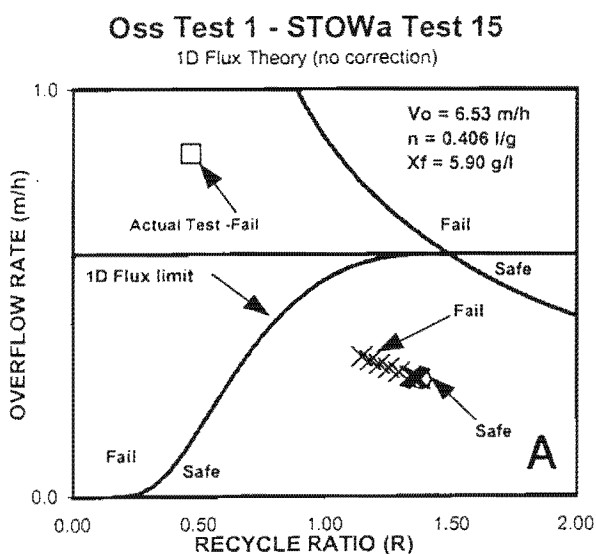
The results of the simulation runs at the actual test influent flow are summarised below in Table 6.7.

Table 6.7 : Summary of the SettlerCAD simulations results for the Oss full-scale SST actual test.

Actual test influent flow	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6a	Test 6b	Test 7	Test 8	Test 9
Influent flow (m ³ /h) for 1 SST	1 125.4	1 125.4	1 015.6	1 015.6	933.3	933.3	878.4	878.4	700.0	631.3
% of 1DFT maximum Q _i	177.2	57.8	55.6	28.4	57.9	71.1	123.1	132.0	43.1	32.1
Overflow rate (m/h)	0.82	0.82	0.74	0.74	0.68	0.68	0.64	0.64	0.51	0.46
Recycle flow (m ³ /h)	13.0	20.3	13.2	20.5	13.2	20.4	13.1	20.5	20.2	20.6
Underflow rate (m/h)	0.394	0.615	0.400	0.622	0.401	0.619	0.397	0.621	0.612	0.626
Recycle ratio	0.480	0.750	0.541	0.841	0.590	0.910	0.620	0.970	1.200	1.361
Applied flux [(kgSS)/(m ² .h)]	7.16	4.45	3.08	2.59	2.85	3.83	5.58	6.57	3.93	2.72
% of 1DFT maximum flux	141.7	70.6	65.9	42.2	68.6	82.5	113.1	114.0	62.5	52.7
Actual retention time (h)	2.1	1.8	2.3	1.9	2.4	2.0	2.5	2.0	2.3	2.4
Duration of run (min)	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000
Duration of run (# of R _{ha})	31.4	37.1	29.5	35.2	27.9	33.6	26.8	32.6	29.0	28.1
Sim time step (min)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sim time step (% R _{ha})	1.96	2.32	1.84	2.20	1.75	2.10	1.67	2.04	1.81	1.75
Effluent SS (mg/ℓ)*	2 768.1	6.3	2.8	0.9	7.0			2 036.3		
Recycle Conc (mg/ℓ)*	10 929.8	6.3	7 691.0	4 159.4	7 105.6			7 926.0		
Mass balance (%)*	91.8	100.0	100.0	100.0	100.0			94.8		
Test result (ESS > 50 mg/ℓ)	Fail	Safe	Safe	Safe	Safe			Fail		
Observed result	Fail	Safe	Safe	Safe	Safe	Safe	Fail	Fail	Safe	Safe

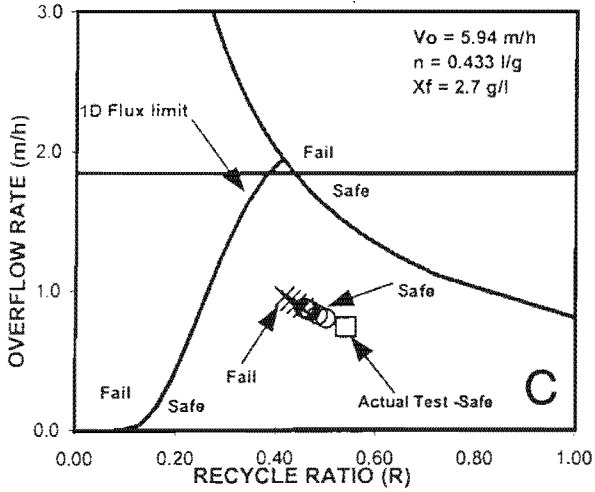
* Mean over the least 2 R_{ha} values.

The position and result (Safe O, fail X) of the SettlerCAD simulation runs for the simulated Tests 15 to 19 and 22 are shown in the D&O charts in Figures 6.11a to 6.11f. The actual test position and result (safe O, fail X) is also indicated. If the actual test position of the safe tests is within or below the safe (O) runs, then SettlerCAD correctly predicted a safe result for the actual test. Similarly, if the actual test position of the fail tests is within or above the fail (X) runs, then SettlerCAD correctly predicted a fail result for the actual test. From the six D&O charts, SettlerCAD correctly predicted the result for all 6 tests simulated. In fact, had all 10 Oss tests been simulated, SettlerCAD would have predicted the test result correctly for all the tests except possibly not Test 20. This is not so remarkable as it may seem because the SLR (and SOR) range between the highest safe test (Test 20) and lowest fail test (Test 21) is 30 % (see Fig. 6.9b). The flux rating range between safe and failure is therefore between 83 % and 113 % and any predicted flux rating in this range would yield a correctly predicted result. This is too wide a range to be meaningful. This is shown in Figures 6.14a and 6.14b, which plot the SettlerCAD predicted maximum SOR and SLR versus the flux load factor.



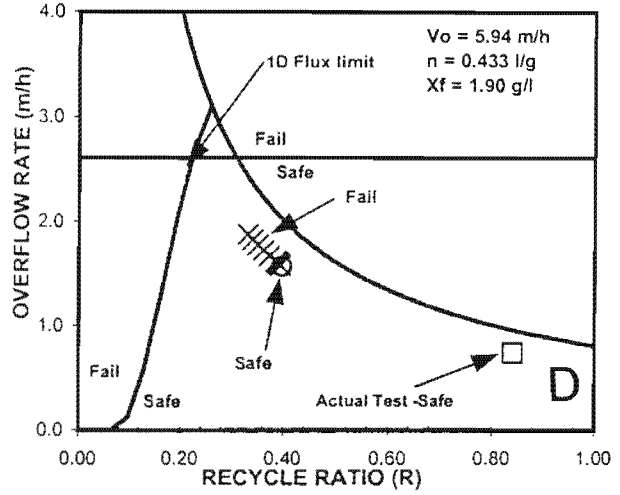
Oss Test 3 - STOWa Test 17

1D Flux Theory (no correction)



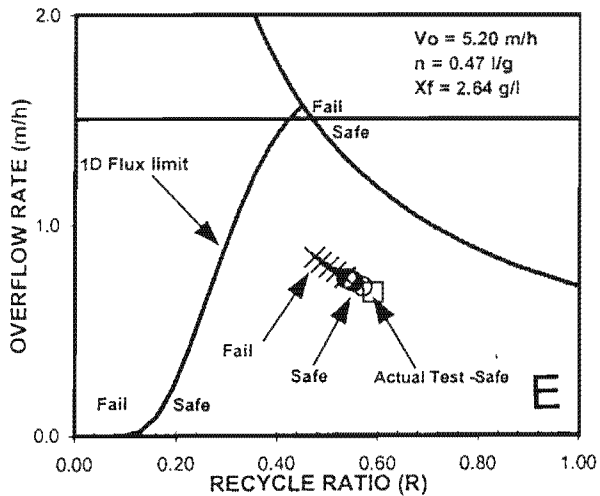
Oss Test 4 - STOWa Test 18

1D Flux Theory (no correction)



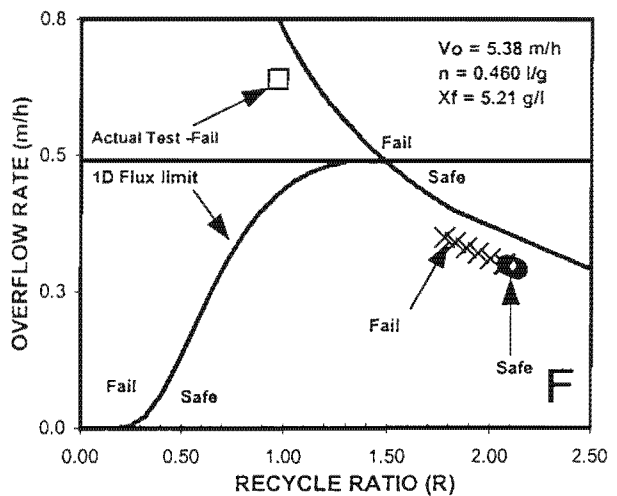
Oss Test 5 - STOWa Test 19

1D Flux Theory (no correction)



Oss Test 8 - STOWa Test 22

1D Flux Theory (no correction)



Figures 6.11a to 6.11f: 1DFT D&O charts showing the SST operating positions and result (safe O, fail X) of the SettlerCAD runs and actual tests for STOWa Test 15 to 19 and 22 on the Oss SST.

6.7 : EVALUATING THE OUTPUT RESULTS OF SettlerCAD

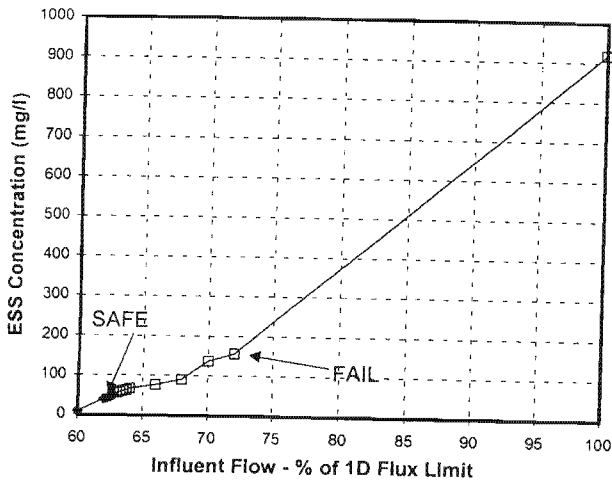
6.7.1 : Determination of solids mass balance

In the simulation runs, a simulation time of 4 000 min was selected which was 18 to 57 times the actual hydraulic retention time (R_{na}) with respect to the SettlerCAD predicted SOR and SLR limits. As for the previous test runs, these run times were sufficiently long to establish a final steady state condition and the final ESS and RAS (X_R) concentrations accepted for each run were the averages of the predicted values over the last $2 \times R_{na}$. The solid mass balance was based on these final average ESS and RAS concentrations (which are listed in Table 6.7). The same pattern regarding the mass balance was observed – provided the run ended safe ($ESS < 50 \text{ mg/} \ell$), the run yielded a solids mass balance within 0.5 % of 100 % and runs that ended in failure ($ESS > 50 \text{ mg/} \ell$) yielded a lower than 99.5 % solids mass balance; the greater the SST overload (i.e. the higher the ESS concentration), the lower the solids mass balance below 99.5 %.

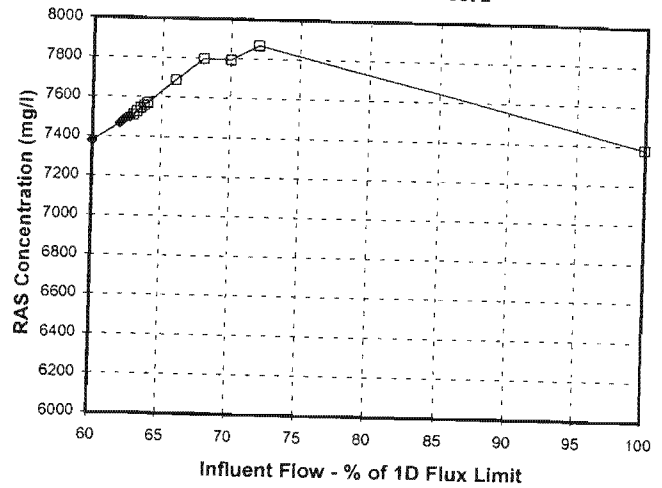
The ESS, RAS and percentage (%) mass balance versus influent flow (as % of the 1DFT limit Q_i) for Test 16, which is one of the safe tests, are shown in Figures 6.12a to 6.12c.

In Figure 6.12d, the % mass balance versus simulation time for runs 1 to 8 of Test 16 at 60 to 72 % and 100 % of the 1DFT maximum influent flow are shown. It can be seen that for the failed runs, even though a final steady state is achieved, this steady state does not yield a mass balance.

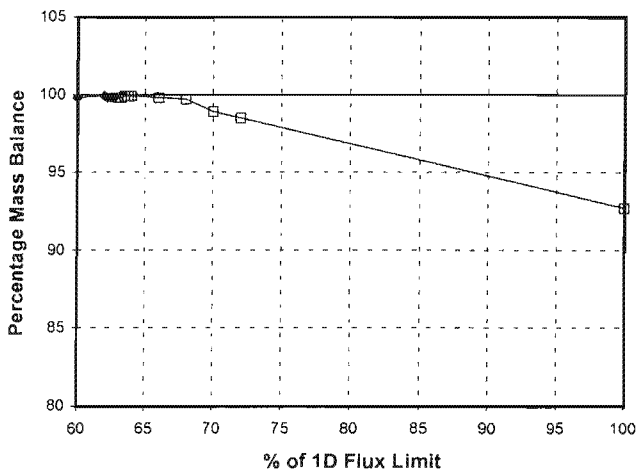
Steady State ESS Concentration
STOWa Test 16 - Oss Test 2



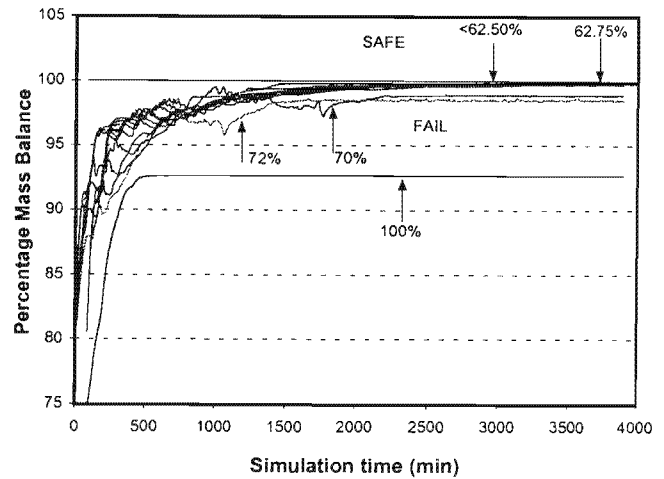
Steady State RAS Concentration
STOWa Test 16 - Oss Test 2



Solids Mass Balance
STOWa Test 16 - Oss Test 2



Solids Mass Balance
STOWa Test 16 - Oss Test 2

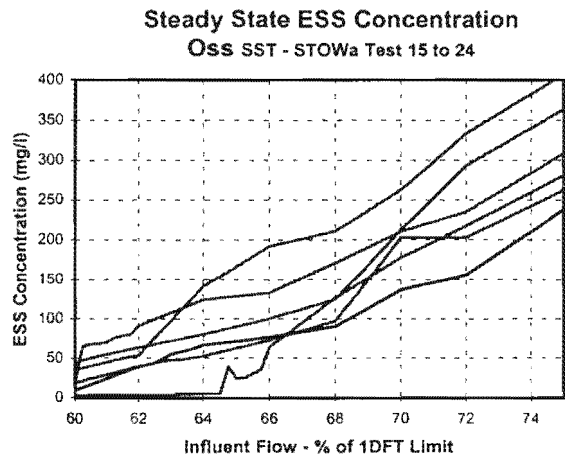
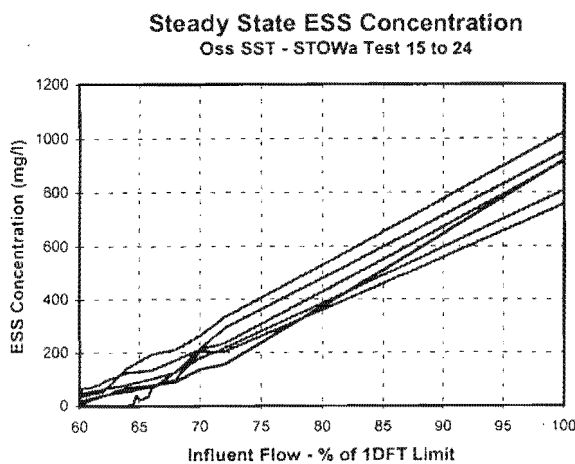


Figures 6.12a to 6.12d: Final ESS and RAS concentrations (Fig. 6.12a, top left and Fig. 6.12b, top right) and percentage (%) mass balance (Fig. 6.12c, bottom left) versus influent flow as % 1DFT limit showing runs ended safe (◆) and fail (□) and percentage (%) mass balance versus simulation time (Fig. 6.12d, bottom right) for the SettlerCAD runs on the STOWa Test 16 on the Oss SST.

6.7.2 : ESS concentration versus influent flow

The final average ESS concentration versus Q_i (as a % of the 1DFT limit) for the 6 Oss tests simulated are shown in Fig. 6.13. It can be seen that the ESS concentration increases gradually above 50 mg/l in the range between 60 and 66 % of the 1DFT limit influent flow. The gradual increase in ESS concentration of the shallow (2.0 m SWD) Oss SST resembles that of the Darvill old and Rijen SSTs.

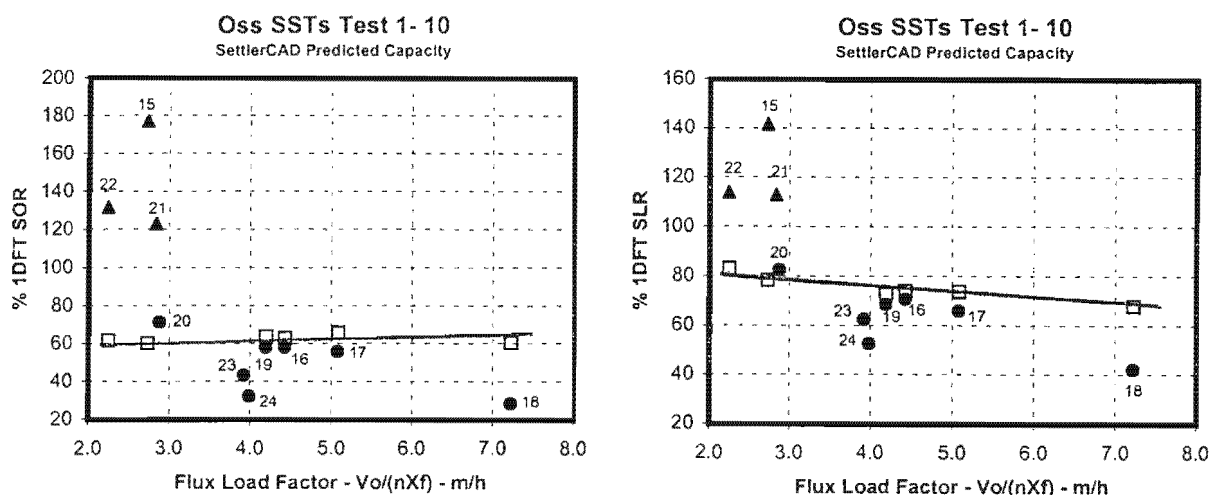
This appears consistent because the average depths (adding the volume of the bottom cone as equivalent SWD) of these SSTs are 2.50 and 2.88 m respectively, while that of the Oss SST is 2.58 m. The diameter to average depth (D/H_{ave}) ratios for Darvill old, Rijen and Oss SSTs are 14.0, 15.8 and 16.2 respectively, whereas those for the Darvill new and Watts SSTs are 7.48 and 7.29 respectively. This indicates that the higher D/H_{ave} value result in a gradual increase in ESS concentration with increased influent flow.



Figures 6.13a and 6.13b: Final steady state ESS concentration versus influent flow as a percentage (%) of the 1DFT limit for the 6 Oss SST tests simulated.

6.7.3 : Flux load factor versus 1DFT limits

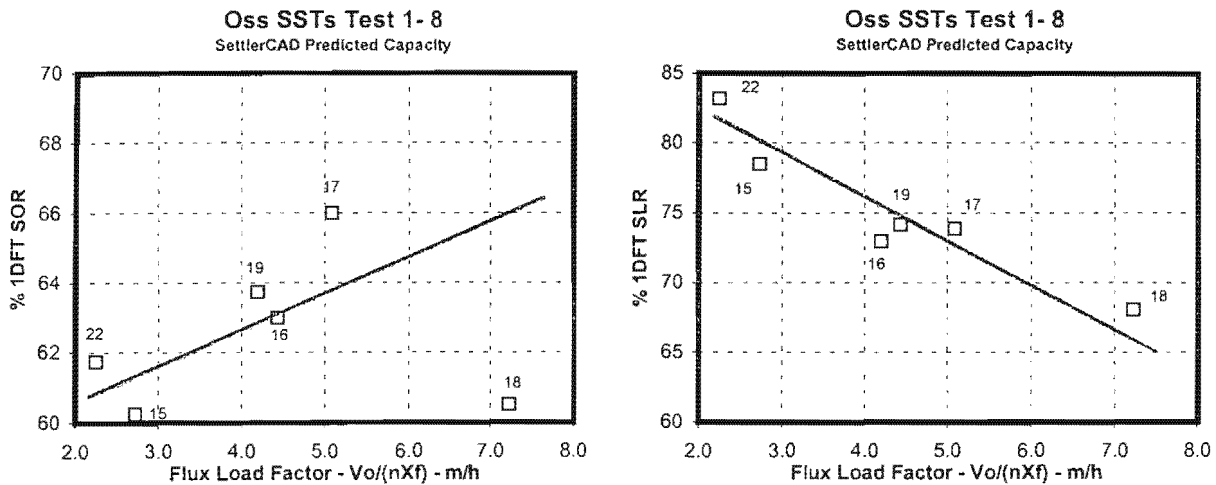
The SettlerCAD predicted maximum SOR and SLR, as a % of the 1DFT limits, are plotted versus the flux load factor $V_o/(n.X_f)$ in Figures 6.14a and 6.14b, respectively.



Figures 6.14a and 6.14b: SettlerCAD predicted maximum SOR (\square) (Fig. 6.14a, left) and SLR (\square) (Fig. 6.14b, right), as a percentage (%) of the 1DFT limit values versus flux load factor $V_o/(n.X_f)$. Also shown are the 10 actual test points safe (\bullet), fail (\blacktriangle) identified by test number.

Also shown in Figures 6.14a and 6.14b are the 10 actual test points. In these figures, the actual tests that ended safe and fail which plot *below* and *above* the SettlerCAD predicted SOR and SLR limits (line through \square) respectively, are the tests that SettlerCAD would predict correctly. Similarly, the actual tests that ended safe and fail which plot *above* and *below* the SettlerCAD predicted SOR and SLR limits (line through \square), are tests which SettlerCAD predicted incorrectly. From this, the only test which SettlerCAD predicted incorrectly is Test 20, which ended safe but plots slightly above the SettlerCAD line. In Figures 6.14a and 6.14b, Tests 21 and 22 (both fail) plot at around 114 % and 125 % of the 1DFT SOR and SLR limits above the “SettlerCAD lines” and Tests 20, 23, 19 16 and 17 (all safe) plot at around 60 % and 70 % of the 1DFT SOR and SLR limits below the “SettlerCAD lines”. The gap between the safe and fail tests therefore is quite large, 40 %.

This means the SettlerCAD lines can plot in a 40 % range and still predict 10 out 10 test results correctly. Therefore, the Rijen tests, and the Oss tests are not very useful for checking the accuracy with which SettlerCAD predicts SST capacity.



Figures 6.15a and 6.15b: SettlerCAD predicted maximum SOR (Fig. 6.15a, left) and SLR (Fig. 6.15b, right), as a percentage (%) of the 1DFT limit values versus flux load factor $V_o/(nX_f)$ for the six Ooss SST tests simulated with SettlerCAD identified by test number.

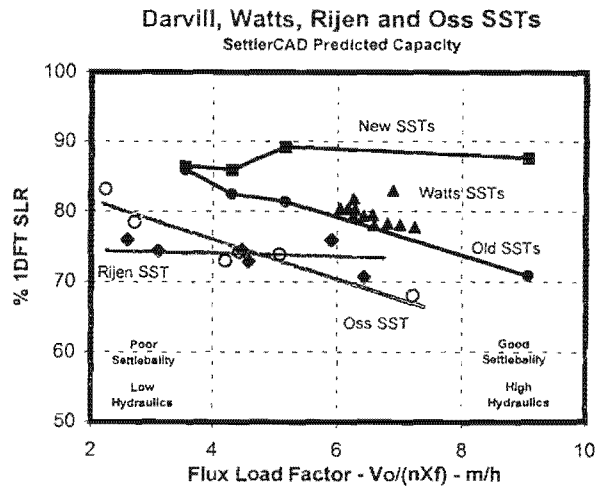
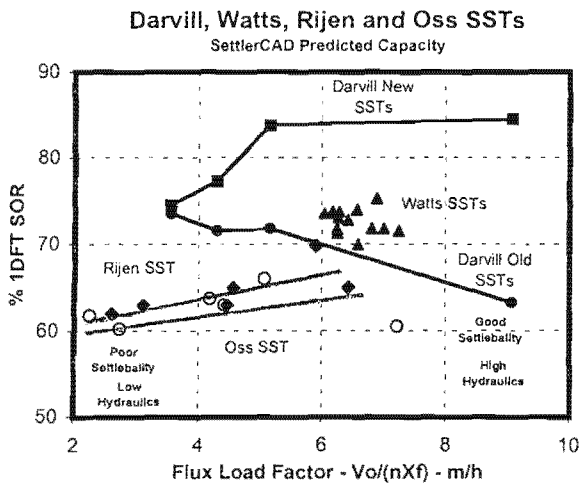
Figures 6.15a and 6.15b, which are the same as Figures 6.14a and 6.14b but with a vertical scale range of only 10 % and 25 % of the 1DFT limit SOR and SLR, respectively, show a small increasing and decreasing trend respectively in the SettlerCAD predicted SOR and SLR as the flux factor increases for the 6 tests simulated – for the SOR (Fig. 6.15a) from 60 % (Test 15) to 66 % (Test 17) and for the SLR (Fig. 6.15b) from 82 % (between Tests 15 and 22) to 68 % (Test 18). This indicates that the Ooss SST has a low hydraulic capacity of around 64 % of the 1DFT SOR limit (or 74 % of the 1DFT SLR limit), but appears to be relatively insensitive to hydraulic loading variation arising from a wide range in flux load factor from 2.5 to 6.4 m/h.

6.8 : CONCLUSION FROM THE RIJEN AND Oss SSTs SIMULATIONS

From the evaluation of the SettlerCAD simulation runs for the Rijen SST and Oss SST, with a diameter to average depth ratio (D/H_{ave}) of 15.79 and 16.20 respectively, the following conclusions can be made:

- The SettlerCAD predicted maximum SOR and SLR flux ratings for the Rijen and Oss SSTs were significantly below those calculated from the 1DFT and ranged between 62 and 67 % and 75 to 72 % respectively as the flux load factor increased from 2.5 to 6.5 m/h.
- The influence of depth on the flux rating is that the deeper the SST and the lower the HLR, the closer the flux rating is to 1.0.
- The Rijen and Oss stress test results show once again that the 1DFT cannot be applied to a full-scale SST without an appropriate reduction factor. The magnitude of this reduction factor is not universal and is influenced by the geometry of the SST.

To place the SettlerCAD simulation results in context, the Darvill, Watts, Rijen and Oss simulation results are plotted together in Figures 6.16a and 6.16b. The Rijen and Oss SettlerCAD predicted SOR and SLR limit results (Rijen \blacklozenge , Oss O) lie below the Darvill old (\bullet) SST line. Considering that with respect to external SST geometry, the Rijen SST (2.25 m SWD and 1:12 bottom slope - 3.03 m average depth, H_{ave}) and Oss SST (2.0 m SWD with 1:12 bottom slope - 2.58 m average depth, H_{ave}) are closer in likeness to the old Darvill SST (2.5 m SWD and flat bottom) than the new Darvill (4.1 m SWD with 1:10 bottom slope - 4.68 m average depth, H_{ave}) and Watts (3.66 m SWD with 1:15 bottom slope - 3.97 m average depth, H_{ave}) SSTs, the results appear to be reasonably consistent.



Figures 6.16a and 6.16b: SettleCAD predicted maximum SOR (Fig. 7.8a, left) and SLR (Fig. 7.8b, right), as a percentage (%) of the 1DFT limit values, versus flux factor $V_o/(nX_f)$ for the 4 tests on the Darvill new (■) and old (●) SSTs, the 15 tests on the Watts' SST (▲) and 6 of the 14 tests on the Rijen SST (◆) and 6 of the 10 tests on the Oss SST (○).

CHAPTER 7

CONCLUSIONS

In this research, the two dimensional (2D) hydrodynamic model SettlerCAD (Zhou *et al.*, 1998) was applied to full scale circular secondary settling tank (SSTs) with the principle aim to:

- 1) establish whether or not it “automatically” reproduces a flux rating < 1.0 with respect to the steady state 1D idealized flux theory (1DFT) and;
- 2) determine what factors influence this flux rating.

To do this, SST solids loading rate (SLR) stress tests reported in the literature were simulated. These are:

- 1) the 4 tests done by de Haas *et al.* (1998) on 4 similar 35 m diameter SSTs (2 new and 2 old) of the Darvill wastewater treatment plant (WWTP), Pietermaritzburg, South Africa;
- 2) the 15 tests done by Watts *et al.* (1996) on a single 3.66 m side water depth (SWD), 28.96, diameter circular SST with centre feed, peripheral and radial effluent overflow and rotating multiple suction pipe sludge collection system at the Kanapaha WWTP (Florida, USA), and;
- 3) 12 of the 47 tests done by STOWa (1981) (Stopkoper and Trentelman, 1982) on 25 different SSTs ranging from 30 to 46 m in diameter, 1.5 to 2.5 m (SWD) and 1:12 sloping bottoms with scraped sludge collection.

7.1 FINDING THE MAXIMUM SLR AND SOR OF SettlerCAD

From the measured V_0 , n and feed concentration (X_F) and recycle flow (Q_R) of a particular SLR stress test, the maximum surface overflow rate (SOR) and minimum recycle ratio (R_{min}) were calculated from the 1DFT. Details on how this calculation is done are given by Ekama *et al.* (1997) but the principles are shown in the 1DFT design and operating (D&O) chart (Fig 3.1a – Chapter 3). The solids handling criterion (SHC) I and II lines and the hyperbola (which marks the boundary where the SHC I does and does not apply) are completely specified by the V_0 , n and X_F values. First the minimum recycle ratio (R_{min}) for the maximum SOR ($q_A = Q_I/A_{ST}$, m/h) is determined by setting the equations for SHC I and II equal and solving for R which is R_{min} . This R_{min} is used as a reference recycle ratio to check whether SHC I or SHC II governs the maximum capacity of the SST for the particular underflow rate ($q_A = Q_R/A_{ST}$, m/h) of the SLR test. If the R of the test is less than R_{min} , the locus of the SST operating points at constant underflow rate (q_R , m/h) and increasing SOR (q_A , m/h) cuts the SHC I line at an R value $< R_{min}$. This means that the SHC I fixes the maximum SOR and SLR of the SST for the fixed q_R and X_F of the particular test and the maximum SOR and SLR capacities in terms of the 1DFT are given by the intersection point of the SOR – R locus line at the SHC I line; viz. $SOR_{max} = q_A$ m/h and $SLR_{max} = (q_A + q_R)X_F$ or $q_A (1 + R)X_F$ kg/(m².h); the maximum hydraulic loading rate (HLR_{max}) associated with this intersection point is $HLR_{max} = (q_A + q_R)$ or SLR_{max}/X_F m/h. If the R of the test is greater than R_{min} , the locus of the SST operating point at constant q_R and increasing SOR cuts the SHC I line with a R value $> R_{min}$. This means that the SHC II fixes the maximum SOR and SLR of the SST for the fixed q_R and X_F of the particular test and the maximum SOR and SLR capacities in terms of the 1DFT are defined by the intersection point of the SOR- R locus line and the SHC II line; viz. $SOR_{max} = q_A$ m/h, $SLR_{max} = (q_A + q_R)X_F$ or $q_A (1 + R) X_F$ kg/(m².h) and $HLR_{max} = q_A + q_R$ or SLR_{max}/X_F m/h.

The design of SST surface area (A_{ST}) with the 1DFT hinges round identifying the intersection point of the SHC I and II lines for the specified X_F and V_O & n , and this point is the SST operating position for the Peak Wet Weather Flow (PWWF, $Q_{i,PWWF}$). It gives the maximum overflow rate (q_{Amax}) for the minimum recycle ratio (R_{min}). From the design SST surface area, A_{ST} is given by $A_{ST} = Q_{i,PWWF}/q_{Amax}$ and the recycle flow (Q_R , PWWF) by Q_R , PWWF = $R_{min} \times q_{Amax}$. The maximum SLR and HLR associated with this design point are $SLR_{max} = q_{Amax}(1+R_{min})X_F$ kg/(m²h) and $HLR_{max} = q_{Amax} (1+R_{min})$ or SLR_{max}/X_F kg/(m²h).

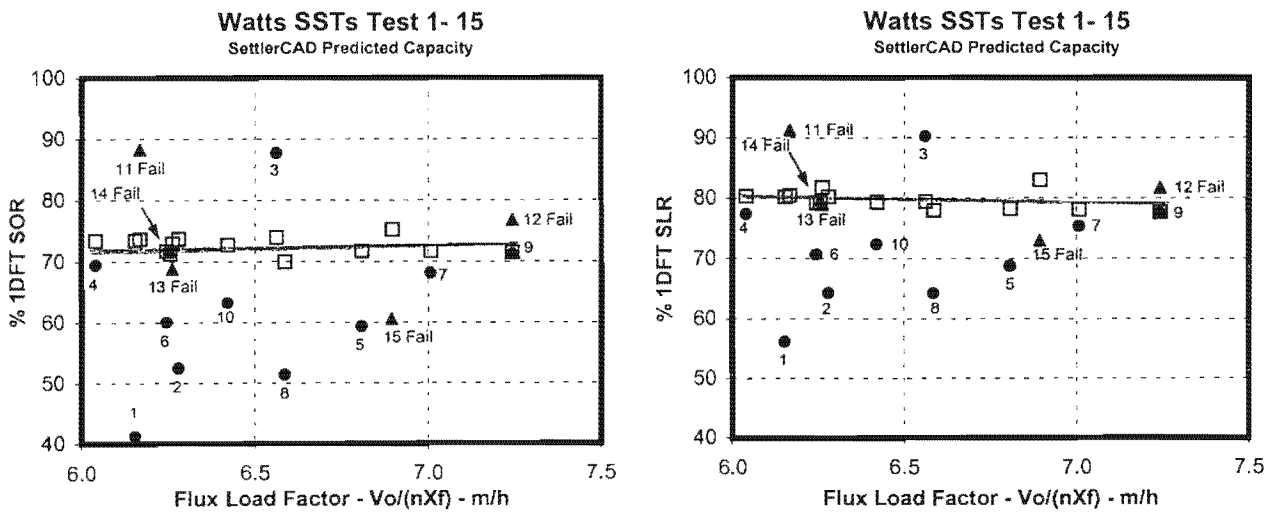
The stress test data and details of the SSTs reported in the literature were used as input to SettlerCAD. Keeping the recycle flow (Q_R) and feed concentration (X_F) constant at the test values, the influent flow (Q_i), calculated as a % of the 1DFT limit value, was increased for successive simulation runs from a low value to a high value, first in 2 % of 1DFT limit increments, and then in 0.25 % of 1DFT limit increments between consecutive safe and fail runs. SST failure was accepted to be an average ESS > 50 mg/l over the final 2 actual hydraulic retention times (R_{ha}) of the run. In this way the steady state influent flow rate (Q_i) for ESS > 50 mg/l was determined for SettlerCAD at an accuracy of 0.25 % of the 1DFT limit and the first run with ESS > 50 mg/l was accepted as the SettlerCAD predicted maximum influent flow rate limit. The SettlerCAD SLR limit was calculated from the predicted influent flow limit and the test Q_R and X_F values. The predicted ESS and RAS concentrations over the complete run were imported into a spreadsheet program, in which were calculated (i) the average ESS and RAS concentrations over the final 2 actual hydraulic retention times ($2 \times R_{ha}$) and (ii) the % solids mass balance as the run proceeded. The outcome (fail or safe) of each simulation run was recorded by checking sludge blanket height in SettlerCAD at the end of each simulation and whether the average ESS concentration over the final $2 \times R_{ha}$ was greater (fail), or less (safe) than 50 mg/l.

The % mass balance was calculated as the sum of the masses of sludge in the return and effluent flows as a % of the mass of sludge entering the SST with the influent and recycle flows.

7.2 VALIDATION OF SettlerCAD PREDICTION ACCURACY

7.2.1 Watts SLR stress tests

The SettlerCAD predicted maximum SOR and SLR (\square), as a % of the 1DFT limits, are plotted versus the flux load factor $V_o/(nX_F)$ in Figures 7.1a and 7.1b. Also shown are the 15 actual test points (safe \bullet and fail \blacktriangle). In these figures, the actual tests that ended safe and fail which plot *below and above* the SettlerCAD predicted SOR and SLR limits, are tests the result of which SettlerCAD predicted correctly; the actual tests that ended safe and fail which plot *above and below* the SettlerCAD predicted SOR and SLR limits, are tests the result of which SettlerCAD predicted incorrectly.



Figures 7.1a and 7.1b: SettlerCAD predicted maximum SOR (\square) (Fig 7.1a, left) and SLR (\square) (Fig 7.1b, right) as a % of the 1DFT limit values versus flux load factor ($V_o/(nX_F)$). Also shown are the 15 actual test points (safe \bullet , fail \blacktriangle) identified by the number

From all 15 tests, SettlerCAD correctly predicted the results of 12 tests, i.e. Tests 1, 2 and 4 to 10 (safe) and 11 to 13 (fail) but incorrectly predicted the results for 3 tests, i.e. Tests 3 (actual test safe, SettlerCAD fail) and 14 and 15 (actual test fail, SettlerCAD safe). Of these 3 tests, only Tests 3 and 15 plot far from the SettlerCAD predicted limit (line through □) and therefore are definitely incorrectly predicted.

However, Tests 4, 14, 13, 7, 9 and 12 all plot very close to the SettlerCAD predicted limits and are correctly predicted. This narrow range, indicates that apart from Test 3 and 15, SettlerCAD accurately identifies the SOR and SLR capacity of the Watts SST. The SettlerCAD results of the Watts tests gives a good indication that the SettlerCAD predictions are valid for the simulation of full scale stress tests.

7.2.2 Determination of solids mass balance

In setting up the simulation runs, a simulation time were selected which is more than 25 times the actual hydraulic retention time ($25 \times R_{ha}$) for all the runs. These run times were sufficiently long to establish a final steady state condition, which was confirmed by constant effluent solids concentration, constant sludge blanket height and at the end of each run, a solids mass balance was calculated. In the solids mass balance, the mass of solids exiting the SST via the underflow and overflow is calculated as a % of the inflow mass of sludge.

The final ESS (X_E) and RAS (X_R) concentrations for each run were the averages of the predicted values over the last $2 \times R_{ha}$. Provided the run ended safe ($ESS < 50 \text{ mg}/\ell$), the final concentrations yielded a solids mass balance within 0.5 % of 100 %. In contrast runs that ended in failure ($ESS > 50 \text{ mg}/\ell$) yielded a lower than 99.5 % solids mass balance and the greater the SST overload (i.e. higher the ESS concentration) the lower the solids mass balance below 99.5 %, even as low as 86 % at 100 % of the 1DFT limit influent flow.

Halving the simulation time steps and/or doubling the number of iterations per time step yielded identical simulation results and no improvement in % mass balance at the end of the run.

As the simulations proceeded it was seen that (i) the simulation runs were long enough to reach a steady state because the mass balance remained constant, and (ii) for the runs which ended in fail the mass balance remained below 99 %. It is suspected that a 100 % mass balance for the failed runs is not achieved due to a simple logical error in SettlerCAD.

It seems that the RAS concentration is "corrected" by subtracting from it the ESS concentration, because the higher the ESS concentration (or overload) the lower the RAS concentration. This is not consistent with the flux theory. Theoretically for increasing Q_i and constant Q_R and q_R the RAS concentration should remain constant (at $X_r = j_i/q_R$) once the SLR capacity (failure) has been reached. This error does not influence the SettlerCAD predicted SOR and SLR limits.

The same low solids mass balance for the failed runs ($ESS > 50 \text{ mg}/\ell$) was observed for all the SSTs simulated.

7.3 FINDING THE SettlerCAD MAXIMUM SOR AND SLR FOR THE DARVILL, WATTS, RIJEN AND Oss SSTs

The data listed in the Tables in Chapter 4, 5 and 6 were used as input to SettlerCAD. For each test, 16 SettlerCAD runs were set-up. For the Darvill new SST, runs 1 to 7 were at Q_i from 74 % to 86 % of the 1DFT SOR in 2 % increments and an 8th run at 100 %. For the Darvill old SST, the 7 runs ranged from 60 to 72 %, with an 8th at 100 %. The Watts SST ranged from 66 to 78 %, the Rijen SST ranged from 60 to 72 % and the Oss SST ranged from 60 to 72 % of the 1DFT SOR, all with an 8th run at 100 %. Runs 9 to 15 were set-up between consecutive safe and fail runs at 0,25 % increments and the 16th run was at the actual test Q_i .

The first run with $ESS > 50 \text{ mg/l}$ was accepted as the SettlerCAD predicted influent flow rate limit. The SettlerCAD flux rating (SLR) was then calculated from the Q_i limit and test Q_R and X_F values.

7.4 SIMULATING THE DARVILL SSTs

For the Darvill SSTs three different cases were simulated with SettlerCAD, and for each case the percentage (%) of the 1DFT maximum influent flow (Q_i) was determined. The three cases were as follows:

Case 1: The Darvill new and old SSTs as built, i.e. with Stamford baffles extending from the side wall and the actual side water depths i.e. old SST 2.5 m and new SST 4.1 m.

Case 2: The Darvill new and old SSTs without Stamford baffles and the actual SWDs.

Case 3: The Darvill new and old SSTs with Stamford baffles, but with interchanged SWD's i.e old SST with 4.1 m SWD and new SST with 2.5 m SWD.

A summary of SettlerCAD results for the three different cases is given in Table 7.1 below.

Table 7.1: Summary of the SettlerCAD predicted to 1DFT calculated maximum SOR and SLR ratios (i.e flux ratings) for Cases 1, 2 and 3

% of 1DFT SOR	Test 1		Test 2		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Case 1 : Normal	77.25	71.50	74.50	73.50	83.75	71.75	84.0	63.25
Case 2 : No baffles	80.00	74.50	74.30	76.25	87.30	75.80	89.00	65.00
Case 3 : Reverse depth	63.00	78.25	67.50	82.50	63.75	82.75	78.50	81.25

% of 1DFT SLR	Test 1		Test 2		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Case 1 : Normal	86.00	82.50	86.50	86.00	89.30	81.40	87.70	70.90
Case 2 : No baffles	87.70	84.30	86.40	87.50	91.60	84.10	91.30	72.30
Case 3 : Reverse depth	77.30	86.60	82.80	90.80	76.10	88.60	83.00	85.20

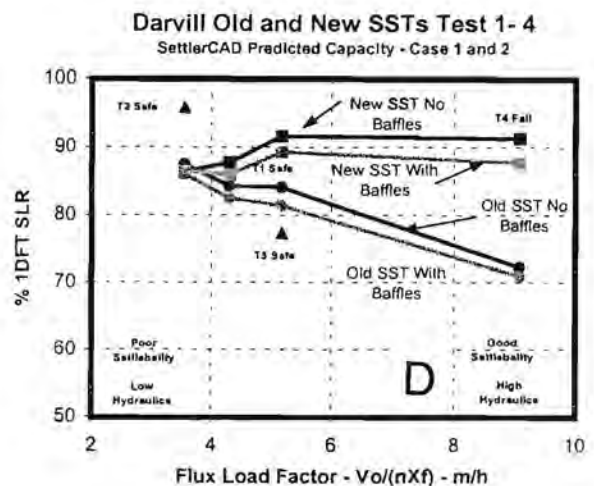
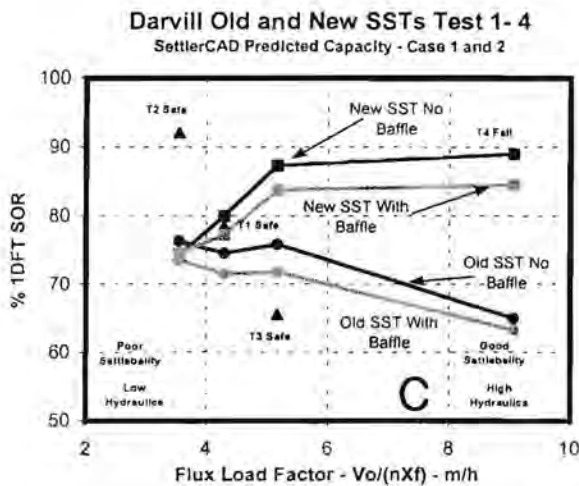
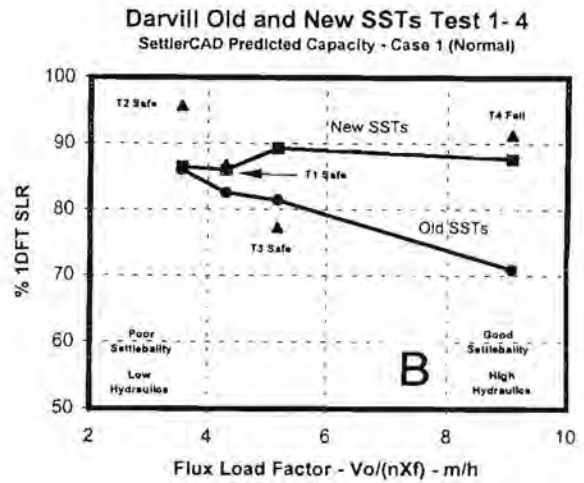
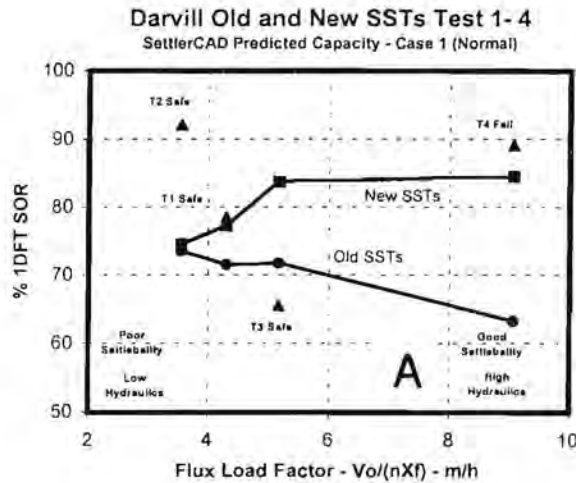
From Table 7.1 for Case 1, SettlerCAD consistently predicts that the new tank fails at a higher percentage (%) of the 1DFT maximum SOR and SLR (flux rating) than that of the old SSTs. At the lower HLRs i.e. Tests 1, 2 and 3, the flux rating of the new and old tanks are close to one another, but at high HLR i.e. Test 4, the new tank has a much higher flux rating than the old tank. The better performance of the new tanks compared with the old tank is most probably due to the greater depth of the new tank. The new tank has a much higher sludge storage capacity than the old tank due to its higher side wall depth and sloping bottom. The difference in flux rating between the new and old tanks is greater when the HLR is higher.

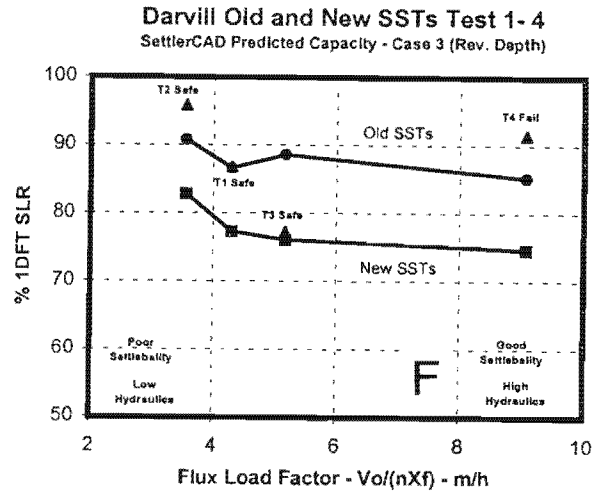
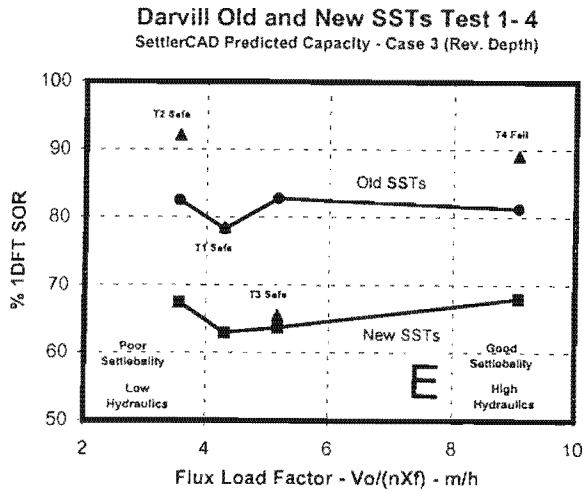
For the Darvill SSTs both the new and the old tanks perform marginally better without a Stamford baffle for all the tests, with the exception of Test 2, new tanks, which has the lowest HLR. For the new SSTs the flux ratings without baffles are 1.7 to 2.6 % (SLR) higher than with baffles and for the old SSTs the flux ratings without baffles are 1.4 to 1.8 % (SLR) higher than with baffles. Because the difference between the flux rating increased from Test 2 through Test 1, Test 3 to Test 4, which is the order of increasing HLR, it was noticed that the Stamford baffle set-up a large vertical circular current extending the full clear water depth and radius of the SST, which is absent when the baffles are removed. However, it must be remembered that the difference in flux rating is very small. Because the difference varies consistently with HLR, it seems that this difference is real and not artificial, due to variation in predicted results of the simulation model.

In Case 3, where the new and old SSTs had interchanged SWD i.e the new SST 2.1 m and the old SST 4.1 m, the SST performance also reversed in that now the old SSTs had higher flux ratings for all the tests than the new SSTs. This is due to the SST volume difference in that now the old SSTs have a greater volume than the new SST. These Case 3 runs clearly demonstrate the significant influence of the SSTs depth on the flux rating – the deeper the tank the closer the flux rating to the theoretical maximum of 1.0.

7.4.1 Flux load factor versus 1DFT limits SOR and SLR

The SettlerCAD predicted maximum SOR and SLR, as a percentage (%) of the 1DFT limits, versus the flux load factor ($V_0/n X_F$) for the new and old SST for all three Cases are plotted in Figures 7.2a and 7.2f. Also shown are the four actual test points.





Figures 7.2a to 7.2f: SettlerCAD predicted capacity as % of the 1DFT maximum HLR (Figures on left) and SLR (Figures on the right) limits versus the flux load factor for the Darvill new and old SSTs. The actual test position and outcome are also shown. The first two figures is for Case 1, the middle two figures are for Case 1 and 2 super-imposed upon each other. The last two figures is for Case 3 – reversed depth.

Figures 7.2a and 7.2b clearly show the greater sensitivity to the HLR of the shallow old SST compared with the deeper new SST. As the HLR increases the difference between the percentage (%) of the 1DFT limits of the new and old tanks increase, with the deeper new tank always performing better (higher flux rating). This indicates that for the shallow old SSTs, the lower the HLR, i.e. for poor settling sludges and/or high X_F , the greater the SST capacity as a percentage (%) of the 1DFT limit. The higher the HLR, i.e. good settling sludges and/or low X_F , the lower the capacity of the SST as a percentage (%) of the 1DFT limit. The new deep SSTs do not show this sensitivity to HLR.

In Figure 7.2d, the flux rating versus flux load factor for the old and new SSTs with and without Stamford baffles are shown. The same performance pattern is observed with and without the Stamford baffles in the new and old tanks, but both old and new SSTs perform marginally better (i.e. are 1.5 to 2 % higher flux rating) without Stamford baffles.

Figure 7.2f shows the flux rating versus the flux load factor for the old and new SSTs with interchanged depths. Now the deep old SST (with 4.1 m SWD and flat bottom) shows an insensitivity to HLR at around 87 % of the 1DFT SOR, which is above that of the shallow new SST (2.5 m SWD and 1:10 sloping bottom) at around 75 %. The shallow new SST (with 2.5 m SWD and 1:10 sloping bottom) now also shows itself to be sensitive to HLR. This comparison clearly shows the significant impact of SST depth on the flux rating.

7.5 SIMULATING THE WATTS SST

For the Kanapaha SST tested by Watts *et al.* (1996), three different cases were simulated with SettlerCAD and for each case the maximum influent flow as a percentage (%) of the 1DFT maximum influent flow (Q_1), was determined. The three cases were as follows:

- Case 1:** Simulation of the 15 stress tests on the SST as-built, i.e. without Stamford baffle and actual SWD of 3.66 m.
- Case 2:** Simulation of Tests 4, 7, 9, 12, 13 and 14 on the SST including a Stamford baffle extending 1.2 m from the side-wall at a height of 3.16 m above the bottom of the side wall, and actual SWD.
- Case 3¹⁾:** Simulation of Tests 4, 7, 9, 12, 13 and 14 on the SST with a SWD of 6.0 m.

¹⁾ Case 3 is an additional simulation that was done after the main objectives have been achieved and are only discussed in the Synopsis and Conclusion

Table 7.2: Summary of the SettlerCAD predicted to 1DFT calculated maximum SOR and SLR (flux rating) ratios for Case 1, 2 and Case 3.

% of 1DFT SOR	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Case 1 : Normal	73.5	73.5	74	73.5	71.75	71.75	71.75	70	71.5	72.75	73.75	71.5	71.25	73	75.25
Case 2 : With baffles				76			75		74.75			74.75	74.5	78	
Case 3 : 6 m SWD				73.5			76.25		77			76.75	78.5	87.25	

% of 1DFT SOR	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Case 1 : Normal	80.3	80.3	79.5	80.4	78.3	79.3	78.1	78	77.7	79.4	80.5	77.7	79.3	81.8	83
Case 2 : With baffles				82.3			80.6		80.2			80.2	81.7	85.1	
Case 3 : 6 m SWD				80.4			81.6		82			81.8	84.5	91.3	

From Table 7.2, the average flux rating (SLR) for Case 1 – no Stamford baffle (Tests 4, 7, 9, 12, 13 and 14) is 79.2 %. For Case 2 – with Stamford baffles the average flux rating is 81.7 % and for Case 3 – 6 m SWD the average flux rating is 83.6 %. Table 7.2 shows that SettlerCAD predicts a 2 % increase in SST capacity with Stamford baffles. This is contrary to the results of the Darvill SST simulations where the SSTs without Stamford baffles performed about 2 % better than with Stamford baffles.

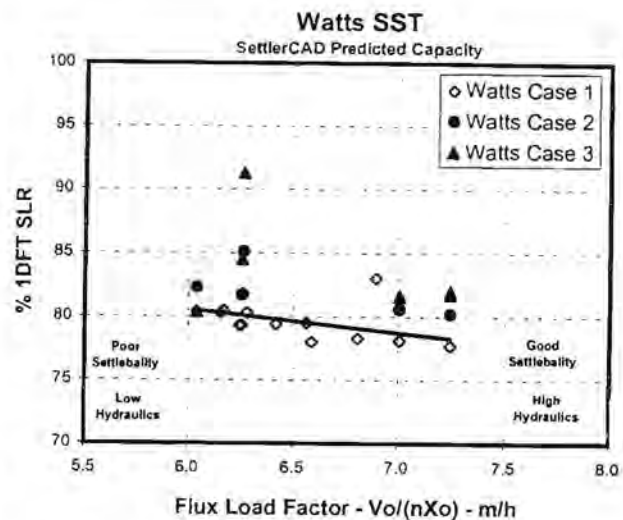
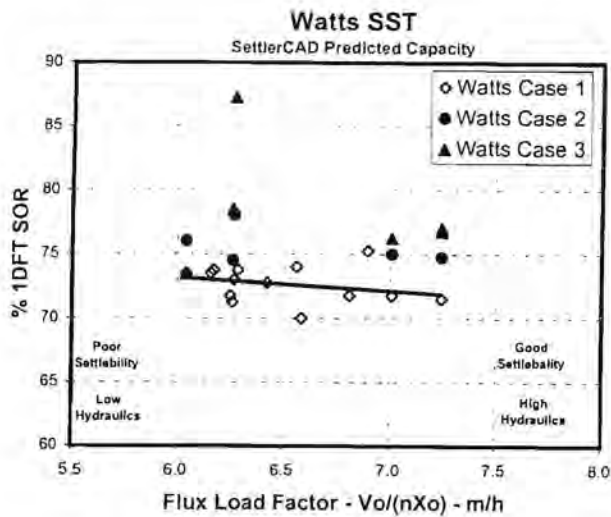
In the Tutorial literature made available with the SettlerCAD program by the developers, the impact of the Stamford baffle is investigated in an example. A comparison of the flow pattern in the different SSTs shows that the Stamford baffle does not have a strong impact on the overall flow field within the SST, an observation also made in this investigation.

Comparing the solids flow pattern, a conclusion was made that the Stamford baffles can improve the effluent concentration, but is unlikely to have a strong effect on the sludge blanket level in the SST. Because of the objective of reaching a final steady state for fixed loading conditions, which caused the sludge blanket for the failed cases to rise to the effluent launder, it seemed reasonable to conclude that the Stamford baffle does not increase the capacity (or flux rating) of the SST much; however for the safe loading conditions, the Stamford baffle helped to keep the ESS concentration low.

The average increase in SettlerCAD predicted SLR for Case 3 – 6 m SWD is 4.4 % higher than that of Case 1 – as-built (3.5 m SWD). The increased SWD increased the performance of the tank but not as significantly as expected.

7.5.1 Flux load factor versus 1DFT limits SOR and SLR

The SettlerCAD predicted maximum SOR and SLR, as a percentage (%) of the 1DFT limits, versus the flux load factor of the three different cases simulated are plotted in Figure 7.3a and 7.3b.



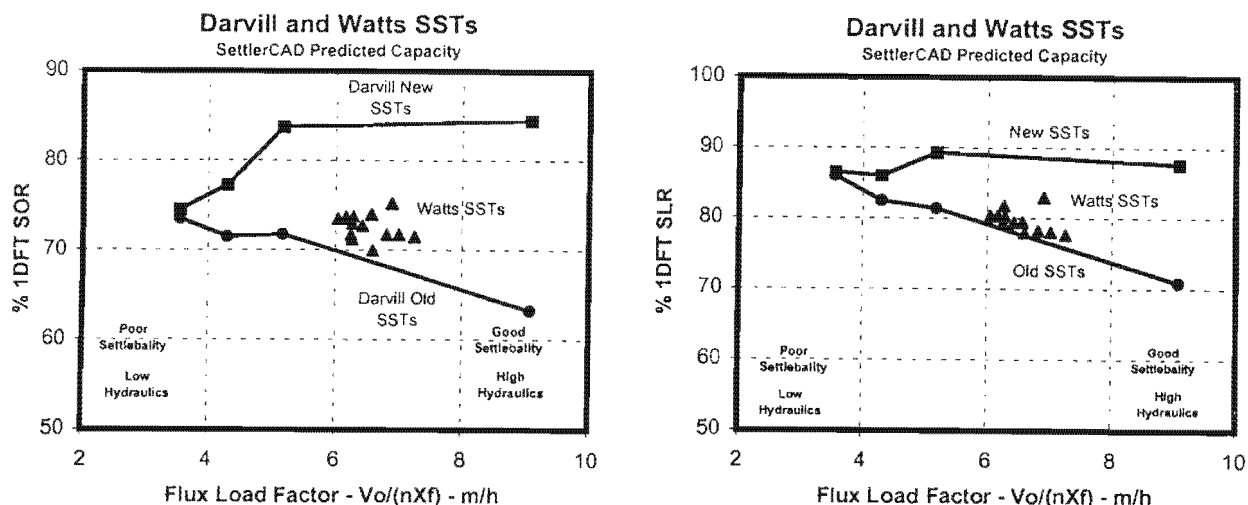
Figures 7.3a and 7.3b: *SettlerCAD predicted SOR (Fig. 7.3a, left) and SLR (Fig. 7.3b, right), as a percentage (%) of 1DFT maximum limits versus flux load factor for the Watts simulation of Case 1, 2 and 3.*

Figure 7.3b shows the flux rating versus flux load factor for the Watts Case 1 - (as-built) is round about 80 %. This is a lower average flux rating than that of Case 2 (with Stamford baffles).

This pattern is different than that observed in the Darvill results where the flux rating of the simulation with Stamford baffles perform marginally poorer than those without Stamford baffles.

The average flux rating of Case 3 - (6 m SWD) is higher than that of Case 1 and 2. This was expected since the increased tank volume results in an increase in flux rating.

To place the Watts SettlerCAD predicted flux rating in perspective, they are plotted together with the Darvill flux ratings in Figures 7.4a and 7.4b. The Watts SettlerCAD predicted SOR and SLR limit results lie between the old and new Darvill SST lines, but closer to the old SST line.



Figures 7.4a and 7.4b: SettleCAD predicted SOR (Fig 7.4a, left) and SLR (Fig 7.4b, right), as a percentage (%) of 1DFT maximum limits versus flux load factor for the Watts (3.66 m SWD), and Darvill new (4.1 m SWD) and old (2.5 m SWD) SSTs.

Considering that with respect to external SST geometry, the Watts SST (3.66 m SWD and 1:15.4 sloping bottom) is closer in likeness to the new Darvill SST (4.1 m SWD and 1:10 sloping bottom) than to the old Darvill SST (2.5 m SWD and flat bottom), the expectation was that the Watts results should fall closer to the new Darvill SST results than those of the old SST, but this did not happen. However, a relatively consistent pattern seemed to be emerging because at least the Watts SST results fell between the Darvill new and old SST results and showed a similar decreasing trend in flux rating or capacity as the flux load factor increased.

7.6 SIMULATING THE RIJEN AND Oss SSTs

For the Rijen and Oss SSTs only one set of simulation, resembling the as-built configuration were conducted. In each instance 6 tests were selected for simulation i.e. the 6 data sets that spanned over the widest range of the calculated flux load factor. The results of these simulations are summarised below.

Table 7.3: Summary of the SettlerCAD predicted to 1DFT calculated maximum SOR and SLR (flux rating) ratios for the Rijen and Oss SSTs.

Parameter	STOWa Test #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14
	Rijen Test #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6a	Test 6b	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13
Flux factor ($v_o/(n.X_F)$ -m/h)		5.91	4.47	6.43	3.11	3.76	5.39	4.03	2.61	2.89	4.42	4.56	5.5	4.32	5.75
% of 1DFT SOR		69.75	63	65	63				62			65			
% of 1DFT SLR		75.9	74.6	70.7	74.4				76.0			72.9			

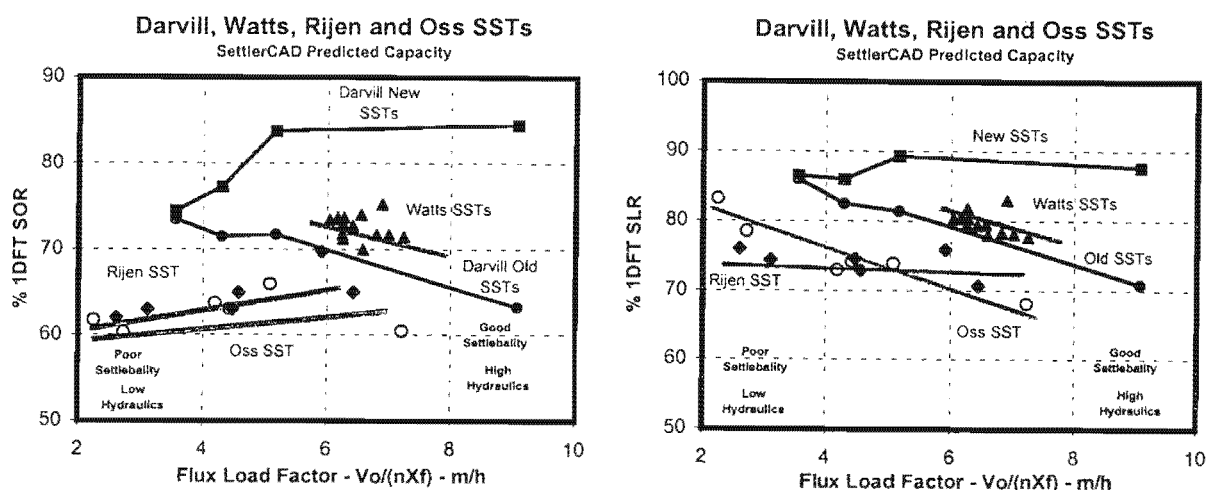
Parameter	STOWa Test #	Test 15	Test 16	Test 17	Test 18	Test 19	Test 20	Test 21	Test 22	Test 23	Test 24
	Oss Test #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
Flux factor ($v_o/(n.X_F)$ -m/h)		2.73	4.42	5.08	7.22	4.20	2.88	2.83	2.24	3.92	3.98
% of 1DFT SOR		60.25	63.00	66.00	60.50	63.75			61.75		
% of 1DFT SLR		78.5	74.2	73.9	68.1	73.0			83.2		

From Table 7.3 it can be seen that the SettlerCAD predicted flux rating (SLR) of the Rijen SST ranged between 70.7 % (Test 3) to 76.0 % (Test 8). For the Oss SST the flux rating (SLR) ranged between 68.1 % (Test 4) to 83.2 % (Test 8).

To place the Rijen and Oss SettlerCAD simulations in context of the Darvill and Watts simulation results, the following emerged. Considering that with respect to external SST geometry, the Rijen SST (2.25 m SWD and 1:12 sloping bottom), and Oss SST (2.0 m SWD and 1:12 sloping bottom) is closer in likeness to the old Darvill SST (2.5 m SWD and flat bottom), the expectation was that the average flux rating (SLR) of the Rijen results (74.08 %) and Oss results (75.15 %) should fall below the average flux rating of the Darvill old SST result (80.2 %) and this did indeed happen.

7.6.1 Flux load factor versus 1DFT limit SOR and SLR

The Rijen and Oss SettlerCAD predicted maximum SOR and SLR, as a percentage (%) of the 1DFT limits, are plotted versus the flux load factor $V_o/(n.X_f)$ in Figures 7.5a and 7.5b.



Figures 7.5a and 7.5b: SettlerCAD predicted maximum SOR (Fig 7.5a, left) and SLR (Fig 7.5b, right) as a % of the 1DFT limit values versus flux load factor for Darvill new, Darvill old, Watts, Rijen and Oss SSTs.

To place the Rijen and Oss SettlerCAD simulation results in context of the Darvill and Watts simulation results, the Darvill and Watts results are also plotted together in Figures 7.5a and 7.5b. The Rijen and Oss SettlerCAD predicted SOR and SLR limits lie below the Darvill old (●) and new (■) and Watts (▲) SST “lines”, but closer to the old SST line. Considering that with respect to external SST geometry, the Rijen SST (2.25 m SWD and 1:12 sloping bottom) and Oss SST (2.0 m SWD and 1:12 sloping bottom) is closer in likeness to the old Darvill SST (2.5 m SWD and flat bottom), the expectation is that the Rijen and Oss results should fall close to the old Darvill SST results, and this to some extent, did indeed happen.

7.7 SUMMARY OF THE SettlerCAD MAXIMUM SOR AND SLR FOR THE DARVILL, WATTS, RIJEN AND Oss SSTs

The results for the SettlerCAD predicted limits are summarised in Table 7.4. For each SST the SettlerCAD predicted limit as a % of 1DFT maximum are listed for the lowest and highest flux load factor of each data set. A high flux load factor represents high hydraulics and good settleability and a low flux load factor represents low hydraulics and poor settleability.

Table 7.4: Summary of SettlerCAD predicted limits for each data set for lowest and highest flux factor

Parameters		Darvill – New		Darvill - Old		Watts		Rijen		Oss	
		Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
Flux factor	$V_o/(n.X_p)$ -m/h	3.55	9.08	3.55	9.08	6.04	7.24	2.61	6.43	2.24	7.22
SOR	1DFT limit (m ³ /h)	746.0	2690.0	746.0	2690.0	1124.2	1428.6	910.3	1476.5	665.3	3578.7
	SettlerCAD Predicted %	74.50	84.50	73.50	63.25	73.50	71.50	62.00	65.00	61.75	60.50
SLR	1DFT limit [kg/(m ² .h)]	6.31	12.19	6.31	12.19	9.54	9.55	3.38	2.71	5.76	6.14
	SettlerCAD Predicted %	86.50	87.70	86.00	70.90	80.40	77.70	76.00	70.70	83.20	68.10
HLR [(qA+qR)	1DFT limit (m/h)	1.75	3.53	1.75	3.53	2.31	2.77	0.89	1.08	1.11	3.01
	SettlerCAD Predicted %	72.63	87.70	72.15	70.97	80.20	77.80	75.96	70.93	83.27	73.16
Average SWD	Have (m)	4.68	4.68	2.5	2.5	3.97	3.97	3.03	3.03	2.58	2.58

Table 7.4 shows that the flux rating at a high flux load factor is higher for the Darvill new SST (87.7 %) than the Darvill old SST (70.9 %). For the low flux load factor, the Darvill new SST fails at 86.5 % and the Darvill old SST fails at 86.0 %. The difference in the new and old SST being the new SST has an average SWD of 4.68 m and the old SST an average SWD of 2.5 m. This indicates that for the shallow old SST, the lower the hydraulic loading on the SST, the greater the SST's flux rating and the higher the hydraulic loading, the lower flux rating. The new deep SST does not show this sensitivity to hydraulic loading rate. This shows that the magnitudes of the flux rating is not a constant value, and seems to be dependent on SST depths and hydraulic loading – the deeper the SST and the lower the HLR the closer the flux rating to 1.0.

Table 7.4 shows the Watts SST has a small decrease in flux rating as the flux load factor increased – (from 80.4 % to 77.7 %). This seems to suggest that the Watts SST is insensitive to hydraulic loading similar to the Darvill new SST. However, the flux load factor range for the Watts tests is very narrow – only from 6.0 to 7.2 m/h, whereas for the Darvill tests the flux load factor range was from 3.5 to 9.0 m/h.

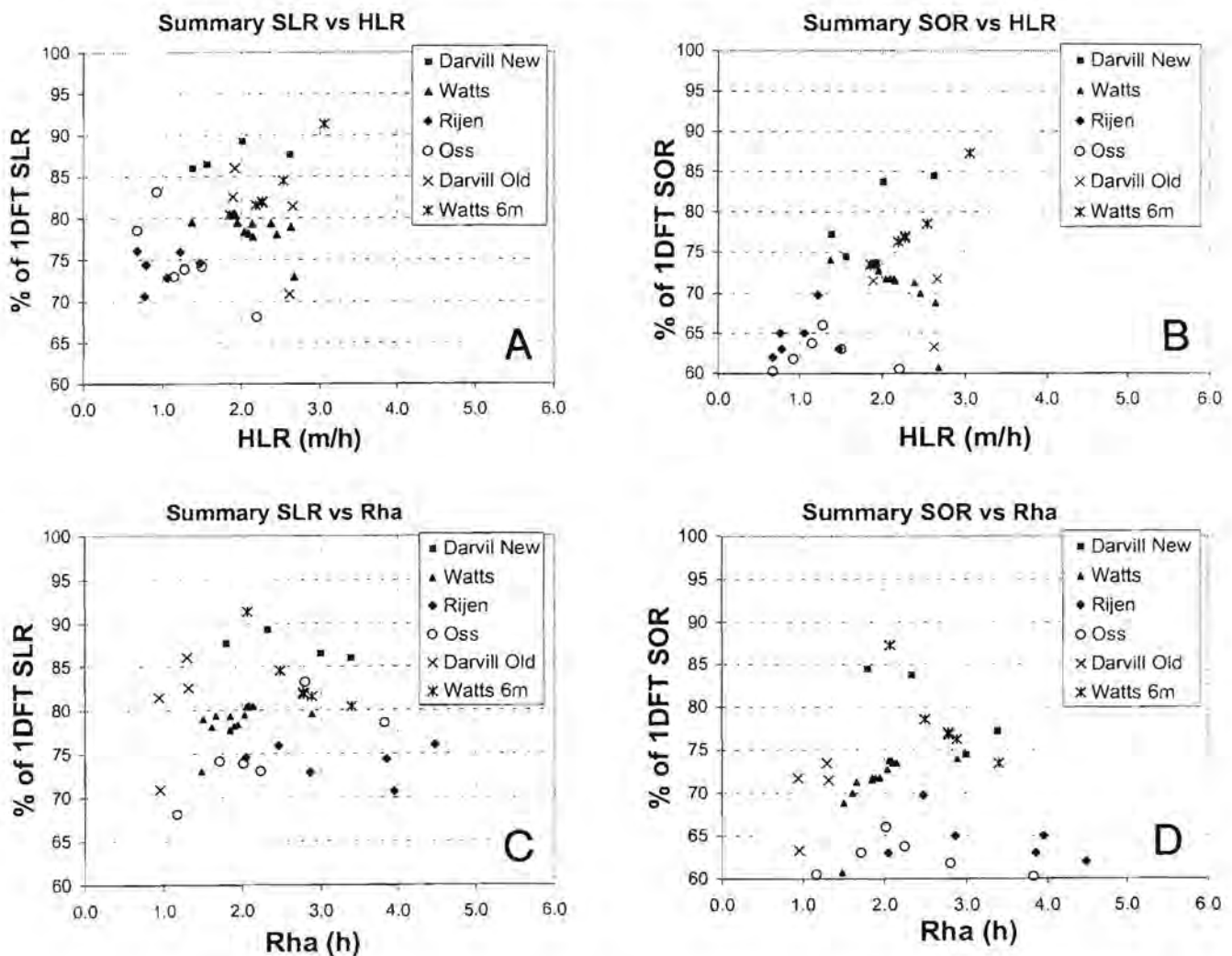
Table 7.4 shows the Rijen SST has a decreasing trend in the flux rating as the flux load factor increased – (76.0 % - 70.7 %) for a flux load factor from 2.61 to 6.43 m/h. This indicates that the Rijen SST has a low hydraulic capacity and is relatively insensitive to a hydraulic loading variation arising from a wide range in flux load factor from 2.61 to 6.43 m/h.

Table 7.4 shows the Oss SSTs has a decreasing trend in the flux rating as the flux load factor increases – (83.2 % - 68.1 %) for a flux load factor from 2.24 to 7.22 m/h. This indicates that the Oss SST flux rating is more sensitive to a hydraulic loading variation arising from a wide range in flux rating from 83.2 % to 68.1 %. Of all five SSTs simulated, the Rijen and Oss SSTs has the lowest flux rating.

The SettlerCAD simulation results (Table 7.4 and Fig 7.5a and 7.5b) shows the following – The Rijen and Oss “average” flux rating lie below the Darvill new and Darvill old and Watts SST “average” flux rating, but closer to the Darvill old SST “average”. Considering that with respect to external SST geometry, the Rijen SST (Have = 3.03m SWD) and Oss SST (Have = 2.58 m SWD) is closer in likeness to the old Darvill SST (HAVE = 2.5 m SWD), the expectation is that the Rijen and Oss results should fall close to the old Darvill results, and this does indeed happen.

7.8 EFFECT OF HLR AND R_{ha} ON FLUX RATING

The SettlerCAD results of the % of 1DFT SOR and SLR were plotted against the hydraulic loading rate (HLR) and hydraulic retention time (R_{ha})



Figures 7.6a to 7.6d: SettlerCAD predicted % of 1DFT SLR (Fig 7.6a, left) and predicted % of 1DFT SOR (Fig 7.6b, right) versus HLR and SettlerCAD predicted % of 1DFT SLR (Fig 7.6c, left) and predicted % of 1DFT SOR (Fig 7.6d, right) versus R_{ha}

Fig 7.6a to 7.6d, shows the results of the Darvill new and old, Watts, Rijen, Oss and Watts (6 m SWD) SSTs. No apparent pattern seems to emerge from these graphs. The HLR range is fairly narrow and the results are scattered across the HLR range. The R_{ha} ranges from 1.0 h to 4.5 h but once again the % of 1DFT SLR and SOR are scattered across the R_{ha} range. Comparing Figures 7.6 with that of Figures 7.5, it appears that the flux load factor gives a better comparison between the results.

7.9 CONCLUSION

The simulations of the full-scale SST SLR stress tests with the 2D hydrodynamic model SettlerCAD indicate, as would be expected, that the SST hydraulic non-idealities are intrinsically part of the model and that an appropriate flux rating for the full-scale SST is reproduced “automatically” in the model. Moreover, the simulations provide further evidence that the 1D idealized flux theory (1DFT) cannot be applied to the design of full-scale SSTs without an appropriate flux rating.

The SettlerCAD simulations of the Darvill SSTs indicated that the *capacity*, or flux rating, of the old flat bottom shallow (2.5 m SWD) SST decreased as the hydraulic loading increased due to an improvement in sludge settleability and/or decrease in feed concentration. The new sloping bottom deep (4.1, SWD) SST did not show this sensitivity of capacity (flux rating) to hydraulic loading rate. The magnitude of the flux rating therefore is not a constant value, and is shown to be dependent on SST depth and hydraulic loading; the deeper the SST and the lower the hydraulic loading the closer the flux rating is to 1.0. Simulations of the sloping bottom shallow (1.5 to 2.5 m SWD) Dutch SSTs tested by STOWa (1981) and the Darvill new and old SSTs with interchanged depths, confirmed this sensitivity of the flux rating to depth and hydraulic loading.

It would appear from the simulations so far that the flux rating of 0.80 of the 1DFT maximum SLR recommendation by Ekama and Marais (1986) remains a reasonable value to apply in the design of full scale SSTs – for deep SSTs (4m SWD) the flux rating could be increased to 0.85 and for shallow SSTs (2.5 m SWD) decreased to 0.75.

From the simulations, some answers to the two crucial questions raised by Ekama *et al.* (1997), viz. (i) are the SST failures observed in this and other studies specific for the particular SSTs investigated and (ii) can the 1DFT be applied to full scale SSTs without correction, are emerging. While the failures observed on the Darvill and other SSTs mentioned may be specific for the particular SSTs, a consistent pattern is appearing i.e. that the 1DFT can be used for design but its predicted maximum SLR needs to be reduced by an appropriate flux rating, the magnitude of which depends on SST depth and hydraulic loading. It is accepted that the magnitude of the flux rating depends also on the design of the internal features built into the external shell of the SST such as (i) inlet arrangement; (ii) tank configuration; (iii) effluent launder position; (iv) control of hydraulic flow patterns, short circuiting and turbulence with baffling; (v) flocculation chambers and (vi) sufficient sludge transport and collection capacity, but such detail cannot be modelled with SettlerCAD, which offers quick and easy data input, no grid-mesh specification and fast run times at the cost of greater tank geometry specification flexibility. While further SLR stress tests will make an important contribution to the full-scale SST performance data base, evaluation of the results with 1D flux models will not provide answers to the two questions above raised by Ekama *et al.*, (1997). These questions will find answers with further 2D hydrodynamic modelling studies on SSTs because these models allow the internal features of the SST to be simulated.

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APPENDIX A

Darvill Results

SettlerCAD Predicted Failure Results - Case 1 (Normal)

PARAMETER	Test 1		Test 2		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Flux Factor $[Vo/(n \cdot X_F) - m/h$	4.30	4.30	3.55	3.55	5.17	5.17	9.08	9.08
Influent Flow (m ³ /h) for 1 SST	820	759	556	548	1211	1038	2273	1701
% of 1DFT maximum Q_i	77.25	71.5	74.5	73.5	83.75	71.75	84.5	63.25
Overflow Rate (m/h)	0.85	0.79	0.58	0.57	1.26	1.08	2.36	1.77
Recycle Flow (m ³ /h)	667	667	667	667	750	750	708	708
Underflow Rate (m/h)	0.693	0.693	0.693	0.693	0.779	0.779	0.736	0.736
Recycle Ratio	0.81	0.88	1.20	1.22	0.62	0.72	0.31	0.42
Applied Flux (kg SS)/(m ² .h)	7.11	6.82	5.46	5.43	7.34	6.69	10.69	8.64
% of 1DFT maximum flux	86.0	82.5	86.5	86.0	89.3	81.4	87.7	70.9
Actual Retention Time (h)	3.0	1.7	3.7	2.0	2.3	1.3	1.5	1.0
Duration of Run (min)	6000	3600	6000	3600	6000	3600	3600	1800
Duration of Run (# of Rha)	33.0	35.6	27.1	30.3	43.5	44.6	39.7	30.1
Sim time Step (min)	2.5	2.5	2.5	2.5	2.5	2.5	1.25	1.25
Sim time Step (%Rha)	1.37	2.47	1.13	2.10	1.81	3.10	1.38	2.09
ESS (mg/l)	279	51	80	54	338	68	452	56
Recycle Conc (mg/l)	9792	9728	7618	7718	8487	8349	13056	11560
Mass Balance (%)	98.8	99.5	97.5	99	95.9	98.4	99.9	99.6
Test Result	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail

Mean over the last 2 R_{na} values

Summary of the SettlerCAD simulation results for the SettlerCAD influent flow limit of Tests 1 to 4 on the new and old Darville SSTs (With Stamford baffle extending from side wall and a 4.1 m SWD for the new SST and 2.5 m SWD for the old SST)

SettlerCAD Predicted Failure Results - Case 2 (Without Stamford Baffle)

PARAMETER	Test 1		Test 2		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Flux Factor $[Vo/(n \cdot X_F) - m/h$	4.30	4.30	3.55	3.55	5.17	5.17	9.08	9.08
Influent Flow (m ³ /h) for 1 SST	850	791	554	569	1262	1096	2394	1749
% of 1DFT maximum Q_i	80	74.5	74.3	76.25	87.3	75.8	89	65
Overflow Rate (m/h)	0.88	0.82	0.58	0.59	1.31	1.14	2.49	1.82
Recycle Flow (m ³ /h)	667	667	667	667	750	750	708	708
Underflow Rate (m/h)	0.693	0.693	0.693	0.693	0.779	0.779	0.736	0.736
Recycle Ratio	0.78	0.84	1.20	1.17	0.59	0.68	0.30	0.41
Applied Flux (kg SS)/(m ² .h)	7.25	6.97	5.46	5.52	7.53	6.91	11.12	8.81
% of 1DFT maximum flux	87.7	84.3	86.4	87.5	91.6	84.1	91.3	72.3
Actual Retention Time (h)	3.0	1.7	3.7	1.9	2.2	1.3	1.5	1.0
Duration of Run (min)	6000	6000	6000	6000	6000	6000	6000	6000
Duration of Run (# of Rha)	33.6	60.6	27.1	51.4	44.7	76.7	68.8	102.1
Sim time Step (min)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sim time Step (%Rha)	1.40	2.53	1.13	2.14	1.86	3.20	2.87	4.26
ESS (mg/l)	326	51	19.8	53	137	74	653	52
Recycle Conc (mg/l)	10422	9907	7806	7844	8599	8596	12787	11813
Mass Balance (%)	95.8	99.1	99.4	99	91.4	98.3	99.2	99.8
Test Result	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail

Mean over the last 2 R_{na} values

Summary of the SettlerCAD simulation results for the SettlerCAD influent flow limit of Tests 1 to 4 on the new and old Darville SSTs (Without Stamford baffle extending from side wall and a 4.1 m SWD for the new SST and 2.5 m SWD for the old SST)

SettlerCAD Predicted Failure Results - Case 3 (Reversed Depths)

PARAMETER	Test 1		Test 2		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Flux Factor [Vol/(n.X _F) - m/h	4.30	4.30	3.55	3.55	5.17	5.17	9.08	9.08
Influent Flow (m ³ /h) for 1 SST	669	831	504	615	922	1197	2112	2186
% of 1DFT maximum Q _i	63	78.25	67.5	82.5	63.75	82.75	78.5	81.25
Overflow Rate (m/h)	0.70	0.86	0.52	0.64	0.96	1.24	2.19	2.27
Recycle Flow (m ³ /h)	667	667	667	667	750	750	708	708
Underflow Rate (m/h)	0.693	0.693	0.693	0.693	0.779	0.779	0.736	0.736
Recycle Ratio	1.00	0.80	1.32	1.08	0.81	0.63	0.34	0.32
Applied Flux (kg SS)/(m ² .h)	6.39	7.16	5.23	5.73	6.25	7.28	10.11	10.38
% of 1DFT maximum flux	77.3	86.6	82.8	90.8	76.1	88.6	83.0	85.2
Actual Retention Time (h)	2.2	2.6	2.5	3.1	1.8	2.0	1.1	1.4
Duration of Run (min)	3600	6000	3600	6000	3600	6000	1800	3600
Duration of Run (# of Rha)	27.0	38.0	23.7	32.5	33.8	49.3	28.5	44.0
Sim time Step (min)	2.5	2.5	2.5	2.5	2.5	2.5	1.25	1.25
Sim time Step (%Rha)	1.88	1.58	1.64	1.35	2.35	2.06	1.98	1.53
ESS (mg/l)	113	61	52	51	93	51	1030	85
Recycle Conc (mg/l)	8798	10206	7093	8168	7683	9221	10399	13761
Mass Balance (%)	96.7	99.5	88.3	99.3	97.2	99.6	98.1	99.5
Test Result	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail

Mean over the last 2 R₉₀ values

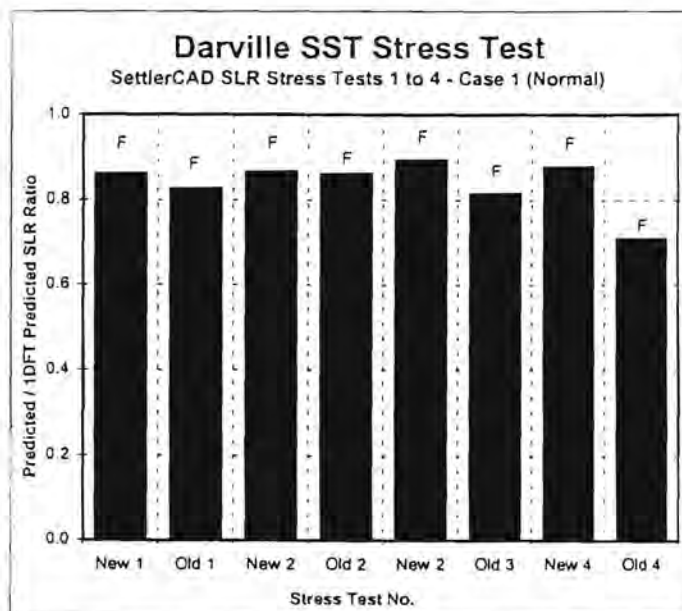
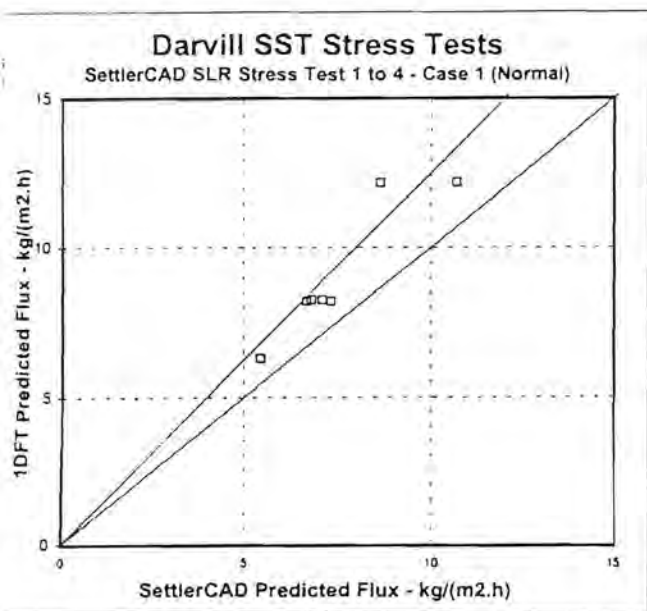
Summary of the SettlerCAD simulation results for the SettlerCAD influent flow limit of Tests 1 to 4 on the new and old Darville SSTs (With Stamford baffle extending from side wall and a 2.5 m SWD for the new SST and 4.1 m SWD for the old SST)

SettlerCAD Prediction of Actual SLR Tests

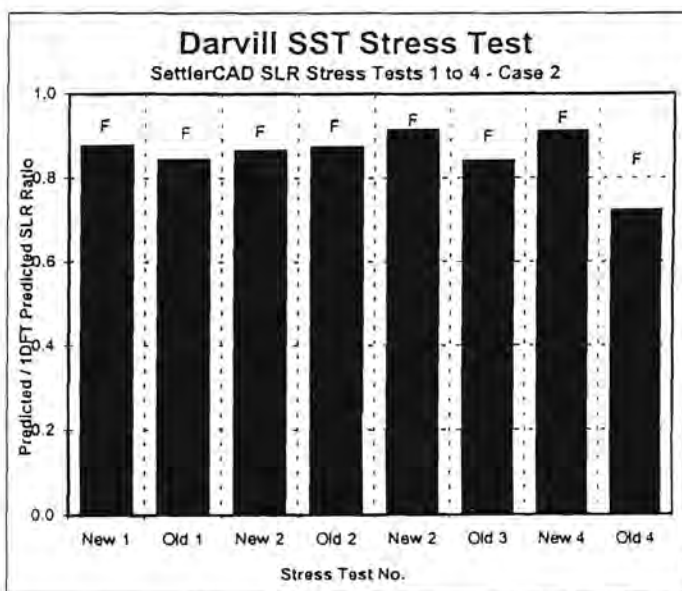
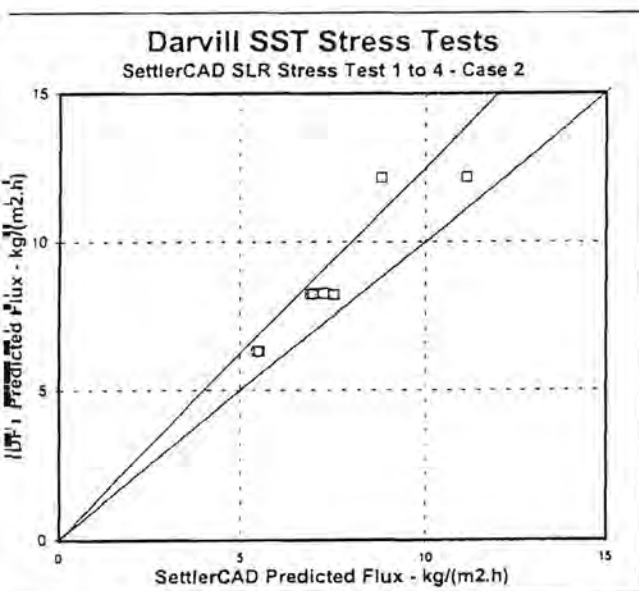
PARAMETER	Test 1		Test 2		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Flux Factor [Vol/(n.X _F) - m/h	4.30	4.30	3.55	3.55	5.17	5.17	9.08	9.08
Influent Flow (m ³ /h) for 1 SST	834	834	687	687	949	949	2397	2397
% of 1DFT maximum Q _i	78.5	78.5	92.1	92.1	65.6	65.6	89.1	89.1
Overflow Rate (m/h)	0.87	0.87	0.71	0.71	0.99	0.99	2.49	2.49
Recycle Flow (m ³ /h)	667	667	667	667	750	750	708	708
Underflow Rate (m/h)	0.693	0.693	0.693	0.693	0.779	0.779	0.736	0.736
Recycle Ratio	0.80	0.80	0.97	0.97	0.79	0.79	0.30	0.30
Applied Flux (kg SS)/(m ² .h)	7.17	7.17	6.05	6.05	6.35	6.35	11.13	11.13
% of 1DFT maximum flux	86.8	86.8	95.8	95.8	77.3	77.3	91.4	91.4
Actual Retention Time (h)	3.0	1.6	3.3	1.8	2.7	1.4	1.5	0.8
Duration of Run (min)	3600	6000	3600	6000	3600	6000	3600	6000
Duration of Run (# of Rha)	20.0	62.4	18.0	56.3	22.6	70.6	41.3	129.1
Sim time Step (min)	2.5	2.5	2.5	2.5	2.5	2.5	1.25	1.25
Sim time Step (%Rha)	1.39	2.60	1.25	2.35	1.57	2.94	1.44	2.69
ESS (mg/l)	495	227	933	348	2.1	13.5	647	541
Recycle Conc (mg/l)	9558	9666	7515	7745	8148	8119	12863	11751
Mass Balance (%)	98.3	96.1	97.1	92.8	100	99.8	99.6	89.8
Test Result (ESS > 50 mg/l)	Fail	Fail	Fail	Fail	Safe	Safe	Fail	Fail
Observed Result	Safe	Safe	Safe	Safe	Safe	Safe	Fail	Fail

Mean over the last 2 R₉₀ values

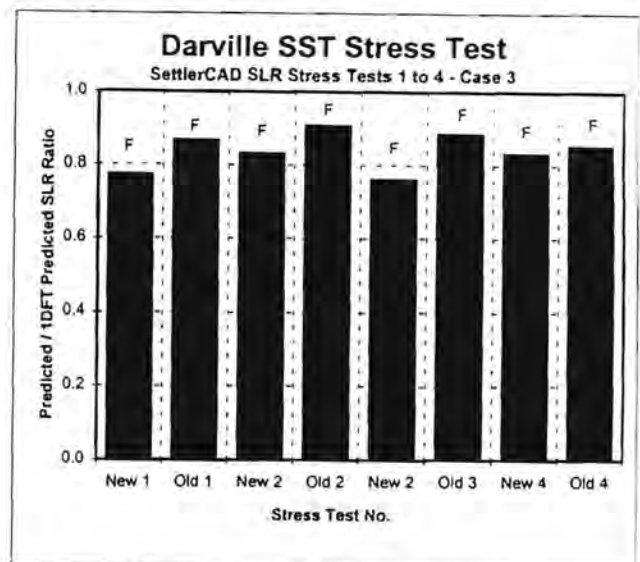
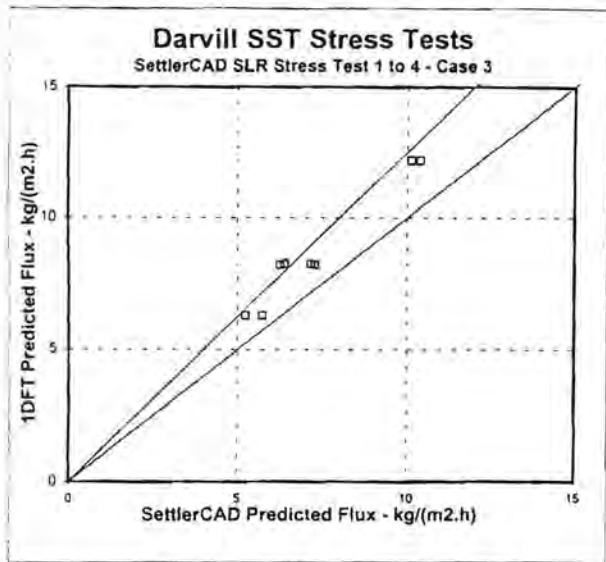
Summary of the SettlerCAD simulation results for the actual Test 1 to 4 on the new old Darvill SST



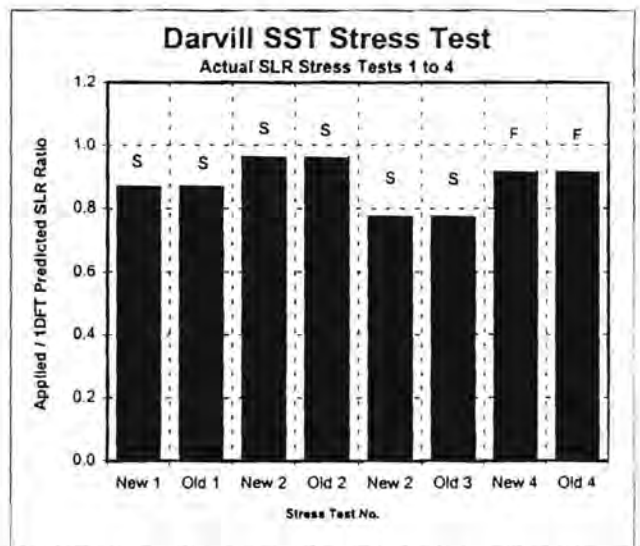
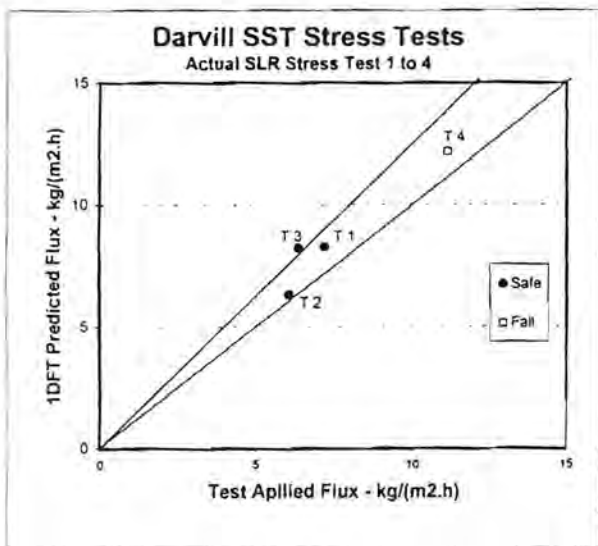
Figs a and b: 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Figs a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig b, right) for the Darville SLR stress tests. Case 1 - With Stamford baffle on side wall and New SST with 4.1 m SWD and Old SST with 2.5 m SWD



Figs a and b: 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Figs a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig b, right) for the Darville SLR stress tests. Case 2 - Without Stamford baffle on side wall and New SST with 4.1 m SWD and Old SST with 2.5 m SWD



Figs a and b: 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Figs a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig b, right) for the Darville SLR stress tests. Case 3 - With Stamford baffle on side wall and New SST with 2.5 m SWD and Old SST with 4.1 m SWD



Figs a and b: 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Figs a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig b, right) for the Darville SLR stress tests. Simulation of Actual SLR stress test

Darvill

Summary of SettlerCAD predicted failures (Case 1, 2 and 3)

	Test 1		Test 2		Test 3		Test 4																																																						
	New	Old	New	Old	New	Old	New	Old																																																					
Maximum flux [kg/(m2.h)]	8.26	8.26	6.31	6.31	8.22	8.22	12.19	12.19																																																					
Maximum Influent flow (m3/h)	1062	1062	746	746	1446	1446	2690	2690																																																					
Case 1 - Normal																																																													
Influent flow (m3/h)	820	759	556	548	1221	1038	2272	1702																																																					
Recycle flow (m3/h)	667	667	667	667	750	750	708	708																																																					
Recycle Ratio	0.81	0.88	1.20	1.22	0.61	0.72	0.31	0.42																																																					
Feed conc. (g/l)	4.6	4.6	4.3	4.3	3.6	3.6	3.45	3.45																																																					
Area (m2)	962	962	962	962	962	962	962	962																																																					
SettlerCAD Predicted Flux [kg/(m2.h)	7.11	6.82	5.47	5.43	7.38	6.69	10.69	8.64																																																					
% of 1DFT Flux	86.1	82.6	86.6	86.1	89.7	81.4	87.7	70.9																																																					
% of 1DFT Flow	77.2	71.5	74.5	73.5	84.4	71.8	84.5	63.3																																																					
Case 2 - No Baffles																																																													
Influent flow (m3/h)	849.6	791.2	553.9	568.8	1261.6	1095.3	2394.1	1748.5																																																					
Recycle flow (m3/h)	667	667	667	667	750	750	708	708																																																					
Recycle Ratio	0.79	0.84	1.20	1.17	0.59	0.68	0.30	0.40																																																					
Feed conc. (g/l)	4.6	4.6	4.3	4.3	3.6	3.6	3.45	3.45																																																					
Area (m2)	962	962	962	962	962	962	962	962																																																					
SettlerCAD Predicted Flux [kg/(m2.h)	7.25	6.97	5.46	5.52	7.53	6.91	11.12	8.81																																																					
% of 1DFT Flux	87.8	84.4	86.5	87.5	91.6	84.0	91.3	72.3																																																					
% of 1DFT Flow	80.0	74.5	74.2	76.2	87.2	75.7	89.0	65.0																																																					
Case 3 - Reverse Depth																																																													
Influent flow (m3/h)	669	830.9	503.6	615.6	921.9	1196.6	2112	2186																																																					
Recycle flow (m3/h)	667	667	667	667	750	750	708	708																																																					
Recycle Ratio	1.00	0.80	1.32	1.08	0.81	0.63	0.34	0.32																																																					
Feed conc. (g/l)	4.6	4.6	4.3	4.3	3.6	3.6	3.45	3.45																																																					
Area (m2)	962	962	962	962	962	962	962	962																																																					
SettlerCAD Predicted Flux [kg/(m2.h)	6.39	7.16	5.23	5.73	6.26	7.28	10.11	10.38																																																					
% of 1DFT Flux	77.3	86.7	82.9	90.9	76.1	88.6	83.0	85.1																																																					
% of 1DFT Flow	63.0	78.2	67.5	82.5	63.8	82.8	78.5	81.3																																																					
<table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2"></th> <th colspan="2">Test 1</th> <th colspan="2">Test 2</th> <th colspan="2">Test 3</th> <th colspan="2">Test 4</th> </tr> <tr> <th>New</th> <th>Old</th> <th>New</th> <th>Old</th> <th>New</th> <th>Old</th> <th>New</th> <th>Old</th> </tr> </thead> <tbody> <tr> <td>% of 1DFT Flux</td> <td>86.1</td> <td>82.6</td> <td>86.6</td> <td>86.1</td> <td>89.7</td> <td>81.4</td> <td>87.7</td> <td>70.9</td> </tr> <tr> <td>Case 1 - Normal</td> <td>86.1</td> <td>82.6</td> <td>86.6</td> <td>86.1</td> <td>89.7</td> <td>81.4</td> <td>87.7</td> <td>70.9</td> </tr> <tr> <td>Case 2 - No Baffles</td> <td>87.8</td> <td>84.4</td> <td>86.5</td> <td>87.5</td> <td>91.6</td> <td>84.0</td> <td>91.3</td> <td>72.3</td> </tr> <tr> <td>Case 3 - Reverse Depth</td> <td>77.3</td> <td>86.7</td> <td>82.9</td> <td>90.9</td> <td>76.1</td> <td>88.6</td> <td>83.0</td> <td>85.1</td> </tr> </tbody> </table>										Test 1		Test 2		Test 3		Test 4		New	Old	New	Old	New	Old	New	Old	% of 1DFT Flux	86.1	82.6	86.6	86.1	89.7	81.4	87.7	70.9	Case 1 - Normal	86.1	82.6	86.6	86.1	89.7	81.4	87.7	70.9	Case 2 - No Baffles	87.8	84.4	86.5	87.5	91.6	84.0	91.3	72.3	Case 3 - Reverse Depth	77.3	86.7	82.9	90.9	76.1	88.6	83.0	85.1
	Test 1		Test 2		Test 3		Test 4																																																						
	New	Old	New	Old	New	Old	New	Old																																																					
% of 1DFT Flux	86.1	82.6	86.6	86.1	89.7	81.4	87.7	70.9																																																					
Case 1 - Normal	86.1	82.6	86.6	86.1	89.7	81.4	87.7	70.9																																																					
Case 2 - No Baffles	87.8	84.4	86.5	87.5	91.6	84.0	91.3	72.3																																																					
Case 3 - Reverse Depth	77.3	86.7	82.9	90.9	76.1	88.6	83.0	85.1																																																					

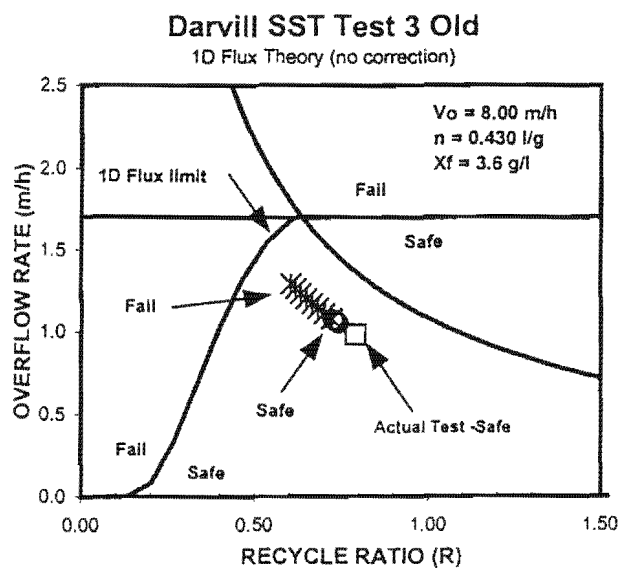
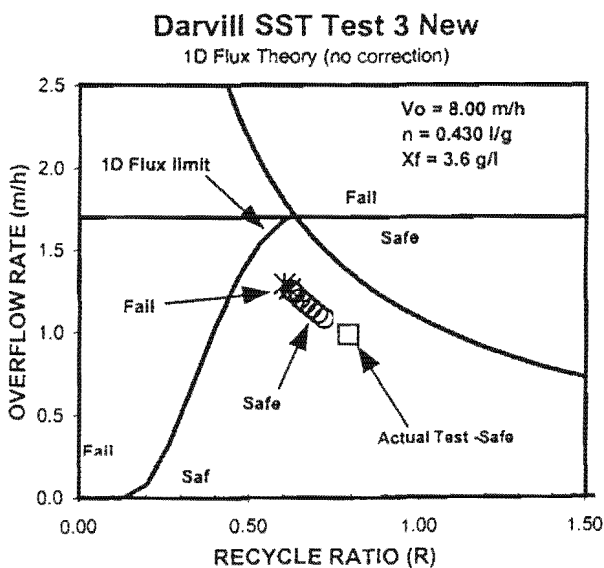
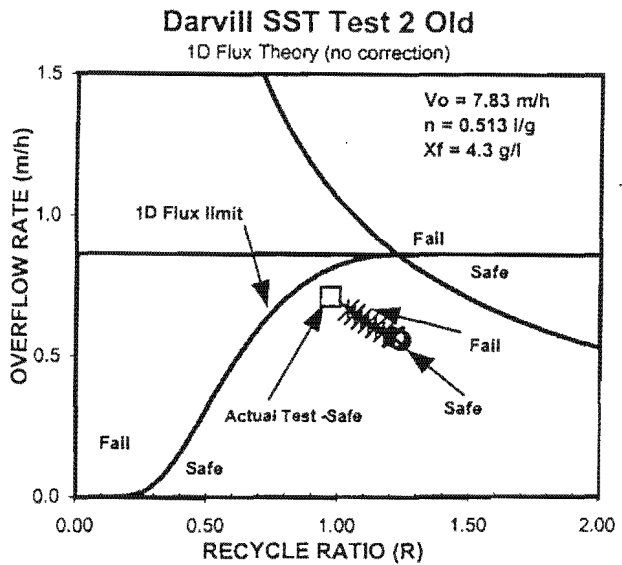
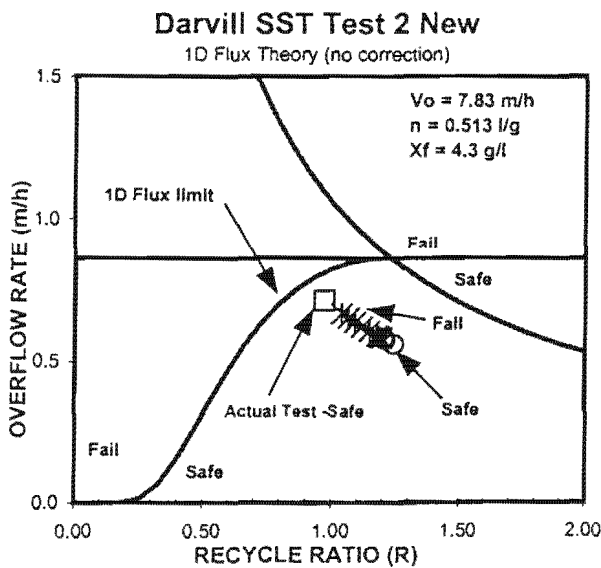
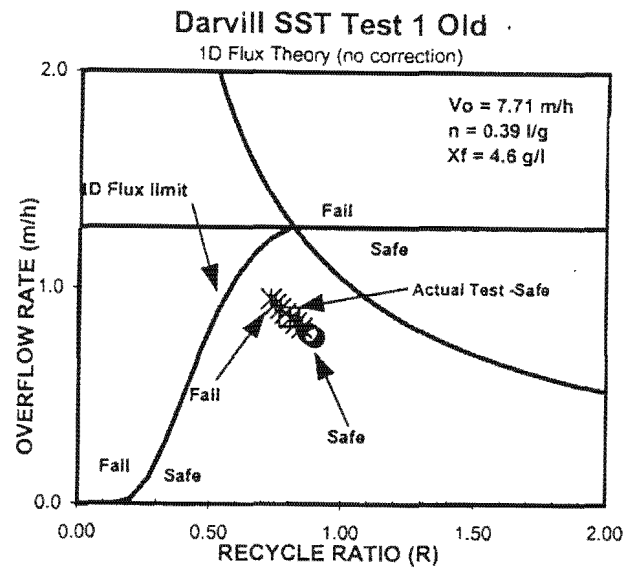
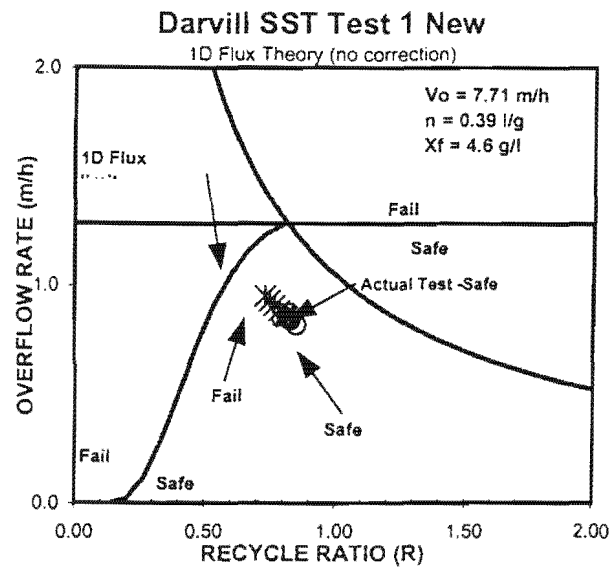
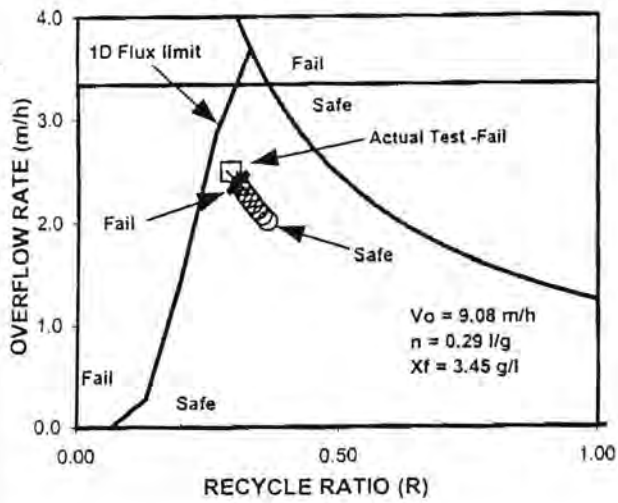


Fig a to f: 1DFT D&O charts showing the SST operating positions and results (Safe, Fail) of the SettlerCAD runs and actual tests for test 1 to 3 on the Darvill New and Old SSTs

Darvill SST Test 4 New

1D Flux Theory (no correction)



Darvill SST Test 4 Old

1D Flux Theory (no correction)

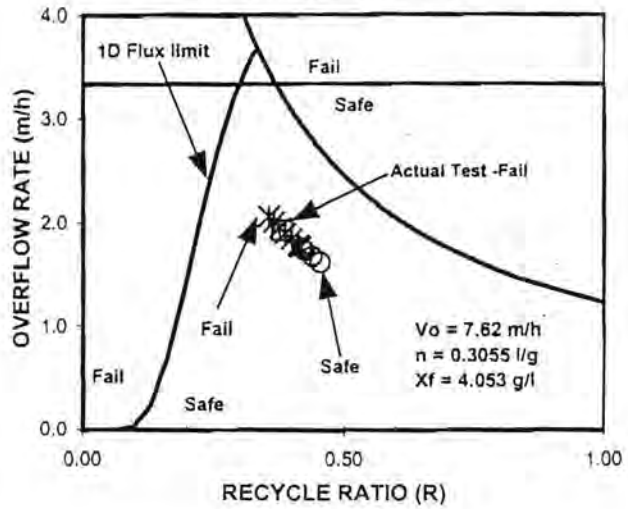


Fig g to h: 1DFT D&O charts showing the SST operating positions and results (Safe, Fail) of the SettlerCAD runs and actual tests for test 4 on the Darvill New and Old SSTs

Construct D&O chart: Test 2 New

Xf = 4.3 kgMLSS/m³
 Vo = 7.83 m/h
 n = 0.513 m³/kg
 Qr = 667 m³/h
 Qi (1D Flux Limit) = 748 m³/h
 A = 962 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	667	0.00	0.00	0.00000	1.0000	0.0000	0.8625	105.9675
F	86	641.6	667	0.67	1.04	0.06667	0.9416	0.0000	0.8625	15.8951
F	84	626.6	667	0.65	1.06	0.13333	0.8869	0.0000	0.8625	7.9476
F	82	611.7	667	0.64	1.09	0.20000	0.8353	0.0023	0.8625	5.2984
F	80	596.8	667	0.62	1.12	0.26667	0.7863	0.0212	0.8625	3.9738
F	78	581.9	667	0.60	1.15	0.33333	0.7394	0.0729	0.8625	3.1790
F	76	567.0	667	0.59	1.18	0.40000	0.6942	0.1566	0.8625	2.6492
F	75.75	565.1	667	0.59	1.18	0.46667	0.6504	0.2595	0.8625	2.2707
F	75.5	563.2	667	0.59	1.18	0.53333	0.6077	0.3676	0.8625	1.9869
F	75.25	561.4	667	0.58	1.19	0.60000	0.5657	0.4705	0.8625	1.7661
F	75	559.5	667	0.58	1.19	0.66667	0.5241	0.5626	0.8625	1.5895
F	74.75	557.6	667	0.58	1.20	0.73333	0.4825	0.6413	0.8625	1.4450
F	74.5	555.8	667	0.58	1.20	0.80000	0.4405	0.7061	0.8625	1.3246
S	74.25	553.9	667	0.58	1.20	0.86667	0.3976	0.7577	0.8625	1.2227
S	74	552.0	667	0.57	1.21	0.93333	0.3530	0.7973	0.8625	1.1354
S	72	537.1	667	0.56	1.24	1.00000	0.3055	0.8264	0.8625	1.0597
S	72	537.1	667	0.56	1.24	1.06667	0.2532	0.8462	0.8625	0.9934
Actual (S)	92.1	687.1	667	0.71	0.97	1.13333	0.1915	0.8580	0.8625	0.9350
						1.20000	0.1045	0.8625	0.8625	0.8831
						1.26667	#NUM!	#NUM!	0.8625	0.8366
						1.33333	#NUM!	#NUM!	0.8625	0.7948
						1.40000	#NUM!	#NUM!	0.8625	0.7569
						1.46667	#NUM!	#NUM!	0.8625	0.7225
						1.53333	#NUM!	#NUM!	0.8625	0.6911
						1.60000	#NUM!	#NUM!	0.8625	0.6623
						1.66667	#NUM!	#NUM!	0.8625	0.6358
						1.73333	#NUM!	#NUM!	0.8625	0.6114
						1.80000	#NUM!	#NUM!	0.8625	0.5887
						1.86667	#NUM!	#NUM!	0.8625	0.5677
						1.93333	#NUM!	#NUM!	0.8625	0.5481
						2.00000	#NUM!	#NUM!	0.8625	0.5298

Construct D&O chart: Test 2 Old

Xf = 4.3 kgMLSS/m³
 Vo = 7.83 m/h
 n = 0.513 m³/kg
 Qr = 667 m³/h
 Qi (1D Flux Limit) = 746 m³/h
 A = 962 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	667	0.00	0.00	0.00000	1.0000	0.0000	0.8625	105.9675
F	86	641.6	667	0.67	1.04	0.06667	0.9416	0.0000	0.8625	15.8951
F	84	626.6	667	0.65	1.06	0.13333	0.8869	0.0000	0.8625	7.9476
F	82	611.7	667	0.64	1.09	0.20000	0.8353	0.0023	0.8625	5.2984
F	80	596.8	667	0.62	1.12	0.26667	0.7863	0.0212	0.8625	3.9738
F	78	581.9	667	0.60	1.15	0.33333	0.7394	0.0729	0.8625	3.1790
F	76	567.0	667	0.59	1.18	0.40000	0.6942	0.1566	0.8625	2.6492
F	74	552.0	667	0.57	1.21	0.46667	0.6504	0.2595	0.8625	2.2707
F	73.75	550.2	667	0.57	1.21	0.53333	0.6077	0.3676	0.8625	1.9869
F	73.5	548.3	667	0.57	1.22	0.60000	0.5657	0.4705	0.8625	1.7661
S	73.25	546.4	667	0.57	1.22	0.66667	0.5241	0.5626	0.8625	1.5895
S	73	544.6	667	0.57	1.22	0.73333	0.4825	0.6413	0.8625	1.4450
S	72.75	542.7	667	0.56	1.23	0.80000	0.4405	0.7061	0.8625	1.3246
S	72.5	540.9	667	0.56	1.23	0.86667	0.3976	0.7577	0.8625	1.2227
S	72.25	539.0	667	0.56	1.24	0.93333	0.3530	0.7973	0.8625	1.1354
S	72	537.1	667	0.56	1.24	1.00000	0.3055	0.8264	0.8625	1.0597
S	72	537.1	667	0.56	1.24	1.06667	0.2532	0.8462	0.8625	0.9934
Actual (S)	92.1	687.1	667	0.71	0.97	1.13333	0.1915	0.8580	0.8625	0.9350
						1.20000	0.1045	0.8625	0.8625	0.8831
						1.26667	#NUM!	#NUM!	0.8625	0.8366
						1.33333	#NUM!	#NUM!	0.8625	0.7948
						1.40000	#NUM!	#NUM!	0.8625	0.7569
						1.46667	#NUM!	#NUM!	0.8625	0.7225
						1.53333	#NUM!	#NUM!	0.8625	0.6911
						1.60000	#NUM!	#NUM!	0.8625	0.6623
						1.66667	#NUM!	#NUM!	0.8625	0.6358
						1.73333	#NUM!	#NUM!	0.8625	0.6114
						1.80000	#NUM!	#NUM!	0.8625	0.5887
						1.86667	#NUM!	#NUM!	0.8625	0.5677
						1.93333	#NUM!	#NUM!	0.8625	0.5481
						2.00000	#NUM!	#NUM!	0.8625	0.5298

Construct D&O chart: Test 3 New

Xf = 3.6 kgMLSS/m³
 Vo = 8.00 m/h
 n = 0.43 m³/kg
 Qr = 750 m³/h
 Qi (1D Flux Limit) = 1446 m³/h
 A = 962 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	750	0.00	0.00	0.00000	1.0000	0.0000	1.7014	108.2682
F	86	1243.6	750	1.29	0.60	0.06667	0.9157	0.0000	1.7014	16.2402
F	84	1214.6	750	1.26	0.62	0.13333	0.8343	0.0038	1.7014	8.1201
F	83.75	1211.0	750	1.26	0.62	0.20000	0.7545	0.0827	1.7014	5.4134
S	83.5	1207.4	750	1.26	0.62	0.26667	0.6753	0.3272	1.7014	4.0601
S	83.25	1203.8	750	1.25	0.62	0.33333	0.5950	0.6775	1.7014	3.2480
S	83	1200.2	750	1.25	0.62	0.40000	0.5116	1.0311	1.7014	2.7067
S	82.75	1196.6	750	1.24	0.63	0.46667	0.4217	1.3267	1.7014	2.3200
S	82.5	1193.0	750	1.24	0.63	0.53333	0.3182	1.5434	1.7014	2.0300
S	82.25	1189.3	750	1.24	0.63	0.60000	0.1761	1.6799	1.7014	1.8045
S	82	1185.7	750	1.23	0.63	0.61333	0.1329	1.6975	1.7014	1.7652
S	80	1156.8	750	1.20	0.65	0.62667	0.0673	1.7113	1.7014	1.7277
S	78	1127.9	750	1.17	0.66	0.64000	#NUM!	#NUM!	1.7014	1.6917
S	76	1099.0	750	1.14	0.68	0.65334	#NUM!	#NUM!	1.7014	1.6572
S	74	1070.0	750	1.11	0.70	0.66667	#NUM!	#NUM!	1.7014	1.6240
S	72	1041.1	750	1.08	0.72	0.73334	#NUM!	#NUM!	1.7014	1.4764
S	72	1041.1	750	1.08	0.72	0.80000	#NUM!	#NUM!	1.7014	1.3533
Actual (S)	65.6	948.6	750	0.99	0.79	0.86667	#NUM!	#NUM!	1.7014	1.2492
						0.93334	#NUM!	#NUM!	1.7014	1.1600
						1.00000	#NUM!	#NUM!	1.7014	1.0827
						1.06667	#NUM!	#NUM!	1.7014	1.0150
						1.13334	#NUM!	#NUM!	1.7014	0.9553
						1.20000	#NUM!	#NUM!	1.7014	0.9022
						1.26667	#NUM!	#NUM!	1.7014	0.8547
						1.33334	#NUM!	#NUM!	1.7014	0.8120
						1.40000	#NUM!	#NUM!	1.7014	0.7733
						1.46667	#NUM!	#NUM!	1.7014	0.7382
						1.53334	#NUM!	#NUM!	1.7014	0.7061
						1.60000	#NUM!	#NUM!	1.7014	0.6767
						1.66667	#NUM!	#NUM!	1.7014	0.6496
						1.73334	#NUM!	#NUM!	1.7014	0.6246

Construct D&O chart: Test 3 Old

Xf = 3.6 kgMLSS/m³
 Vo = 8.00 m/h
 n = 0.43 m³/kg
 Qr = 750 m³/h
 Qi (1D Flux Limit) 1446 m³/h
 A = 962 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	750	0.00	0.00	0.00000	1.0000	0.0000	1.7014	108.2682
F	86	1243.6	750	1.29	0.60	0.06667	0.9157	0.0000	1.7014	16.2402
F	84	1214.6	750	1.26	0.62	0.13333	0.8343	0.0038	1.7014	8.1201
F	82	1185.7	750	1.23	0.63	0.20000	0.7545	0.0827	1.7014	5.4134
F	80	1156.8	750	1.20	0.65	0.26667	0.6753	0.3272	1.7014	4.0601
F	78	1127.9	750	1.17	0.66	0.33333	0.5950	0.6775	1.7014	3.2480
F	76	1099.0	750	1.14	0.68	0.40000	0.5116	1.0311	1.7014	2.7067
F	74	1070.0	750	1.11	0.70	0.46667	0.4217	1.3267	1.7014	2.3200
F	72	1041.1	750	1.08	0.72	0.53333	0.3182	1.5434	1.7014	2.0300
F	71.75	1037.5	750	1.08	0.72	0.60000	0.1761	1.6799	1.7014	1.8045
S	71.5	1033.9	750	1.07	0.73	0.61334	0.1329	1.6975	1.7014	1.7652
S	71.25	1030.3	750	1.07	0.73	0.62667	0.0673	1.7113	1.7014	1.7277
S	71	1026.7	750	1.07	0.73	0.64001	#NUM!	#NUM!	1.7014	1.6917
S	70.75	1023.0	750	1.06	0.73	0.65334	#NUM!	#NUM!	1.7014	1.6571
S	70.5	1019.4	750	1.06	0.74	0.66668	#NUM!	#NUM!	1.7014	1.6240
S	70.25	1015.8	750	1.06	0.74	0.68002	#NUM!	#NUM!	1.7014	1.5921
S	70	1012.2	750	1.05	0.74	0.74668	#NUM!	#NUM!	1.7014	1.4500
Actual (S)	65.6	948.6	750	0.99	0.79	0.81335	#NUM!	#NUM!	1.7014	1.3311
						0.88002	#NUM!	#NUM!	1.7014	1.2303
						0.94668	#NUM!	#NUM!	1.7014	1.1437
						1.01335	#NUM!	#NUM!	1.7014	1.0684
						1.08002	#NUM!	#NUM!	1.7014	1.0025
						1.14668	#NUM!	#NUM!	1.7014	0.9442
						1.21335	#NUM!	#NUM!	1.7014	0.8923
						1.28002	#NUM!	#NUM!	1.7014	0.8458
						1.34668	#NUM!	#NUM!	1.7014	0.8040
						1.41335	#NUM!	#NUM!	1.7014	0.7660
						1.48002	#NUM!	#NUM!	1.7014	0.7315
						1.54668	#NUM!	#NUM!	1.7014	0.7000
						1.61335	#NUM!	#NUM!	1.7014	0.6711
						1.68002	#NUM!	#NUM!	1.7014	0.6444

Construct D&O chart: Test 4 New

Xf = 3.45 kgMLSS/m³
 Vo = 9.08 m/h
 n = 0.29 m³/kg
 Qr = 708 m³/h
 Qi (1D Flux Limit) = 2690 m³/h
 A = 962 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	708	0.00	0.00	0.00000	1.0000	0.0000	3.3387	122.8844
F	86	2313.4	708	2.40	0.31	0.06667	0.8661	0.0006	3.3387	18.4327
F	85.75	2306.7	708	2.40	0.31	0.13333	0.7278	0.2787	3.3387	9.2163
F	85.5	2300.0	708	2.39	0.31	0.20000	0.5776	1.4889	3.3387	6.1442
F	85.25	2293.2	708	2.38	0.31	0.26667	0.3979	2.8533	3.3387	4.6082
F	85	2286.5	708	2.38	0.31	0.33333	0.0224	3.6828	3.3387	3.6865
F	84.75	2279.8	708	2.37	0.31	0.40000	#NUM!	#NUM!	3.3387	3.0721
F	84.5	2273.1	708	2.36	0.31	0.46667	#NUM!	#NUM!	3.3387	2.6332
S	84.25	2266.3	708	2.36	0.31	0.53333	#NUM!	#NUM!	3.3387	2.3041
S	84	2259.6	708	2.35	0.31	0.60000	#NUM!	#NUM!	3.3387	2.0481
S	82	2205.8	708	2.29	0.32	0.66667	#NUM!	#NUM!	3.3387	1.8433
S	80	2152.0	708	2.24	0.33	0.73333	#NUM!	#NUM!	3.3387	1.6757
S	78	2098.2	708	2.18	0.34	0.80000	#NUM!	#NUM!	3.3387	1.5361
S	76	2044.4	708	2.13	0.35	0.86667	#NUM!	#NUM!	3.3387	1.4179
S	74	1990.6	708	2.07	0.36	0.93333	#NUM!	#NUM!	3.3387	1.3166
S	72	1936.8	708	2.01	0.37	1.00000	#NUM!	#NUM!	3.3387	1.2288
S	72	1936.8	708	2.01	0.37	1.06667	#NUM!	#NUM!	3.3387	1.1520
Actual (F)	89.1	2396.8	708	2.49	0.30	1.13333	#NUM!	#NUM!	3.3387	1.0843
						1.20000	#NUM!	#NUM!	3.3387	1.0240
						1.26667	#NUM!	#NUM!	3.3387	0.9701
						1.33333	#NUM!	#NUM!	3.3387	0.9216
						1.40000	#NUM!	#NUM!	3.3387	0.8777
						1.46667	#NUM!	#NUM!	3.3387	0.8378
						1.53333	#NUM!	#NUM!	3.3387	0.8014
						1.60000	#NUM!	#NUM!	3.3387	0.7680
						1.66667	#NUM!	#NUM!	3.3387	0.7373
						1.73333	#NUM!	#NUM!	3.3387	0.7089
						1.80000	#NUM!	#NUM!	3.3387	0.6827
						1.86667	#NUM!	#NUM!	3.3387	0.6583
						1.93333	#NUM!	#NUM!	3.3387	0.6356
						2.00000	#NUM!	#NUM!	3.3387	0.6144

Construct D&O chart: Test 4 Old

Xf = 3.45 kgMLSS/m³
 Vo = 9.08 m/h
 n = 0.29 m³/kg
 Qr = 708 m³/h
 Qi (1D Flux Limit) = 2690 m³/h
 A = 962 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	708	0.00	0.00	0.00000	1.0000	0.0000	3.3387	122.8844
F	74	1990.6	708	2.07	0.36	0.03225	0.9355	0.0000	3.3387	38.1037
F	72	1936.8	708	2.01	0.37	0.06450	0.8705	0.0004	3.3387	19.0519
F	70	1883.0	708	1.96	0.38	0.09675	0.8046	0.0312	3.3387	12.7012
F	68	1829.2	708	1.90	0.39	0.12900	0.7370	0.2315	3.3387	9.5259
F	66	1775.4	708	1.85	0.40	0.16125	0.6670	0.6949	3.3387	7.6207
F	64	1721.6	708	1.79	0.41	0.19350	0.5931	1.3470	3.3387	6.3506
F	63.75	1714.9	708	1.78	0.41	0.22575	0.5135	2.0511	3.3387	5.4434
F	63.5	1708.2	708	1.78	0.41	0.25800	0.4243	2.6981	3.3387	4.7630
F	63.25	1701.4	708	1.77	0.42	0.29025	0.3172	3.2252	3.3387	4.2337
S	63	1694.7	708	1.76	0.42	0.32250	0.1583	3.5997	3.3387	3.8104
S	62.75	1688.0	708	1.75	0.42	0.32895	0.1019	3.6528	3.3387	3.7357
S	62.5	1681.3	708	1.75	0.42	0.36120	#NUM!	#NUM!	3.3387	3.4021
S	62.25	1674.5	708	1.74	0.42	0.39990	#NUM!	#NUM!	3.3387	3.0729
S	62	1667.8	708	1.73	0.42	0.40635	#NUM!	#NUM!	3.3387	3.0241
S	60	1614.0	708	1.68	0.44	0.41280	#NUM!	#NUM!	3.3387	2.9769
S	58	1560.2	708	1.62	0.45	0.41925	#NUM!	#NUM!	3.3387	2.9311
Actual (F)	69.1	1858.8	708	1.93	0.38	0.45150	#NUM!	#NUM!	3.3387	2.7217
						0.48375	#NUM!	#NUM!	3.3387	2.5402
						0.51600	#NUM!	#NUM!	3.3387	2.3815
						0.54825	#NUM!	#NUM!	3.3387	2.2414
						0.58050	#NUM!	#NUM!	3.3387	2.1169
						0.61275	#NUM!	#NUM!	3.3387	2.0055
						0.64500	#NUM!	#NUM!	3.3387	1.9052
						0.67725	#NUM!	#NUM!	3.3387	1.8145
						0.70950	#NUM!	#NUM!	3.3387	1.7320
						0.74175	#NUM!	#NUM!	3.3387	1.6567
						0.77400	#NUM!	#NUM!	3.3387	1.5877
						0.80625	#NUM!	#NUM!	3.3387	1.5241
						0.83850	#NUM!	#NUM!	3.3387	1.4655
						1.00000	#NUM!	#NUM!	3.3387	1.2288

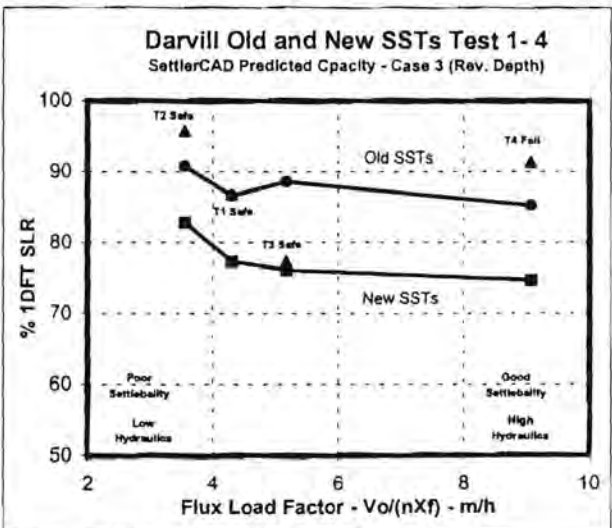
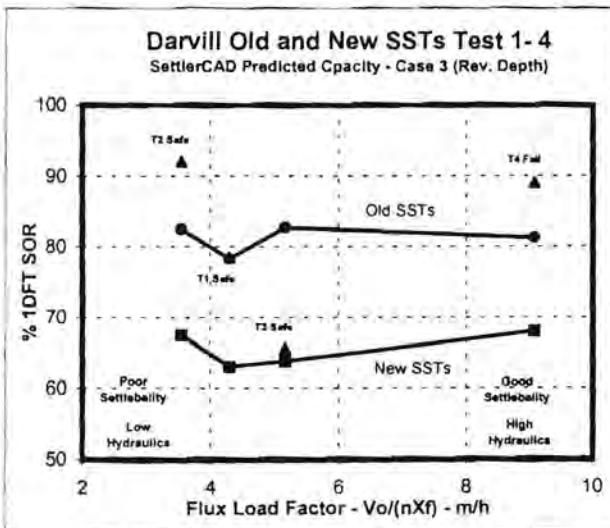
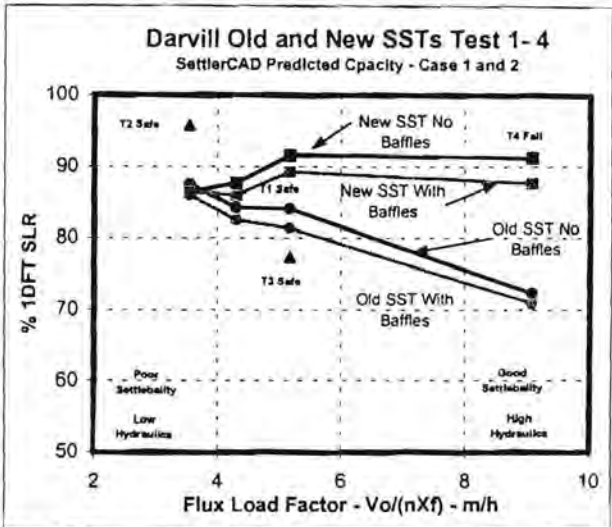
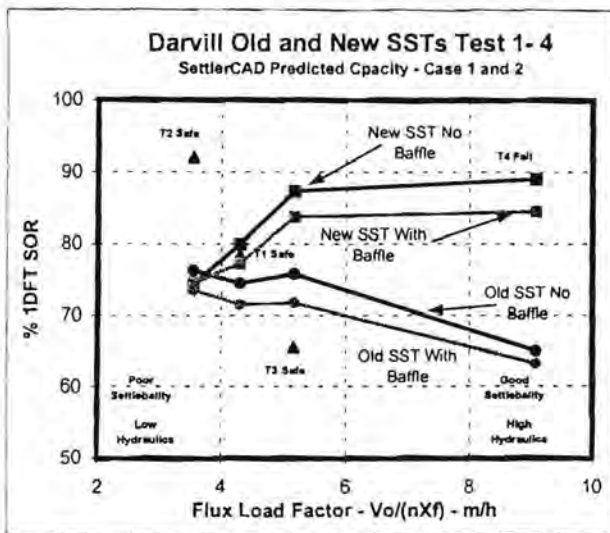
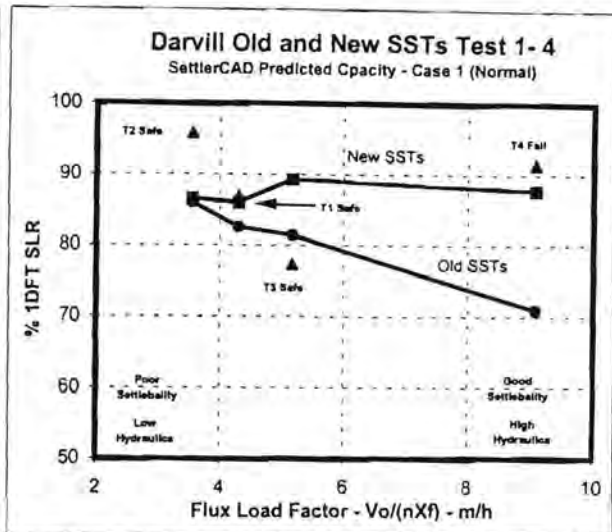
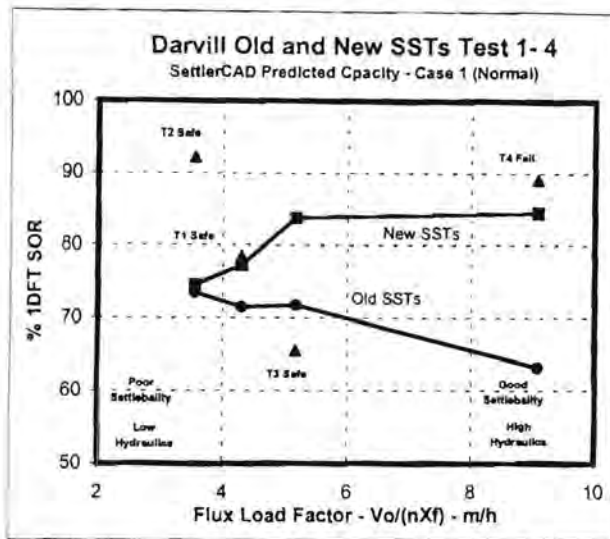


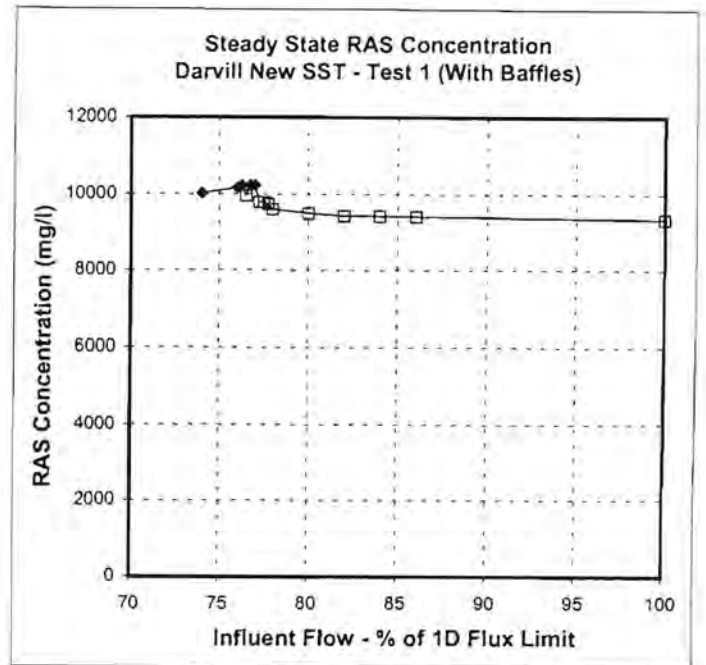
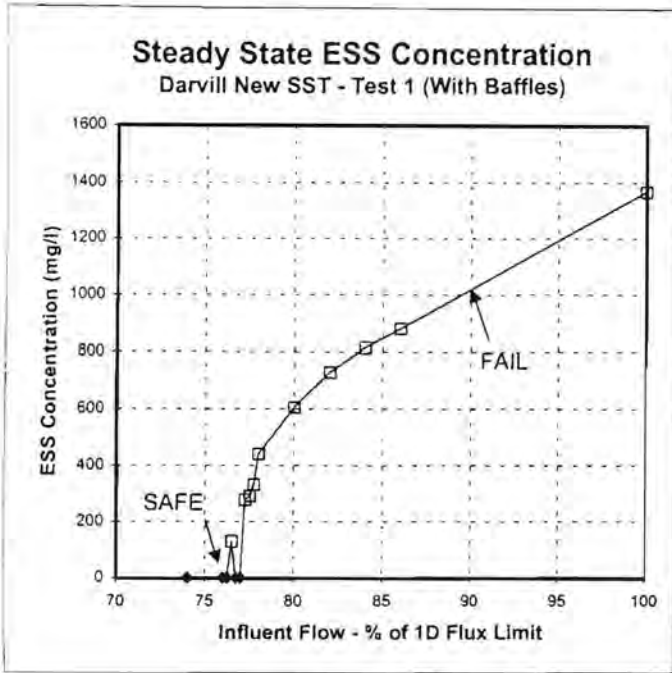
Fig a to f: SettlerCAD predicted capacity as % of the 1DFT maximum HLR (Figures on left) and SLR (Figures on the right) limits versus the flux load factor for the Darvill new and old SSTs. The actual test position and outcome are also shown. The first two figures is for Case 1, the middle two figures are for Case 1 and 2 superimposed upon each other. The last two figures is for Case 3 - reversed depth.

Darvill Flux Load Factor

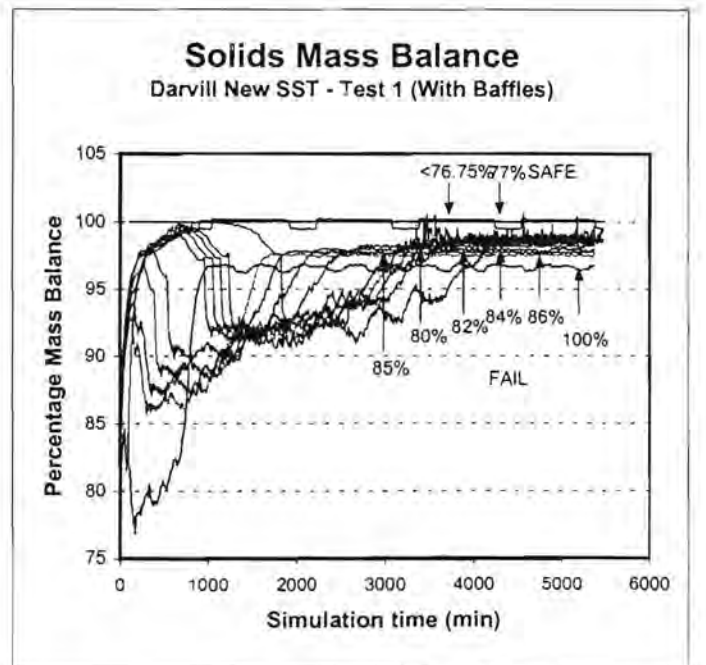
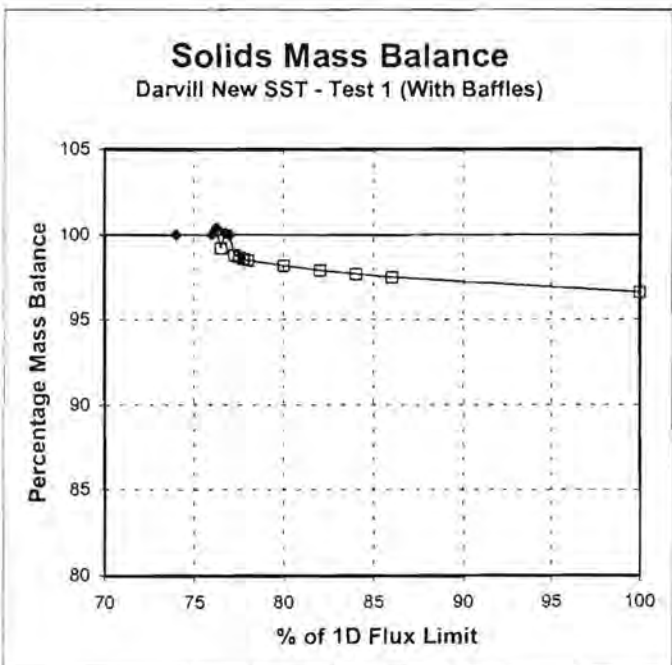
	Test 2		Test 1		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Flux Constant V_0 (m/h)	7.83	7.83	7.71	7.71	8.00	8.00	9.08	9.08
Flux Constant n (m ³ /kgTSS)	0.513	0.513	0.39	0.39	0.43	0.43	0.29	0.29
Feed Conc. (g/l)	4.300	4.300	4.600	4.600	3.600	3.600	3.450	3.450
Flux Factor $V_0/(n \cdot X_F)$ - m/h	3.5	3.5	4.3	4.3	5.2	5.2	9.1	9.1

	Test 2		Test 1		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
% of 1 DFT Overflow Rate								
Case 1 - Normal	74.50	73.50	77.25	71.50	83.75	71.75	84.50	63.25
Case 2 - No Baffles	74.30	76.25	80.00	74.50	87.30	75.80	89.00	65.00
Case 3 - Reverse Depth	67.50	82.50	63.00	78.25	63.75	82.75	68.00	81.25
Actual Test	92.10	92.10	78.50	78.50	65.60	65.60	89.10	89.10

	Test 2		Test 1		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
% of 1 DFT SLR								
Case 1 - Normal	86.5	86	86	82.5	89.3	81.4	87.7	70.9
Case 2 - No Baffles	86.4	87.5	87.7	84.3	91.6	84.1	91.3	72.3
Case 3 - Reverse Depth	82.8	90.8	77.3	86.6	76.1	88.6	74.67	85.2
Actual Test	95.8	95.8	86.8	86.8	77.3	77.3	91.4	91.4

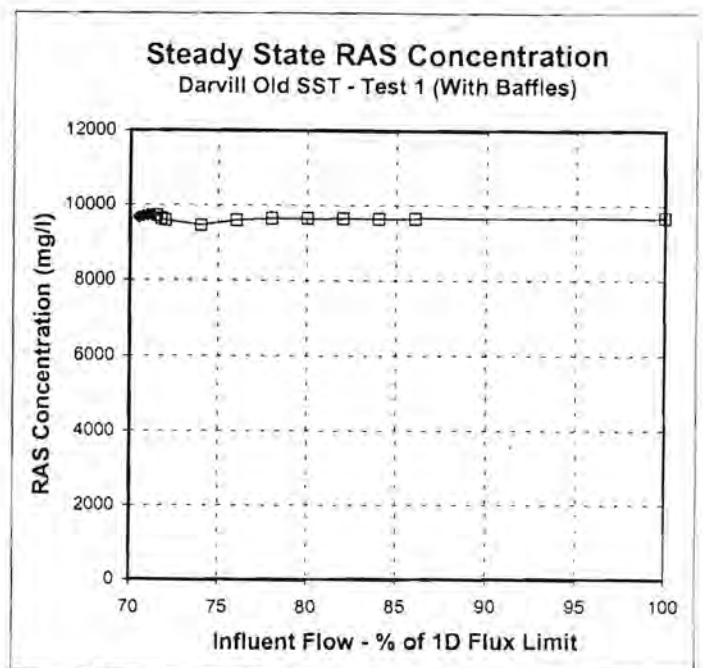
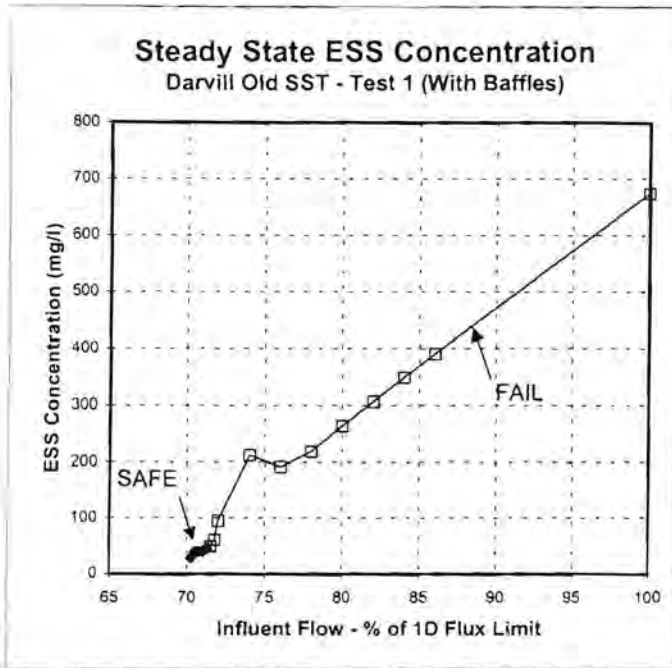


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

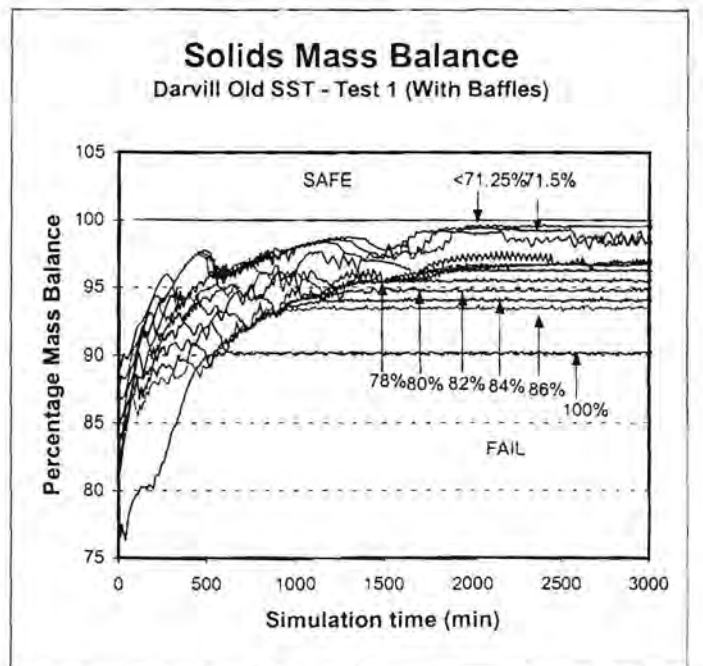
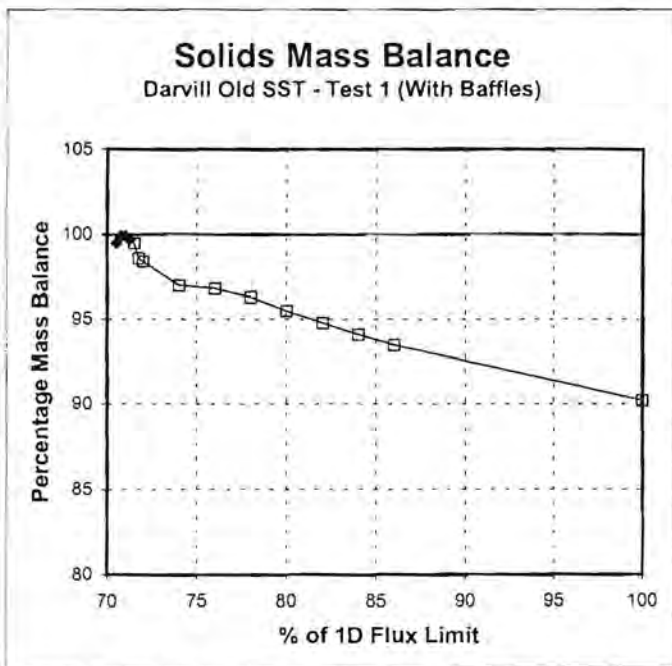


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 1 simulation on the new SST - With Baffles

Test1 New - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.71	74	1.40	10023.00	S	100.0
n (l/g)	0.39	74	1.40	10023.00	S	100.0
Xf (g/l)	4.6	76	1.30	10166.00	S	100.0
1DFT predicted limits		76.25	1.30	10225.00	S	100.4
		76.5	130.80	9962.00	F	99.2
		76.75	1.30	10227.00	S	100.1
Maximun flux [kg/(m ² .h)]	8.28	77	1.30	10240.00	S	100.0
Overflow rate (m/h)	1.1	77.25	279.30	9792.00	F	98.8
Influent flow (m ³ /h)	1062	77.5	291.70	9789.00	F	98.7
Flux ratings		77.75	333.50	9743.00	F	98.6
		78	442.00	9601.00	F	98.5
		80	605.50	9500.00	F	98.2
Flux load factor [Vo/(n.Xf)] (m/h)	4.30	82	728.20	9434.00	F	97.9
		84	814.20	9420.00	F	97.7
Simulation Data		86	881.20	9419.00	F	97.5
		100	1368.30	9339.00	F	96.6
Recycle flow (m ³ /h)	866.7					
Area (m ²)	962					

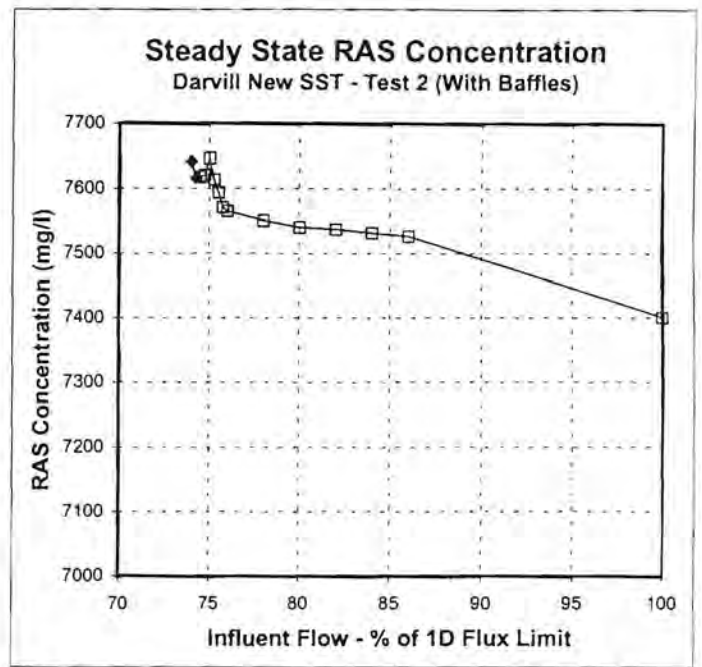
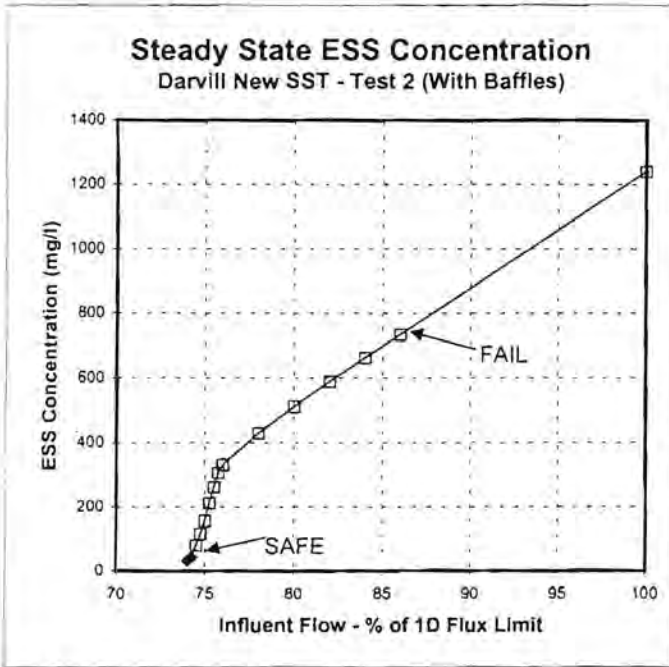


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

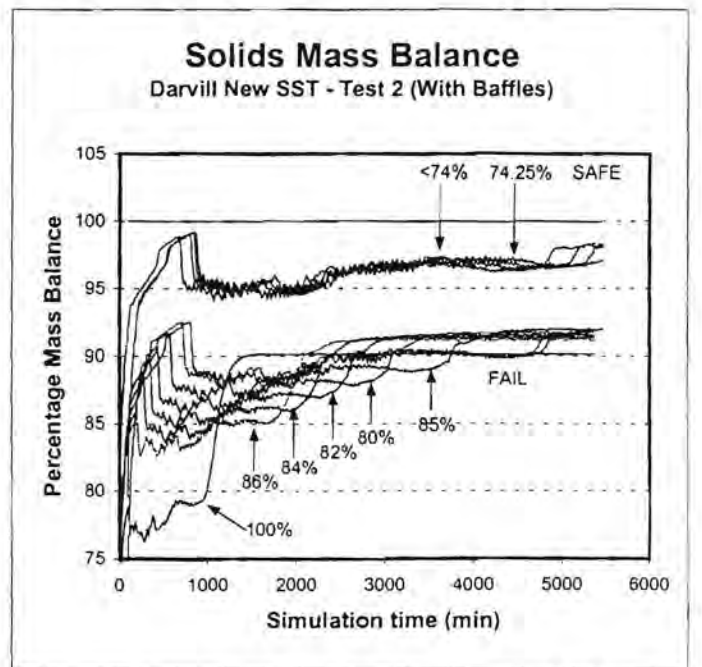
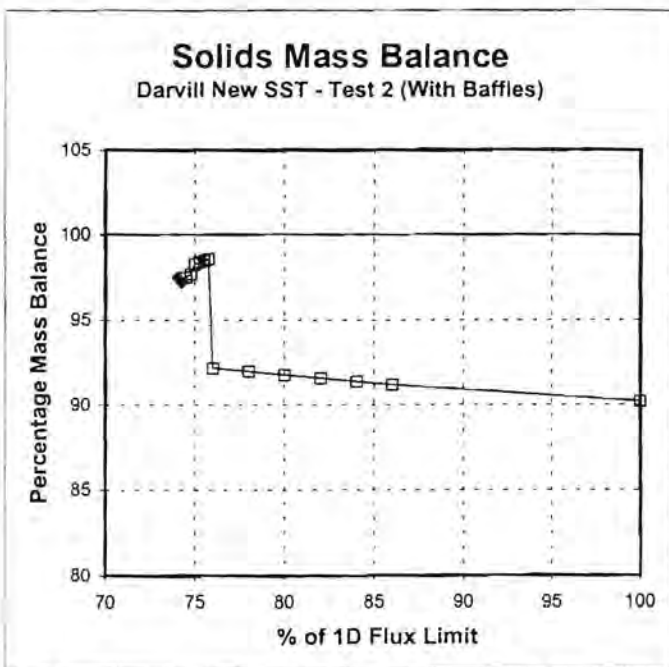


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 1 simulation on the old SST - With Baffles

Test 1 Old - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.71					
n (l/g)	0.39	70.25	28.50	9624.00	S	99.1
Xf (g/l)	4.6	70.5	39.60	9673.00	S	99.5
		70.75	40.60	9724.00	S	99.9
		71	40.50	9742.00	S	99.9
1DFT predicted limits		71.25	45.00	9741.00	S	99.7
		71.5	50.20	9728.00	F	99.5
Maximun flux [kg/(m ² .h)]	8.26	71.75	61.60	9653.00	F	98.6
Overflow rate (m/h)	1.1	72	95.30	9604.00	F	98.4
Influent flow (m ³ /h)	1062	74	212.10	9474.00	F	97.0
		76	191.20	9609.00	F	96.8
Flux ratings		78	218.40	9660.00	F	96.3
		80	263.90	9657.00	F	95.5
Flux load factor [Vo/(n.Xf)] (m/h)	4.30	82	306.30	9656.00	F	94.8
		84	349.10	9654.00	F	94.1
Simulation Data		86	390.50	9660.00	F	93.5
		100	674.30	9679.00	F	90.2
Recycle flow (m ³ /h)	666.7					
Area (m ²)	962					

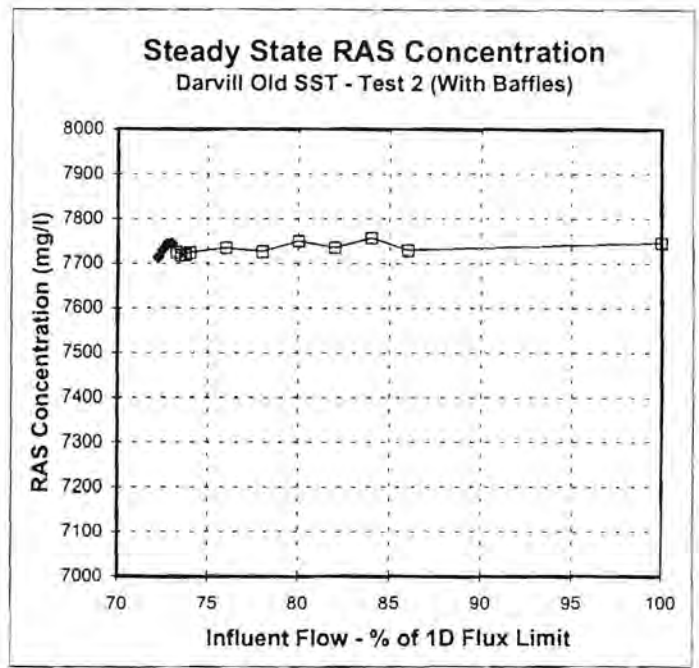
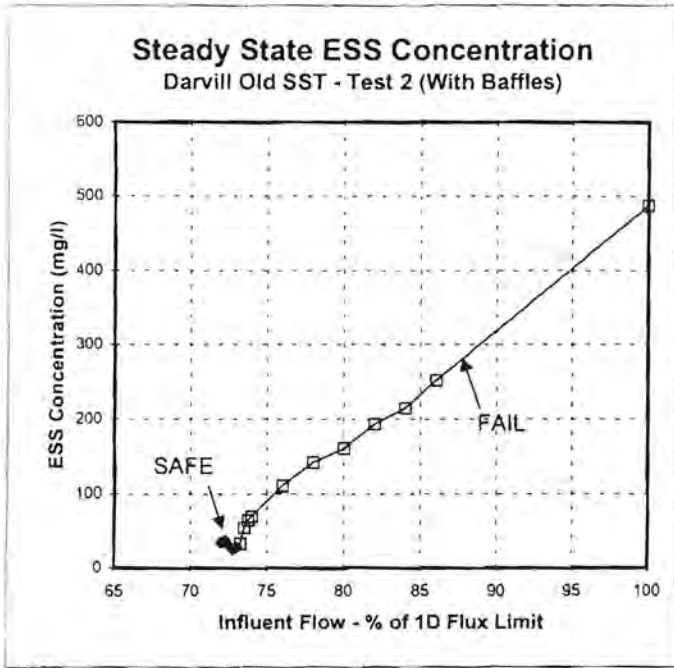


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

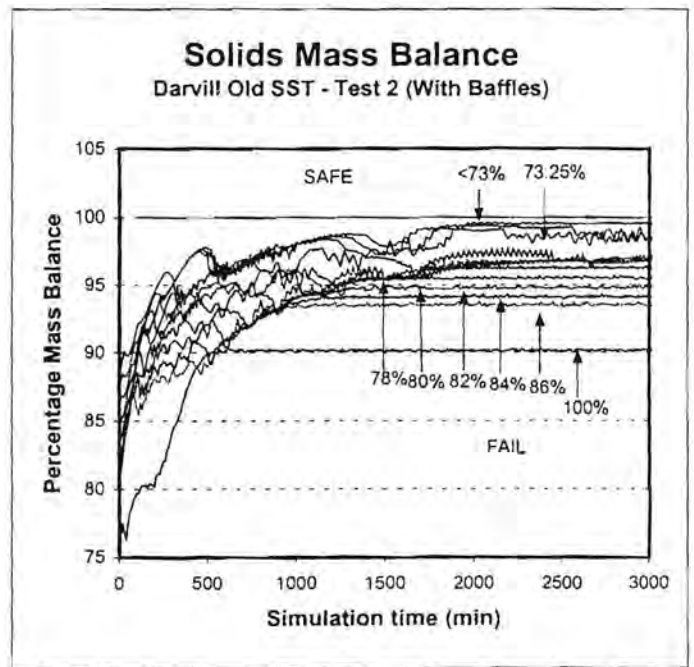
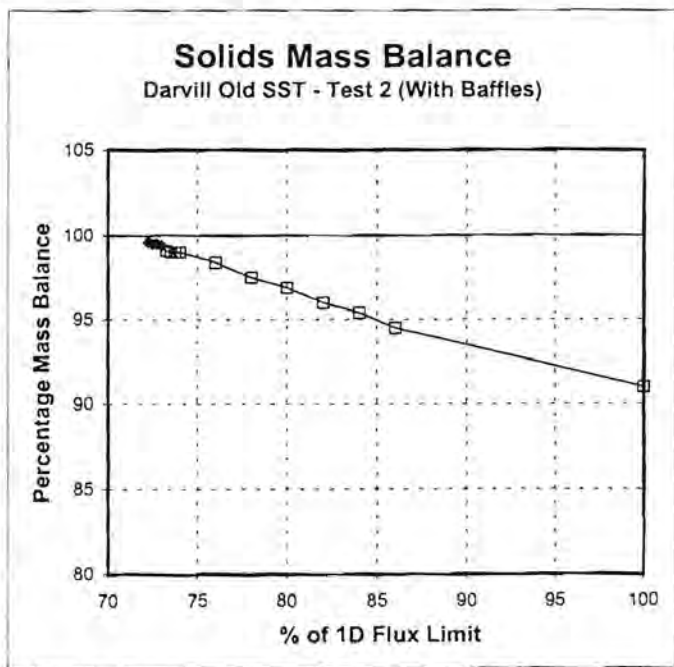


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 2 simulation on the new SST - With Baffles

Test 2 New - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.83	74	31.20	7642.00	S	97.5
n (l/g)	0.513	74	31.20	7642.00	S	97.5
Xf (g/l)	4.3	74.25	43.10	7616.00	S	97.2
1DFT predicted limits		74.5	80.00	7618.00	F	97.5
		74.75	116.50	7621.00	F	97.7
Maximun flux [kg/(m ² .h)]	6.31	75	157.00	7647.00	F	98.3
Overflow rate (m/h)	0.775	75.25	212.10	7614.00	F	98.4
Influent flow (m ³ /h)	746	75.5	262.40	7594.00	F	98.5
		75.75	308.40	7571.00	F	98.6
Flux ratings		76	332.00	7565.00	F	92.2
		78	429.50	7551.00	F	92.0
Flux load factor [Vo/(n.Xf)] (m	3.55	80	512.50	7541.00	F	91.8
		82	588.20	7538.00	F	91.6
Simulation Data		84	663.00	7532.00	F	91.4
		86	734.60	7527.00	F	91.2
Recycle flow (m ³ /h)	666.7	100	1241.00	7401.00	F	90.2
Area (m ²)	962					

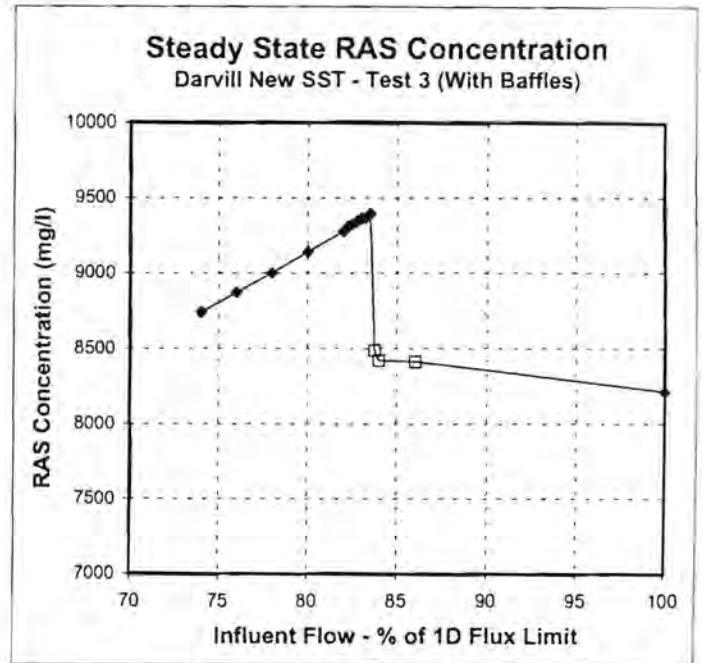
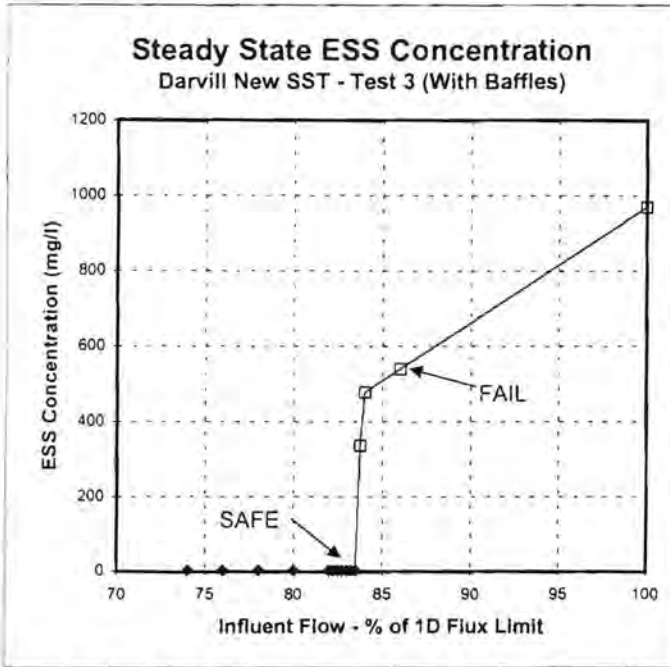


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

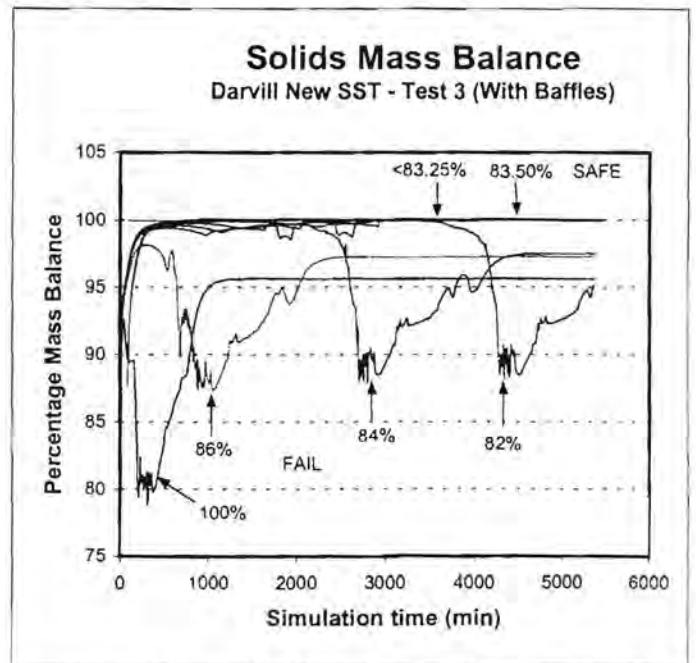
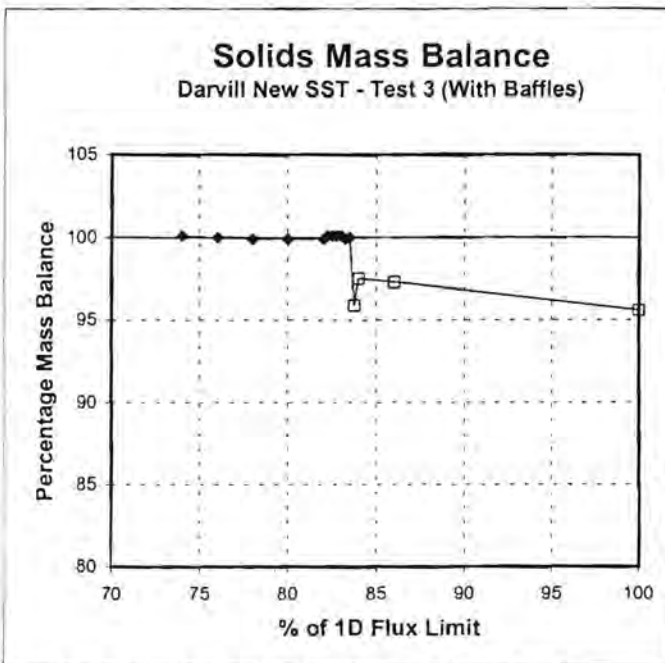


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 2 simulation on the old SST - With Baffles

Test 2 Old - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.83	72	34.50	7702.00	S	99.5
n (l/g)	0.513	72.25	36.40	7713.00	S	99.6
Xf (g/l)	4.3	72.5	30.50	7729.00	S	99.5
1DFT predicted limits		72.75	25.00	7743.00	S	99.5
		73	28.40	7744.00	S	99.4
Maximun flux [kg/(m ² .h)]	6.31	73.25	32.70	7725.00	S	99.1
Overflow rate (m/h)	0.78	73.5	54.40	7718.00	F	99.0
Influent flow (m ³ /h)	746	73.75	64.50	7719.00	F	99.0
		74	69.70	7724.00	F	99.0
Flux ratings		76	110.80	7734.00	F	98.4
		78	142.10	7726.00	F	97.5
Flux load factor [Vo/(n.Xf)] (m/h)	3.55	80	160.60	7750.00	F	96.9
		82	193.50	7735.00	F	96.0
Simulation Data		84	214.90	7757.00	F	95.4
		86	252.00	7729.00	F	94.5
Recycle flow (m ³ /h)	666.7	100	487.10	7746.00	F	91.0
Area (m ²)	962					

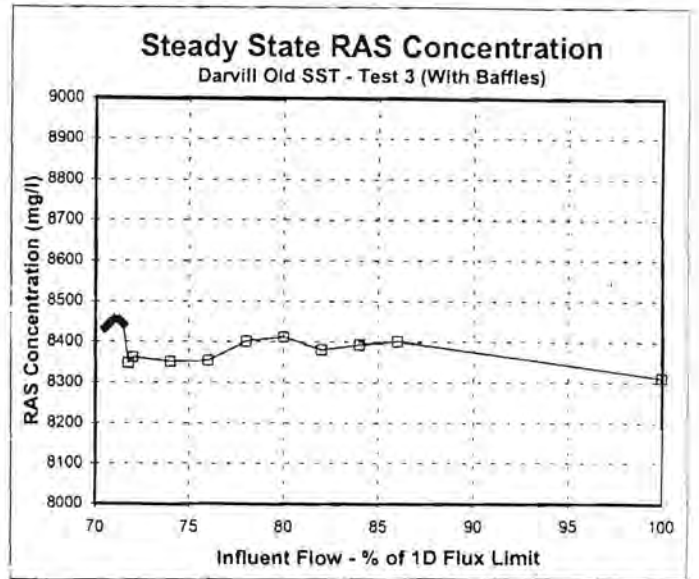
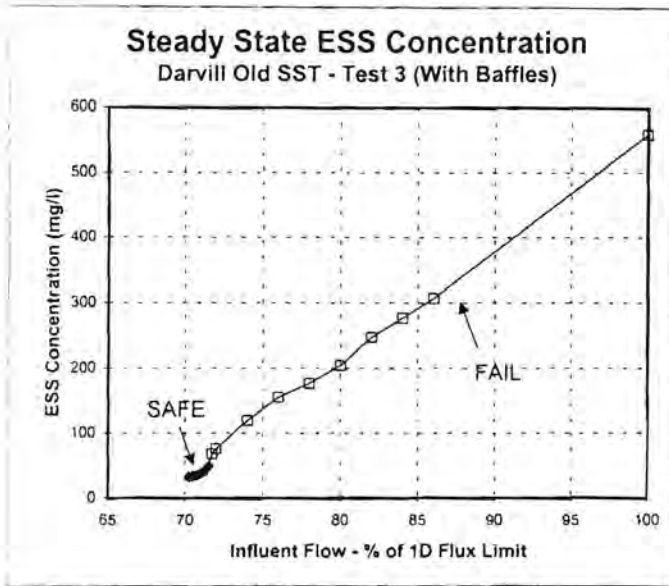


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig , right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

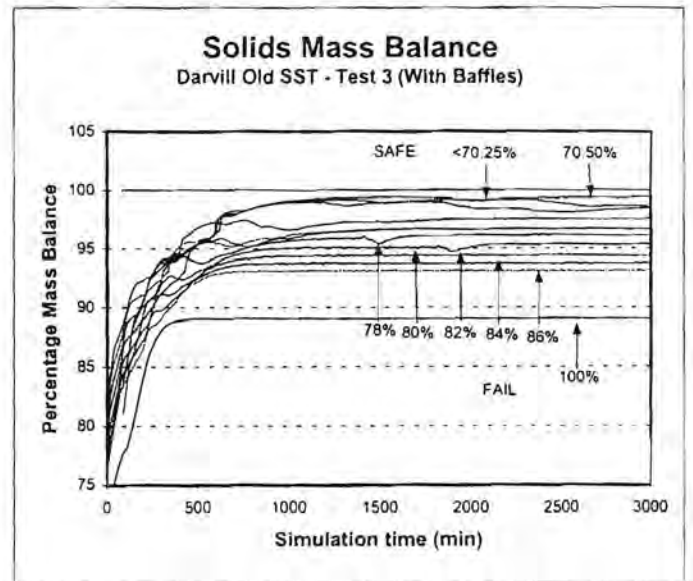
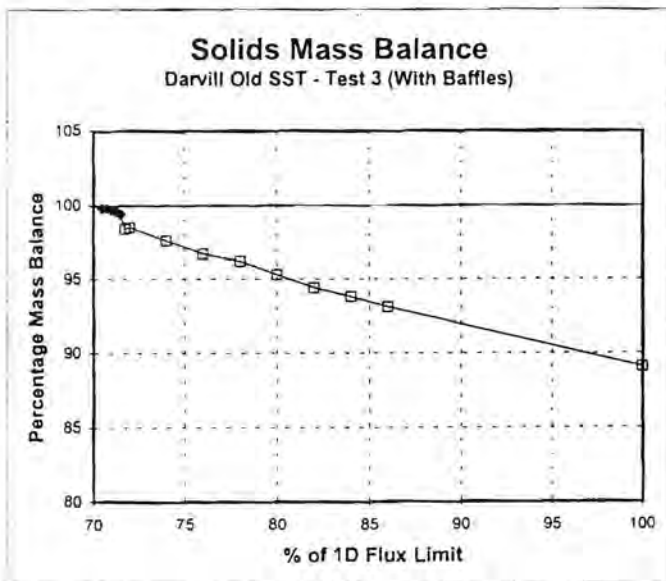


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 3 simulation on the new SST - With Baffles

Test 3 New - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	8.00					
n (l/g)	0.43	74	2.60	8739.00	S	100.1
Xf (g/l)	3.6	74	2.60	8739.00	S	100.1
1DFT predicted limits		76	2.70	8870.00	S	100.0
		78	2.80	9001.00	S	99.9
		80	2.90	9141.00	S	99.9
Maximun flux [kg/(m ² .h)]	8.22	82	3.00	9279.00	S	99.9
Overflow rate (m/h)	1.5	82.25	2.90	9313.00	S	100.1
Influent flow (m ³ /h)	1446	82.5	2.90	9327.00	S	100.1
		82.75	2.90	9346.00	S	100.1
Flux ratings		83	2.90	9364.00	S	100.1
		83.25	2.80	9366.00	S	99.9
Flux load factor [Vo/(n.Xf)] (m/h)	5.17	83.5	2.80	9396.00	S	100.0
		83.75	337.60	8487.00	F	95.9
Simulation Data		84	478.20	8421.00	F	97.5
		86	539.80	8412.00	F	97.3
Recycle flow (m ³ /h)	750	100	969.40	8211.00	F	95.6
Area (m ²)	962					

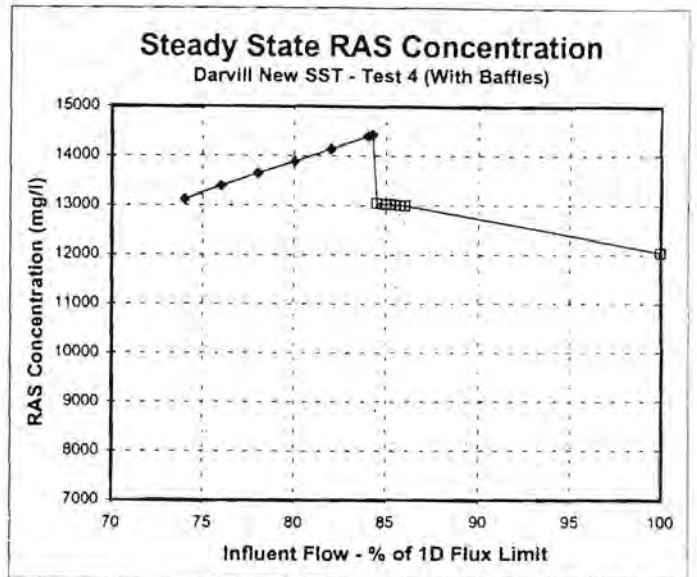
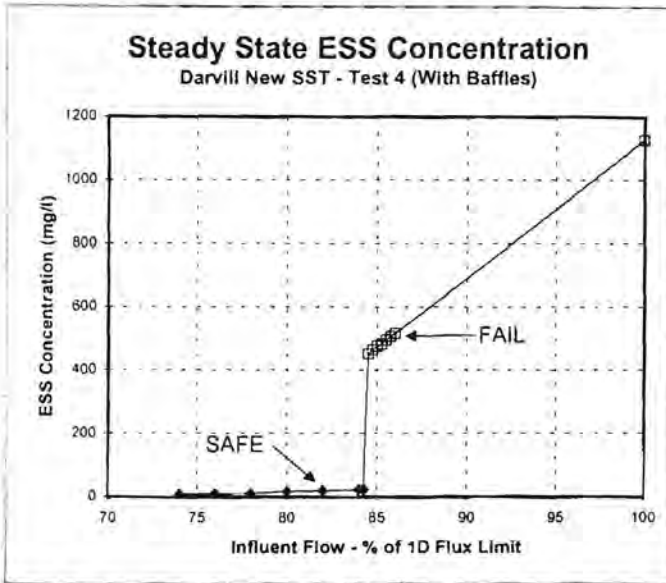


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

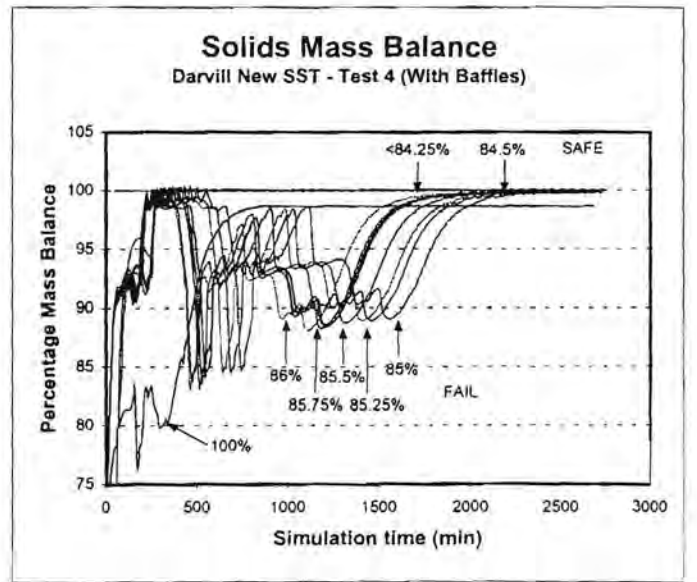
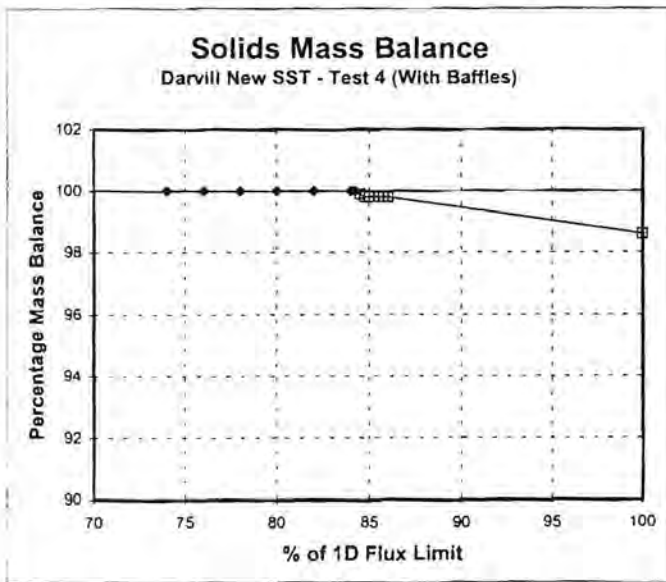


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 3 simulation on the old SST - With Baffles

Test 3 Old - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	8.00	70.25	32.00	8419.00	S	99.8
n (l/g)	0.43	70.5	33.30	8433.00	S	99.8
Xf (g/l)	3.6	70.75	34.90	8445.00	S	99.8
1DFT predicted limits		71	37.10	8456.00	S	99.7
Maximum flux [kg/(m ² .h)]	8.22	71.25	41.40	8454.00	S	99.6
Overflow rate (m/h)	1.5	71.5	48.50	8443.00	S	99.4
Influent flow (m ³ /h)	1446	71.75	67.90	8349.00	F	98.4
Flux ratings		72	75.80	8363.00	F	98.5
Flux load factor [Vo/(n.Xf)] (m/h)	5.17	74	119.70	8352.00	F	97.6
Simulation Data		76	155.20	8355.00	F	96.7
Recycle flow (m ³ /h)	750	78	176.60	8402.00	F	96.2
Area (m ²)	962	80	204.30	8412.00	F	95.3
		82	246.90	8382.00	F	94.4
		84	276.60	8394.00	F	93.8
		86	306.80	8402.00	F	93.1
		100	558.20	8311.00	F	89.1

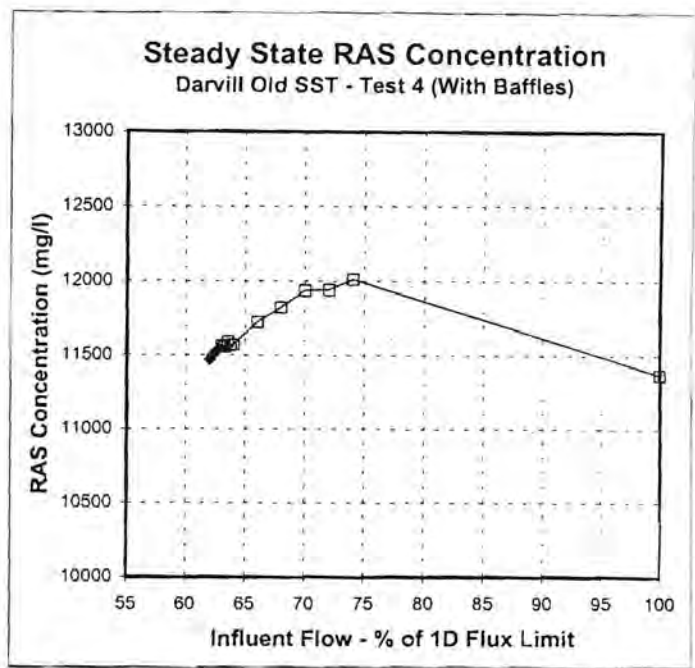
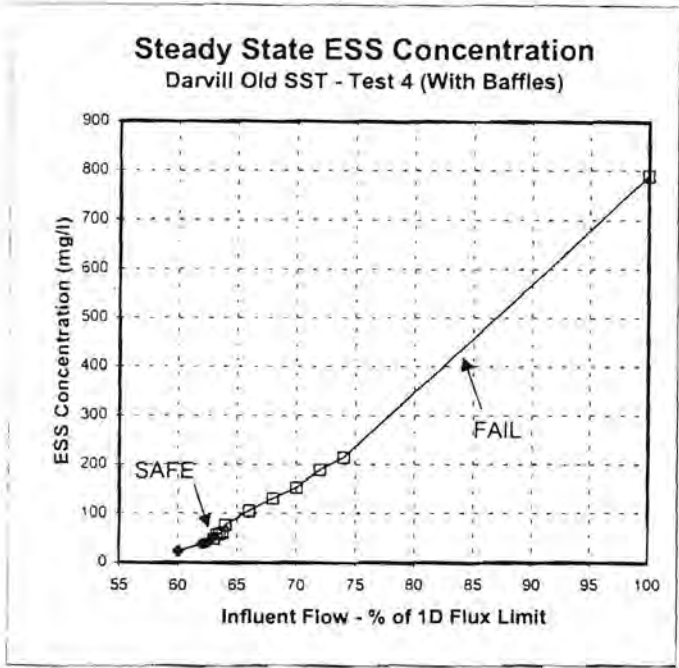


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

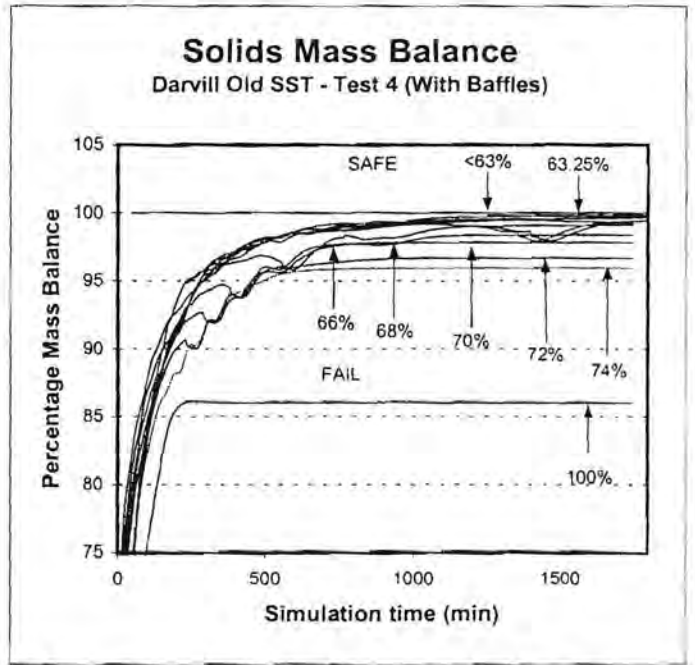
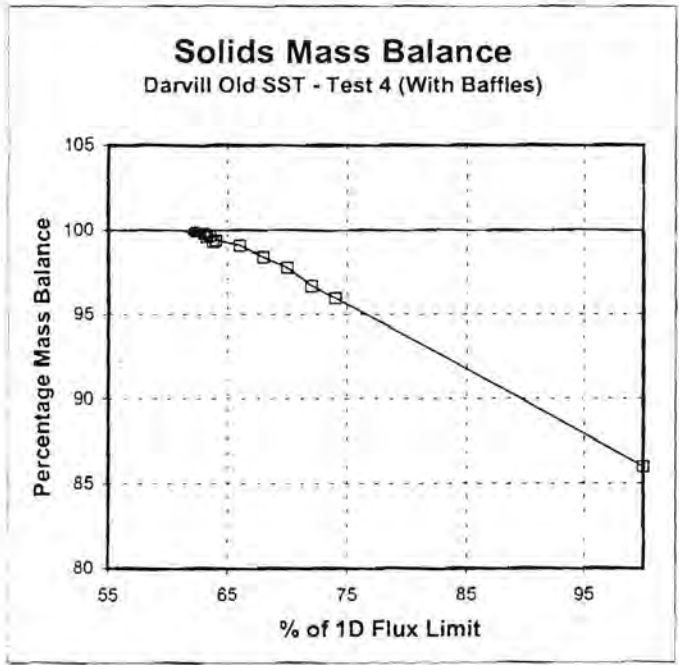


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the new SST - With Baffles

Test 4 New - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	9.08					
n (l/g)	0.29	74	8.70	13121.00	S	100.0
Xf (g/l)	3.45	74	8.70	13121.00	S	100.0
		76	9.50	13382.00	S	100.0
		78	10.20	13642.00	S	100.0
1DFT predicted limits		80	16.30	13884.00	S	100.0
		82	18.20	14142.00	S	100.0
Maximun flux [kg/(m ² .h)]	12.19	84	21.40	14392.00	S	100.0
Overflow rate (m/h)	2.8	84.25	21.80	14422.00	S	100.0
Influent flow (m ³ /h)	2690	84.5	452.20	13056.00	F	99.9
		84.75	465.10	13036.00	F	99.8
Flux ratings		85	475.50	13029.00	F	99.8
		85.25	483.10	13030.00	F	99.8
Flux load factor [Vo/(n.Xf)] (m/h)	9.08	85.5	495.10	13014.00	F	99.8
		85.75	505.50	13009.00	F	99.8
Simulation Data		86	515.90	13002.00	F	99.8
Recycle flow (m ³ /h)	708.3	100	1126.90	12045.00	F	98.6
Area (m ²)	962					

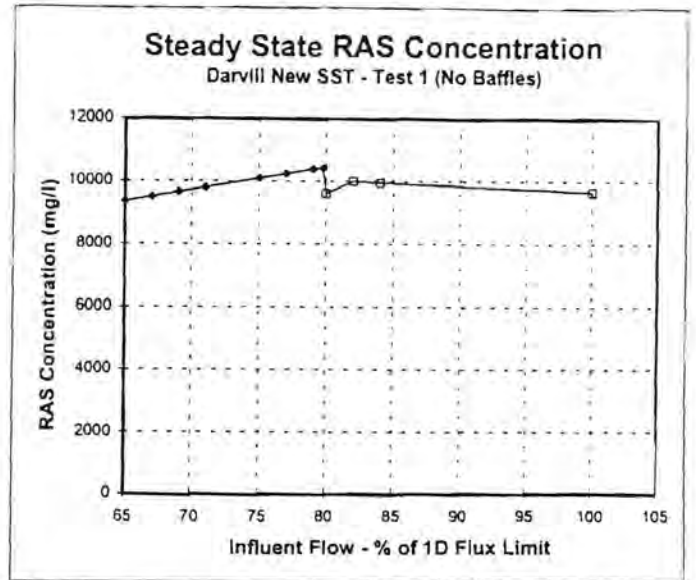
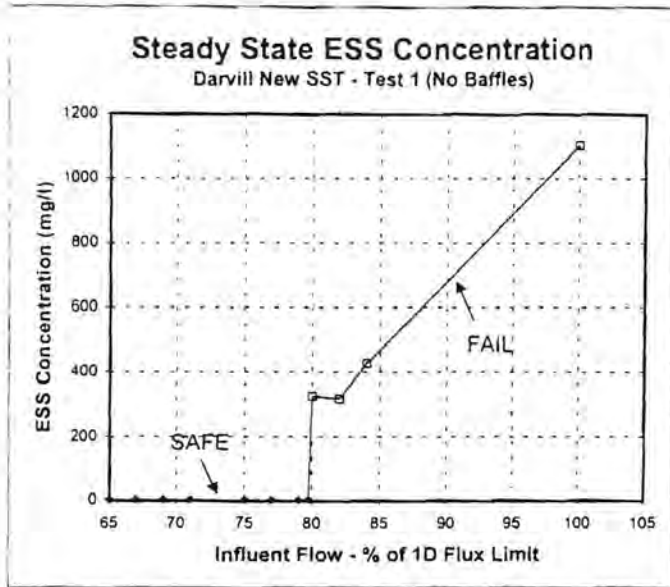


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

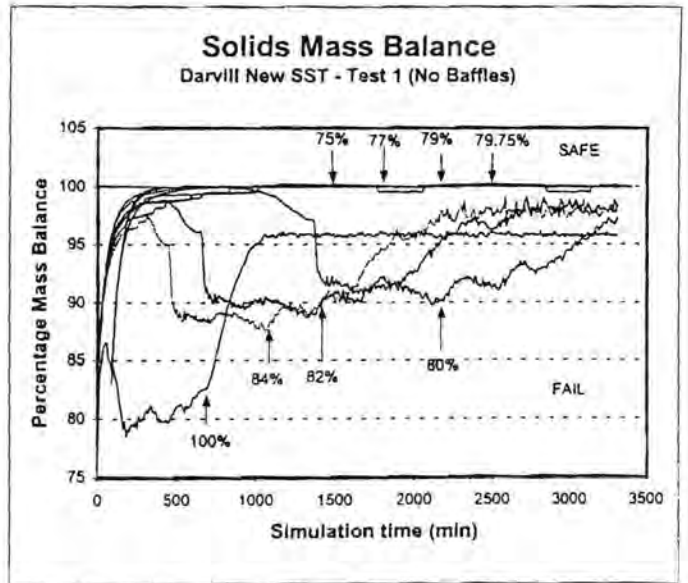
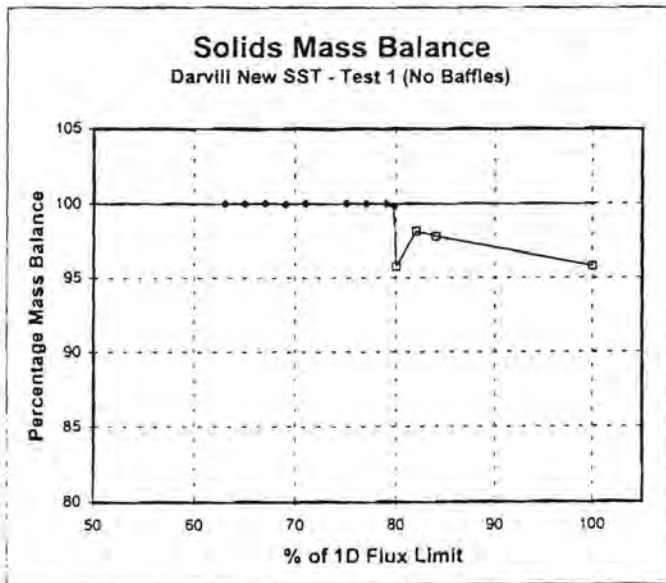


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the old SST - With Baffles

Test 4 Old - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	9.08	60	22.40	11255.00	S	99.9
n (l/g)	0.29	62	37.60	11472.00	S	99.9
Xf (g/l)	3.45	62.25	39.00	11501.00	S	99.9
1DFT predicted limits		62.5	41.00	11527.00	S	99.9
		62.75	46.00	11543.00	S	99.8
Maximun flux [kg/(m ² .h)]	12.19	63	48.20	11569.00	S	99.8
Overflow rate (m/h)	2.8	63.25	56.50	11560.00	F	99.6
Influent flow (m ³ /h)	2690	63.5	58.30	11594.00	F	99.7
		63.75	61.20	11572.00	F	99.3
Flux ratings		64	76.90	11575.00	F	99.4
		66	105.50	11726.00	F	99.1
Flux load factor [Vo/(n.Xf)] (m/h)	9.08	68	130.50	11825.00	F	98.4
		70	153.30	11940.00	F	97.8
Simulation Data		72	189.80	11943.00	F	96.7
		74	214.50	12014.00	F	96.0
Recycle flow (m ³ /h)	708.3	100	790.20	11372.00	F	86.0
Area (m ²)	962					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) - Case 2 No Baffles



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 1 simulation on the new SST - Case 2 No Baffles

Test 1 New - No Baffles

Vo (m/h) 7.71
 n (l/g) 0.39
 Xf (g/l) 4.6

1DFT predicted limits

Maximun flux [kg/(m².h)] 8.26
 Overflow rate (m/h) 1.10
 Influent flow (m³/h) 1062

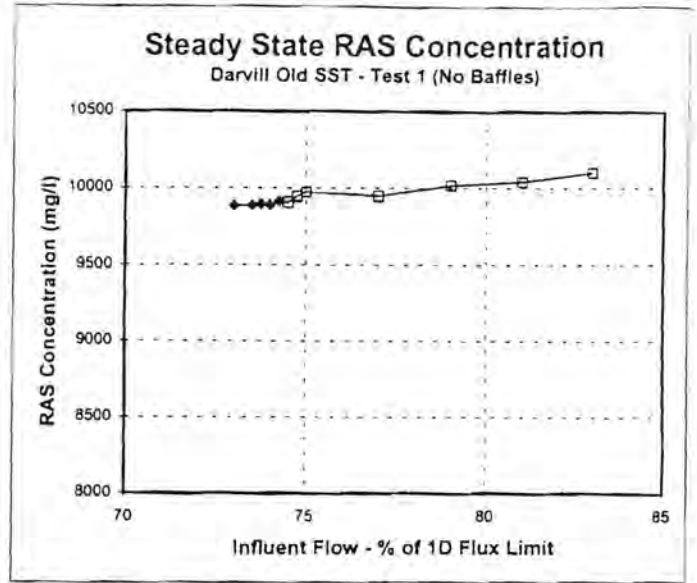
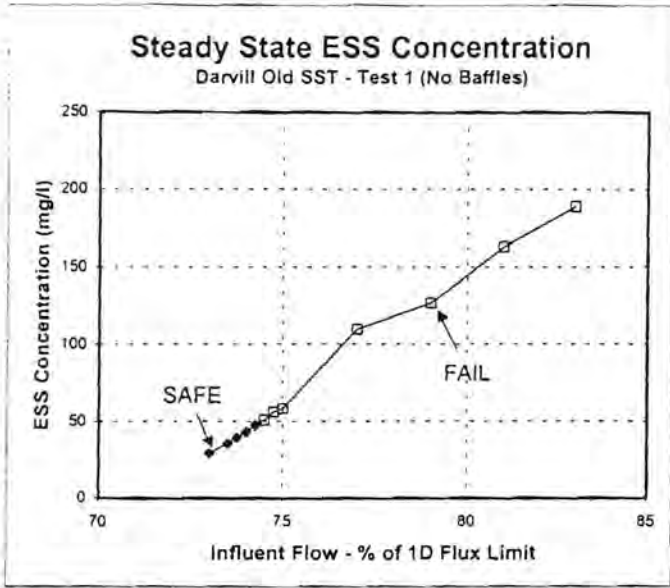
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 4.30

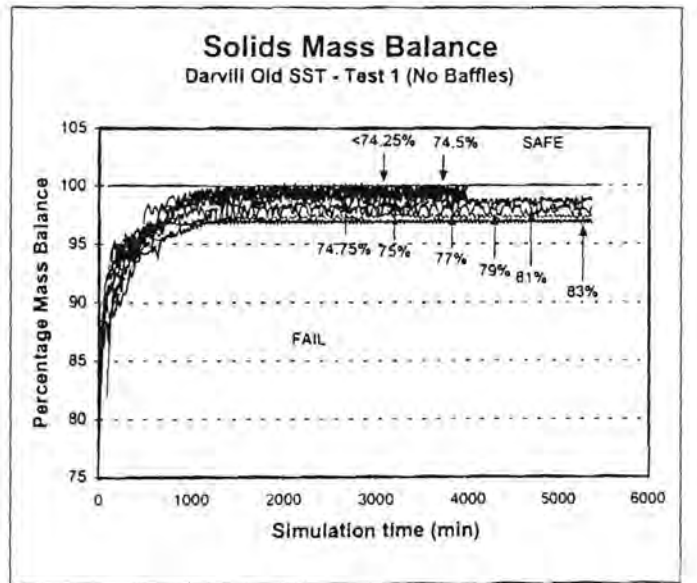
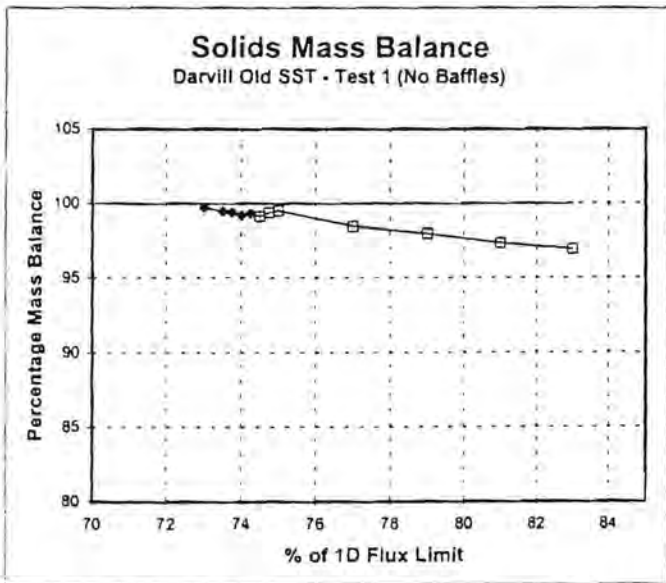
Simulation Data

Recycle flow (m³/h) 666.7
 Area (m²) 962

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
63	2.76	9212.85	S	100.0
65	2.76	9359.77	S	100.0
67	2.79	9508.17	S	100.0
69	2.77	9648.76	S	100.0
71	2.74	9798.04	S	100.0
75	2.62	10092.92	S	100.0
77	2.55	10238.98	S	100.0
79	2.55	10384.24	S	100.0
79.75	2.65	10421.59	S	99.8
80	325.73	9607.48	F	95.8
82	317.88	9997.61	F	98.2
84	426.73	9948.54	F	97.8
100	1104.70	9667.22	F	95.8



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) - Case 2 No Baffles

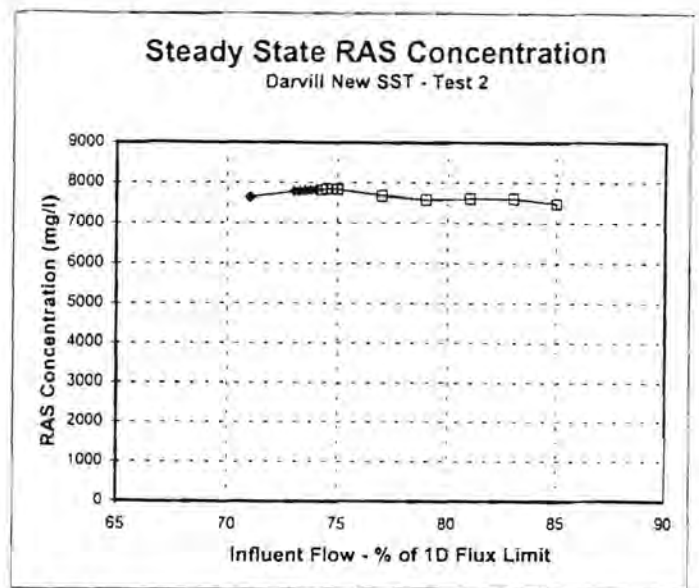
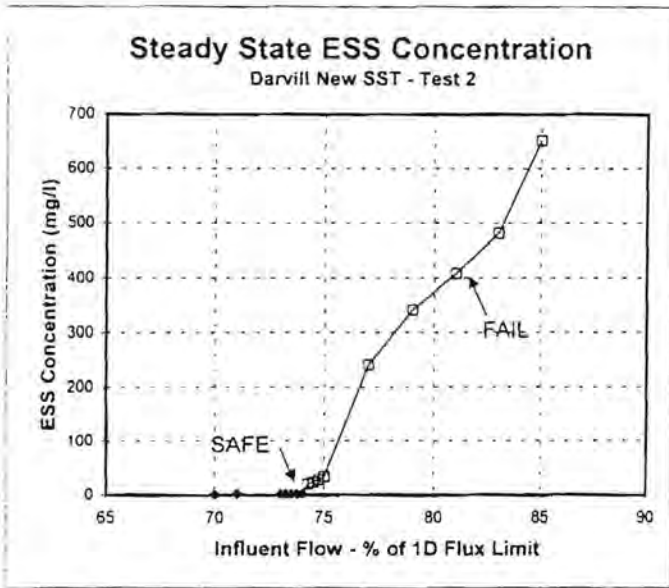


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 1 simulation on the old SST - Case 2 No Baffles

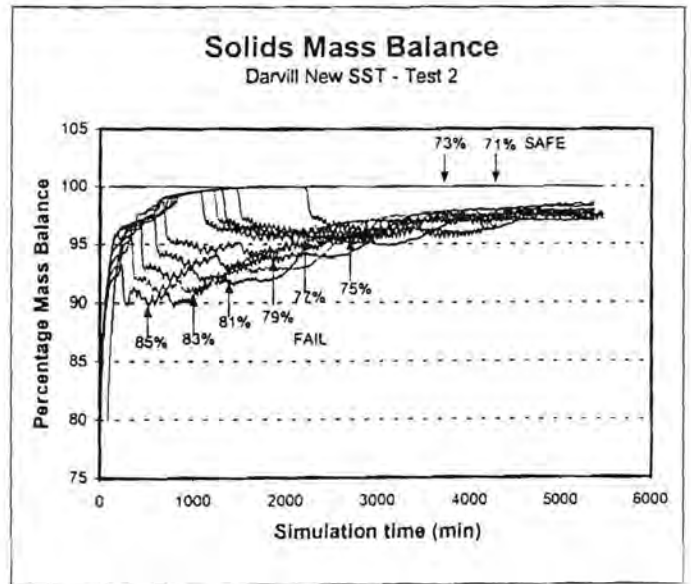
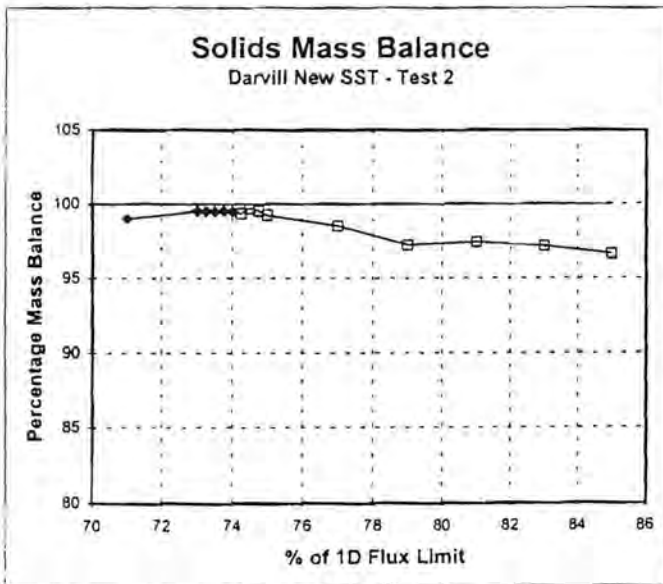
Test 1 Old - No Baffles

Vo (m/h)	7.71
n (l/g)	0.39
Xf (g/l)	4.6
1DFT predicted limits	
Maximum flux [kg/(m ² .h)]	8.26
Overflow rate (m/h)	1.10
Influent flow (m ³ /h)	1062
Flux ratings	
Flux load factor [Vo/(n.Xf)] (m/h)	4.30
Simulation Data	
Recycle flow (m ³ /h)	666.7
Area (m ²)	962

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
73	29.18	9885.15	S	99.7
73.5	35.64	9887.43	S	99.4
73.75	39.69	9895.94	S	99.4
74	43.17	9889.67	S	99.2
74.25	47.43	9915.41	S	99.3
74.5	50.86	9906.98	F	99.1
74.75	56.08	9946.31	F	99.4
75	58.13	9974.32	F	99.5
77	109.92	9947.13	F	98.4
79	126.70	10016.02	F	97.9
81	163.03	10043.40	F	97.3
83	189.25	10102.04	F	96.9



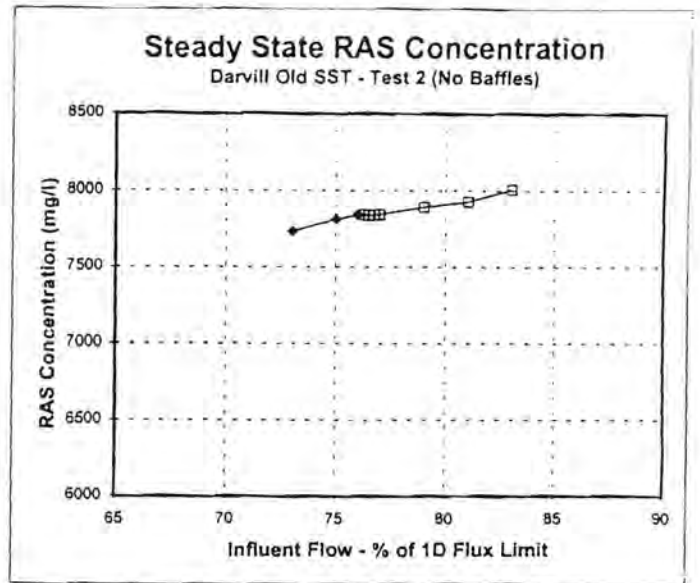
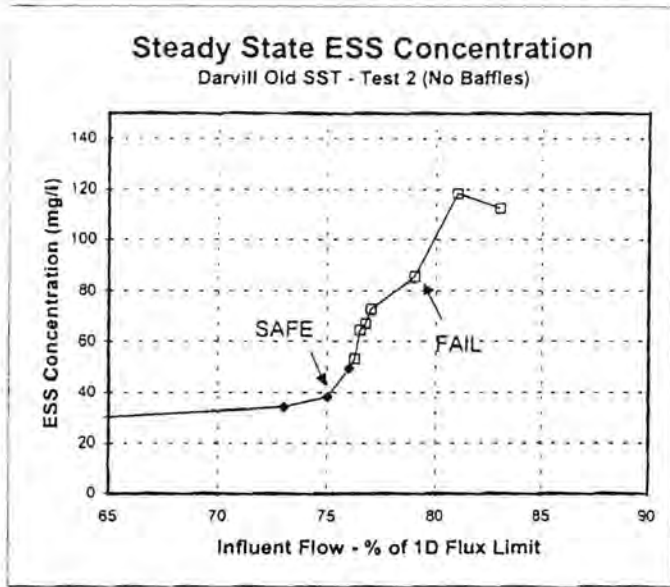
Figs 6a and b: Final ESS and RAS concentrations (Figs 6a, left and Fig 6b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



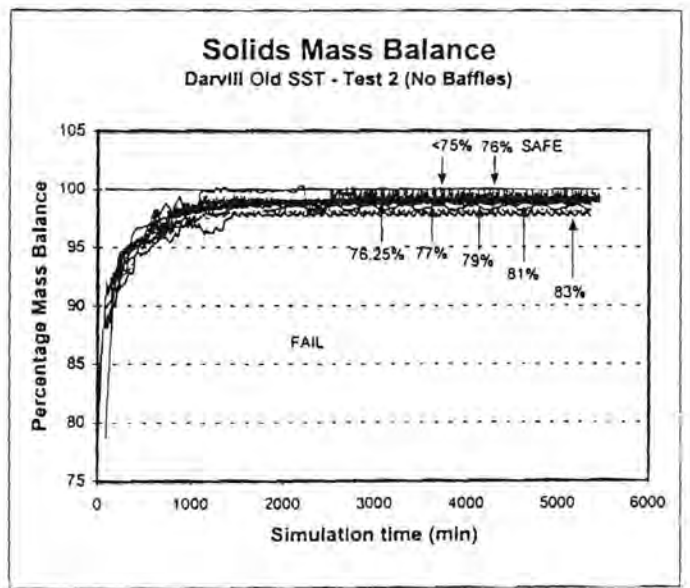
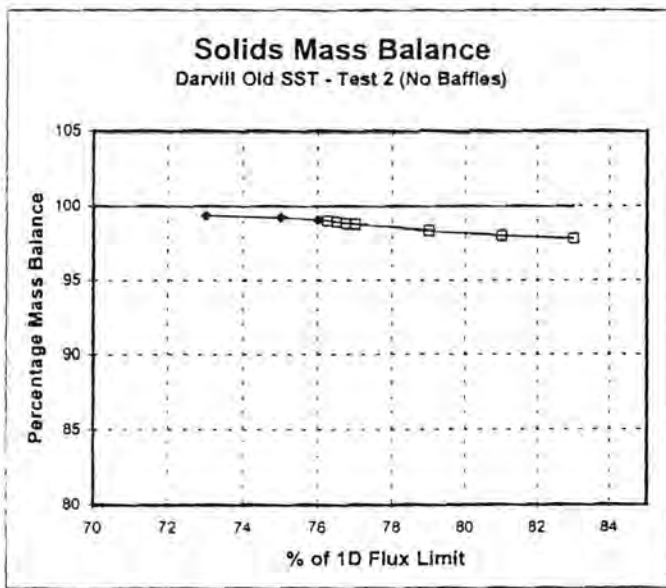
Figs 6c and d: % Mass balance (Figs 6c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig 6d, right) for the SettlerCAD Test 2 simulation on the new SST.

Test 2 New - No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.83					
n (l/g)	0.513	70	0.00	0.00	S	0.0
Xf (g/l)	4.3	71	1.36	7638.07	S	99.0
		73	1.38	7772.28	S	99.5
1DFT predicted limits		73.25	1.37	7783.72	S	99.5
		73.5	1.37	7795.95	S	99.5
Maximun flux [kg/(m ² .h)]	6.31	73.75	1.36	7808.21	S	99.5
Overflow rate (m/h)	0.775	74	1.35	7820.17	S	99.5
Influent flow (m ³ /h)	746	74.25	19.79	7805.93	F	99.4
		74.5	23.92	7841.87	F	99.7
Flux ratings		74.75	28.43	7836.38	F	99.5
		75	33.80	7821.55	F	99.3
Flux load factor [Vo/(n.Xf)] (m/h)	3.55	77	240.34	7679.37	F	98.5
		79	341.99	7573.60	F	97.2
Simulation Data		81	408.45	7614.06	F	97.4
		83	482.00	7608.79	F	97.1
Recycle flow (m ³ /h)	666.7	85	650.82	7487.11	F	96.6
Area (m ²)	962					

Note: Failure is indicated at a ESS concentration of 19,79 mg/l. This is because the SettlerCAD model could not simulate the run any longer then 7500 min. An evaluation of the ESS vs time showed that the ESS concentration was increasing and that failure would have occurred if the SettlerCAD model could simulate the run longer

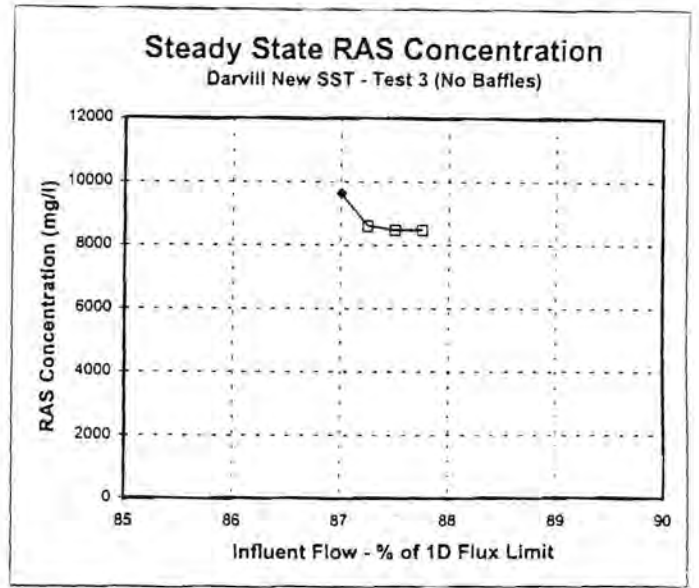
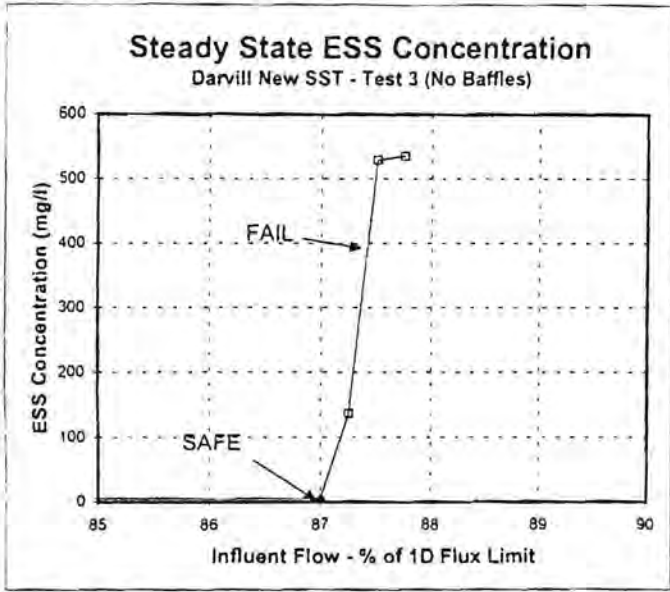


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) - Case 2 No Baffles

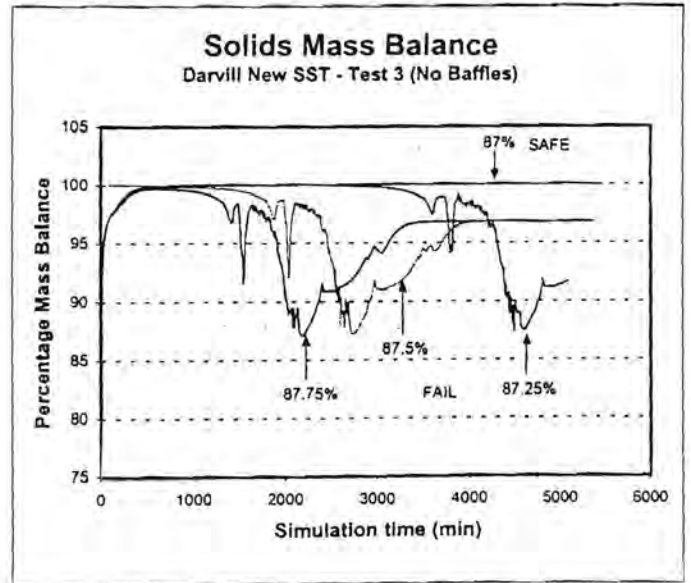
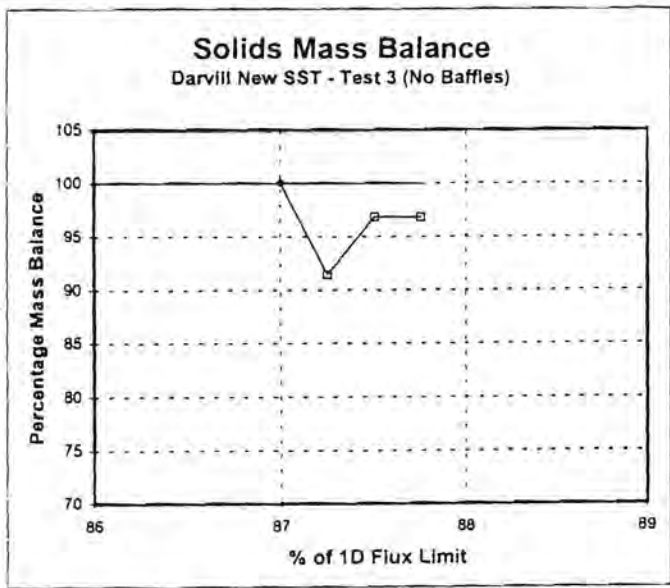


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 2 simulation on the old SST - Case 2 No Baffles

Test 2 Old - No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.83	0	0.00	0.00	S	0.0
n (l/g)	0.513	0	0.00	0.00	S	0.0
Xf (g/l)	4.3	0	0.00	0.00	S	0.0
1DFT predicted limits		0	0.00	0.00	S	0.0
		0	0.00	0.00	S	0.0
Maximum flux [kg/(m ² .h)]	6.31	0	0.00	0.00	S	0.0
Overflow rate (m/h)	0.78	73	34.27	7732.90	S	99.3
Influent flow (m ³ /h)	746	75	38.28	7813.54	S	99.2
		76	49.34	7839.97	S	99.1
Flux ratings		76.25	53.17	7843.68	F	99.0
		76.5	64.56	7837.19	F	98.9
Flux load factor [Vo/(n.Xf)] (m/h)	3.55	76.75	67.13	7840.31	F	98.8
		77	72.78	7843.14	F	98.8
Simulation Data		79	85.53	7890.70	F	98.3
		81	118.41	7927.04	F	98.0
Recycle flow (m ³ /h)	666.7	83	112.39	8007.19	F	97.8
Area (m ²)	962					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) - Case 2 No Baffles



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 3 simulation on the new SST - Case 2 No Baffles

Test 3 New - No Baffles

Vo (m/h)	8
n (l/g)	0.43
Xf (g/l)	3.6

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	8.22
Overflow rate (m/h)	1.50
Influent flow (m ³ /h)	1446

Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	5.17
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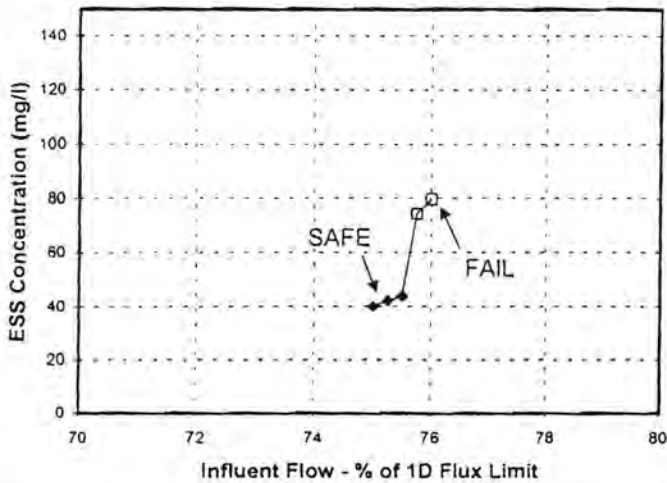
Simulation Data

Recycle flow (m ³ /h)	750
Area (m ²)	962

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
87	5.13	9633.21	S	100.0
87.25	136.65	8599.34	F	91.4
87.5	528.70	8475.09	F	96.8
87.75	534.80	8475.66	F	96.8

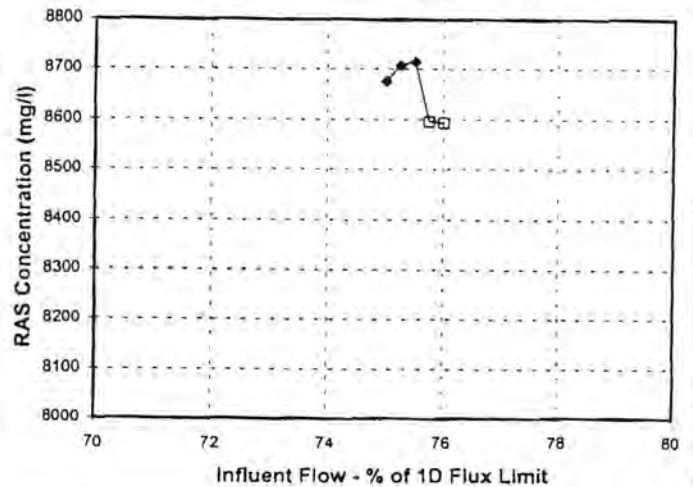
Steady State ESS Concentration

Darvill Old SST - Test 3 (No Baffles)



Steady State RAS Concentration

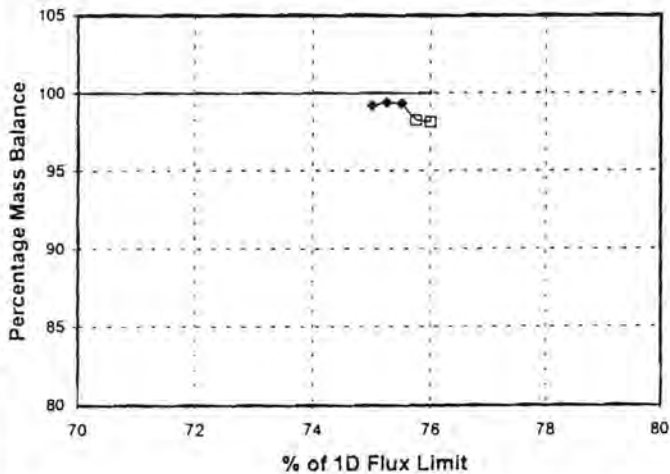
Darvill Old SST - Test 3 (No Baffles)



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) - Case 2 No Baffles

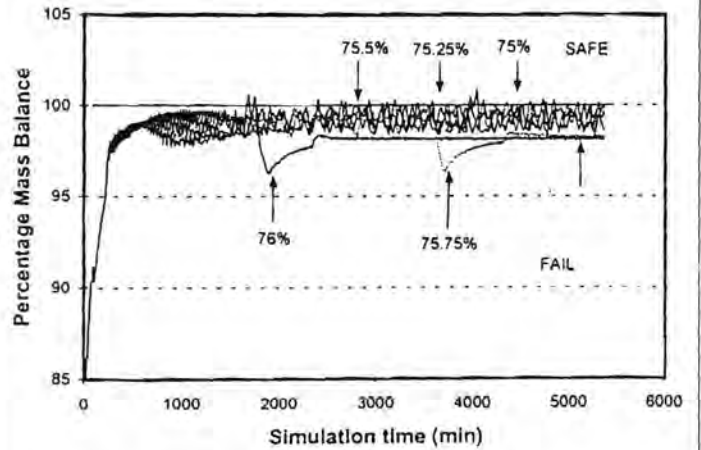
Solids Mass Balance

Darvill Old SST - Test 3 (No Baffles)



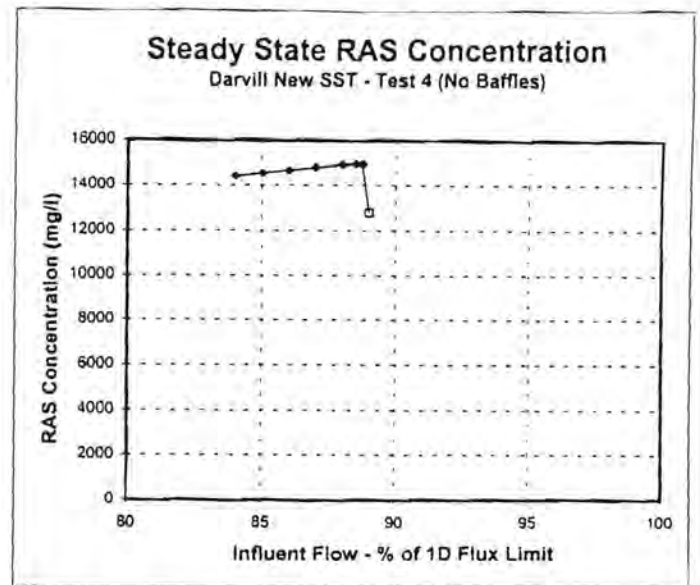
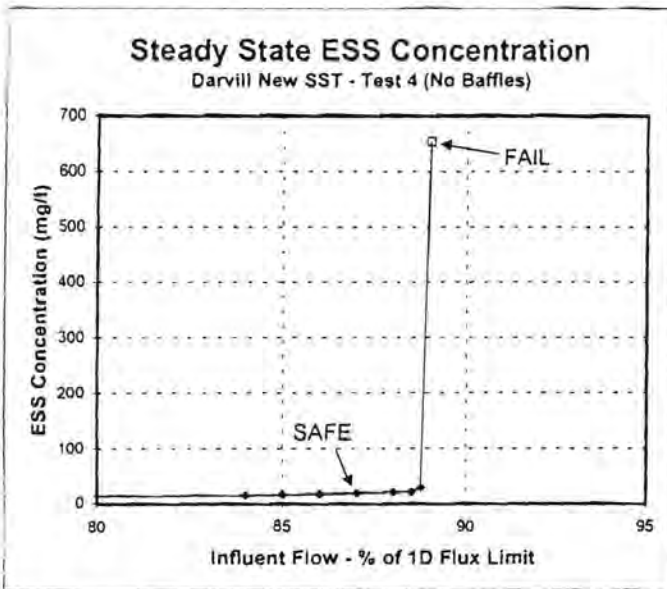
Solids Mass Balance

Darvill Old SST - Test 3 (No Baffles)

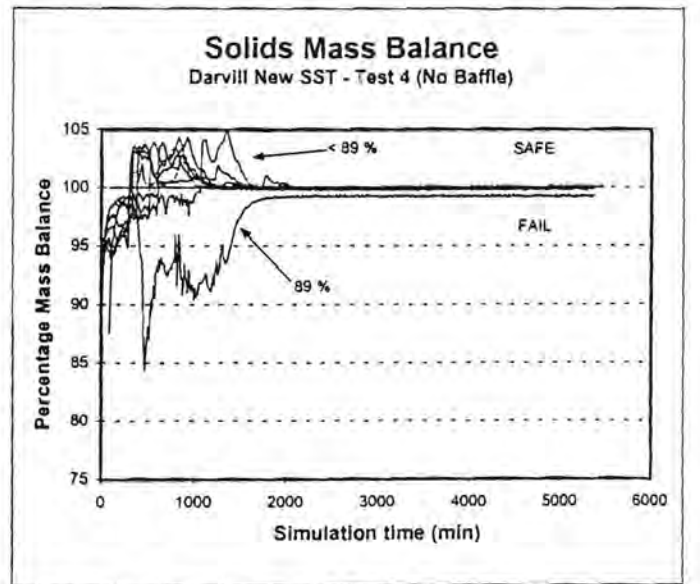
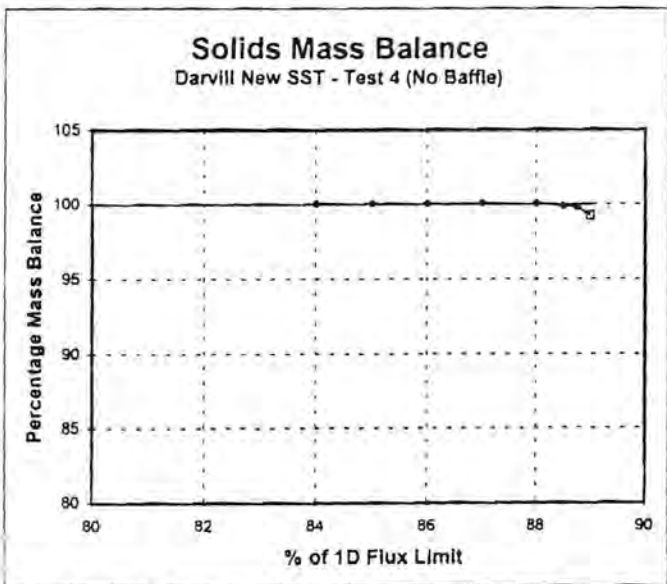


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 3 simulation on the old SST - Case 2 No Baffles

Test 3 Old - No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	8	0	0.00	0.00	S	0.0
n (l/g)	0.43	0	0.00	0.00	S	0.0
Xf (g/l)	3.6	0	0.00	0.00	S	0.0
1DFT predicted limits		0	0.00	0.00	S	0.0
		0	0.00	0.00	S	0.0
Maximun flux [kg/(m ² .h)]	8.22	0	0.00	0.00	S	0.0
Overflow rate (m/h)	1.50	0	0.00	0.00	S	0.0
Influent flow (m ³ /h)	1446	0	0.00	0.00	S	0.0
		0	0.00	0.00	S	0.0
Flux ratings		0	0.00	0.00	S	0.0
		75	40.02	8675.48	S	99.2
Flux load factor [Vo/(n.Xf)] (m/h)	5.17	75.25	42.19	8707.76	S	99.4
		75.5	43.78	8714.84	S	99.3
Simulation Data		75.75	74.29	8595.57	F	98.3
		76	79.70	8593.11	F	98.1
Recycle flow (m ³ /h)	750					
Area (m ²)	962					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) - Case 2 No Baffles



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the new SST - Case 2 No Baffles

Test 4 New - No Baffles

Vo (m/h) 9.08
 n (l/g) 0.29
 Xf (g/l) 3.45

1DFT predicted limits

Maximum flux [kg/(m².h)] 12.19
 Overflow rate (m/h) 2.80
 Influent flow (m³/h) 2690

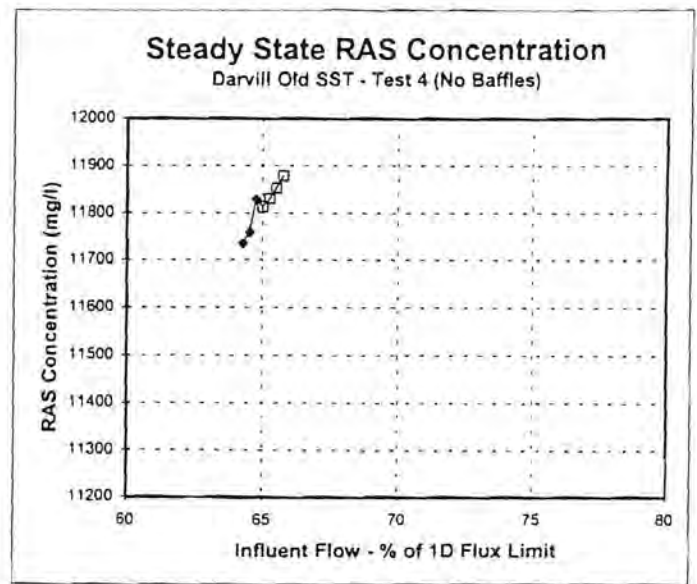
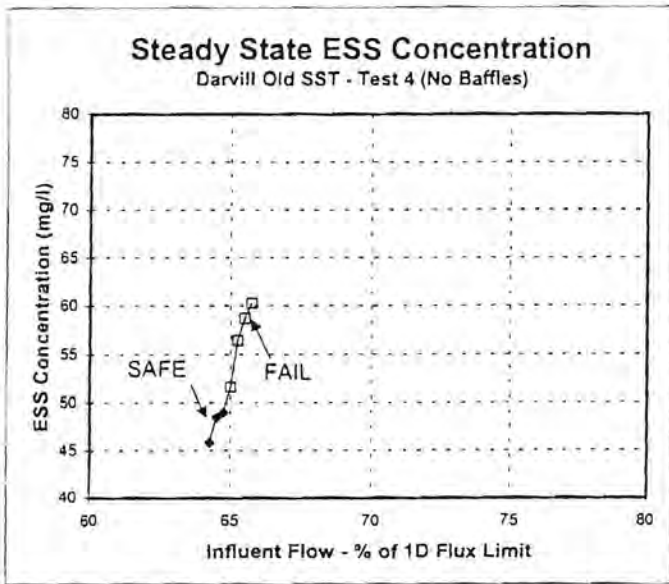
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 9.08

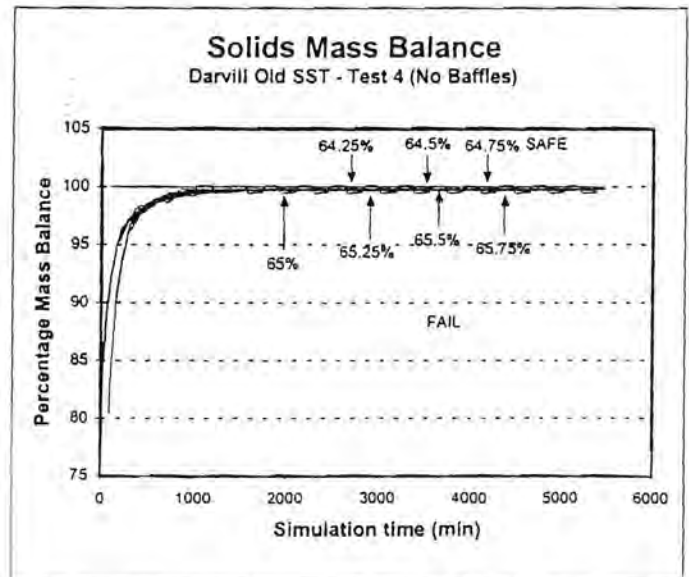
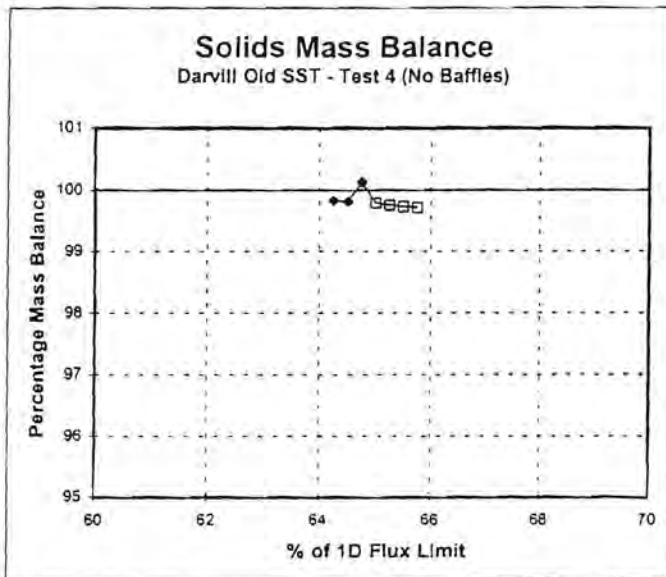
Simulation Data

Recycle flow (m³/h) 708.3
 Area (m²) 962

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
0	0.00	0.00	S	0.0
84	15.00	14414.66	S	100.0
85	15.90	14539.55	S	100.0
86	16.76	14667.13	S	100.0
87	18.66	14797.31	S	100.1
88	20.18	14916.72	S	100.0
88.5	20.75	14951.60	S	99.8
88.75	28.77	14948.67	S	99.8
89	653.17	12786.61	F	99.2

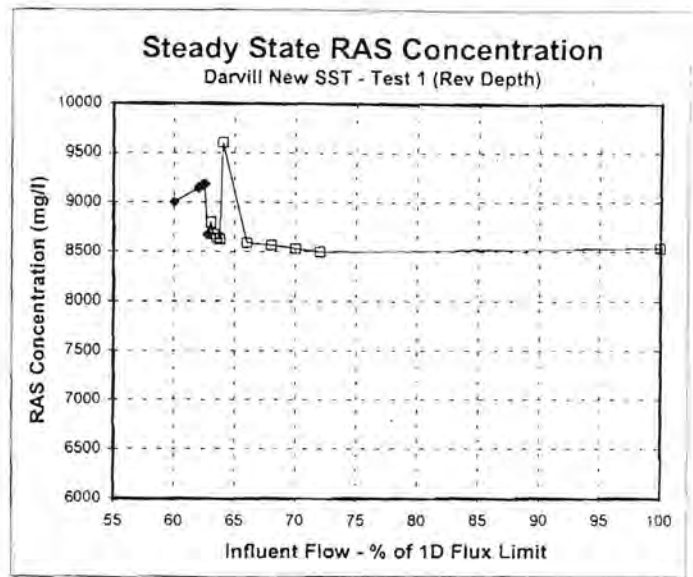
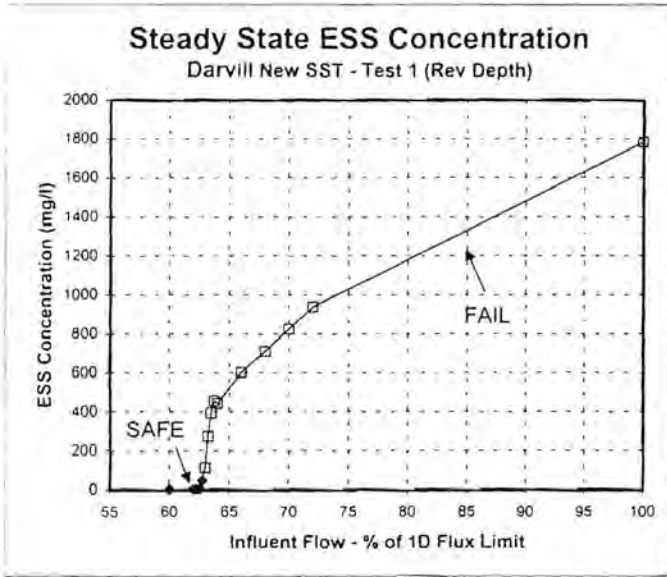


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) - Case 2 No Baffles

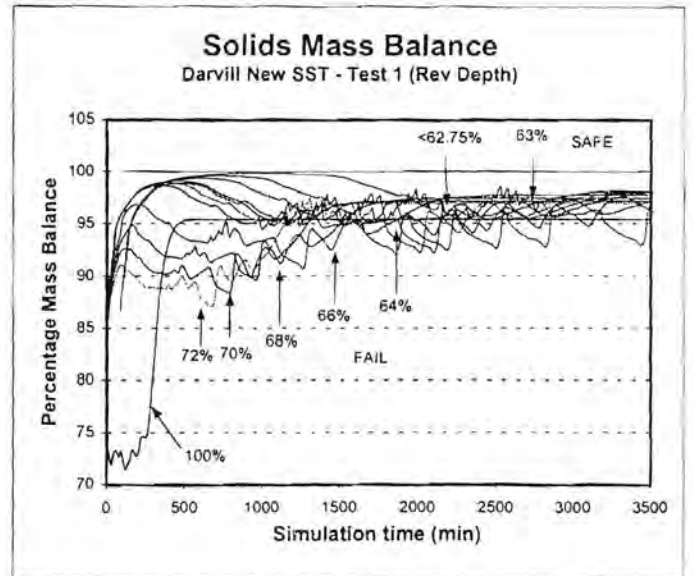
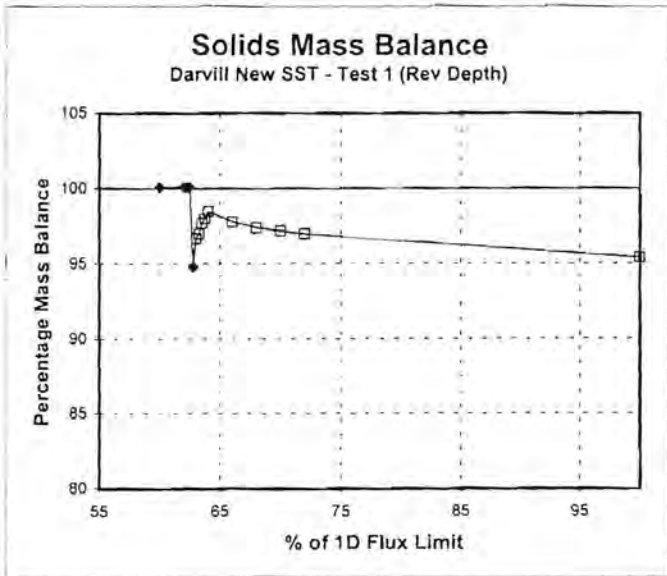


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the old SST - Case 2 No Baffles

Test 4 Old - No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	9.08	0	0.00	0.00	S	0.0
n (l/g)	0.29	0	0.00	0.00	S	0.0
Xf (g/l)	3.45	0	0.00	0.00	S	0.0
1DFT predicted limits		0	0.00	0.00	S	0.0
		0	0.00	0.00	S	0.0
Maximun flux [kg/(m ² .h)]	12.19	64	0.00	0.00	S	0.0
Overflow rate (m/h)	2.80	64.25	45.81	11735.30	S	99.8
Influent flow (m ³ /h)	2690	64.5	48.46	11758.97	S	99.8
		64.75	48.96	11828.42	S	100.1
Flux ratings		65	51.60	11813.08	F	99.8
		65.25	56.41	11829.37	F	99.7
Flux load factor [Vo/(n.Xf)] (m/h)		65.5	58.69	11853.08	F	99.7
	9.08	65.75	60.28	11879.10	F	99.7
Simulation Data		66	0.00	0.00	S	0.0
		68	0.00	0.00	S	0.0
Recycle flow (m ³ /h)	708.3	70	0.00	0.00	S	0.0
Area (m ²)	962					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 1 simulation on the new SST - Reversed Depth

Test1 New - Reversed Depth

Vo (m/h)	7.71
n (l/g)	0.39
Xf (g/l)	4.6

1DFT predicted limits

Maximum flux [kg/(m ² .h)]	8.26
Overflow rate (m/h)	1.1
influent flow (m ³ /h)	1062

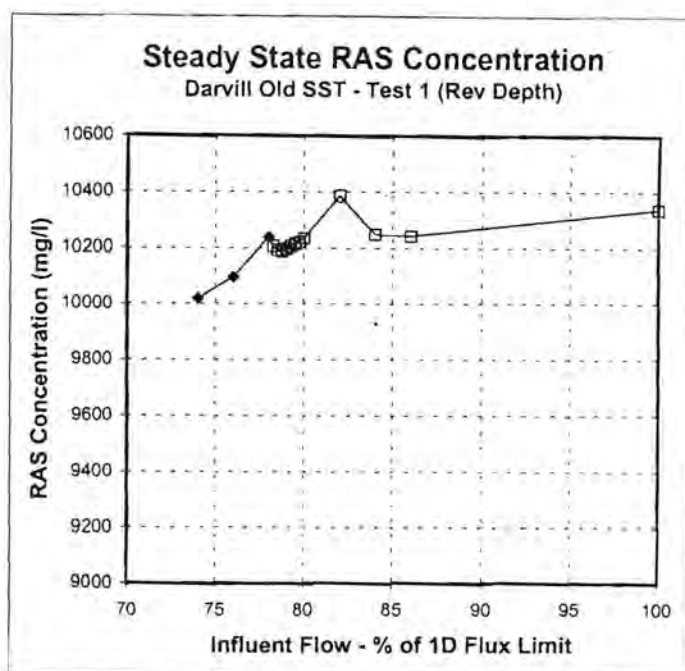
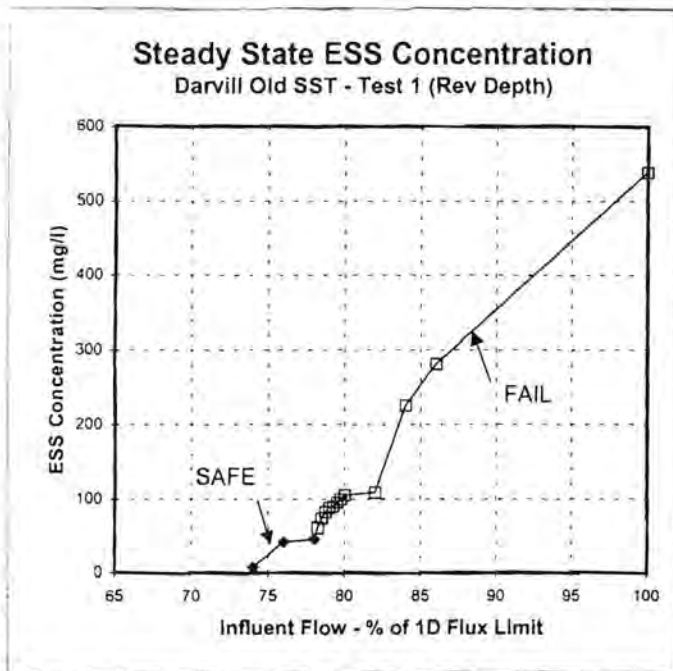
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	4.30
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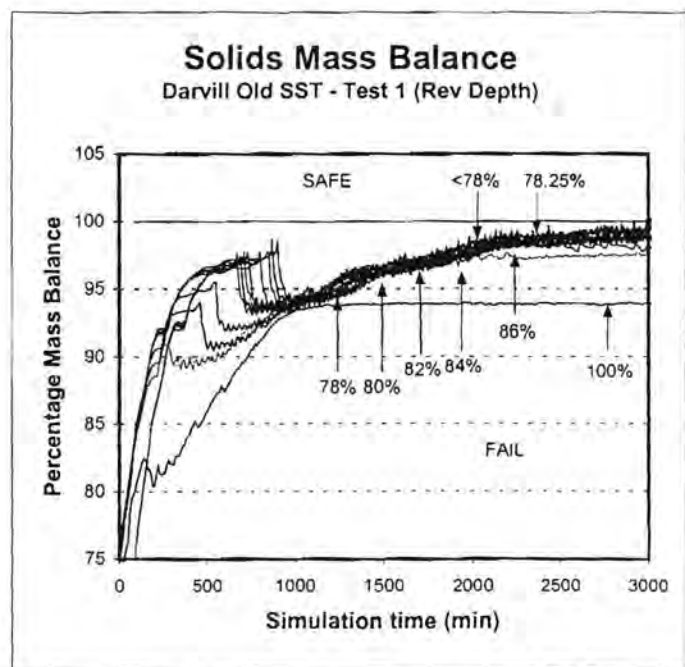
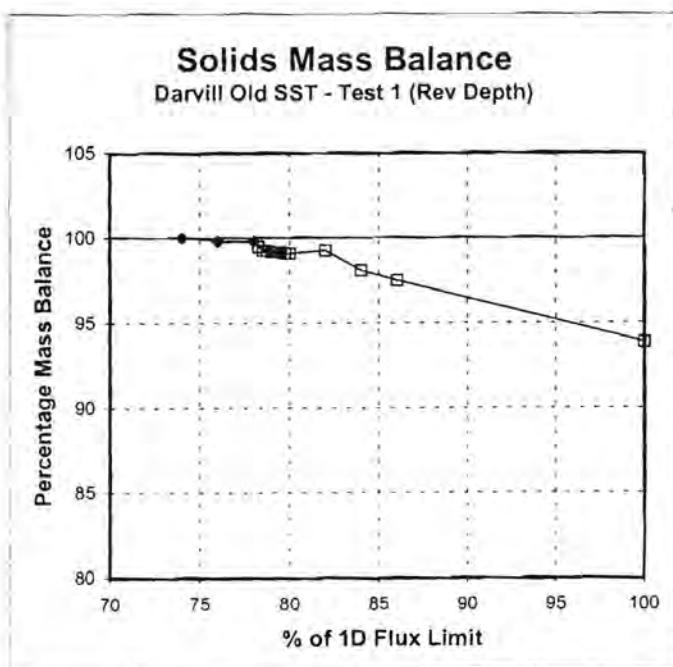
Simulation Data

Recycle flow (m ³ /h)	666.7
Area (m ²)	962

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	2.30	9001.00	S	100.1
60	2.30	9001.00	S	100.1
62	3.00	9145.00	S	100.1
62.25	3.10	9165.00	S	100.1
62.5	3.40	9184.00	S	100.1
62.75	46.10	8676.00	S	94.8
63	113.30	8798.00	F	96.7
63.25	274.60	8677.00	F	97.0
63.5	395.10	8644.00	F	97.7
63.75	455.70	8627.00	F	98.0
64	442.00	9601.00	F	98.5
66	603.70	8590.00	F	97.8
68	712.10	8567.00	F	97.4
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72	939.80	8497.00	F	97.0
100	1784.30	8536.00	F	95.4

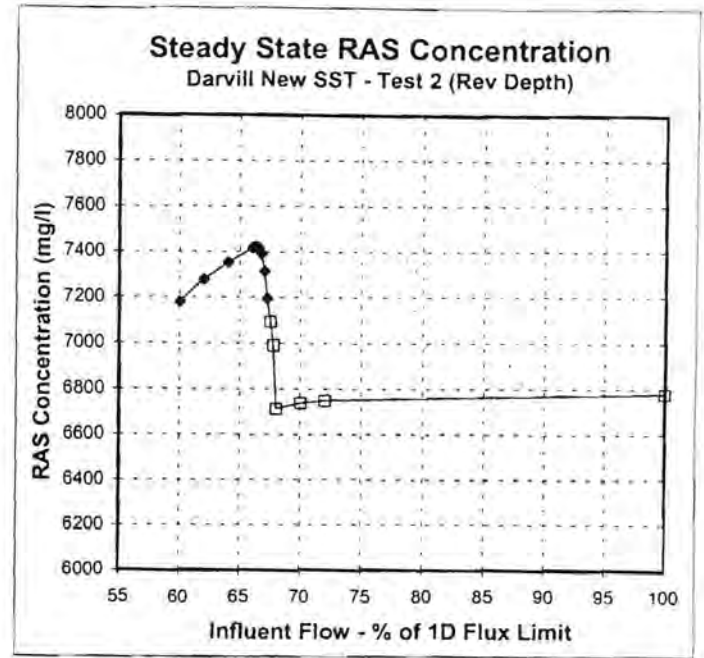
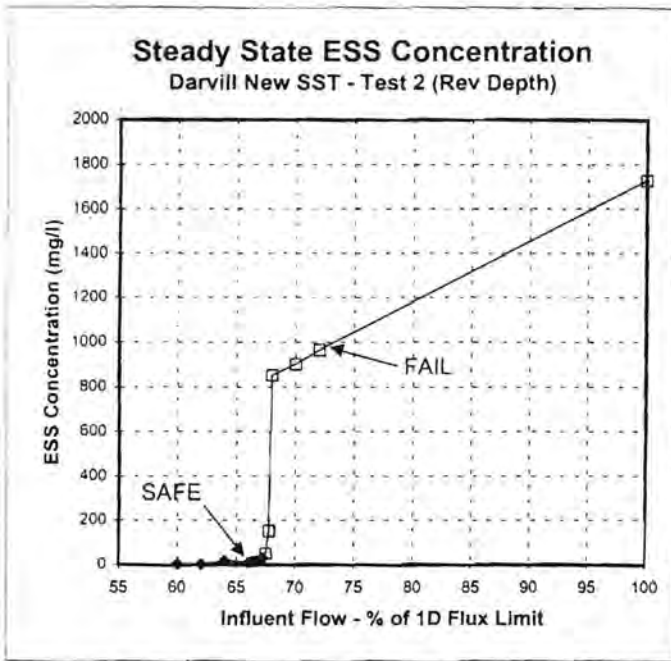


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

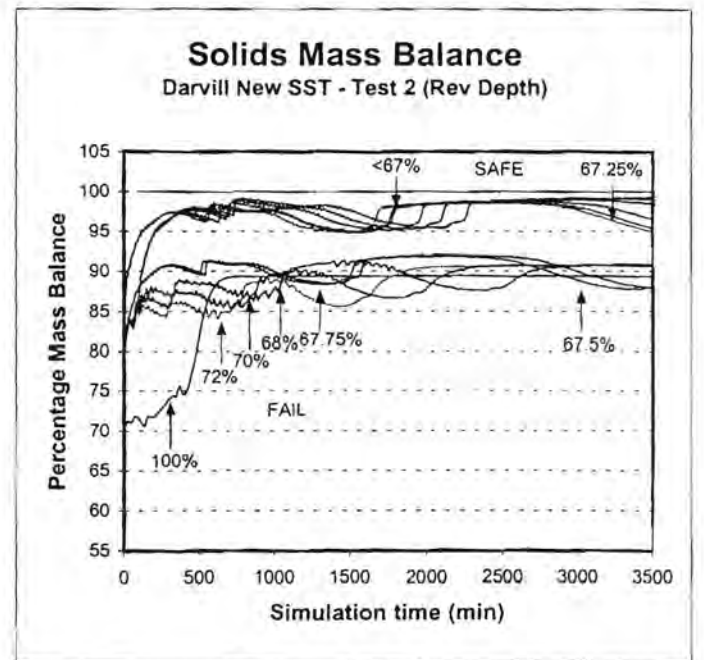
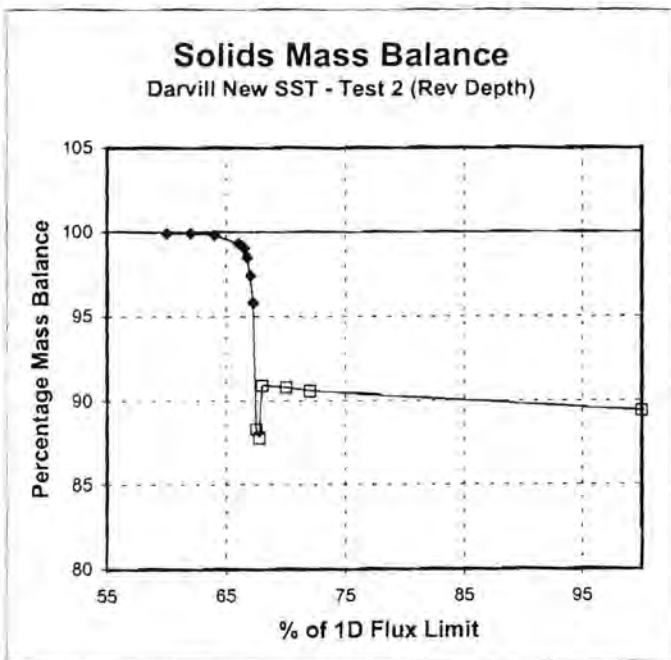


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 1 simulation on the old SST - Reversed Depth

Test 1 Old - Reversed Depth		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.71	74	7.30	10018.00	S	100.0
n (l/g)	0.39	74	7.30	10018.00	S	100.0
Xf (g/l)	4.6	76	42.20	10094.00	S	99.8
1DFT predicted limits		78	45.90	10238.00	S	99.8
		78.25	61.10	10206.00	F	99.5
Maximun flux [kg/(m ² .h)]	8.26	78.5	74.10	10192.00	F	99.3
Overflow rate (m/h)	1.1	78.75	82.50	10189.00	F	99.3
Influent flow (m ³ /h)	1062	79	88.20	10197.00	F	99.2
Flux ratings		79.25	90.30	10207.00	F	99.2
		79.5	95.70	10216.00	F	99.2
		79.75	100.20	10223.00	F	99.1
Flux load factor [Vo/(n.Xf)] (m/h)	4.30	80	105.60	10235.00	F	99.1
Simulation Data		82	109.40	10388.00	F	99.3
		84	226.20	10248.00	F	98.1
Recycle flow (m ³ /h)	666.7	86	281.30	10243.00	F	97.5
Area (m ²)	962	100	538.80	10339.00	F	93.9

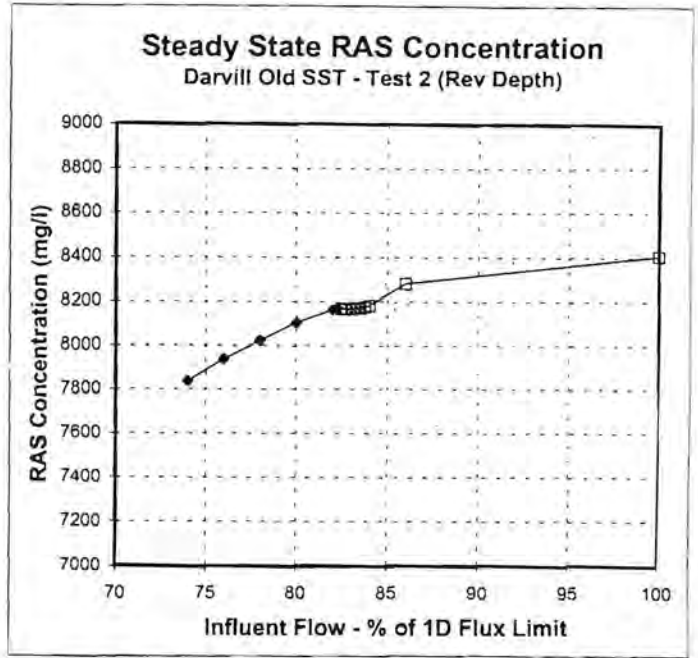
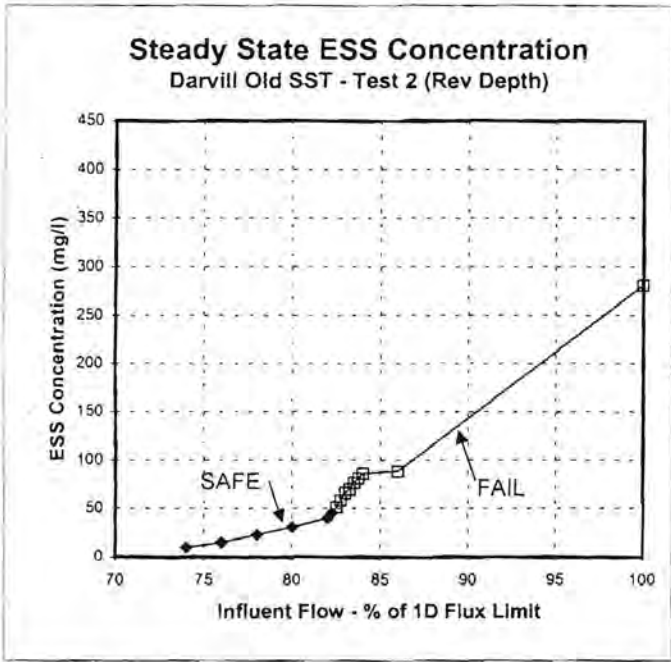


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

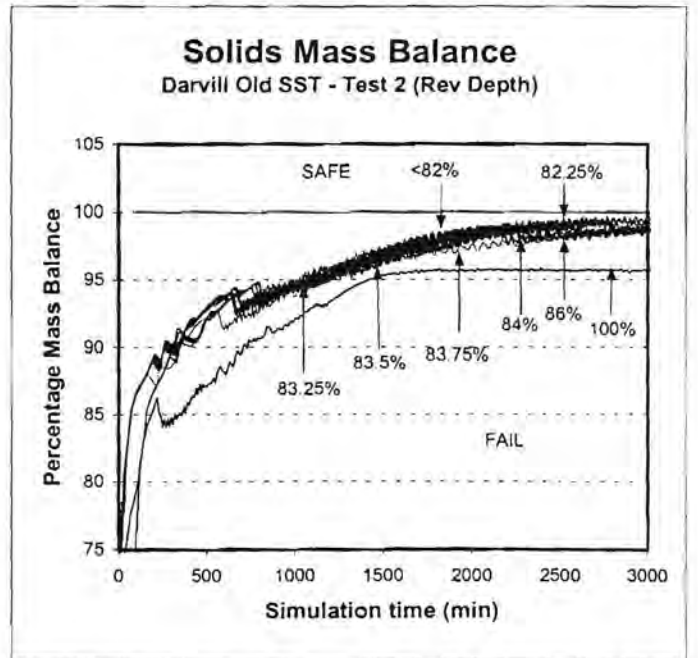
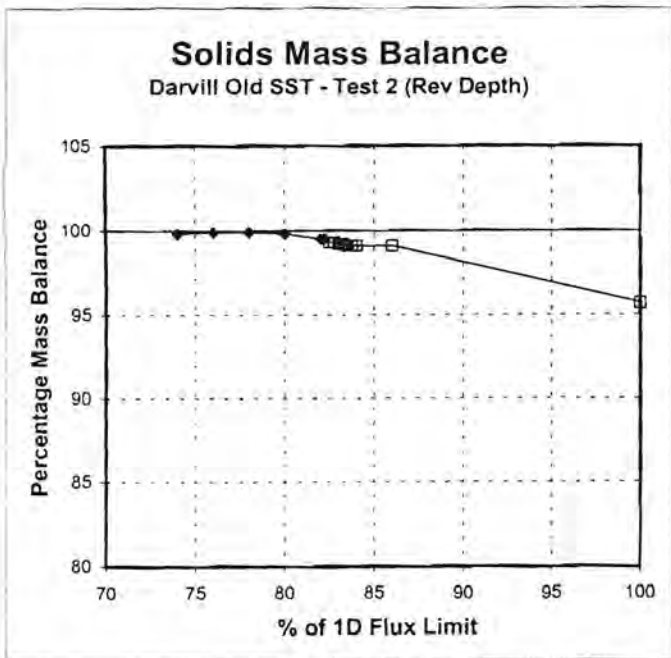


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 2 simulation on the new SST - Reversed Depth

Test 2 New - Rev Depth		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.83					
n (l/g)	0.513	60	1.10	7180.00	S	99.9
Xf (g/l)	4.3	60	1.10	7180.00	S	99.9
1DFT predicted limits		62	1.40	7278.00	S	99.9
		64	17.50	7353.00	S	99.8
		66	10.30	7418.00	S	99.3
Maximun flux [kg/(m ² .h)]	6.31	66.25	11.90	7422.00	S	99.2
Overflow rate (m/h)	0.775	66.5	13.00	7418.00	S	99.0
Influent flow (m ³ /h)	746	66.75	15.20	7391.00	F	98.5
		67	20.00	7312.00	F	97.4
Flux ratings		67.25	29.60	7195.00	F	95.8
		67.5	51.50	7093.00	F	88.3
Flux load factor [Vo/(n.Xf)] (m/h)	3.55	67.75	152.00	6989.00	F	87.8
		68	853.10	6713.00	F	90.9
Simulation Data		70	904.50	6739.00	F	90.8
		72	966.70	6750.00	F	90.6
Recycle flow (m ³ /h)	666.7	100	1728.50	6779.00	F	89.4
Area (m ²)	962					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 2 simulation on the old SST - Reversed Depth

Test 2 Old - Reversed Depth

Vo (m/h)	7.83
n (l/g)	0.513
Xf (g/l)	4.3

1DFT predicted limits

Maximum flux [kg/(m ² .h)]	6.31
Overflow rate (m/h)	0.78
Influent flow (m ³ /h)	746

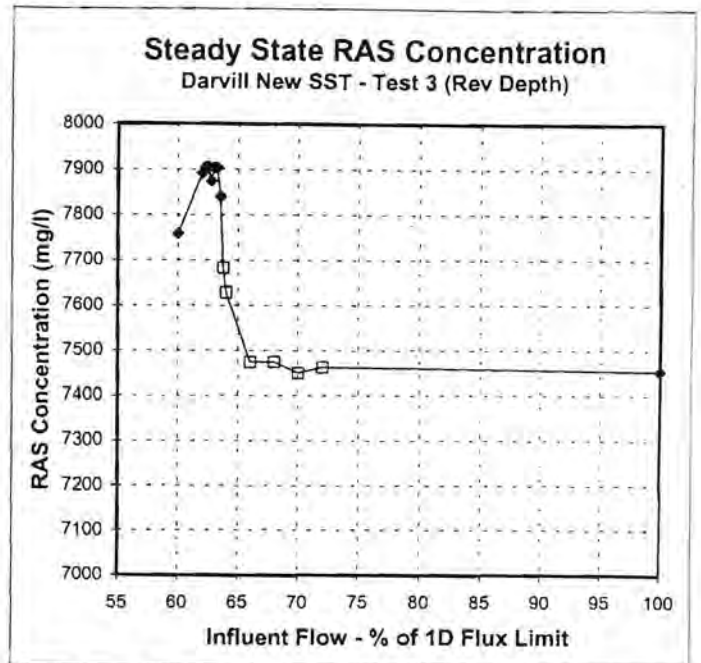
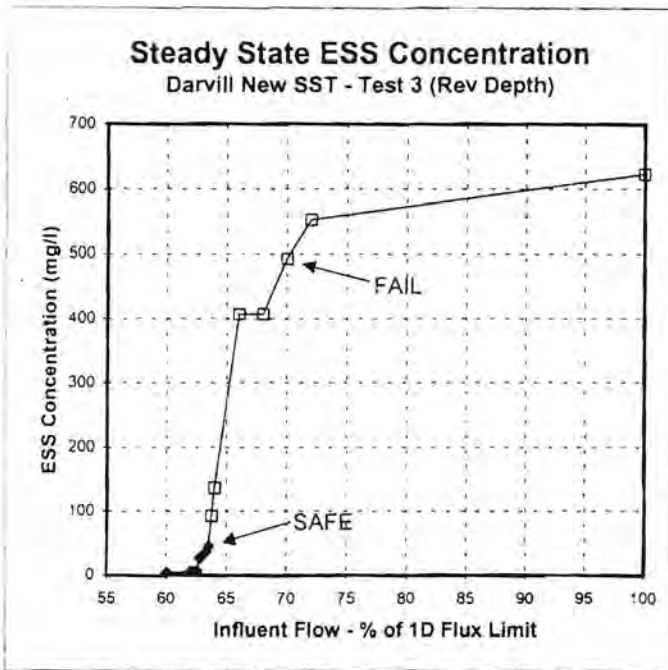
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	3.55
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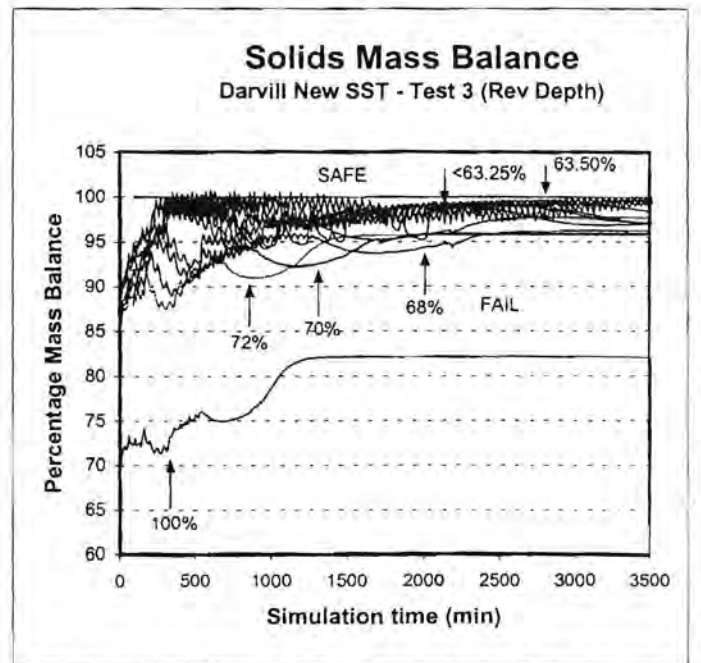
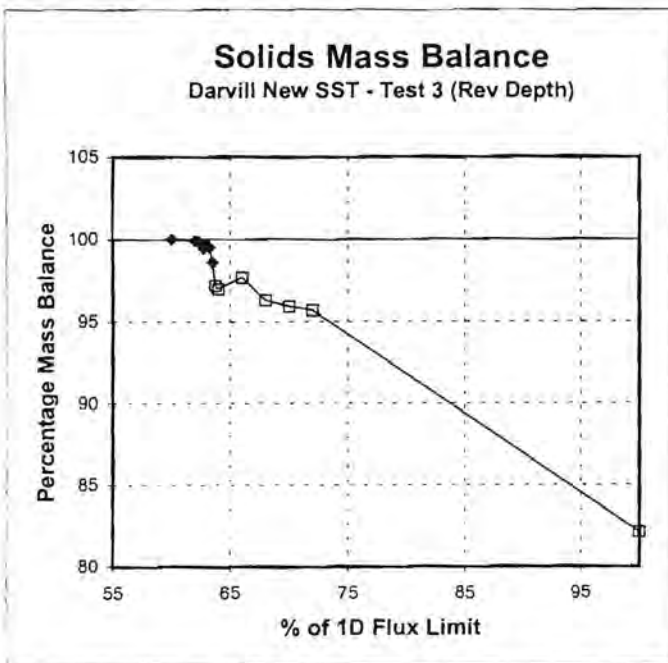
Simulation Data

Recycle flow (m ³ /h)	666.7
Area (m ²)	962

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
74	9.90	7837.00	S	99.8
74	9.90	7837.00	S	99.8
76	15.20	7939.00	S	99.9
78	22.80	8023.00	S	99.9
80	30.80	8105.00	S	99.8
82	39.80	8165.00	S	99.5
82.25	45.00	8172.00	S	99.5
82.5	51.40	8168.00	F	99.3
82.75	58.40	8169.00	F	99.3
83	65.90	8168.00	F	99.2
83.25	69.90	8173.00	F	99.2
83.5	76.20	8171.00	F	99.1
83.75	80.80	8176.00	F	99.1
84	85.70	8183.00	F	99.1
86	88.10	8281.00	F	99.1
100	280.70	8407.00	F	95.7



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig , right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamants) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamants) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 3 simulation on the new SST - Reversed Depth

Test 3 New - Reversed Depth

Vo (m/h)	8.00
n (l/g)	0.43
Xf (g/l)	3.6

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	8.22
Overflow rate (m/h)	1.5
Influent flow (m ³ /h)	1446

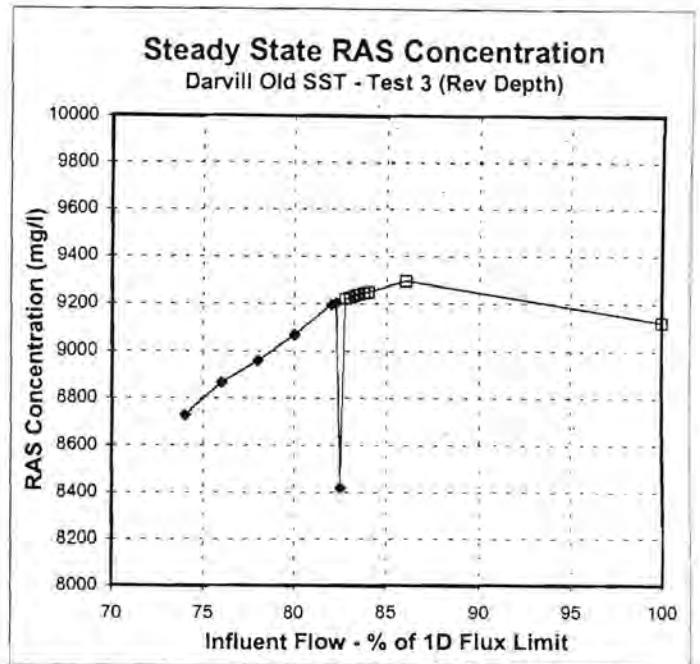
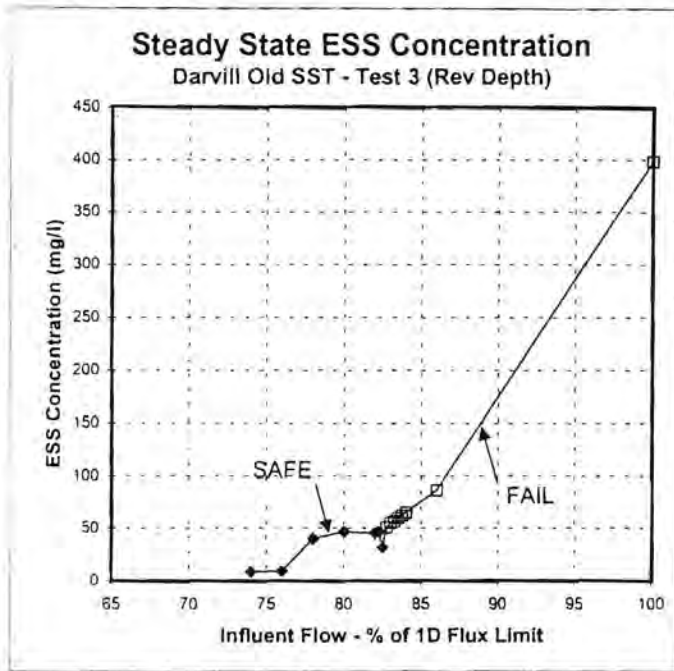
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	5.17
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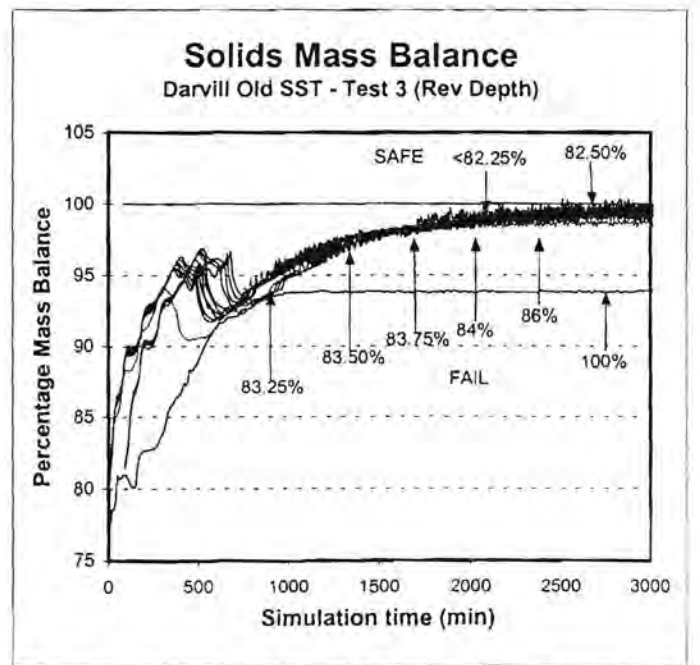
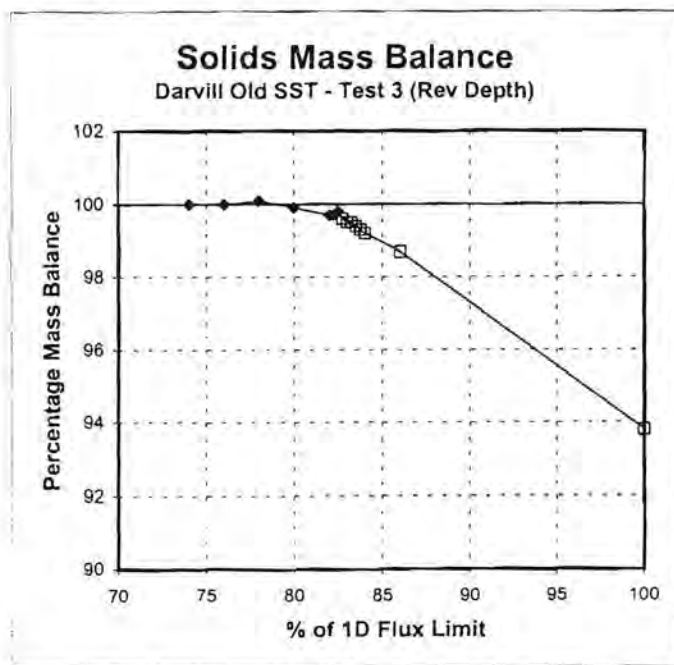
Simulation Data

Recycle flow (m ³ /h)	750
Area (m ²)	962

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	4.30	7758.00	S	100.0
60	4.30	7758.00	S	100.0
62	5.60	7891.00	S	99.9
62.25	5.80	7905.00	S	99.9
62.5	6.80	7906.00	S	99.7
62.75	27.10	7874.00	S	99.4
63	32.20	7904.00	S	99.6
63.25	36.50	7903.00	S	99.5
63.5	45.90	7840.00	S	98.6
63.75	93.10	7683.00	F	97.2
64	136.80	7629.00	F	97.0
66	407.10	7475.00	F	97.7
68	407.10	7475.00	F	96.3
70	492.90	7450.00	F	95.9
72	552.90	7463.00	F	95.7
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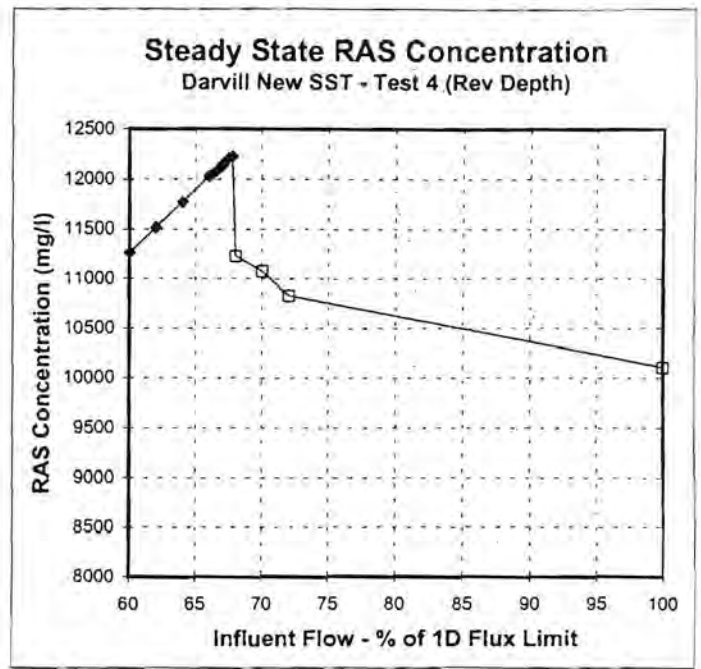
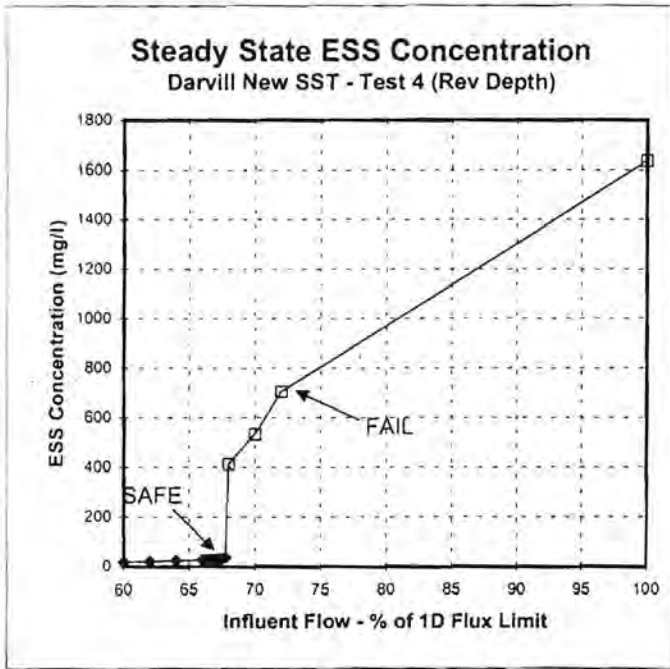
Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



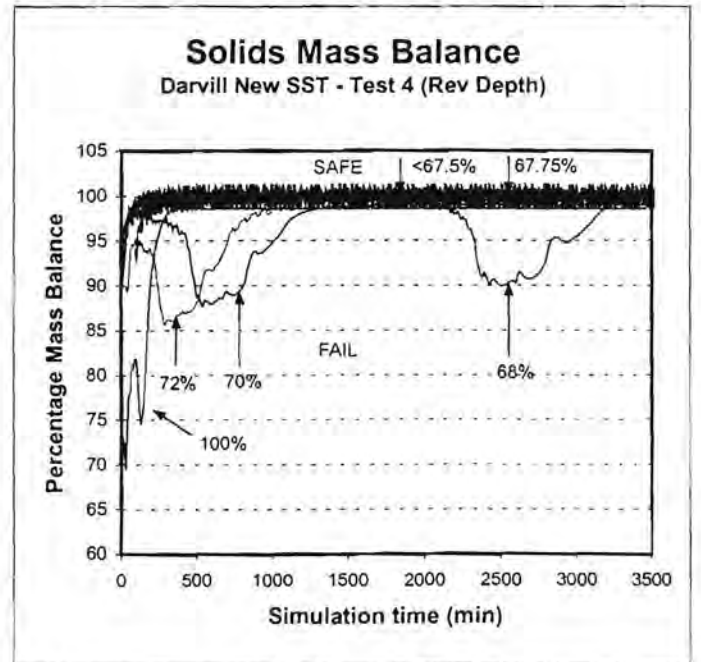
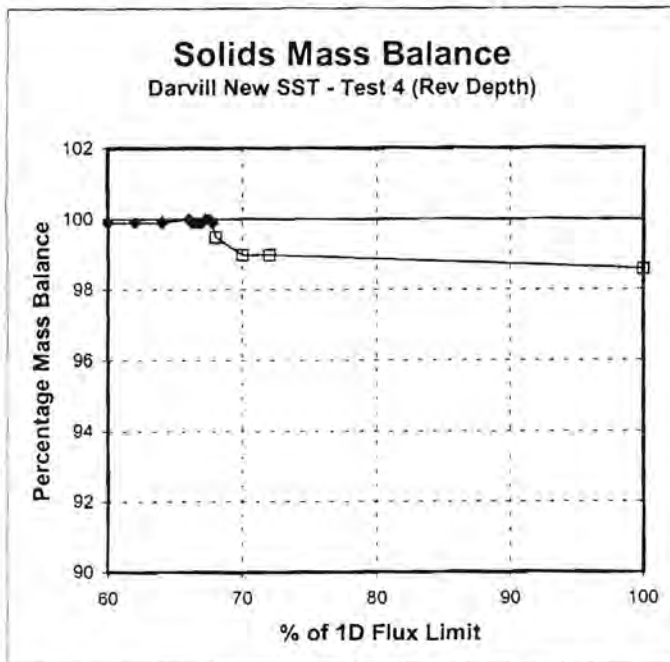
Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 3 simulation on the old SST - Reversed Depth

Test 3 Old - Reversed Depth		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	8.00					
n (l/g)	0.43	74	8.80	8728.00	S	100.0
Xf (g/l)	3.6	74	8.80	8728.00	S	100.0
1DFT predicted limits		76	9.20	8866.00	S	100.0
		78	40.20	8959.00	S	100.1
		80	46.60	9068.00	S	99.9
Maximun flux [kg/(m ² .h)]	8.22	82	45.30	9197.00	S	99.7
Overflow rate (m/h)	1.5	82.25	46.90	9204.00	S	99.7
Influent flow (m ³ /h)	1446	82.5	32.00	8419.00	S	99.8
Flux ratings		82.75	51.10	9221.00	F	99.6
		83	55.00	9227.00	F	99.5
		83.25	57.00	9236.00	F	99.5
Flux load factor [Vo/(n.Xf)] (m/h)	5.17	83.5	60.00	9241.00	F	99.4
		83.75	62.60	9247.00	F	99.3
Simulation Data		84	65.40	9249.00	F	99.2
		86	86.80	9297.00	F	98.7
Recycle flow (m ³ /h)	750	100	398.30	9122.00	F	93.8
Area (m ²)	962					

Note: The SettlerCAD simulation crashed for the simulation that is 82.50 % of the 1DFT limit

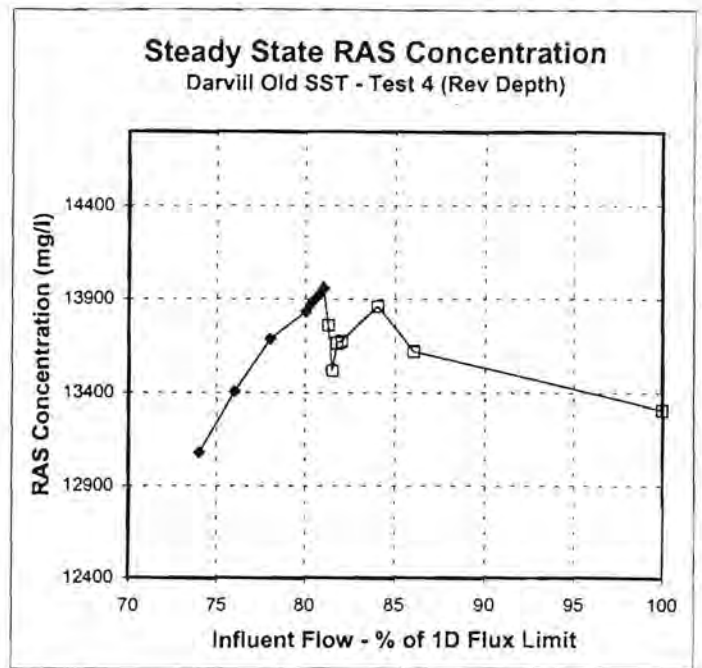
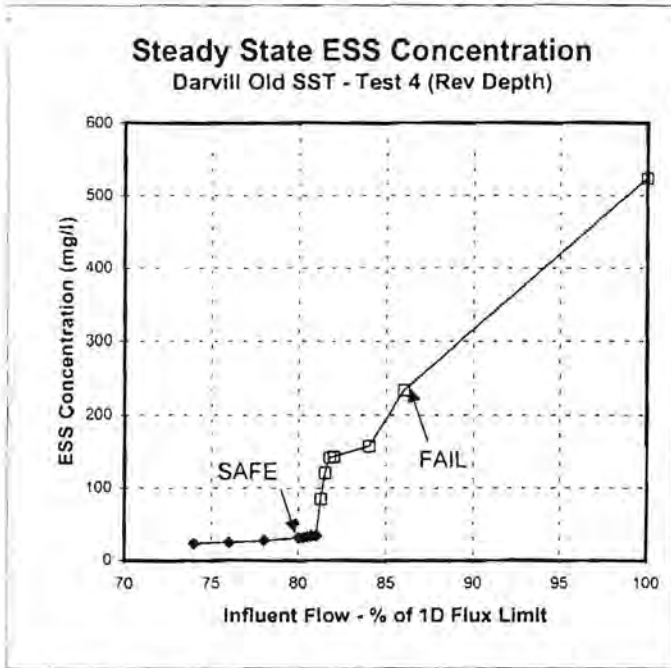


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

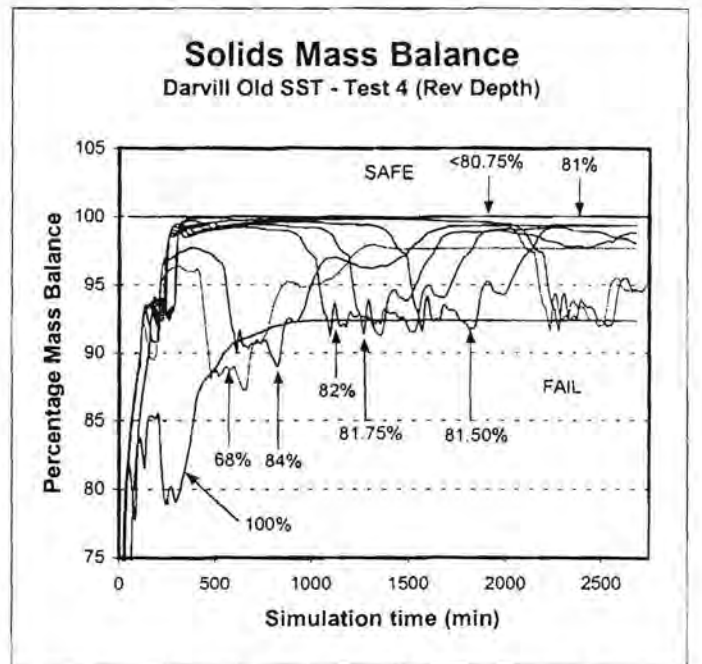
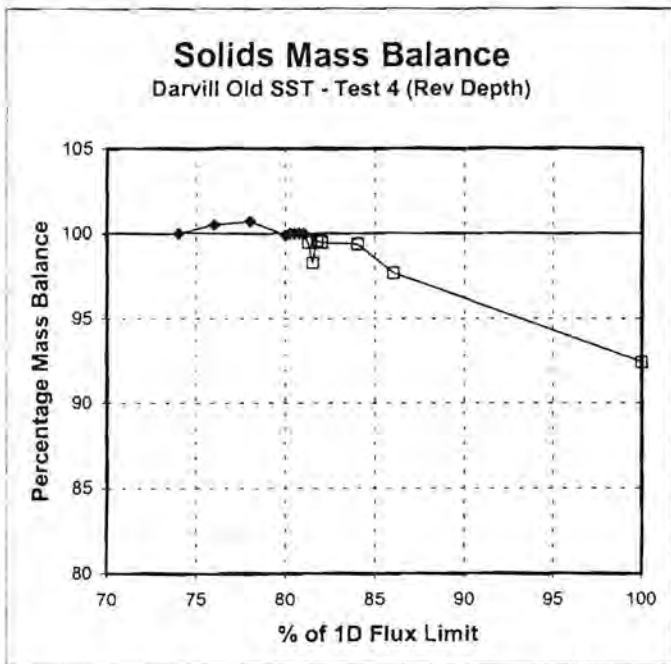


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the new SST - Reversed Depth

Test 4 New - Reversed Depth		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	9.08					
n (l/g)	0.29	60	18.80	11263.00	S	99.9
Xf (g/l)	3.45	60	18.80	11263.00	S	99.9
1DFT predicted limits		62	21.20	11518.00	S	99.9
		64	24.20	11770.00	S	99.9
		66	28.10	12030.00	S	100.0
Maximun flux [kg/(m ² .h)]	12.19	66.25	28.60	12053.00	S	99.9
Overflow rate (m/h)	2.8	66.5	29.20	12081.00	S	99.9
Influent flow (m ³ /h)	2690	66.75	30.10	12112.00	S	99.9
Flux ratings		67	30.90	12134.00	S	99.9
		67.25	31.90	12177.00	S	100.0
		67.5	32.70	12211.00	S	100.0
Flux load factor [Vo/(n.Xf)] (m/h)	9.08	67.75	35.00	12225.00	S	99.9
Simulation Data		68	413.40	11230.00	F	99.5
		70	534.30	11076.00	F	99.0
		72	704.20	10833.00	F	99.0
Recycle flow (m ³ /h)	708.3	100	1636.10	10107.00	F	98.6
Area (m ²)	962					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the old SST - Reversed Depth

Test 4 Old - Reversed Depth

Vo (m/h) 9.08
 n (l/g) 0.29
 Xf (g/l) 3.45

1DFT predicted limits

Maximum flux [kg/(m².h)] 12.19
 Overflow rate (m/h) 2.8
 Influent flow (m³/h) 2690

Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 9.08

Simulation Data

Recycle flow (m³/h) 708.3
 Area (m²) 962

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
74	23.30	13076.00	S	100.0
74	23.30	13076.00	S	100.0
76	25.20	13406.00	S	100.5
78	27.40	13684.00	S	100.7
80	31.00	13831.00	S	99.9
80.25	31.30	13872.00	S	100.0
80.5	33.00	13899.00	S	100.0
80.75	34.00	13926.00	S	100.0
81	34.60	13957.00	S	100.0
81.25	84.90	13761.00	F	99.5
81.5	120.40	13519.00	F	98.3
81.75	141.70	13666.00	F	99.6
82	142.80	13675.00	F	99.5
84	157.50	13861.00	F	99.4
86	233.50	13621.00	F	97.7
100	523.80	13310.00	F	92.4

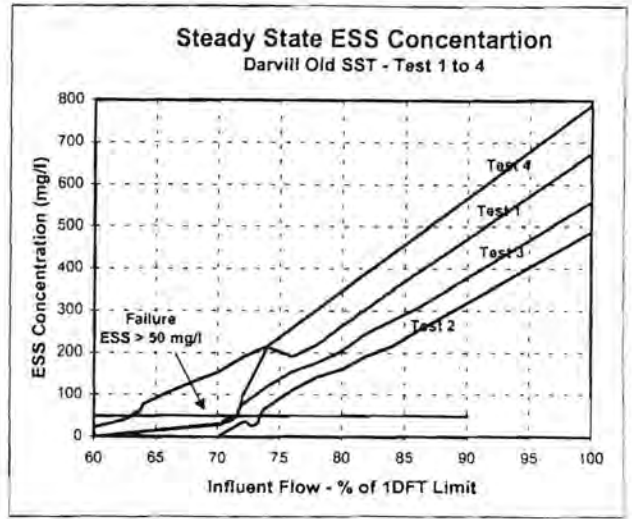
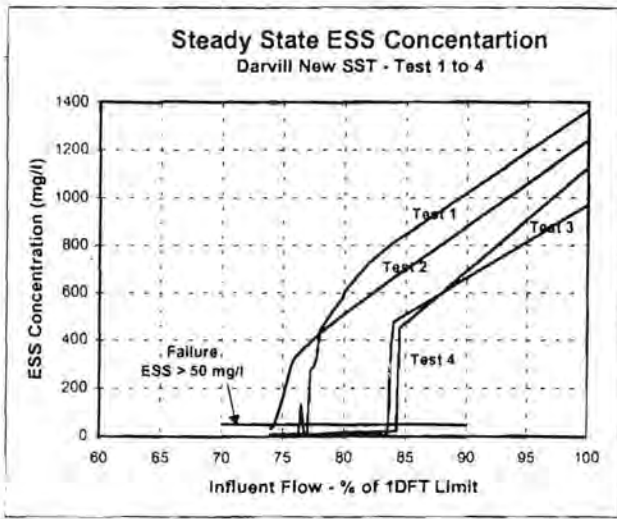


Fig a and b: SettlerCAD predicted ESS concentration versus influent flow (as a % of 1DFT limit) for Test 1 to 4 on the Darvill new (Fig 4.6a, left) and old (Fig 4.6b, right) SSTs

APPENDIX B

Watts Results



SettlerCAD Predicted Failure Results - Case 1 (Normal)

PARAMETER	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Flux Factor [Vol/(n.X _F) - m/h	6.15	6.28	6.56	6.04	6.81	6.25	7.01	6.59	7.24	6.42	6.17	7.24	6.26	6.26	6.89
Influent Flow (m ³ /h) for 1 SST	848.1	875.0	665.9	826.3	946.7	938.1	982.3	1066.7	1021.4	888.8	853.2	1021.4	1014.3	1085.4	1250.9
% of 1DFT maximum Q _i	73.5	73.75	74	73.5	71.75	71.75	71.75	70	71.5	72.75	73.75	71.5	71.25	73	75.25
Overflow Rate (m/h)	1.29	1.33	1.01	1.25	1.44	1.42	1.49	1.62	1.55	1.35	1.30	1.55	1.54	1.65	1.90
Recycle Flow (m ³ /h)	397.5	398.0	239.9	396.9	397.7	475.7	397.7	552.8	397.7	397.7	397.2	397.7	555.6	714.0	753.5
Underflow Rate (m/h)	0.603	0.604	0.364	0.602	0.604	0.722	0.604	0.839	0.604	0.604	0.603	0.604	0.843	1.084	1.144
Recycle Ratio	0.47	0.45	0.36	0.48	0.42	0.51	0.40	0.52	0.39	0.45	0.47	0.39	0.55	0.66	0.60
Applied Flux (kg SS)/(m ² .h)	7.66	7.68	5.23	7.67	7.48	8.57	7.46	9.31	7.42	7.59	7.68	7.42	9.50	10.88	11.01
% of 1DFT maximum flux	80.3	80.3	79.5	80.4	78.3	79.3	78.1	78.0	77.7	79.4	80.5	77.7	79.3	81.8	83.0
Actual Retention Time (h)	2.1	2.0	2.7	2.2	1.9	1.9	1.8	1.7	1.7	2.0	2.1	1.7	1.8	1.6	1.4
Duration of Run (min)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Duration of Run (# of Rha)	47.6	49.1	37.4	46.4	53.2	52.7	55.2	59.9	57.4	49.9	47.9	57.4	57.0	60.9	70.2
Sim time Step (min)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sim time Step (%Rha)	1.98	2.05	1.56	1.93	2.21	2.19	2.30	2.50	2.39	2.08	2.00	2.39	2.37	2.54	2.93
ESS (mg/l)*	53.5	51.4	55	57.7	81	97.2	92.2	50.6	50.2	54.5	52.2	50.2	52	50.5	64.2
Recycle Conc (mg/l)*	12492	12479	14152	12459	11988	11431	11909	10927	11888.7	12337.1	12488.8	11888.7	11079.7	9911.2	9431
Mass Balance (%)*	99.3	99.1	99.7	98.8	98.4	97.9	98.3	99.4	97.8	99.1	99	97.8	99.2	99.5	99.1
Test Result	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail

* Mean over the last 2 R₉₀ values

Summary of the SettlerCAD simulation results for the SettlerCAD influent flow limit of Test 1 to 15 for the Watts results Case 1 (Normal - No Stamford Baffle)

SettlerCAD Predicted Failure Results - Case 2 (With Stamford Baffle)

PARAMETER	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Flux Factor [Vol/(n.X _F) - m/h				6.04			7.01		7.24			7.24	6.26	6.26	
Influent Flow (m ³ /h) for 1 SST				854.4			1026.8		1067.9			1067.9	1060.6	1159.8	
% of 1DFT maximum Q _i				76			75		74.75			74.75	74.5	78	
Overflow Rate (m/h)				1.30			1.56		1.62			1.62	1.61	1.76	
Recycle Flow (m ³ /h)				396.9			397.7		397.7			397.7	555.6	714.0	
Underflow Rate (m/h)				0.602			0.604		0.604			0.604	0.843	1.084	
Recycle Ratio				0.46			0.39		0.37			0.37	0.52	0.62	
Applied Flux (kg SS)/(m ² .h)				7.84			7.70		7.66			7.66	9.78	11.33	
% of 1DFT maximum flux				82.3			80.6		80.2			80.2	81.7	85.1	
Actual Retention Time (h)				2.1			1.7		1.7			1.7	1.7	1.5	
Duration of Run (min)				6000			6000		6000			6000	6000	6000	
Duration of Run (# of Rha)				48.0			57.7		60.0			60.0	59.5	65.1	
Sim time Step (min)				2.5			2.5		2.5			2.5	2.5	2.5	
Sim time Step (%Rha)				2.00			2.40		2.50			2.50	2.48	2.71	
ESS (mg/l)*				23.4			77.86		70.6			70.6	78.92	53.32	
Recycle Conc (mg/l)*				12789.5			12352.6		12334.2			12334.2	11312.5	10318.7	
Mass Balance (%)*				98.6			98.4		98.7			98.7	98.8	99.5	
Test Result				Fail			Fail		Fail			Fail	Fail	Fail	

* Mean over the last 2 R₉₀ values

Summary of the SettlerCAD simulation results for the SettlerCAD influent flow limit of Test 4, 7, 9, 12, 13, and 14 for the Watts results Case 2 (With Stamford Baffle)

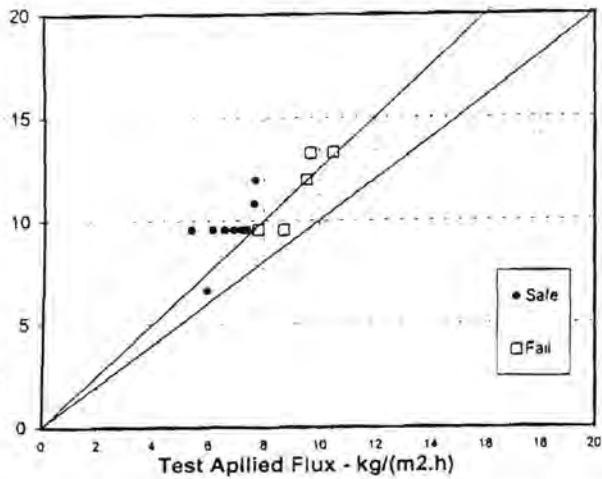
SettlerCAD Prediction of Actual SLR Tests

PARAMETER	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Flux Factor $[Vo/(n \cdot X_F) - m/h]$	6.15	6.28	6.56	6.04	6.81	6.25	7.01	6.59	7.24	6.42	6.17	7.24	6.26	6.26	6.89
Influent Flow (m ³ /h) for 1 SST	475.4	622.9	789.2	781.3	783.7	785.7	933.7	783.2	1017.2	773.3	1021.5	1095.7	1022.1	1023.0	1009.0
% of 1DFT maximum Q_i	41.2	52.5	87.7	69.5	59.4	60.1	68.2	51.4	71.2	63.3	88.3	76.7	71.8	68.8	60.7
Overflow Rate (m/h)	0.72	0.95	1.20	1.19	1.19	1.19	1.42	1.19	1.54	1.17	1.55	1.66	1.55	1.55	1.53
Recycle Flow (m ³ /h)	397.5	398.0	239.9	396.9	397.7	475.7	397.7	552.8	397.7	397.7	397.2	397.7	555.6	714.0	753.5
Underflow Rate (m/h)	0.60	0.60	0.36	0.60	0.60	0.72	0.60	0.84	0.60	0.60	0.60	0.60	0.84	1.08	1.14
Recycle Ratio	0.836	0.639	0.304	0.508	0.507	0.605	0.426	0.706	0.391	0.514	0.389	0.363	0.544	0.698	0.747
Applied Flux (kg SS)/(m ² ·h)	5.37	6.16	5.94	7.39	6.57	7.65	7.19	7.68	7.40	6.91	8.71	7.81	9.55	10.50	9.68
% of 1DFT maximum flux	56.3	64.4	90.3	77.5	68.8	70.7	75.4	64.3	77.5	72.3	91.3	81.8	79.7	78.9	73.0
Actual Retention Time (h)	3.7	2.9	2.3	2.3	2.3	2.3	1.9	2.3	1.8	2.3	1.7	1.6	1.7	1.7	1.8
Duration of Run (min)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Duration of Run (# of Rha)	26.7	35.0	44.3	43.9	44.0	44.1	52.4	44.0	57.1	43.4	57.4	61.5	57.4	57.4	56.7
Sim time Step (min)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sim time Step (%Rha)	1.11	1.46	1.85	1.83	1.83	1.84	2.18	1.83	2.38	1.81	2.39	2.56	2.39	2.39	2.36
ESS (mg/l)*	3.9	5	484.3	5.7	5.8	5.7	6.8	6.1	17.90	5.3	479.9	238	66.9	9.9	7.5
Recycle Conc (mg/l)*	8891.9	10200.2	13268.3	12236.7	10879.7	10577.1	11900.8	9137.8	12205.3	11430.2	12150.5	11792.4	11078.1	9672.4	8453.7
Mass Balance (%)*	100	100.2	91.2	99.9	100	100	100	100	100	100	92.7	96.3	98.9	100	100
Test Result (ESS > 50 mg/l)	Safe	Safe	Fail	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Fail	Fail	Fail	Safe	Fail
Observed Result	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Safe	Fail	Fail	Fail	Fail	Fail

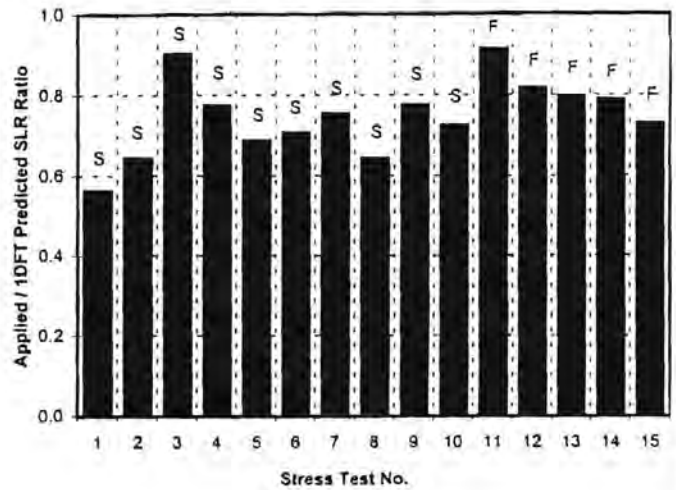
* Mean over the last 2 R_{90} values

Summary of the SettlerCAD simulation results for the actual Test 1 to 15 of the Watts results

Watts SST Stress Tests
Actual SLR Stress Test 1 to 15

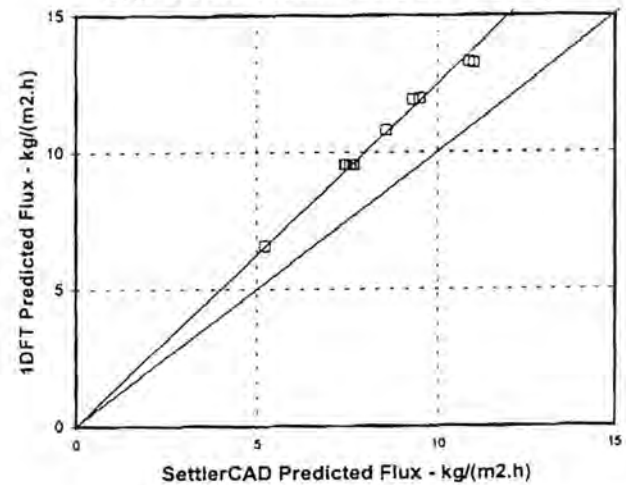


Watts SST Stress Test
Actual Stress Tests 1 to 15

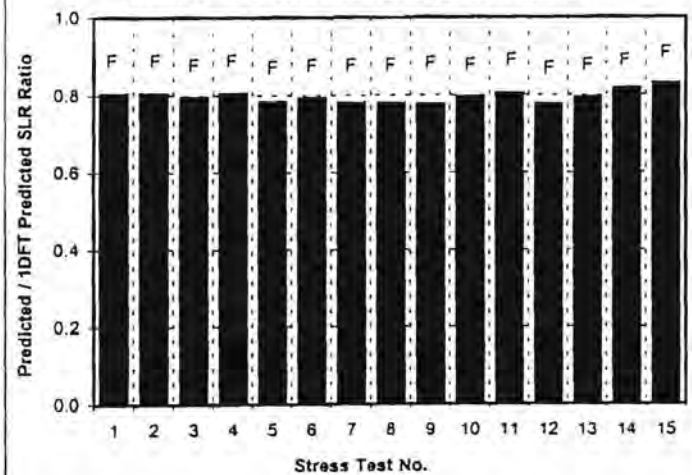


Figs a and b: Calculated 1DFT maximum SLR versus test applied SLR (Fig a, left) and test applied to 1DFT calculated maximum SLR ratios (Fig b, right) for the 15 Watt's SLR stress tests on the Kanapaha SSTs

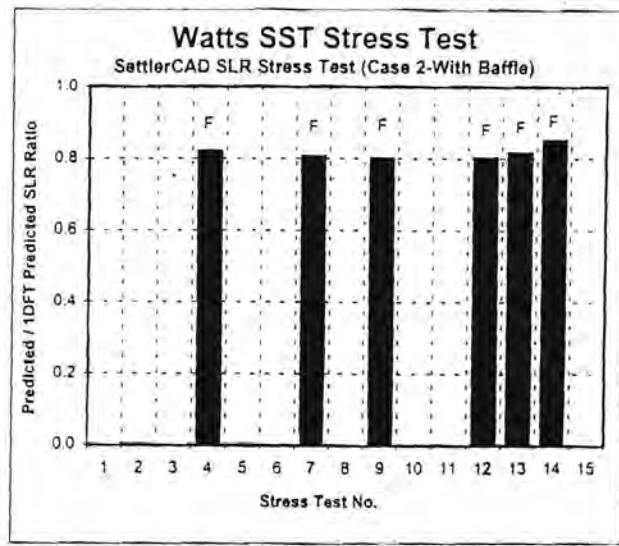
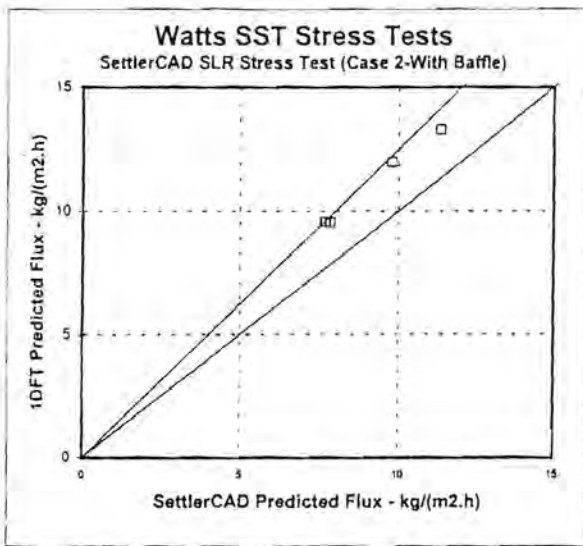
Watts SST Stress Tests
SettlerCAD SLR Stress Test (Case 1-Normal)



Watts SST Stress Test
SettlerCAD SLR Stress Tests (Case 1-Normal)



Figs a and b: 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Fig a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig b, right) for the 15 Watts SLR stress tests on the Kanapaha SSTs (Case 1 - Normal, without Stamford Baffle)



Figs a and b: 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Figs a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig b, right) for Test 4, 7, 9, 12, 13 and 14 of the Watts SLR stress tests on the Kanapaha SSTs (Case 2 - With Stamford Baffle)

Watts

Summary of SettlerCAD predicted failures (Case 1 and 2)

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Maximum flux [kg/(m2.h)]	9.54	9.55	6.58	9.54	9.55	10.81	9.55	11.94	9.55	9.55	9.54	9.55	11.98	13.31	13.27
Maximum Influent flow (m3/h)	1153.9	1186.5	899.9	1124.2	1319.4	1307.4	1369.1	1523.8	1428.6	1221.7	1156.9	1428.6	1423.6	1486.9	1662.3
Case 1 - Normal															
Influent flow (m3/h)	848.1	875.1	665.9	826.3	946.7	938	982.3	1066.6	1021.4	888.8	853.2	1021.4	1014.3	1085.5	1250.9
Recycle flow (m3/h)	397.5	398	239.9	396.9	397.7	475.7	397.7	552.8	397.7	397.7	397.2	397.7	555.6	714	753.5
Recycle Ratio	0.47	0.45	0.36	0.48	0.42	0.51	0.40	0.52	0.39	0.45	0.47	0.39	0.55	0.66	0.60
Feed conc. (g/l)	4.053	3.972	3.801	4.13	3.664	3.994	3.56	3.787	3.444	3.885	4.044	3.444	3.987	3.983	3.618
Area (m2)	659	659	659	659	659	659	659	659	659	659	659	659	659	659	659
SettlerCAD Predicted Flux [kg/(m2.h)]	7.66	7.67	5.22	7.67	7.47	8.57	7.45	9.31	7.42	7.58	7.67	7.42	9.50	10.88	11.00
% of 1DFT Flux	80.3	80.3	79.4	80.4	78.3	79.3	78.1	77.9	77.7	79.4	80.4	77.7	79.3	81.7	82.9
% of 1DFT Flow	73.5	73.8	74.0	73.5	71.8	71.7	71.7	70.0	71.5	72.8	73.7	71.5	71.2	73.0	75.3
Case 2 - With Stamford Baffle															
Influent flow (m3/h)				854.4			1026.8		1067.9			1067.9	1060.6	1159.8	
Recycle flow (m3/h)				396.9			397.7		397.7			397.7	555.6	714	
Recycle Ratio				0.46			0.39		0.37			0.37	0.52	0.62	
Feed conc. (g/l)				4.13			3.56		3.444			3.444	3.987	3.983	
Area (m2)				659			659		659			659	659	659	
SettlerCAD Predicted Flux [kg/(m2.h)]				7.84			7.70		7.66			7.66	9.78	11.33	
% of 1DFT Flux				82.26			80.63		80.25			80.25	81.66	85.14	
% of 1DFT Flow				76.00			75.00		74.75			74.75	74.50	78.00	
% of 1DFT Flux															
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Case 1 - Normal	80.3	80.3	79.4	80.4	78.3	79.3	78.1	77.9	77.7	79.4	80.4	77.7	79.3	81.7	82.9
Case 2 - With Stamford Baffle	-	-	-	82.3	-	-	80.6	-	80.2	-	-	80.2	81.7	85.1	-

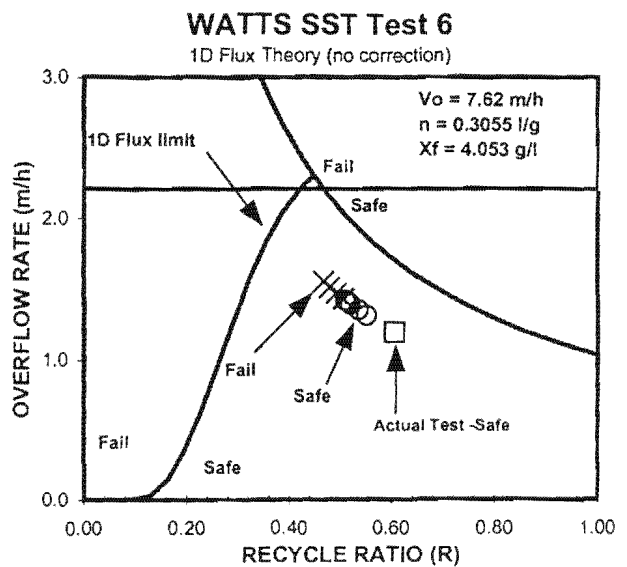
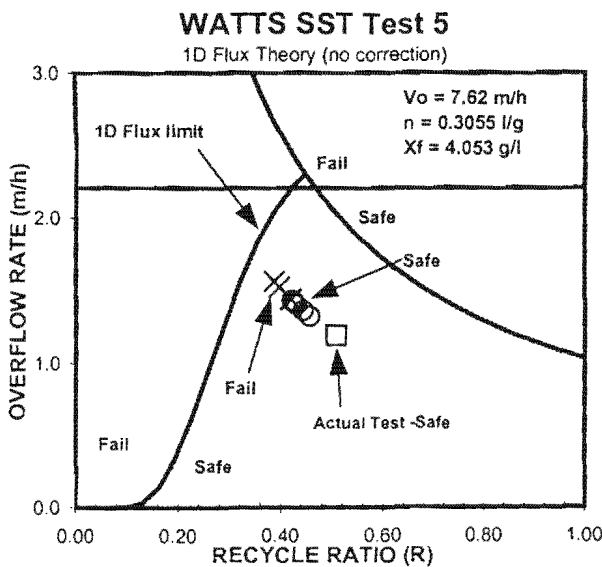
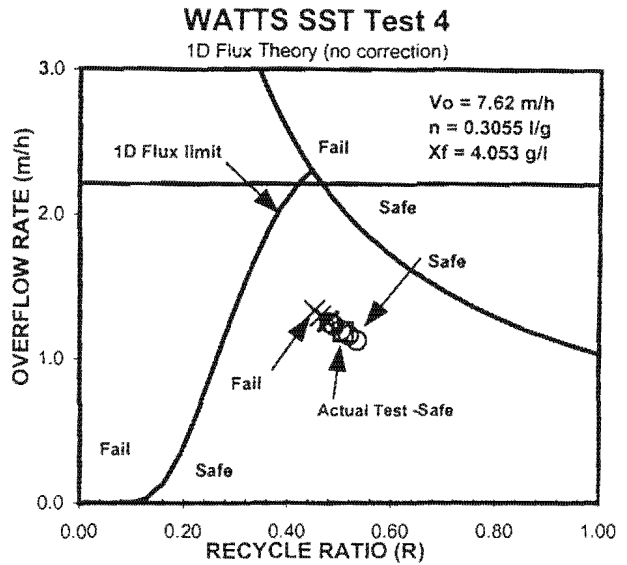
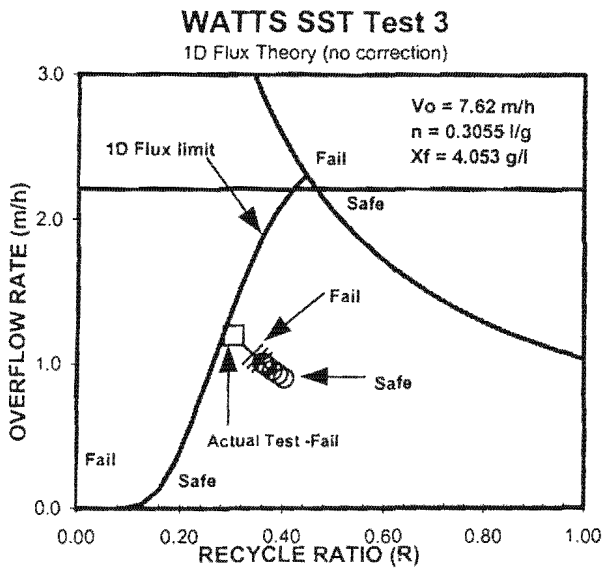
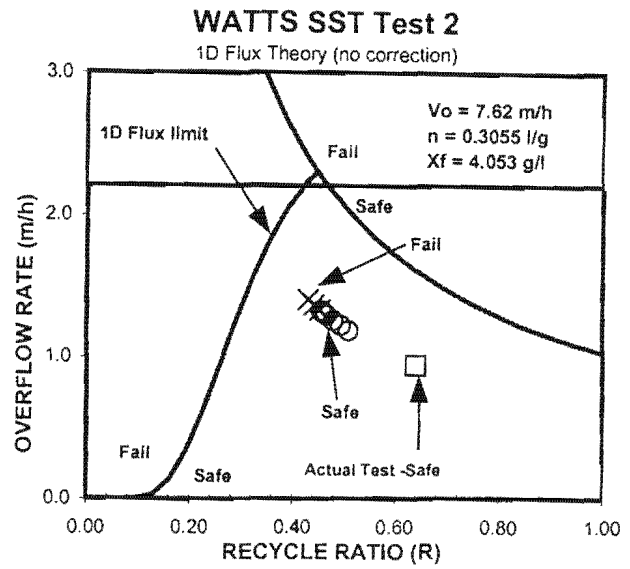
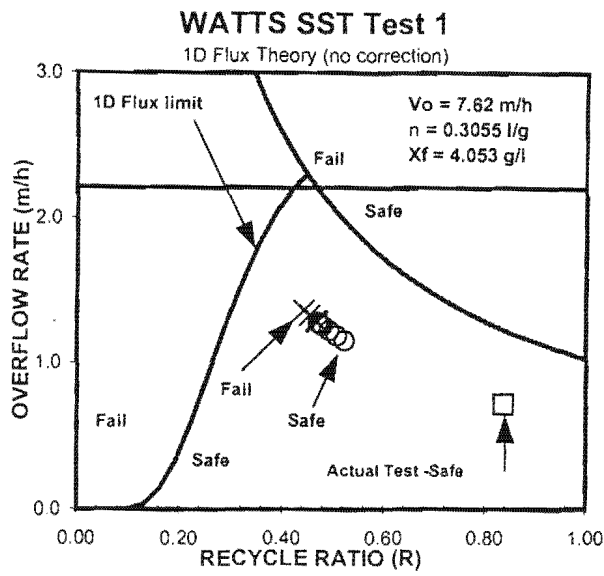


Fig a to f: 1DFT D&O charts showing the SST operating positions and results (Safe, Fail) of the SettlerCAD runs and actual tests for test 1 to 6

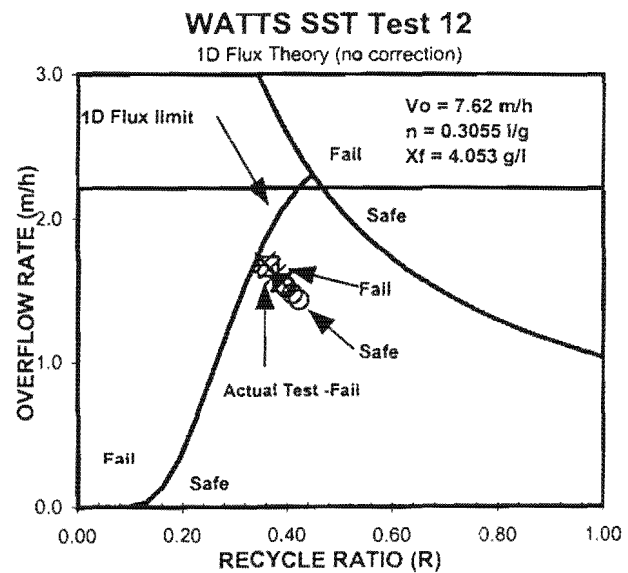
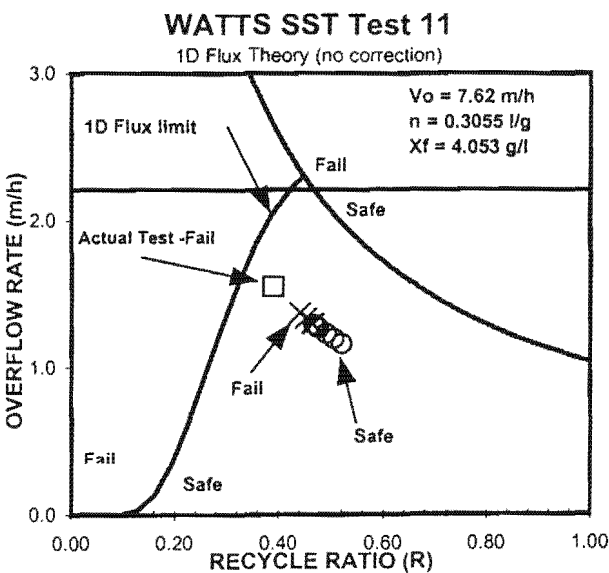
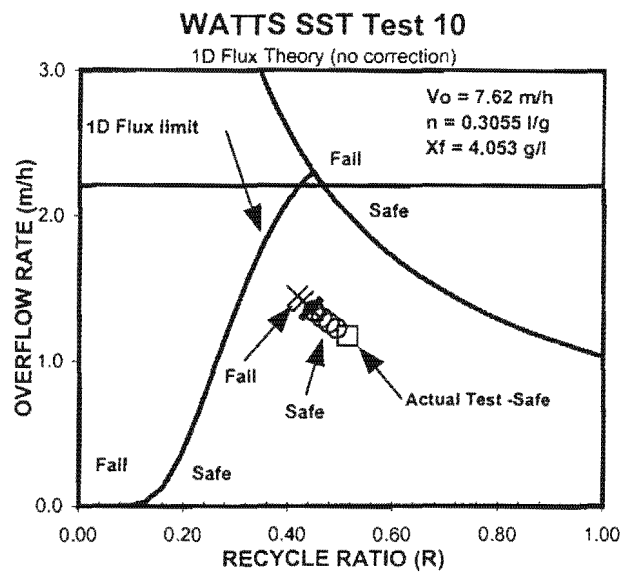
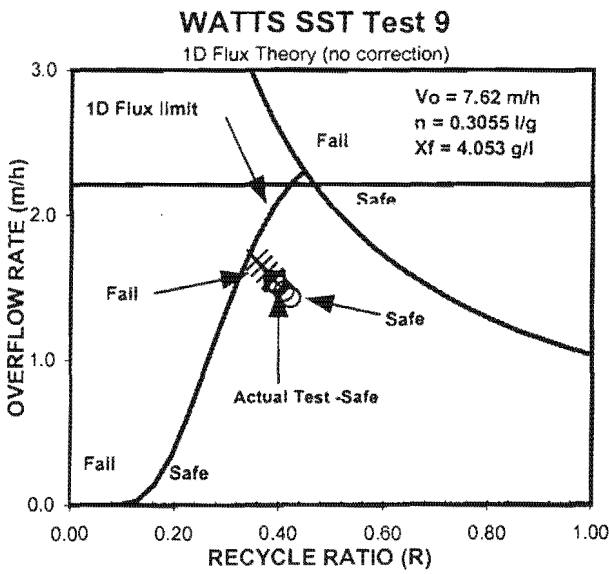
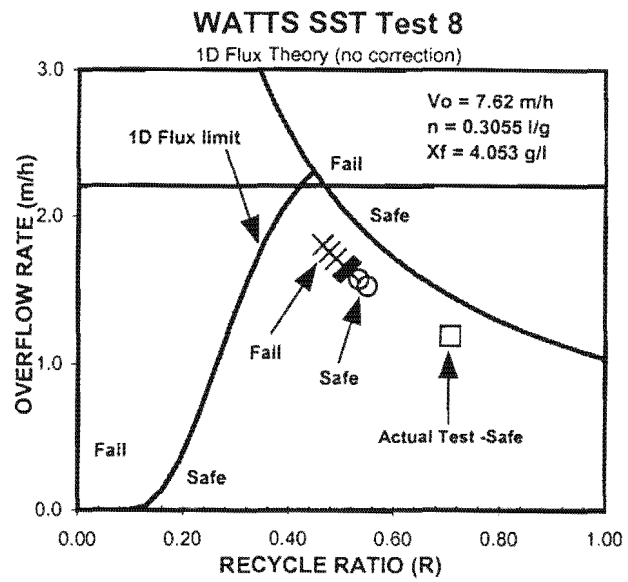
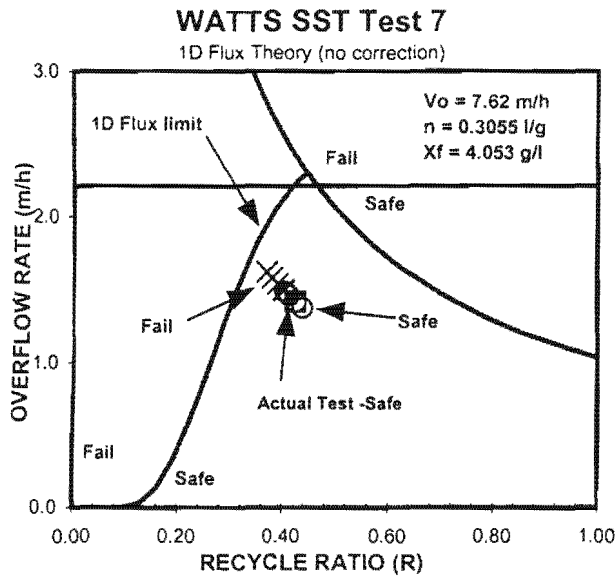


Fig g to i: 1DFT D&O charts showing the SST operating positions and results (Safe, Fail) of the SettlerCAD runs and actual tests for test 7 to 12

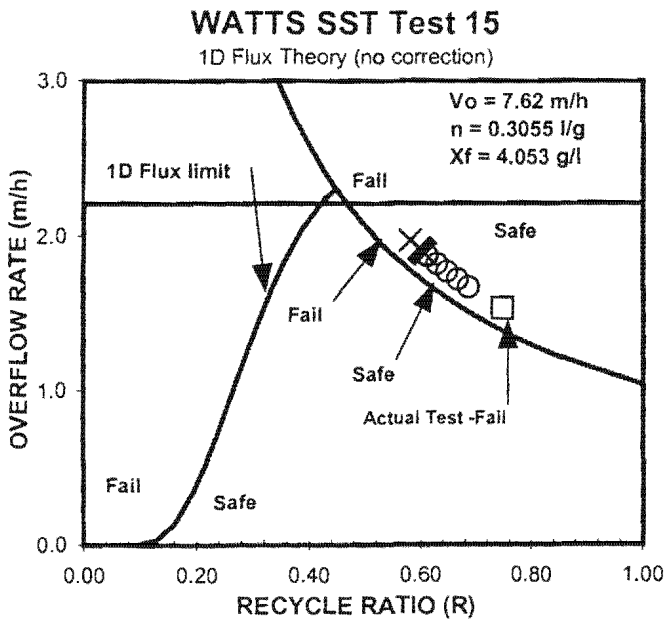
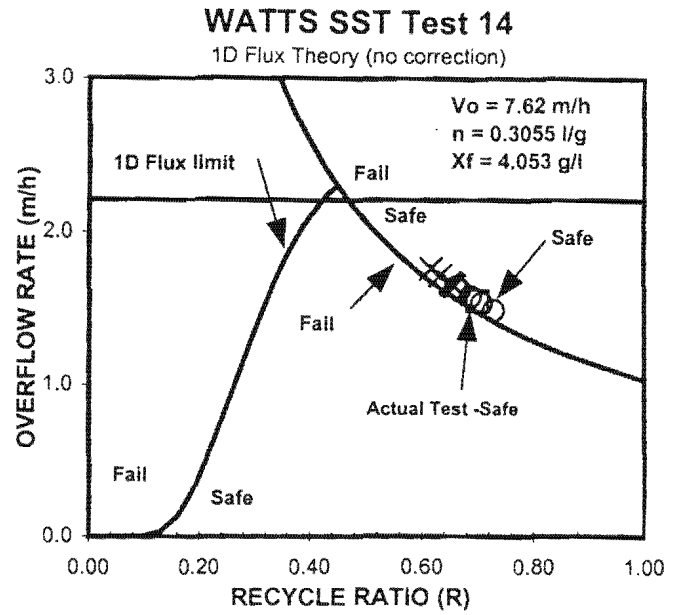
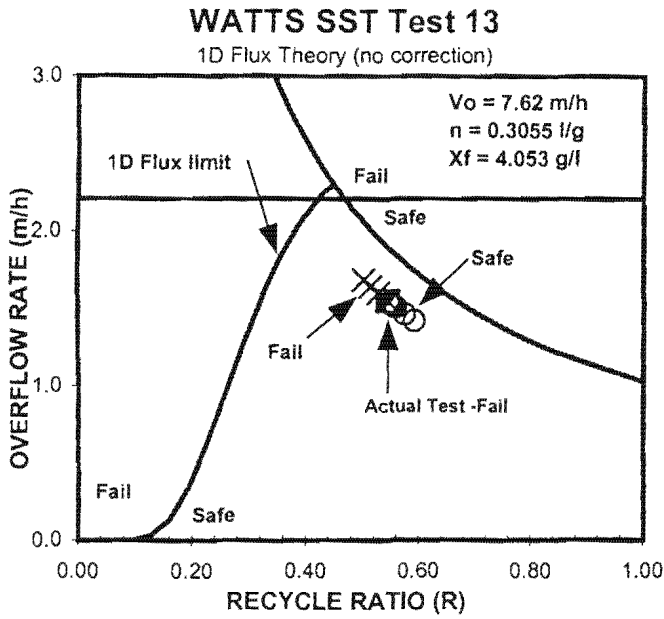


Fig j to l: 1DFT D&O charts showing the SST operating positions and results (Safe, Fail) of the SettlerCAD runs and actual tests for test 13 to 15

Construct D&O Chart chart: Test 1

Xf = **4.053** kgMLSS/m³
 Vo = **7.62** m/h
 n = **0.3055** m³/kg
 Qr = **397.5** m³/h
 Qi (1D Flux Limit) = **1153.9** m³/h
 A = **659** m²

AttlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	397.5	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	900.0	397.5	1.37	0.44	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	877.0	397.5	1.33	0.45	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	853.9	397.5	1.30	0.47	0.09675	0.8456	0.0022	2.2091	10.6590
F	73.75	851.0	397.5	1.29	0.47	0.12900	0.7943	0.0309	2.2091	7.9942
F	73.5	848.1	397.5	1.29	0.47	0.16125	0.7426	0.1352	2.2091	6.3954
S	73.25	845.2	397.5	1.28	0.47	0.19350	0.6901	0.3382	2.2091	5.3295
S	73	842.3	397.5	1.28	0.47	0.22575	0.6364	0.6204	2.2091	4.5681
S	72.75	839.5	397.5	1.27	0.47	0.25800	0.5809	0.9427	2.2091	3.9971
S	72.5	836.6	397.5	1.27	0.48	0.29025	0.5228	1.2678	2.2091	3.5530
S	72.25	833.7	397.5	1.27	0.48	0.32250	0.4607	1.5690	2.2091	3.1977
S	72	830.8	397.5	1.26	0.48	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	807.7	397.5	1.23	0.49	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	784.7	397.5	1.19	0.51	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	761.6	397.5	1.16	0.52	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	761.6	397.5	1.16	0.52	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	761.6	397.5	1.16	0.52	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	41.2	475.4	397.5	0.72	0.84	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 2

Xf = 4.053 kgMLSS/m³
 Vo = 7.62 m/h
 n= 0.3055 m³/kg
 Qr= 398 m³/h
 Qi (1D Flux Limit) 1186.5 m³/h
 A= 659 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	398	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	925.5	398	1.40	0.43	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	901.7	398	1.37	0.44	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	878.0	398	1.33	0.45	0.09675	0.8456	0.0022	2.2091	10.6590
F	73.75	875.0	398	1.33	0.45	0.12900	0.7943	0.0309	2.2091	7.9942
S	73.5	872.1	398	1.32	0.46	0.16125	0.7426	0.1352	2.2091	6.3954
S	73.25	869.1	398	1.32	0.46	0.19350	0.6901	0.3382	2.2091	5.3295
S	73	866.1	398	1.31	0.46	0.22575	0.6364	0.6204	2.2091	4.5681
S	72.75	863.2	398	1.31	0.46	0.25800	0.5809	0.9427	2.2091	3.9971
S	72.5	860.2	398	1.31	0.46	0.29025	0.5228	1.2678	2.2091	3.5530
S	72.25	857.2	398	1.30	0.46	0.32250	0.4607	1.5690	2.2091	3.1977
S	72	854.3	398	1.30	0.47	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	830.6	398	1.26	0.48	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	806.8	398	1.22	0.49	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	783.1	398	1.19	0.51	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	783.1	398	1.19	0.51	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	783.1	398	1.19	0.51	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	52.5	622.9	398	0.95	0.64	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 3

$X_f = 4.053 \text{ kgMLSS/m}^3$
 $V_o = 7.62 \text{ m/h}$
 $n = 0.3055 \text{ m}^3/\text{kg}$
 $Q_r = 239.9 \text{ m}^3/\text{h}$
 $Q_i \text{ (1D Flux Limit)} = 899.9 \text{ m}^3/\text{h}$
 $A = 659 \text{ m}^2$

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Q_i (m^3/h)	Recycle Flow Q_r (m^3/h)	Overflow rate (m/d) Q_i/A	Recycle rate (m^3/d) $Q_r/Q_i = s$	Recycle ratio Q_r/Q_i s	alfa	Criterion 1 Thickening Q_i/A (m/d)	Criterion 2 Clarification Q_i/A (m/d)	Hyperbola Q_i/A (m/d)
	0	0.0	239.9	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	701.9	239.9	1.07	0.34	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	683.9	239.9	1.04	0.35	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	665.9	239.9	1.01	0.36	0.09675	0.8456	0.0022	2.2091	10.6590
S	73.75	663.7	239.9	1.01	0.36	0.12900	0.7943	0.0309	2.2091	7.9942
S	73.5	661.4	239.9	1.00	0.36	0.16125	0.7426	0.1352	2.2091	6.3954
S	73.25	659.2	239.9	1.00	0.36	0.19350	0.6901	0.3382	2.2091	5.3295
S	73	656.9	239.9	1.00	0.37	0.22575	0.6364	0.6204	2.2091	4.5681
S	72.75	654.7	239.9	0.99	0.37	0.25800	0.5809	0.9427	2.2091	3.9971
S	72.5	652.4	239.9	0.99	0.37	0.29025	0.5228	1.2678	2.2091	3.5530
S	72.25	650.2	239.9	0.99	0.37	0.32250	0.4607	1.5690	2.2091	3.1977
S	72	647.9	239.9	0.98	0.37	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	629.9	239.9	0.96	0.38	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	611.9	239.9	0.93	0.39	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	593.9	239.9	0.90	0.40	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	593.9	239.9	0.90	0.40	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	593.9	239.9	0.90	0.40	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (F)	87.7	789.2	239.9	1.20	0.30	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 4

Xf = 4.053 kgMLSS/m³
 Vo = 7.62 m/h
 n = 0.3055 m³/kg
 Qr = 396.9 m³/h
 Qi (1D Flux Limit) = 1124.2 m³/h
 A = 659 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	396.9	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	876.9	396.9	1.33	0.45	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	854.4	396.9	1.30	0.46	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	831.9	396.9	1.26	0.48	0.09675	0.8456	0.0022	2.2091	10.6590
F	73.75	829.1	396.9	1.26	0.48	0.12900	0.7943	0.0309	2.2091	7.9942
F	73.5	826.3	396.9	1.25	0.48	0.16125	0.7426	0.1352	2.2091	6.3954
S	73.25	823.5	396.9	1.25	0.48	0.19350	0.6901	0.3382	2.2091	5.3295
S	73	820.7	396.9	1.25	0.48	0.22575	0.6364	0.6204	2.2091	4.5681
S	72.75	817.9	396.9	1.24	0.49	0.25800	0.5809	0.9427	2.2091	3.9971
S	72.5	815.0	396.9	1.24	0.49	0.29025	0.5228	1.2678	2.2091	3.5530
S	72.25	812.2	396.9	1.23	0.49	0.32250	0.4607	1.5690	2.2091	3.1977
S	72	809.4	396.9	1.23	0.49	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	786.9	396.9	1.19	0.50	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	764.5	396.9	1.16	0.52	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	742.0	396.9	1.13	0.53	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	742.0	396.9	1.13	0.53	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	742.0	396.9	1.13	0.53	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	69.5	781.3	396.9	1.19	0.51	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 5

Xf = 4.053 kgMLSS/m³
 Vo = 7.62 m/h
 n = 0.3055 m³/kg
 Qr = 397.7 m³/h
 Qi (1D Flux Limit) 1319.4 m³/h
 A = 659 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	397.7	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	1029.1	397.7	1.56	0.39	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	1002.7	397.7	1.52	0.40	0.06450	0.8968	0.0000	2.2091	15.9884
F	72	950.0	397.7	1.44	0.42	0.09675	0.8456	0.0022	2.2091	10.6590
F	71.75	946.7	397.7	1.44	0.42	0.12900	0.7943	0.0309	2.2091	7.9942
S	71.5	943.4	397.7	1.43	0.42	0.16125	0.7426	0.1352	2.2091	6.3954
S	71.25	940.1	397.7	1.43	0.42	0.19350	0.6901	0.3382	2.2091	5.3295
S	71	936.8	397.7	1.42	0.42	0.22575	0.6364	0.6204	2.2091	4.5681
S	70.75	933.5	397.7	1.42	0.43	0.25800	0.5809	0.9427	2.2091	3.9971
S	70.5	930.2	397.7	1.41	0.43	0.29025	0.5228	1.2678	2.2091	3.5530
S	70.25	926.9	397.7	1.41	0.43	0.32250	0.4607	1.5690	2.2091	3.1977
S	70	923.6	397.7	1.40	0.43	0.35475	0.3925	1.8301	2.2091	2.9070
S	68	897.2	397.7	1.36	0.44	0.38700	0.3140	2.0432	2.2091	2.6647
S	66	870.8	397.7	1.32	0.46	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	870.8	397.7	1.32	0.46	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	870.8	397.7	1.32	0.46	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	870.8	397.7	1.32	0.46	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	59.4	783.7	397.7	1.19	0.51	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 6

Xf = 4.053 kgMLSS/m³
 Vo = 7.62 m/h
 n = 0.3055 m³/kg
 Qr = 475.7 m³/h
 Qi (1D Flux Limit) 1307.4 m³/h
 A = 659 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	475.7	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	1019.8	475.7	1.55	0.47	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	993.6	475.7	1.51	0.48	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	967.5	475.7	1.47	0.49	0.09675	0.8456	0.0022	2.2091	10.6590
F	72	941.3	475.7	1.43	0.51	0.12900	0.7943	0.0309	2.2091	7.9942
F	71.75	938.1	475.7	1.42	0.51	0.16125	0.7426	0.1352	2.2091	6.3954
S	71.5	934.8	475.7	1.42	0.51	0.19350	0.6901	0.3382	2.2091	5.3295
S	71.25	931.5	475.7	1.41	0.51	0.22575	0.6364	0.6204	2.2091	4.5681
S	71	928.3	475.7	1.41	0.51	0.25800	0.5809	0.9427	2.2091	3.9971
S	70.75	925.0	475.7	1.40	0.51	0.29025	0.5228	1.2678	2.2091	3.5530
S	70.5	921.7	475.7	1.40	0.52	0.32250	0.4607	1.5690	2.2091	3.1977
S	70.25	918.4	475.7	1.39	0.52	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	915.2	475.7	1.39	0.52	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	889.0	475.7	1.35	0.54	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	862.9	475.7	1.31	0.55	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	862.9	475.7	1.31	0.55	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	862.9	475.7	1.31	0.55	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	60.1	785.7	475.7	1.19	0.61	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 7

Xf = 4.053 kgMLSS/m³
 Vo = 7.62 m/h
 n= 0.3055 m³/kg
 Qr= 397.7 m³/h
 Qi (1D Flux Limit) 1369.1 m³/h
 A= 659 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	397.7	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	1067.9	397.7	1.62	0.37	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	1040.5	397.7	1.58	0.38	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	1013.1	397.7	1.54	0.39	0.09675	0.8456	0.0022	2.2091	10.6590
F	72	985.8	397.7	1.50	0.40	0.12900	0.7943	0.0309	2.2091	7.9942
F	71.75	982.3	397.7	1.49	0.40	0.16125	0.7426	0.1352	2.2091	6.3954
S	71.5	978.9	397.7	1.49	0.41	0.19350	0.6901	0.3382	2.2091	5.3295
S	71.25	975.5	397.7	1.48	0.41	0.22575	0.6364	0.6204	2.2091	4.5681
S	71	972.1	397.7	1.48	0.41	0.25800	0.5809	0.9427	2.2091	3.9971
S	70.75	968.6	397.7	1.47	0.41	0.29025	0.5228	1.2678	2.2091	3.5530
S	70.5	965.2	397.7	1.46	0.41	0.32250	0.4607	1.5690	2.2091	3.1977
S	70.25	961.8	397.7	1.46	0.41	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	958.4	397.7	1.45	0.41	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	931.0	397.7	1.41	0.43	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	903.6	397.7	1.37	0.44	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	903.6	397.7	1.37	0.44	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	903.6	397.7	1.37	0.44	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	68.2	933.7	397.7	1.42	0.43	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 8

Xf = 4.053 kgMLSS/m³
 Vo = 7.62 m/h
 n = 0.3055 m³/kg
 Qr = 552.8 m³/h
 Qi (1D Flux Limit) 1523.8 m³/h
 A = 659 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	552.8	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	1188.6	552.8	1.80	0.47	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	1158.1	552.8	1.76	0.48	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	1127.6	552.8	1.71	0.49	0.09675	0.8456	0.0022	2.2091	10.6590
F	72	1097.1	552.8	1.66	0.50	0.12900	0.7943	0.0309	2.2091	7.9942
F	71.75	1093.3	552.8	1.66	0.51	0.16125	0.7426	0.1352	2.2091	6.3954
F	71.5	1089.5	552.8	1.65	0.51	0.19350	0.6901	0.3382	2.2091	5.3295
F	71.25	1085.7	552.8	1.65	0.51	0.22575	0.6364	0.6204	2.2091	4.5681
F	71	1081.9	552.8	1.64	0.51	0.25800	0.5809	0.9427	2.2091	3.9971
F	70.75	1078.1	552.8	1.64	0.51	0.29025	0.5228	1.2678	2.2091	3.5530
F	70.5	1074.3	552.8	1.63	0.51	0.32250	0.4607	1.5690	2.2091	3.1977
F	70.25	1070.5	552.8	1.62	0.52	0.35475	0.3925	1.8301	2.2091	2.9070
F	70	1066.7	552.8	1.62	0.52	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	1036.2	552.8	1.57	0.53	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	1005.7	552.8	1.53	0.55	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	1005.7	552.8	1.53	0.55	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	1005.7	552.8	1.53	0.55	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	51.4	783.2	552.8	1.19	0.71	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 9

Xf = 4.053 kgMLSS/m³
 Vo = 7.62 m/h
 n= 0.3055 m³/kg
 Qr= 397.7 m³/h
 Qi (1D Flux Limit) 1428.6 m³/h
 A= 659 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	397.7	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	1114.3	397.7	1.69	0.36	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	1085.7	397.7	1.65	0.37	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	1057.2	397.7	1.60	0.38	0.09675	0.8456	0.0022	2.2091	10.6590
F	72	1028.6	397.7	1.56	0.39	0.12900	0.7943	0.0309	2.2091	7.9942
F	71.75	1025.0	397.7	1.56	0.39	0.16125	0.7426	0.1352	2.2091	6.3954
F	71.5	1021.4	397.7	1.55	0.39	0.19350	0.6901	0.3382	2.2091	5.3295
S	71.25	1017.9	397.7	1.54	0.39	0.22575	0.6364	0.6204	2.2091	4.5681
S	71	1014.3	397.7	1.54	0.39	0.25800	0.5809	0.9427	2.2091	3.9971
S	70.75	1010.7	397.7	1.53	0.39	0.29025	0.5228	1.2678	2.2091	3.5530
S	70.5	1007.2	397.7	1.53	0.39	0.32250	0.4607	1.5690	2.2091	3.1977
S	70.25	1003.6	397.7	1.52	0.40	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	1000.0	397.7	1.52	0.40	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	971.4	397.7	1.47	0.41	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	942.9	397.7	1.43	0.42	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	942.9	397.7	1.43	0.42	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	942.9	397.7	1.43	0.42	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	71.2	1017.2	397.7	1.54	0.39	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 10

$X_f = 4.053 \text{ kgMLSS/m}^3$
 $V_o = 7.62 \text{ m/h}$
 $n = 0.3055 \text{ m}^3/\text{kg}$
 $Q_r = 397.7 \text{ m}^3/\text{h}$
 $Q_i \text{ (1D Flux Limit)} = 1221.7 \text{ m}^3/\text{h}$
 $A = 659 \text{ m}^2$

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Q_i (m^3/h)	Recycle Flow Q_r (m^3/h)	Overflow rate (m/d) Q_i/A	Recycle rate (m^3/d) $Q_r/Q_i = s$	Recycle ratio Q_r/Q_i s	alfa	Criterion 1 Thickening Q_i/A (m/d)	Criterion 2 Clarification Q_i/A (m/d)	Hyperbola Q_i/A (m/d)
	0	0.0	397.7	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	952.9	397.7	1.45	0.42	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	928.5	397.7	1.41	0.43	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	904.1	397.7	1.37	0.44	0.09675	0.8456	0.0022	2.2091	10.6590
F	73.75	901.0	397.7	1.37	0.44	0.12900	0.7943	0.0309	2.2091	7.9942
F	73.5	897.9	397.7	1.36	0.44	0.16125	0.7426	0.1352	2.2091	6.3954
F	73.25	894.9	397.7	1.36	0.44	0.19350	0.6901	0.3382	2.2091	5.3295
F	73	891.8	397.7	1.35	0.45	0.22575	0.6364	0.6204	2.2091	4.5681
F	72.75	888.8	397.7	1.35	0.45	0.25800	0.5809	0.9427	2.2091	3.9971
S	72.5	885.7	397.7	1.34	0.45	0.29025	0.5228	1.2678	2.2091	3.5530
S	72.25	882.7	397.7	1.34	0.45	0.32250	0.4607	1.5690	2.2091	3.1977
S	72	879.6	397.7	1.33	0.45	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	855.2	397.7	1.30	0.47	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	830.8	397.7	1.26	0.48	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	806.3	397.7	1.22	0.49	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	806.3	397.7	1.22	0.49	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	806.3	397.7	1.22	0.49	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	63.3	773.3	397.7	1.17	0.51	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 11

$X_f = 4.053 \text{ kgMLSS/m}^3$
 $V_o = 7.62 \text{ m/h}$
 $n = 0.3055 \text{ m}^3/\text{kg}$
 $Q_r = 397.2 \text{ m}^3/\text{h}$
 $Q_i \text{ (1D Flux Limit)} = 1156.9 \text{ m}^3/\text{h}$
 $A = 659 \text{ m}^2$

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Q_i (m^3/h)	Recycle Flow Q_r (m^3/h)	Overflow rate (m/d) Q_i/A	Recycle rate (m^3/d) $Q_r/Q_i = s$	Recycle ratio Q_r/Q_i s	alfa	Criterion 1 Thickening Q_i/A (m/d)	Criterion 2 Clarification Q_i/A (m/d)	Hyperbola Q_i/A (m/d)
	0	0.0	397.2	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	902.4	397.2	1.37	0.44	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	879.2	397.2	1.33	0.45	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	856.1	397.2	1.30	0.46	0.09675	0.8456	0.0022	2.2091	10.6590
F	73.75	853.2	397.2	1.29	0.47	0.12900	0.7943	0.0309	2.2091	7.9942
S	73.5	850.3	397.2	1.29	0.47	0.16125	0.7426	0.1352	2.2091	6.3954
S	73.25	847.4	397.2	1.29	0.47	0.19350	0.6901	0.3382	2.2091	5.3295
S	73	844.5	397.2	1.28	0.47	0.22575	0.6364	0.6204	2.2091	4.5681
S	72.75	841.6	397.2	1.28	0.47	0.25800	0.5809	0.9427	2.2091	3.9971
S	72.5	838.8	397.2	1.27	0.47	0.29025	0.5228	1.2678	2.2091	3.5530
S	72.25	835.9	397.2	1.27	0.48	0.32250	0.4607	1.5690	2.2091	3.1977
S	72	833.0	397.2	1.26	0.48	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	809.8	397.2	1.23	0.49	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	786.7	397.2	1.19	0.50	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	763.6	397.2	1.16	0.52	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	763.6	397.2	1.16	0.52	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	763.6	397.2	1.16	0.52	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (F)	88.3	1021.5	397.2	1.55	0.39	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 12

Xf = 4.053 kgMLSS/m³
 Vo = 7.62 m/h
 n = 0.3055 m³/kg
 Qr = 397.7 m³/h
 Qi (1D Flux Limit) 1428.6 m³/h
 A = 659 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	397.7	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	1114.3	397.7	1.69	0.36	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	1085.7	397.7	1.65	0.37	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	1057.2	397.7	1.60	0.38	0.09675	0.8456	0.0022	2.2091	10.6590
F	72	1028.6	397.7	1.56	0.39	0.12900	0.7943	0.0309	2.2091	7.9942
F	71.75	1025.0	397.7	1.56	0.39	0.16125	0.7426	0.1352	2.2091	6.3954
F	71.5	1021.4	397.7	1.55	0.39	0.19350	0.6901	0.3382	2.2091	5.3295
S	71.25	1017.9	397.7	1.54	0.39	0.22575	0.6364	0.6204	2.2091	4.5681
S	71	1014.3	397.7	1.54	0.39	0.25800	0.5809	0.9427	2.2091	3.9971
S	70.75	1010.7	397.7	1.53	0.39	0.29025	0.5228	1.2678	2.2091	3.5530
S	70.5	1007.2	397.7	1.53	0.39	0.32250	0.4607	1.5690	2.2091	3.1977
S	70.25	1003.6	397.7	1.52	0.40	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	1000.0	397.7	1.52	0.40	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	971.4	397.7	1.47	0.41	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	942.9	397.7	1.43	0.42	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	942.9	397.7	1.43	0.42	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	942.9	397.7	1.43	0.42	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (F)	76.7	1095.7	397.7	1.66	0.36	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 13

$X_f = 4.053 \text{ kgMLSS/m}^3$
 $V_o = 7.62 \text{ m/h}$
 $n = 0.3055 \text{ m}^3/\text{kg}$
 $Q_r = 555.6 \text{ m}^3/\text{h}$
 $Q_i \text{ (1D Flux Limit)} = 1423.6 \text{ m}^3/\text{h}$
 $A = 659 \text{ m}^2$

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Q_i (m^3/h)	Recycle Flow Q_r (m^3/h)	Overflow rate (m/d) Q_i/A	Recycle rate (m^3/d) $Q_r/Q_i = s$	Recycle ratio Q_r/Q_i s	alfa	Criterion 1 Thickening Q_i/A (m/d)	Criterion 2 Clarification Q_i/A (m/d)	Hyperbola Q_i/A (m/d)
	0	0.0	555.6	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	1110.4	555.6	1.68	0.50	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	1081.9	555.6	1.64	0.51	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	1053.5	555.6	1.60	0.53	0.09675	0.8456	0.0022	2.2091	10.6590
F	72	1025.0	555.6	1.56	0.54	0.12900	0.7943	0.0309	2.2091	7.9942
F	71.75	1021.4	555.6	1.55	0.54	0.16125	0.7426	0.1352	2.2091	6.3954
F	71.5	1017.9	555.6	1.54	0.55	0.19350	0.6901	0.3382	2.2091	5.3295
F	71.25	1014.3	555.6	1.54	0.55	0.22575	0.6364	0.6204	2.2091	4.5681
S	71	1010.8	555.6	1.53	0.55	0.25800	0.5809	0.9427	2.2091	3.9971
S	70.75	1007.2	555.6	1.53	0.55	0.29025	0.5228	1.2678	2.2091	3.5530
S	70.5	1003.6	555.6	1.52	0.55	0.32250	0.4607	1.5690	2.2091	3.1977
S	70.25	1000.1	555.6	1.52	0.56	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	996.5	555.6	1.51	0.56	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	968.0	555.6	1.47	0.57	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	939.6	555.6	1.43	0.59	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	939.6	555.6	1.43	0.59	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	939.6	555.6	1.43	0.59	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (F)	71.8	1022.1	555.6	1.55	0.54	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 14

Xf = 4.053 kgMLSS/m³
 Vo = 7.62 m/h
 n = 0.3055 m³/kg
 Qr = 714 m³/h
 Qi (1D Flux Limit) = 1486.9 m³/h
 A = 659 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	714	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	1159.8	714	1.76	0.62	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	1130.0	714	1.71	0.63	0.06450	0.8968	0.0000	2.2091	15.9884
F	74	1100.3	714	1.67	0.65	0.09675	0.8456	0.0022	2.2091	10.6590
F	73.75	1096.6	714	1.66	0.65	0.12900	0.7943	0.0309	2.2091	7.9942
F	73.5	1092.9	714	1.66	0.65	0.16125	0.7426	0.1352	2.2091	6.3954
F	73.25	1089.2	714	1.65	0.66	0.19350	0.6901	0.3382	2.2091	5.3295
F	73	1085.4	714	1.65	0.66	0.22575	0.6364	0.6204	2.2091	4.5681
S	72.75	1081.7	714	1.64	0.66	0.25800	0.5809	0.9427	2.2091	3.9971
S	72.5	1078.0	714	1.64	0.66	0.29025	0.5228	1.2678	2.2091	3.5530
S	72.25	1074.3	714	1.63	0.66	0.32250	0.4607	1.5690	2.2091	3.1977
S	72	1070.6	714	1.62	0.67	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	1040.8	714	1.58	0.69	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	1011.1	714	1.53	0.71	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	981.4	714	1.49	0.73	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	981.4	714	1.49	0.73	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	981.4	714	1.49	0.73	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (S)	68.8	1023.0	714	1.55	0.70	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

Construct D&O Chart chart: Test 15

$X_f = 4.053 \text{ kgMLSS/m}^3$
 $V_o = 7.62 \text{ m/h}$
 $\eta = 0.3055 \text{ m}^3/\text{kg}$
 $Q_r = 753.5 \text{ m}^3/\text{h}$
 $Q_i \text{ (1D Flux Limit)} = 1662.3 \text{ m}^3/\text{h}$
 $A = 659 \text{ m}^2$

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Q_i (m^3/h)	Recycle Flow Q_r (m^3/h)	Overflow rate (m/d) Q_i/A	Recycle rate (m^3/d) $Q_r/Q_i = s$	Recycle ratio Q_r/Q_i s	alfa	Criterion 1 Thickening Q_i/A (m/d)	Criterion 2 Clarification Q_i/A (m/d)	Hyperbola Q_i/A (m/d)
	0	0.0	753.5	0.00	0.00	0.00000	1.0000	0.0000	2.2091	103.1255
F	78	1296.6	753.5	1.97	0.58	0.03225	0.9482	0.0000	2.2091	31.9769
F	76	1263.3	753.5	1.92	0.60	0.06450	0.8968	0.0000	2.2091	15.9884
F	75.75	1259.2	753.5	1.91	0.60	0.09675	0.8456	0.0022	2.2091	10.6590
F	75.5	1255.0	753.5	1.90	0.60	0.12900	0.7943	0.0309	2.2091	7.9942
F	75.25	1250.9	753.5	1.90	0.60	0.16125	0.7426	0.1352	2.2091	6.3954
F	75	1246.7	753.5	1.89	0.60	0.19350	0.6901	0.3382	2.2091	5.3295
F	74.75	1242.6	753.5	1.89	0.61	0.22575	0.6364	0.6204	2.2091	4.5681
F	74.5	1238.4	753.5	1.88	0.61	0.25800	0.5809	0.9427	2.2091	3.9971
S	74.25	1234.3	753.5	1.87	0.61	0.29025	0.5228	1.2678	2.2091	3.5530
S	74	1230.1	753.5	1.87	0.61	0.32250	0.4607	1.5690	2.2091	3.1977
S	72	1196.9	753.5	1.82	0.63	0.35475	0.3925	1.8301	2.2091	2.9070
S	70	1163.6	753.5	1.77	0.65	0.38700	0.3140	2.0432	2.2091	2.6647
S	68	1130.4	753.5	1.72	0.67	0.42570	0.1881	2.2303	2.2091	2.4225
S	66	1097.1	753.5	1.66	0.69	0.43215	0.1587	2.2537	2.2091	2.3863
S	66	1097.1	753.5	1.66	0.69	0.43860	0.1228	2.2746	2.2091	2.3512
S	66	1097.1	753.5	1.66	0.69	0.44505	0.0711	2.2926	2.2091	2.3172
Actual (F)	60.7	1009.0	753.5	1.53	0.75	0.47730	#NUM!	#NUM!	2.2091	2.1606
						0.50955	#NUM!	#NUM!	2.2091	2.0239
						0.54180	#NUM!	#NUM!	2.2091	1.9034
						0.57405	#NUM!	#NUM!	2.2091	1.7965
						0.60630	#NUM!	#NUM!	2.2091	1.7009
						0.63855	#NUM!	#NUM!	2.2091	1.6150
						0.67080	#NUM!	#NUM!	2.2091	1.5374
						0.70305	#NUM!	#NUM!	2.2091	1.4668
						0.73530	#NUM!	#NUM!	2.2091	1.4025
						0.76755	#NUM!	#NUM!	2.2091	1.3436
						0.79980	#NUM!	#NUM!	2.2091	1.2894
						0.83205	#NUM!	#NUM!	2.2091	1.2394
						0.86430	#NUM!	#NUM!	2.2091	1.1932
						1.00000	#NUM!	#NUM!	2.2091	1.0313

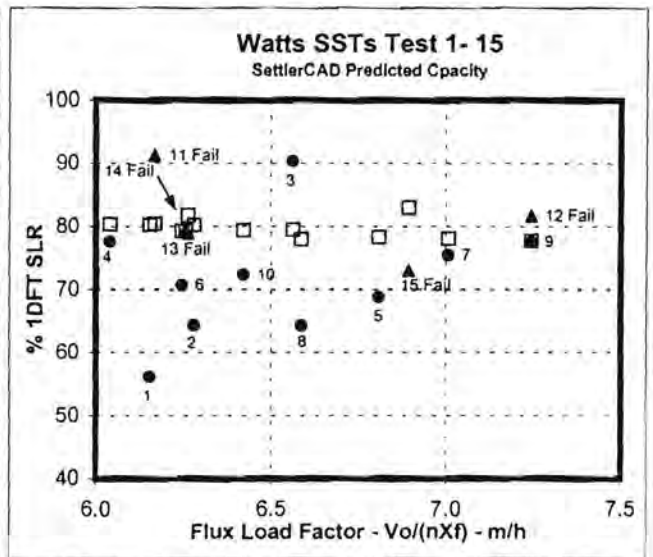
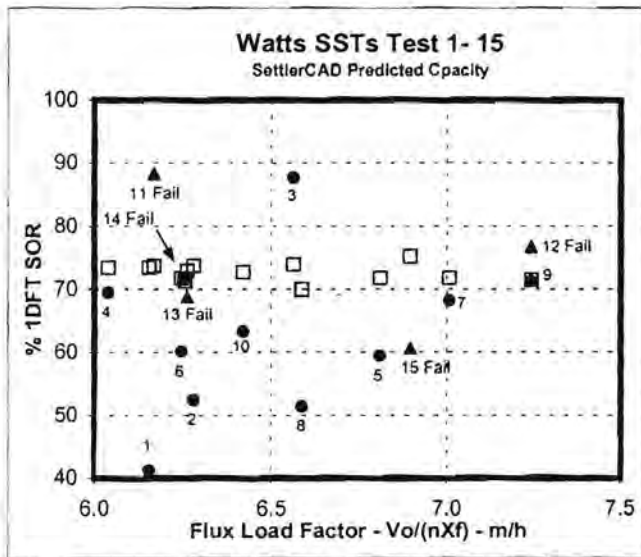
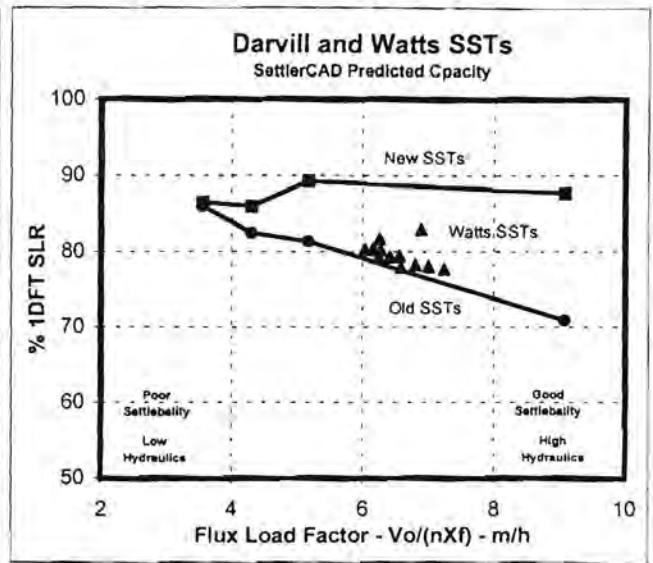
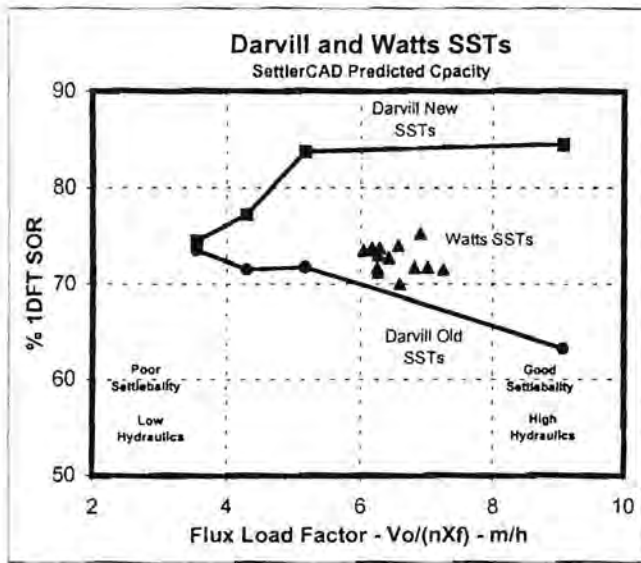


Fig a to d: SettlerCAD predicted capacity as % of the 1DFT maximum HLR (Figures on left) and SLR (Figures on the right) limits versus the flux load factor for Watts Test 1 to 15 superimposed on the Darvill results (Fig a and b). Fig c and d shows a detail look at the Watts results. The actual test positions and outcome is also shown in Fig c and d

Flux Load Factor

Darvill	Test 2		Test 1		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Flux Constant V_0 (m/h)	7.83	7.83	7.71	7.71	8.00	8.00	9.08	9.08
Flux Constant n (m ³ /kgTSS)	0.513	0.513	0.39	0.39	0.43	0.43	0.29	0.29
Feed Conc. (g/l)	4.300	4.300	4.600	4.600	3.600	3.600	3.450	3.450
Flux Factor $V_0/(n \cdot X_F)$ - m/h	3.5	3.5	4.3	4.3	5.2	5.2	9.1	9.1

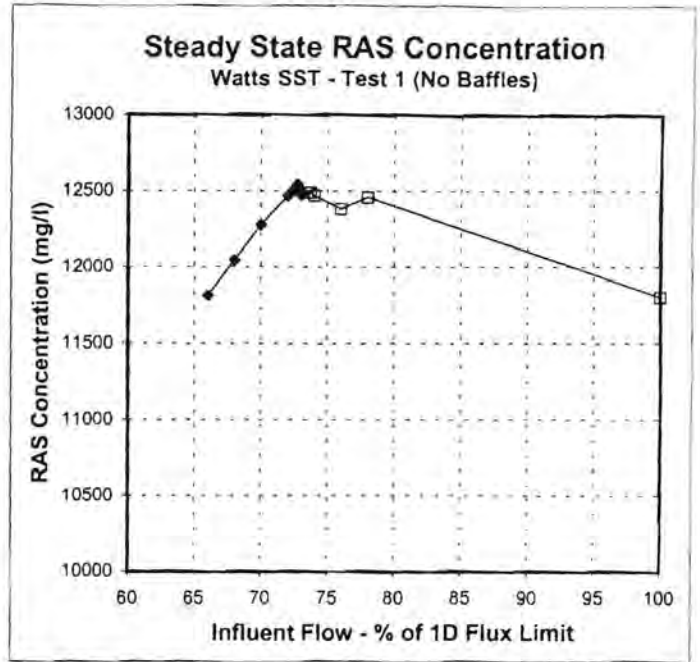
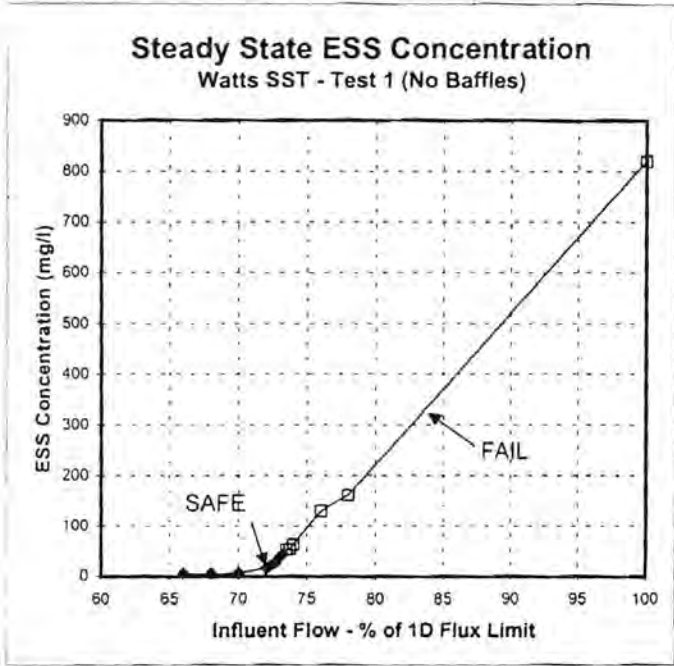
% of 1 DFT Overflow Rate	Test 2		Test 1		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Case 1 - Normal	74.50	73.50	77.25	71.50	83.75	71.75	84.50	63.25
Case 2 - No Baffles	74.30	76.25	80.00	74.50	87.30	75.80	89.00	65.00
Case 3 - Reverse Depth	67.50	82.50	63.00	78.25	63.75	82.75	68.00	81.25
Actual Test	92.10	92.10	78.50	78.50	65.60	65.60	89.10	89.10

% of 1 DFT SLR	Test 2		Test 1		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Case 1 - Normal	86.5	86	86	82.5	89.3	81.4	87.7	70.9
Case 2 - No Baffles	86.4	87.5	87.7	84.3	91.6	84.1	91.3	72.3
Case 3 - Reverse Depth	82.8	90.8	77.3	86.6	76.1	88.6	74.67	85.2
Actual Test	95.8	95.8	86.8	86.8	77.3	77.3	91.4	91.4

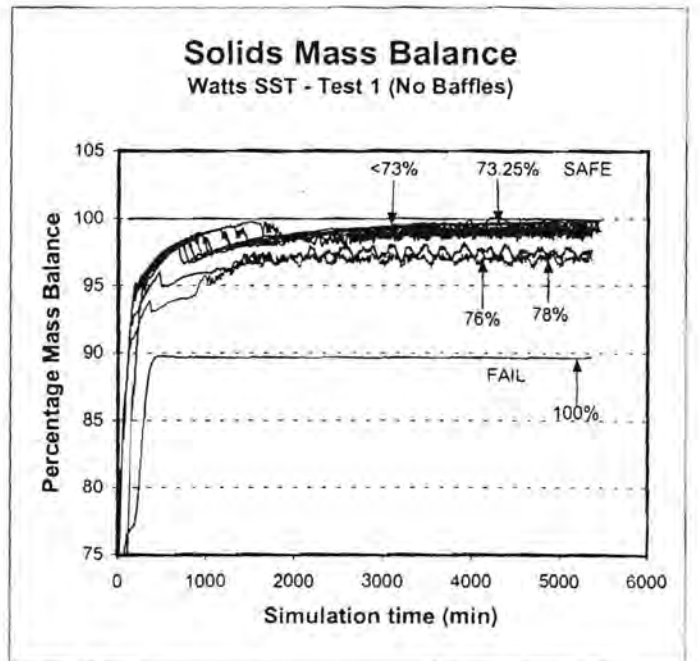
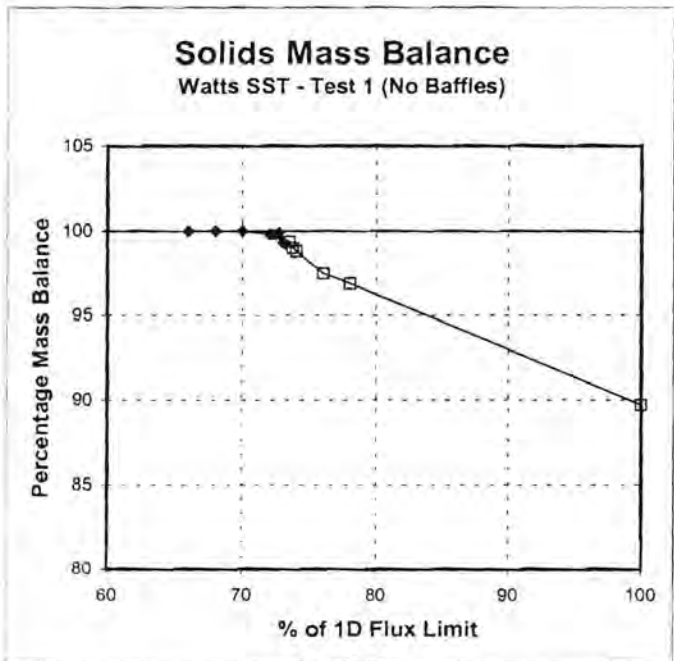
Watts	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Flux Constant V_0 (m/h)	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62
Flux Constant n (m ³ /kgTSS)	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055
Feed Conc. (g/l)	4.053	3.972	3.801	4.130	3.664	3.994	3.560	3.787	3.444	3.885	4.044	3.444	3.987	3.983	3.618
Flux Factor $V_0/(n \cdot X_F)$ - m/h	6.2	6.3	6.6	6.0	6.8	6.2	7.0	6.6	7.2	6.4	6.2	7.2	6.3	6.3	6.9

% of 1 DFT Overflow Rate	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Case 1 - Normal	73.5	73.75	74	73.5	71.75	71.75	71.75	70	71.5	72.75	73.75	71.5	71.25	73	75.25
Actual Test	41.2	52.5	87.7	69.5	59.4	60.1	68.2	51.4	71.2	63.3	88.3	76.7	71.8	68.8	60.7

% of 1 DFT SLR	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Case 1 - Normal	80.3	80.3	79.5	80.4	78.3	79.3	78.1	78	77.7	79.4	80.5	77.7	79.3	81.8	83
Actual Test	56.2	64.4	90.3	77.5	68.8	70.7	75.4	64.3	77.5	72.3	91.3	81.7	79.7	78.9	73



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

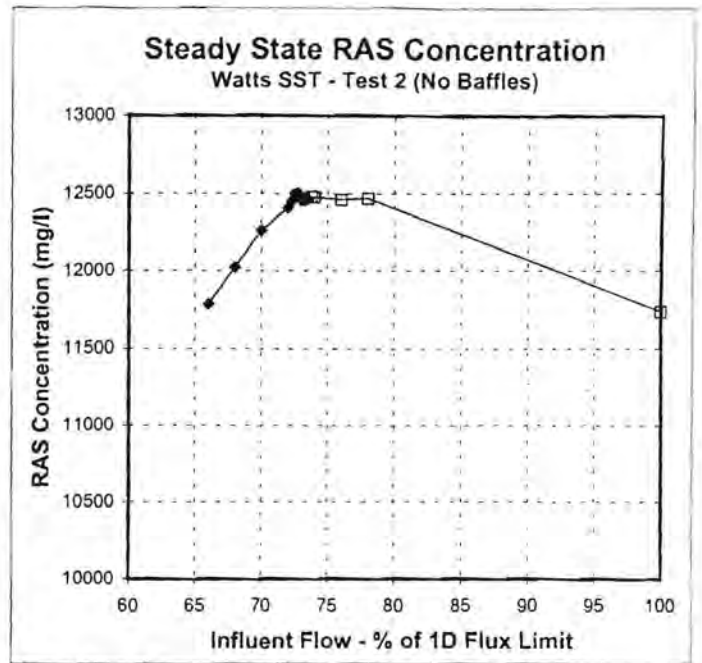
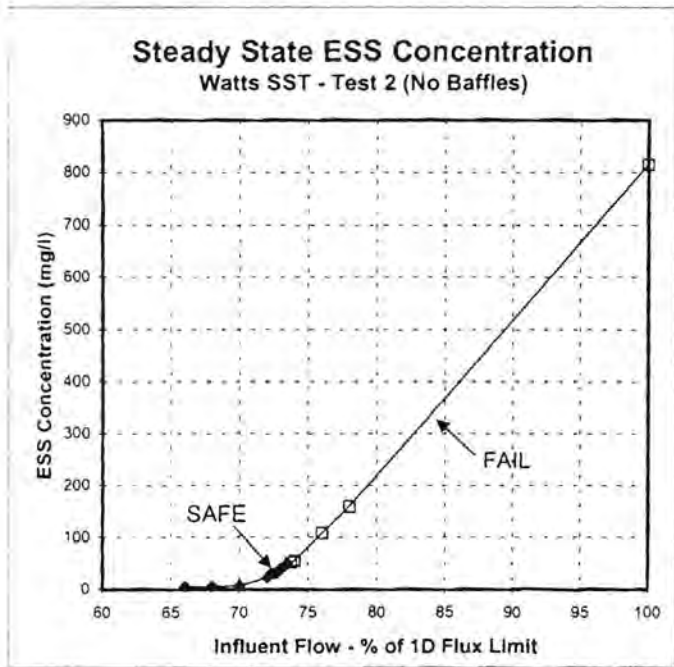


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 1 simulation on the Watts SST - No Baffles

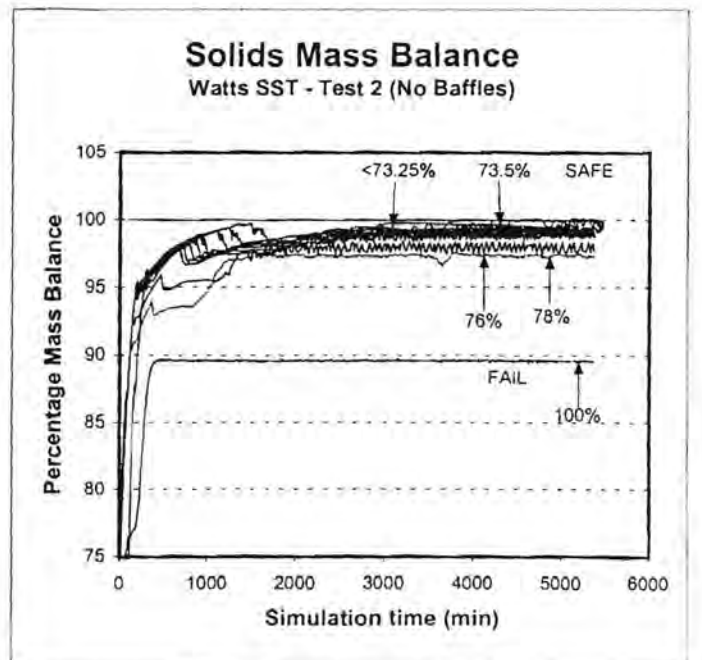
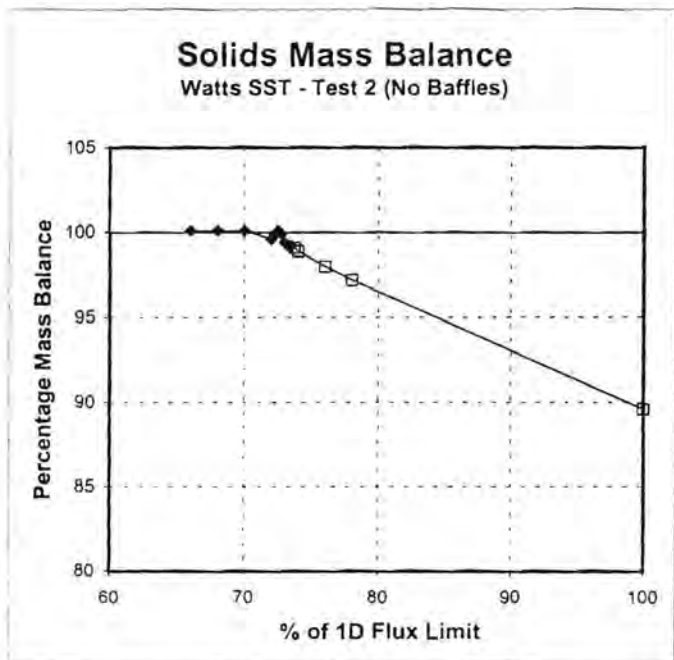
Test 1 - Normal No Baffles

Vo (m/h)	7.62
n (l/g)	0.3055
Xf (g/l)	4.053
1DFT predicted limits	
Maximun flux [kg/(m ² .h)]	9.54
Overflow rate (m/h)	1.75
Influent flow (m ³ /h)	1153.9
Flux ratings	
Flux load factor [Vo/(n.Xf)] (m/h)	6.15
Simulation Data	
Recycle flow (m ³ /h)	397.5
Area (m ²)	658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
66	5.00	11811.00	S	100.0
66	5.00	11811.00	S	100.0
68	5.40	12046.00	S	100.0
70	6.50	12277.00	S	100.0
72	15.80	12466.00	S	99.8
72.25	18.70	12490.00	S	99.8
72.5	23.60	12510.00	S	99.8
72.75	27.10	12543.00	S	99.9
73	38.10	12473.00	S	99.3
73.25	43.80	12482.00	S	99.2
73.5	53.50	12492.00	F	99.4
73.75	54.80	12489.00	F	99.0
74	63.30	12471.00	F	98.8
76	129.60	12382.00	F	97.5
78	161.20	12459.00	F	96.9
100	819.90	11803.00	F	89.7

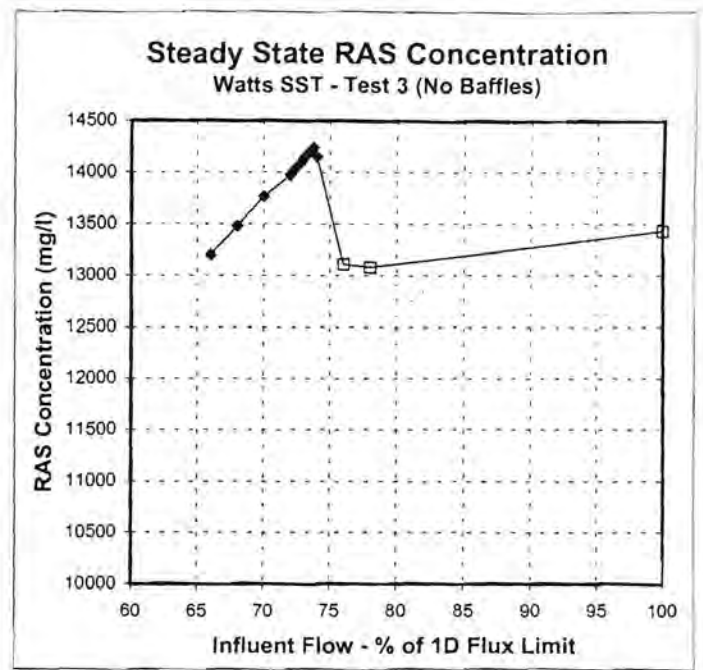
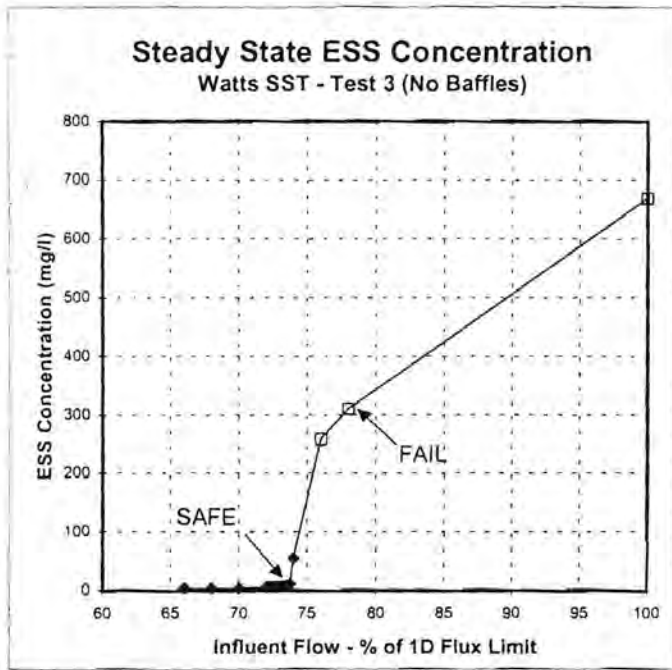


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

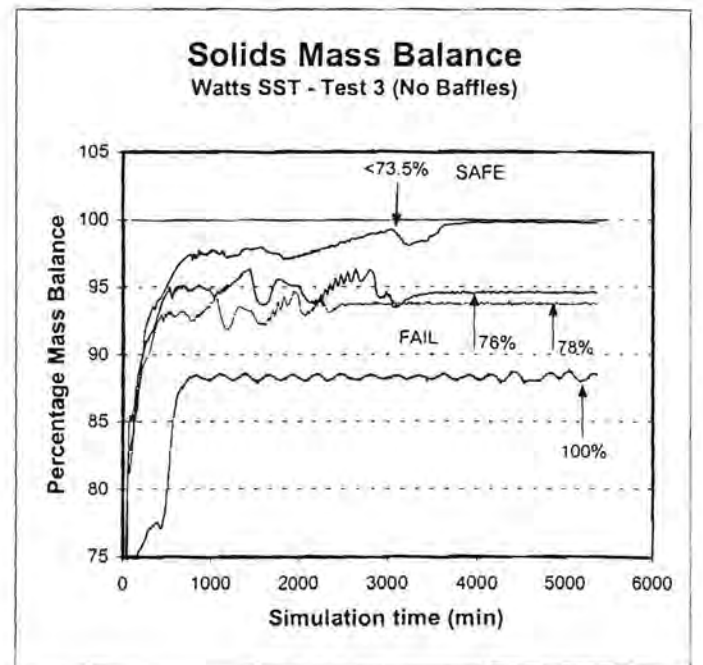
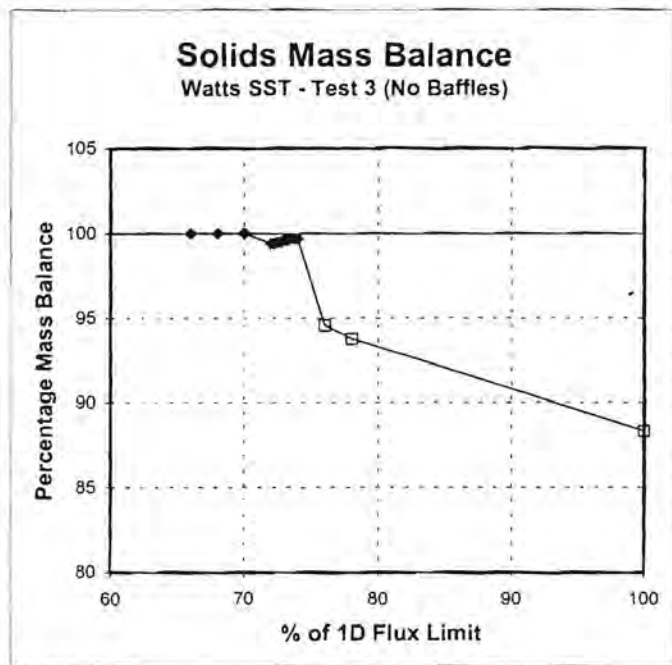


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 2 simulation on the Watts SST - No Baffles

Test 2 - Normal No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.62					
n (l/g)	0.3055	66	5.20	11785.00	S	100.1
Xf (g/l)	3.972	66	5.20	11785.00	S	100.1
1DFT predicted limits		68	5.50	12023.00	S	100.1
		70	7.20	12259.00	S	100.1
		72	22.70	12405.00	S	99.6
Maximun flux [kg/(m ² .h)]	9.55	72.25	29.20	12448.00	S	99.9
Overflow rate (m/h)	1.80	72.5	31.00	12499.00	S	100.1
Influent flow (m ³ /h)	1186.5	72.75	31.80	12503.00	S	99.9
		73	39.20	12454.00	S	99.4
Flux ratings		73.25	43.30	12455.00	S	99.2
		73.5	49.00	12462.00	S	99.2
Flux load factor [Vo/(n.Xf)] (m/h)	6.28	73.75	51.40	12479.00	F	99.1
		74	55.30	12475.00	F	98.9
Simulation Data		76	108.10	12461.00	F	98.0
		78	159.70	12470.00	F	97.2
Recycle flow (m ³ /h)	398	100	815.80	11737.00	F	89.6
Area (m ²)	658.78					

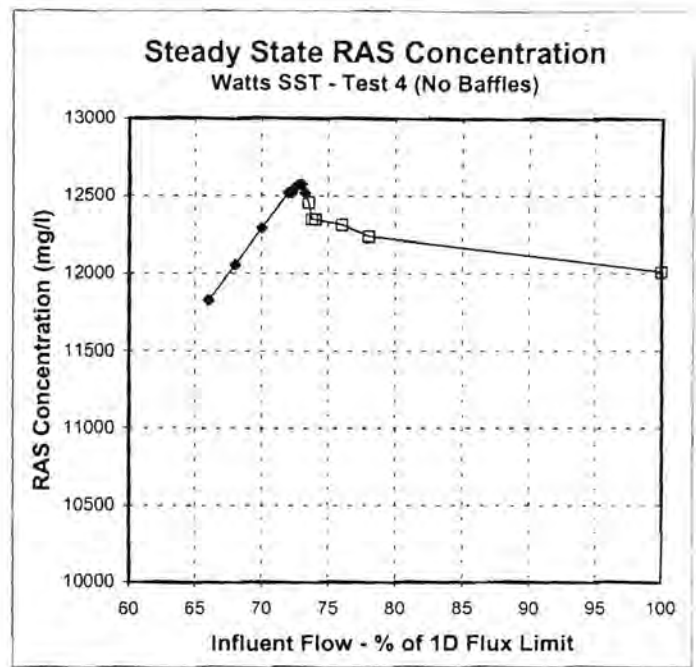
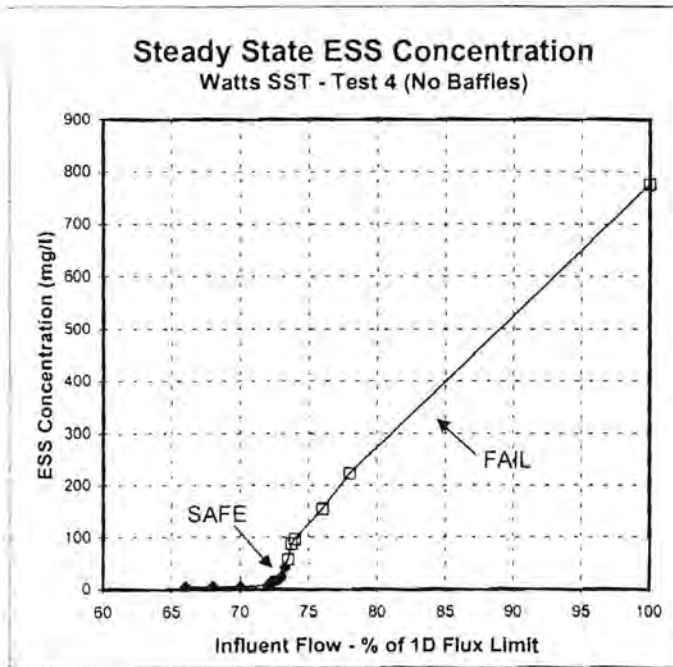


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

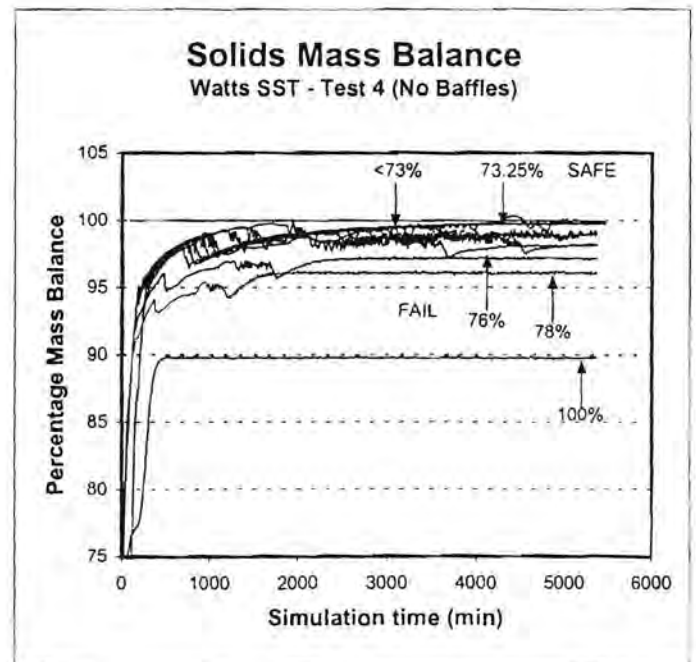
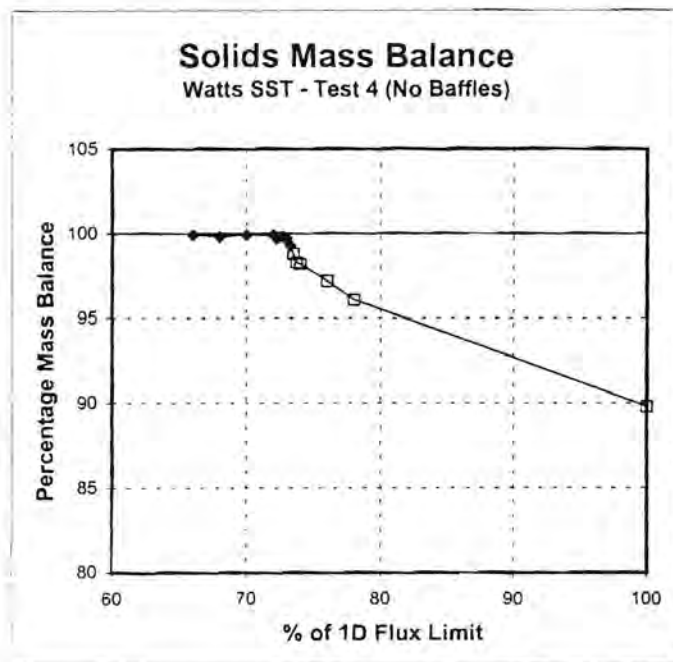


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 3 simulation on the Watts SST - No Baffles

Test 3 - Normal No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.62					
n (l/g)	0.3055	66	3.40	13199.00	S	100.0
Xf (g/l)	3.801	66	3.40	13199.00	S	100.0
		68	3.30	13483.00	S	100.0
1DFT predicted limits		70	3.40	13768.00	S	100.0
		72	5.80	13973.00	S	99.4
Maximun flux [kg/(m ² .h)]	6.58	72.25	6.10	14014.00	S	99.4
Overflow rate (m/h)	1.37	72.5	6.40	14054.00	S	99.5
Influent flow (m ³ /h)	899.9	72.75	6.70	14084.00	S	99.5
		73	7.00	14134.00	S	99.6
Flux ratings		73.25	7.40	14174.00	S	99.6
		73.5	7.90	14216.00	S	99.7
Flux load factor [Vo/(n.Xf)] (m/h)	6.56	73.75	10.00	14242.00	S	99.7
		74	55.00	14152.00	F	99.7
Simulation Data		76	258.70	13113.00	F	94.6
		78	310.70	13083.00	F	93.8
Recycle flow (m ³ /h)	239.9	100	668.80	13432.00	F	88.3
Area (m ²)	658.78					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the Watts SST - No Baffles

Test 4 - Normal No Baffles

Vo (m/h)	7.62
n (l/g)	0.3055
Xf (g/l)	4.13

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	9.54
Overflow rate (m/h)	1.71
Influent flow (m ³ /h)	1124.2

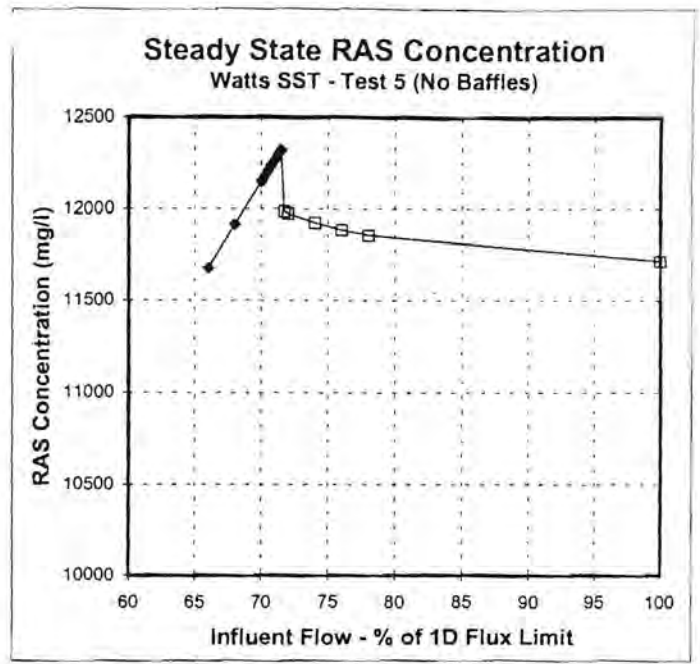
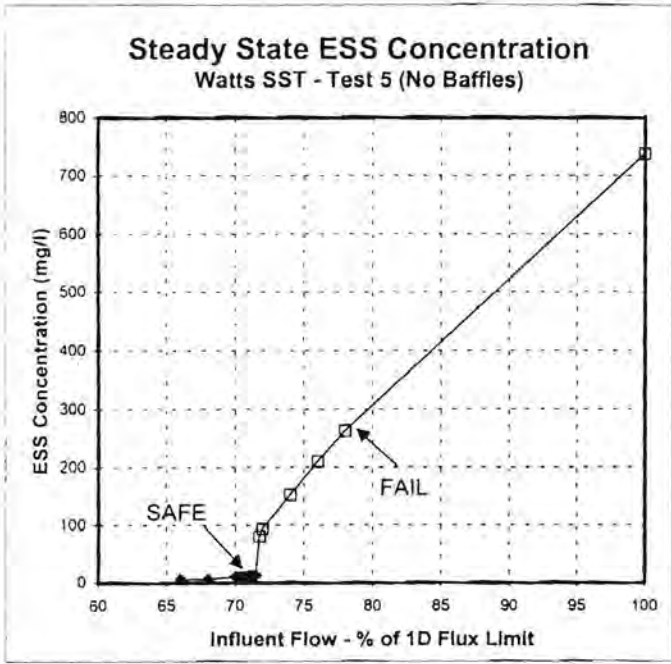
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	6.04
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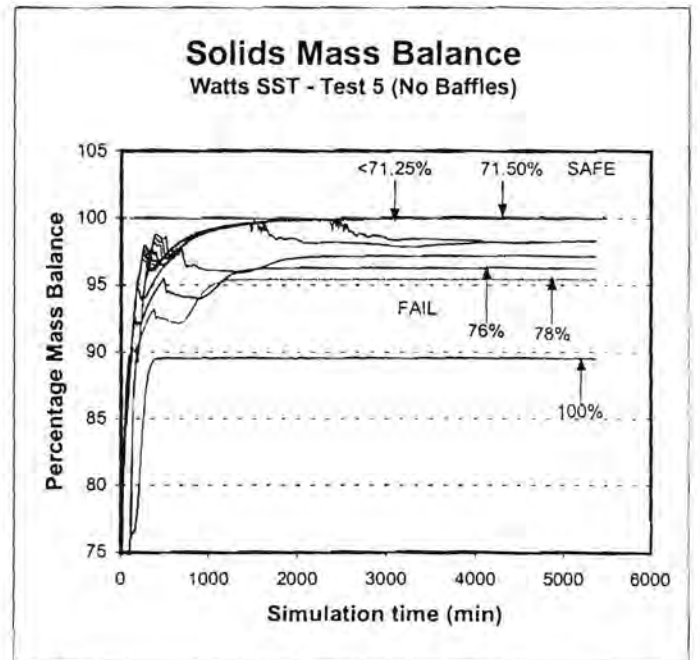
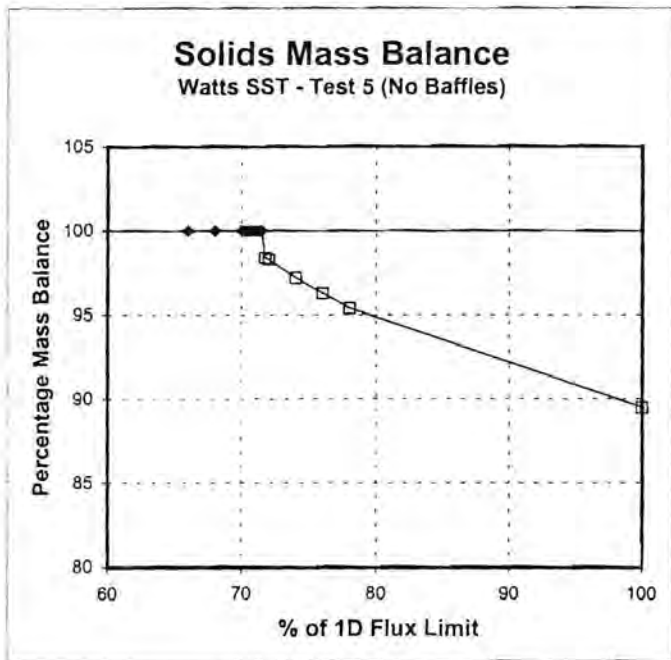
Simulation Data

Recycle flow (m ³ /h)	396.9
Area (m ²)	658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
66	4.90	11829.00	S	99.9
66	4.90	11829.00	S	99.9
68	5.40	12055.00	S	99.8
70	5.80	12293.00	S	99.9
72	7.50	12520.00	S	99.9
72.25	14.30	12519.00	S	99.7
72.5	15.70	12555.00	S	99.8
72.75	17.70	12573.00	S	99.8
73	23.60	12576.00	S	99.7
73.25	40.60	12518.00	S	99.3
73.5	57.70	12459.00	F	98.8
73.75	88.10	12350.00	F	98.3
74	96.60	12350.00	F	98.2
76	155.10	12318.00	F	97.2
78	223.10	12241.00	F	96.1
100	776.10	12013.00	F	89.8

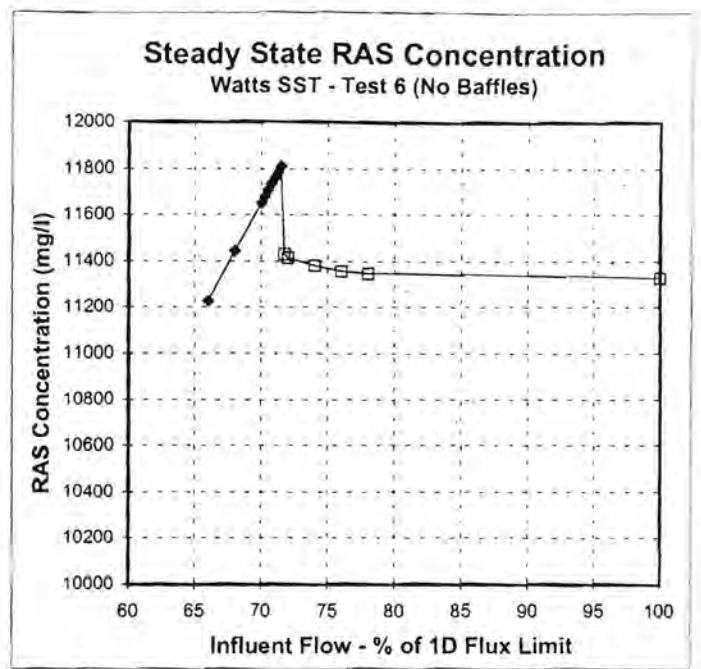
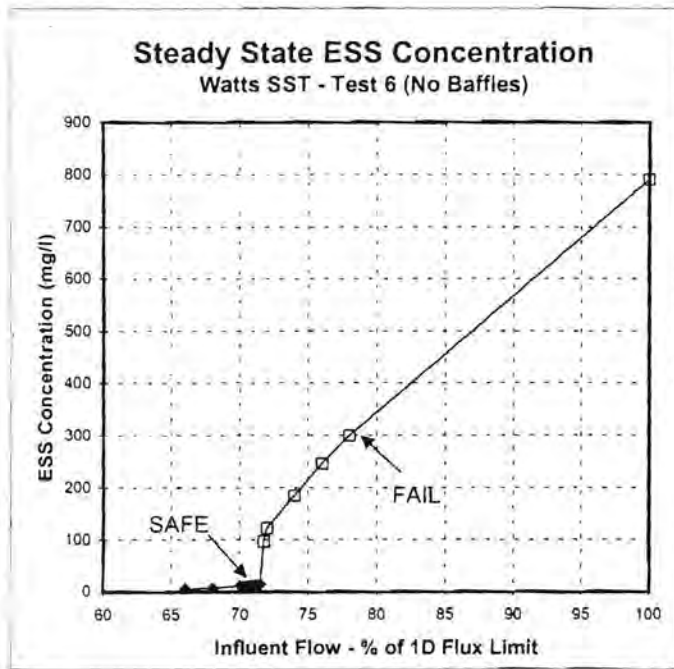


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

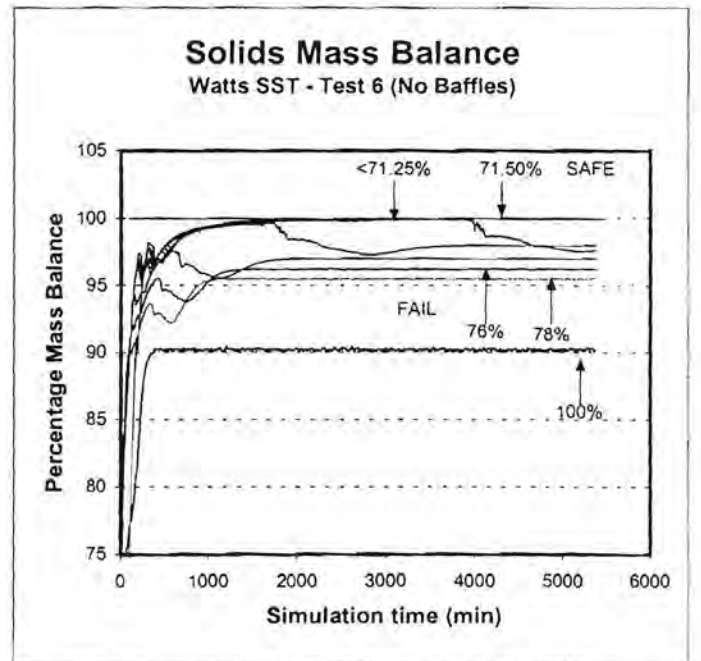
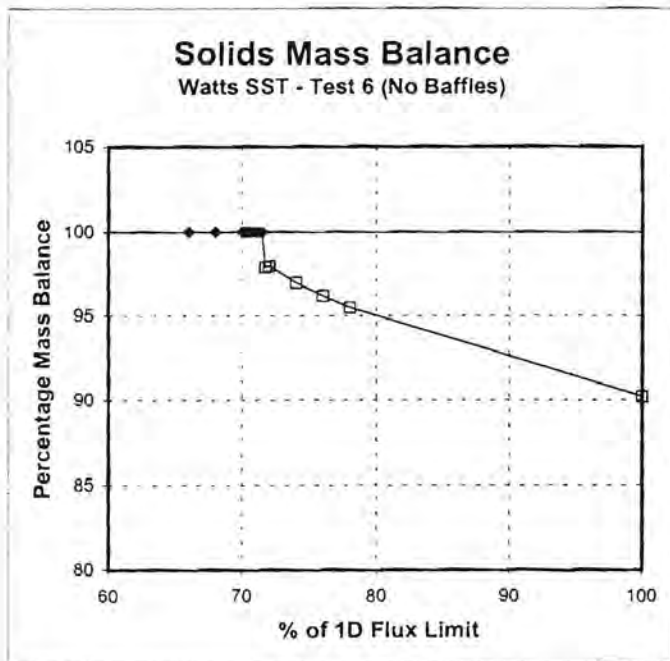


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 5 simulation on the Watts SST - No Baffles

Test 5 - Normal No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.62					
n (l/g)	0.3055	66	6.10	11677.00	S	100.0
Xf (g/l)	3.664	66	6.10	11677.00	S	100.0
1DFT predicted limits		68	6.30	11916.00	S	100.0
		70	10.60	12153.00	S	100.0
		70.25	10.90	12179.00	S	100.0
Maximun flux [kg/(m ² .h)]	9.55	70.5	11.20	12208.00	S	100.0
Overflow rate (m/h)	2.00	70.75	11.60	12238.00	S	100.0
Influent flow (m ³ /h)	1319.4	71	12.10	12268.00	S	100.0
Flux ratings		71.25	12.60	12298.00	S	100.0
		71.5	13.00	12321.00	S	100.0
		71.75	81.00	11988.00	F	98.4
Flux load factor [Vo/(n.Xf)] (m/h)	6.81	72	93.80	11975.00	F	98.3
		74	153.00	11926.00	F	97.2
Simulation Data		76	210.80	11887.00	F	96.3
		78	263.40	11857.00	F	95.4
Recycle flow (m ³ /h)	397.7	100	738.20	11716.00	F	89.5
Area (m ²)	658.78					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 6 simulation on the Watts SST - No Baffles

Test 6 - Normal No Baffles

Vo (m/h) 7.62
 n (l/g) 0.3055
 Xf (g/l) 3.994

1DFT predicted limits

Maximun flux [kg/(m².h)] 10.81
 Overflow rate (m/h) 1.98
 Influent flow (m³/h) 1307.4

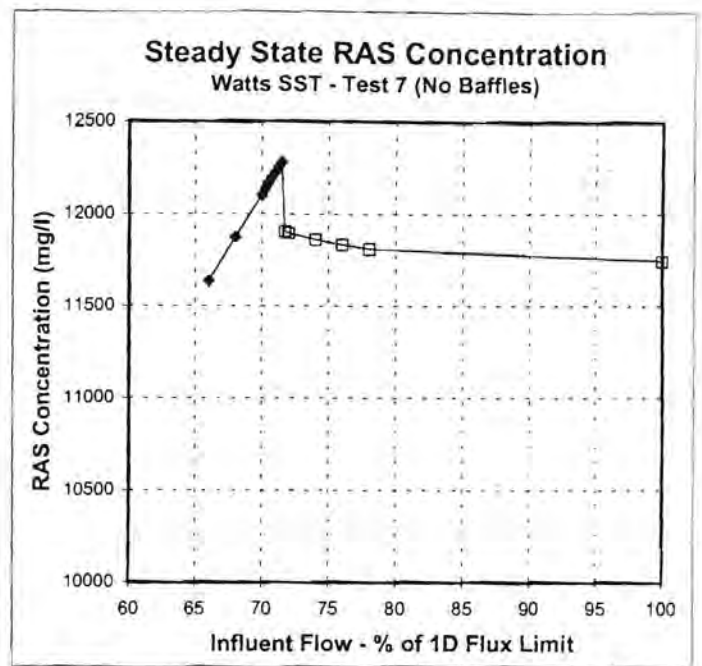
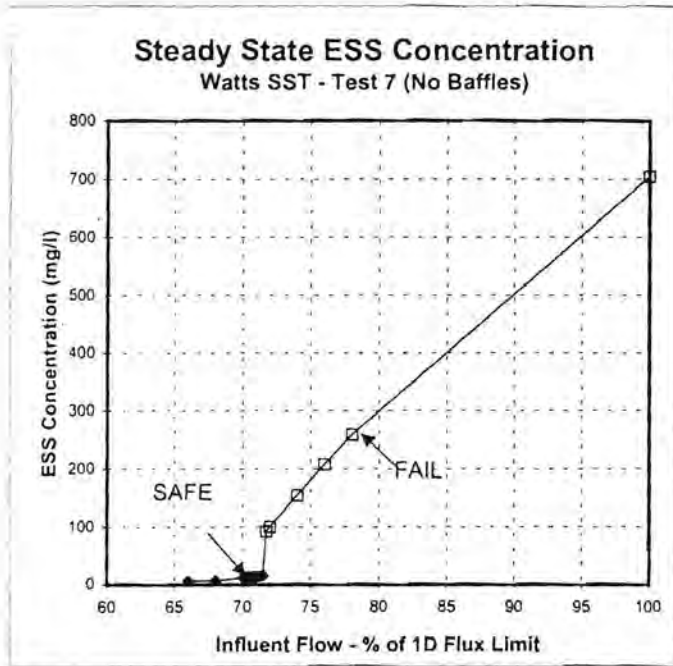
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 6.25

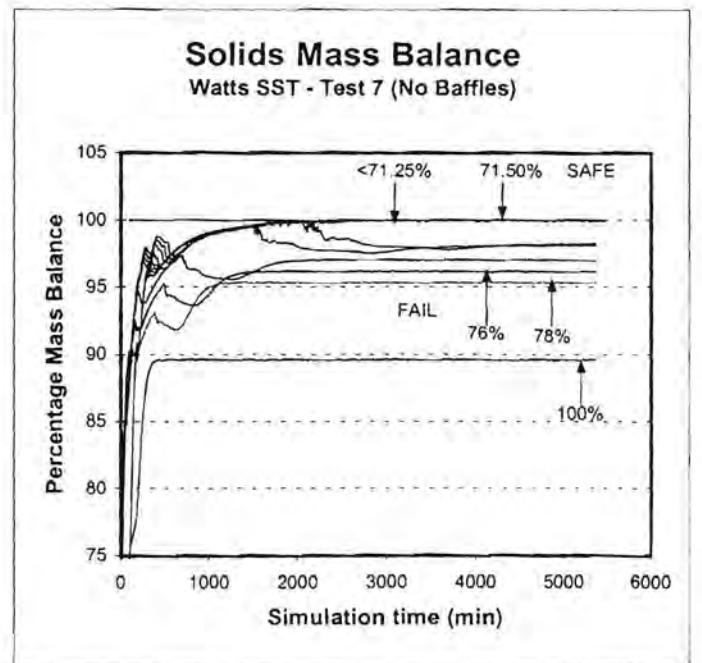
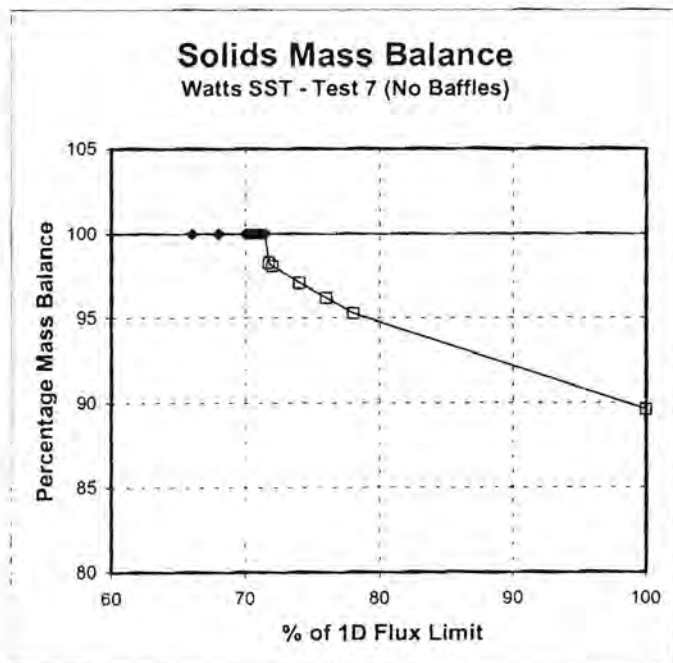
Simulation Data

Recycle flow (m³/h) 475.7
 Area (m²) 658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
66	5.90	11227.00	S	100.0
66	5.90	11227.00	S	100.0
68	6.80	11444.00	S	100.0
70	11.30	11651.00	S	100.0
70.25	11.60	11680.00	S	100.0
70.5	12.10	11706.00	S	100.0
70.75	12.60	11733.00	S	100.0
71	13.20	11759.00	S	100.0
71.25	13.90	11782.00	S	100.0
71.5	14.70	11811.00	S	100.0
71.75	97.20	11431.00	F	97.9
72	122.70	11415.00	F	98.0
74	185.30	11382.00	F	97.0
76	246.00	11358.00	F	96.2
78	299.80	11347.00	F	95.5
100	790.60	11327.00	F	90.2

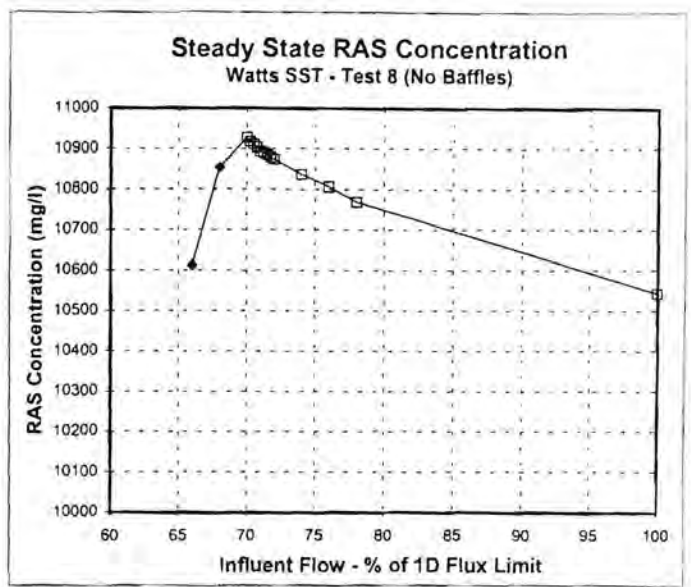
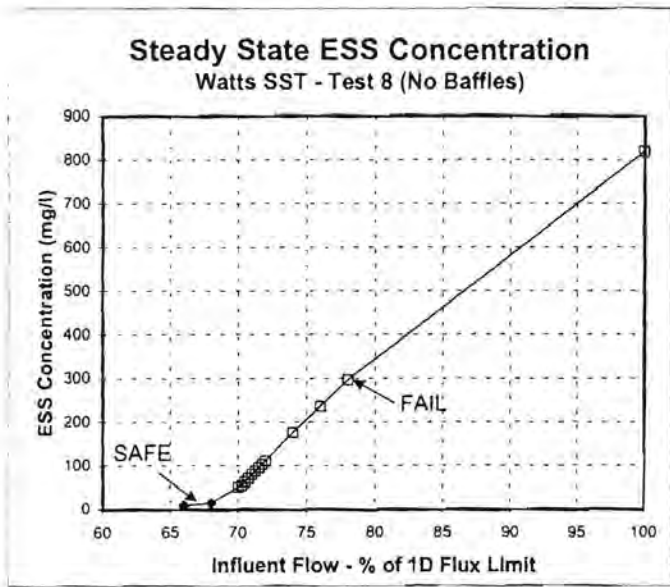


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

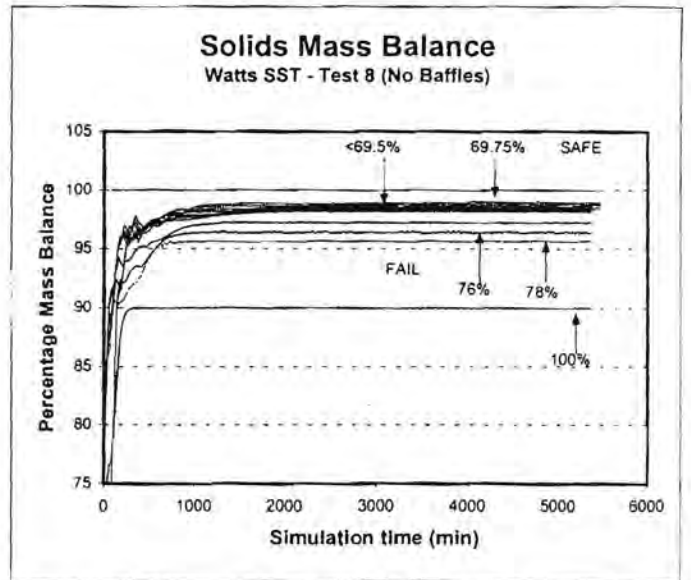
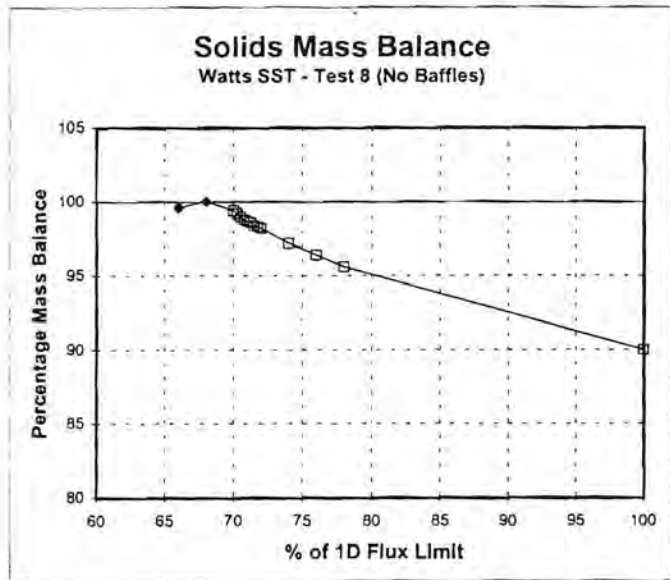


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 7 simulation on the Watts SST - No Baffles

Test 7 - Normal No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.62					
n (l/g)	0.3055	66	6.40	11636.00	S	100.0
Xf (g/l)	3.56	66	6.40	11636.00	S	100.0
		68	6.80	11875.00	S	100.0
1DFT predicted limits		70	12.10	12103.00	S	100.0
		70.25	12.50	12139.00	S	100.0
Maximum flux [kg/(m ² .h)]	9.55	70.5	12.90	12170.00	S	100.0
Overflow rate (m/h)	2.08	70.75	13.50	12199.00	S	100.0
Influent flow (m ³ /h)	1369.1	71	14.10	12227.00	S	100.0
		71.25	14.70	12255.00	S	100.0
Flux ratings		71.5	15.40	12282.00	S	100.0
		71.75	92.20	11909.00	F	98.3
Flux load factor [Vo/(n.Xf)] (m/h)	7.01	72	100.30	11899.00	F	98.1
		74	154.90	11863.00	F	97.1
Simulation Data		76	208.20	11835.00	F	96.2
		78	258.90	11811.00	F	95.3
Recycle flow (m ³ /h)	397.7	100	704.30	11748.00	F	89.6
Area (m ²)	658.78					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 8 simulation on the Watts SST - No Baffles

Test 8 - Normal No Baffles

Vo (m/h) 7.62
 n (l/g) 0.3055
 Xf (g/l) 3.787

1DFT predicted limits

Maximun flux [kg/(m².h)] 11.94
 Overflow rate (m/h) 2.31
 Influent flow (m³/h) 1523.8

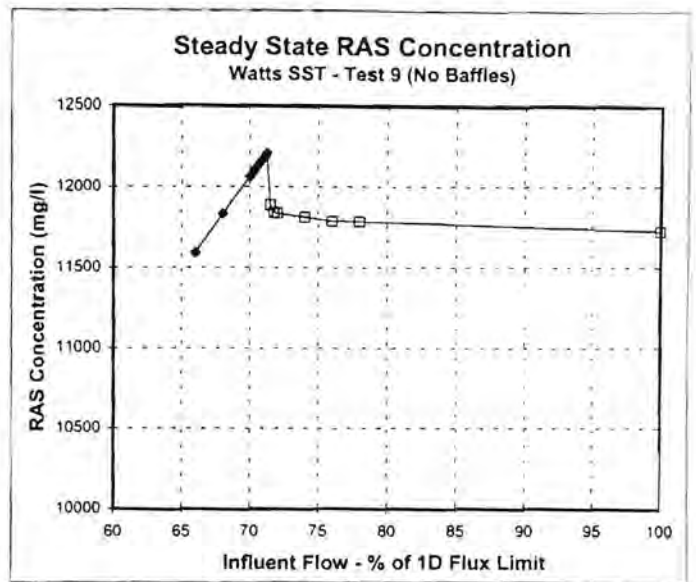
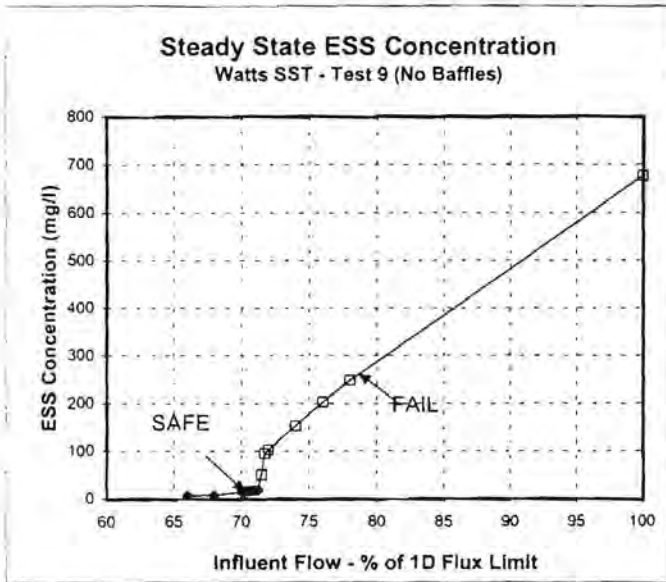
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 6.59

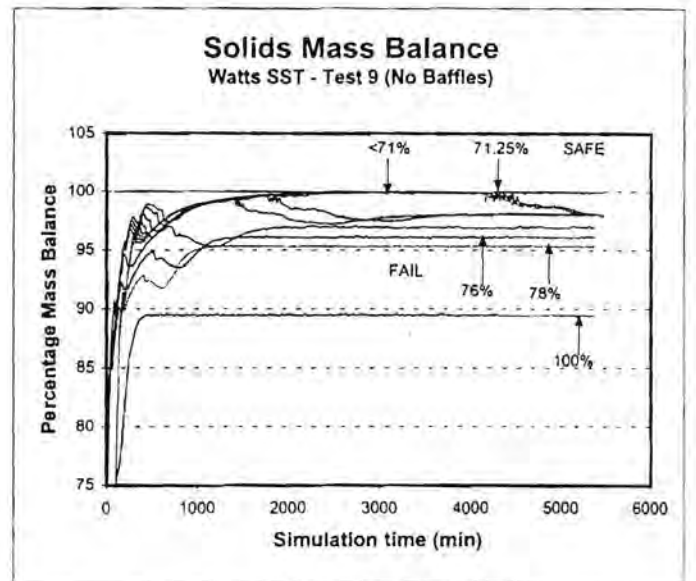
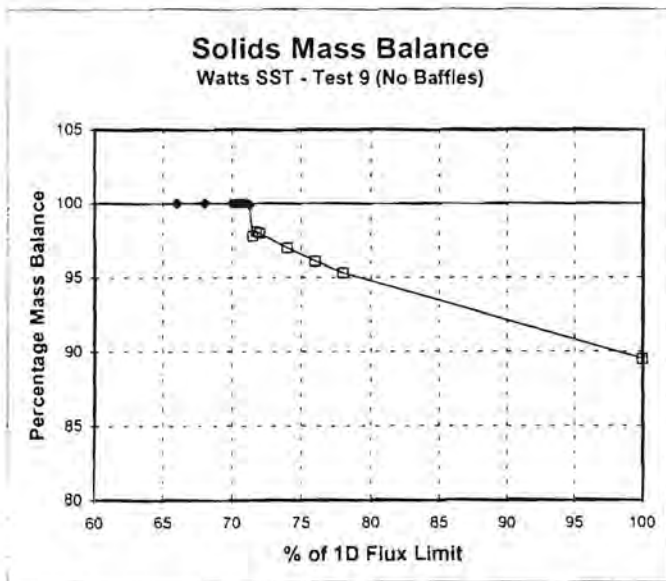
Simulation Data

Recycle flow (m³/h) 552.8
 Area (m²) 658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
66	8.90	10612.00	S	99.6
66	8.90	10612.00	S	99.6
68	14.00	10854.00	S	100.0
70	50.60	10927.00	F	99.4
70.25	55.60	10918.00	F	99.2
70.5	62.50	10911.00	F	99.0
70.75	71.20	10904.00	F	98.8
71	80.30	10893.00	F	98.7
71.25	87.90	10890.00	F	98.6
71.5	95.80	10885.00	F	98.4
71.75	103.50	10880.00	F	98.3
72	111.50	10874.00	F	98.2
74	174.70	10836.00	F	97.2
76	234.70	10806.00	F	96.4
78	296.10	10769.00	F	95.6
100	818.60	10543.00	F	90.0



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 9 simulation on the Watts SST - No Baffles

Test 9 - Normal No Baffles

Vo (m/h) 7.62
 n (l/g) 0.3055
 Xf (g/l) 3.444

1DFT predicted limits

Maximun flux [kg/(m².h)] 9.55
 Overflow rate (m/h) 2.17
 Influent flow (m³/h) 1428.6

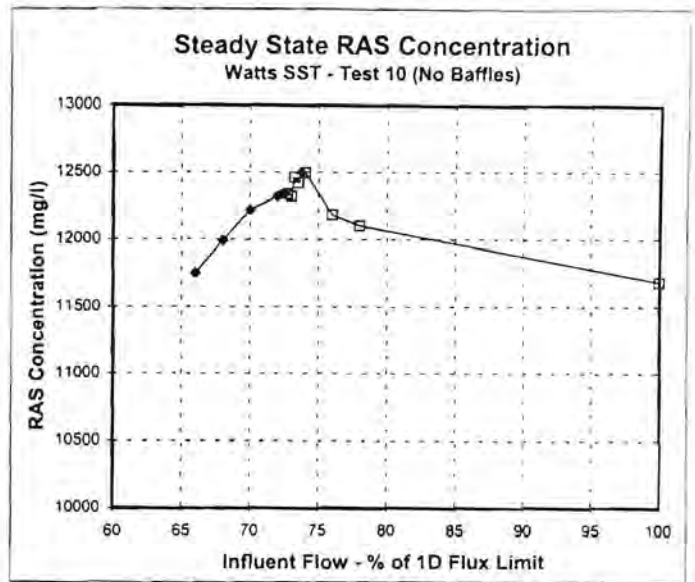
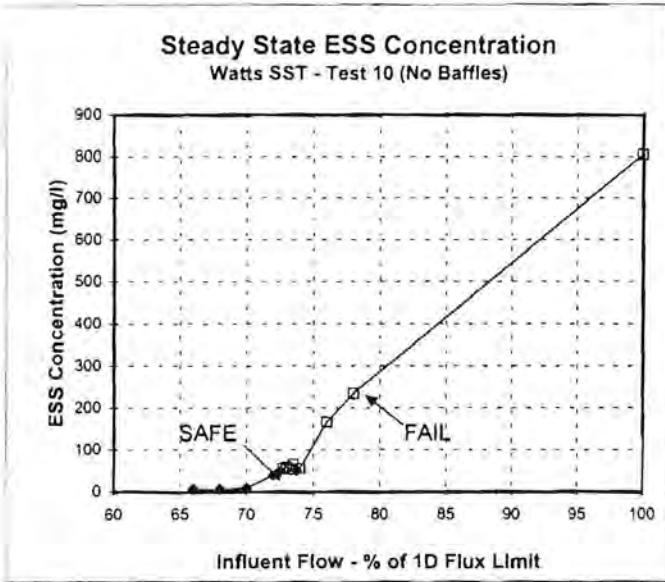
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 7.24

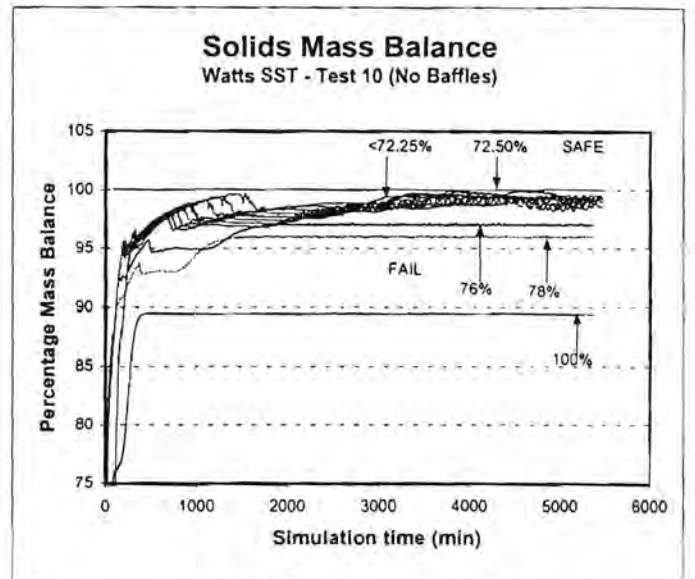
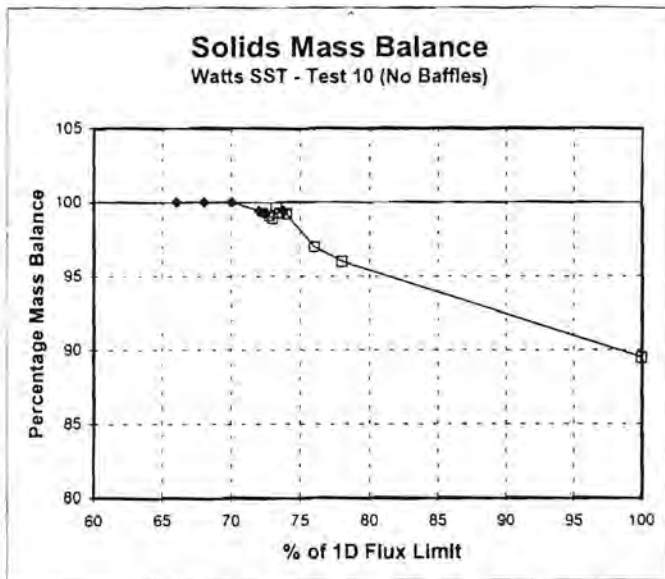
Simulation Data

Recycle flow (m³/h) 397.7
 Area (m²) 658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
66	6.90	11592.00	S	100.0
66	6.90	11592.00	S	100.0
68	7.40	11833.00	S	100.0
70	14.30	12062.00	S	100.0
70.25	14.80	12093.00	S	100.0
70.5	15.40	12121.00	S	100.0
70.75	16.10	12151.00	S	100.0
71	17.10	12178.00	S	100.0
71.25	17.90	12204.00	S	99.9
71.5	50.20	11889.00	F	97.8
71.75	94.90	11844.00	F	98.1
72	102.80	11838.00	F	98.0
74	152.60	11813.00	F	97.0
76	203.00	11790.00	F	96.1
78	248.40	11787.00	F	95.3
100	676.60	11725.00	F	89.5



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 10 simulation on the Watts SST - No Baffles

Test 10 - Normal No Baffles

Vo (m/h) 7.62
 n (l/g) 0.3055
 Xf (g/l) 3.885

1DFT predicted limits

Maximum flux [kg/(m².h)] 9.55
 Overflow rate (m/h) 1.85
 Influent flow (m³/h) 1221.7

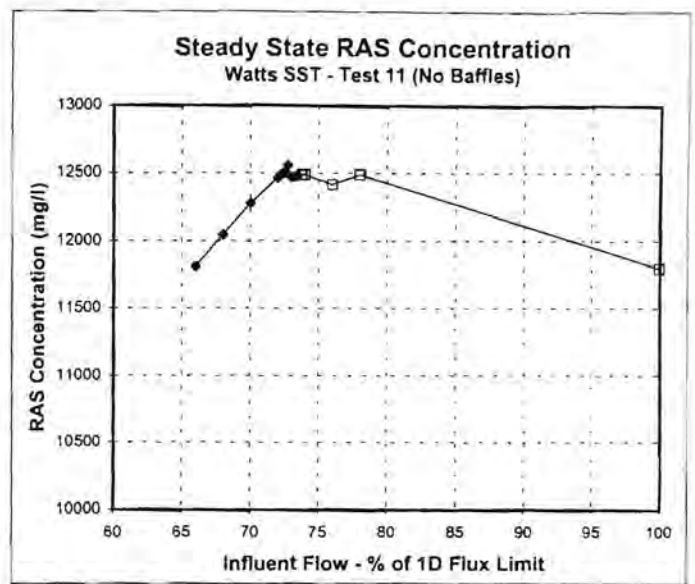
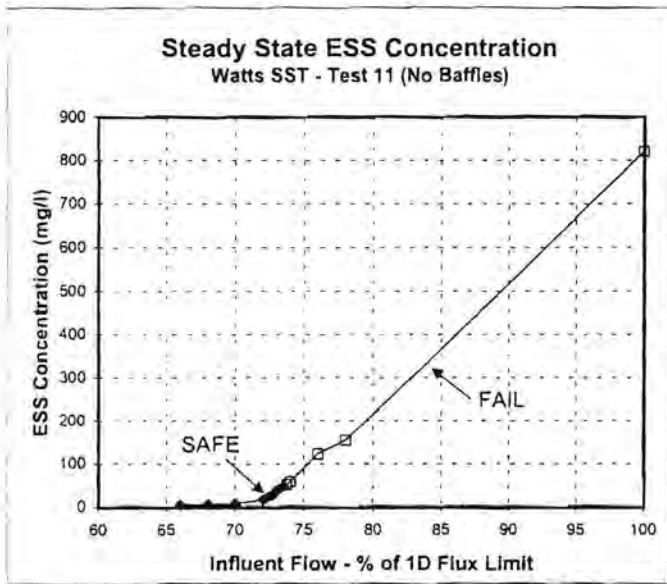
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 6.42

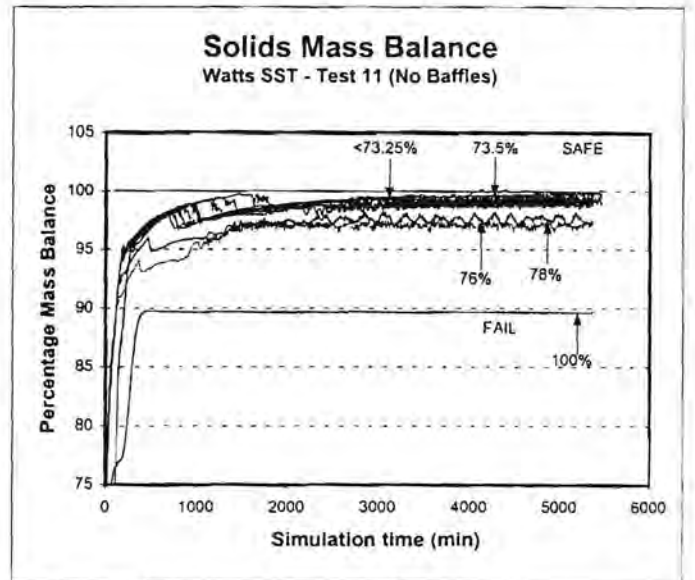
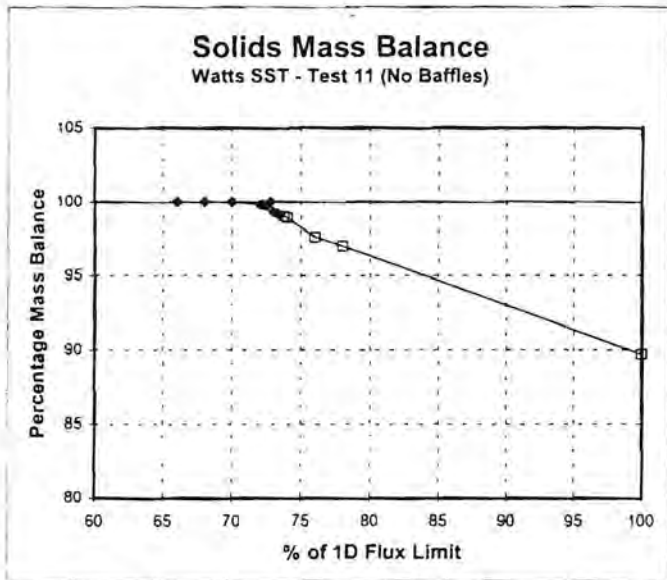
Simulation Data

Recycle flow (m³/h) 397.7
 Area (m²) 658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
66	5.40	11747.00	S	100.0
66	5.40	11747.00	S	100.0
68	5.60	11990.00	S	100.0
70	8.00	12218.00	S	100.0
72	37.90	12320.00	S	99.4
72.25	41.30	12332.00	S	99.3
72.5	47.30	12339.00	S	99.3
72.75	54.50	12337.00	F	99.1
73	59.10	12319.00	F	98.9
73.25	53.30	12460.00	F	99.6
73.5	65.50	12419.00	F	99.3
73.75	49.90	12495.00	S	99.4
74	54.30	12496.00	F	99.2
76	165.50	12185.00	F	97.0
78	234.30	12102.00	F	96.0
100	804.40	11681.00	F	89.5

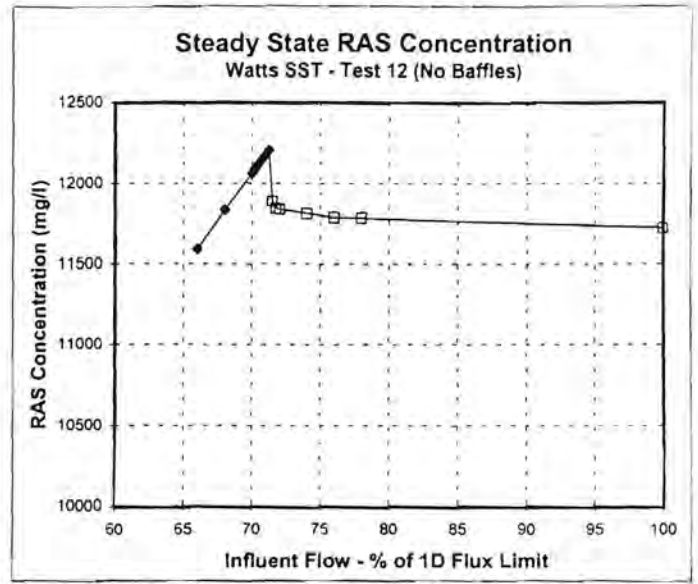
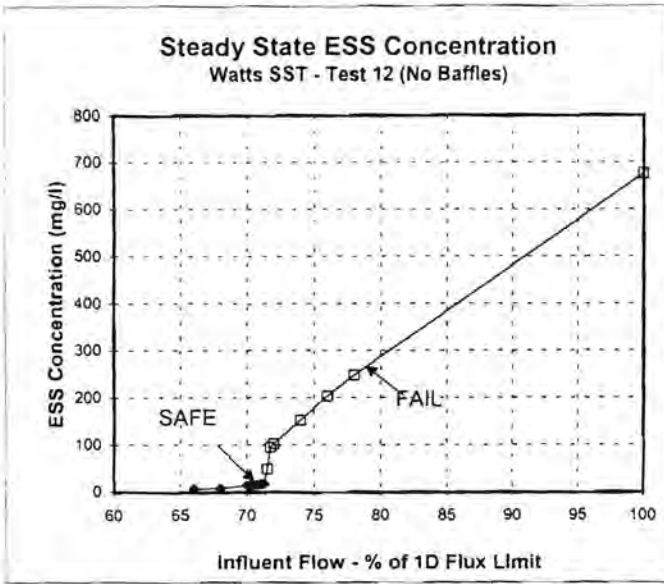


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

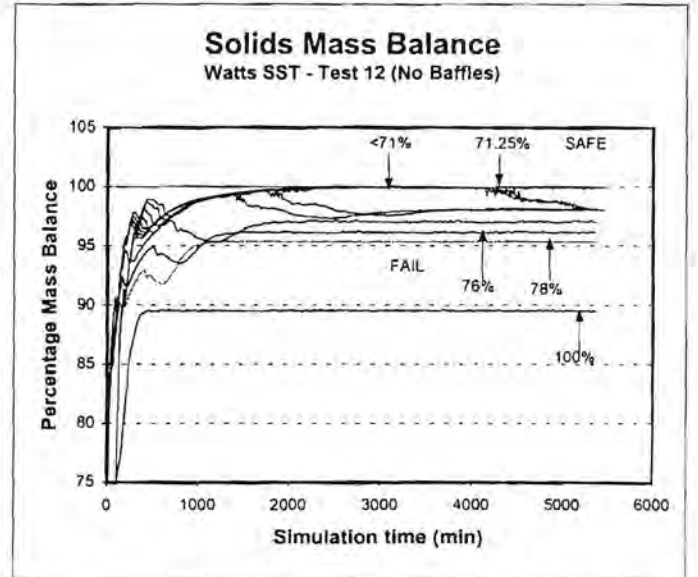
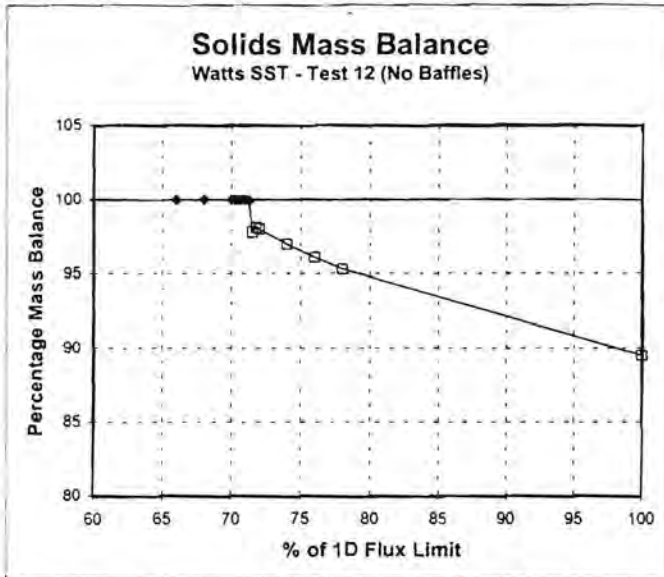


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 11 simulation on the Watts SST - No Baffles

Test 11 - Normal No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.62					
n (l/g)	0.3055	66	5.10	11810.00	S	100.0
Xf (g/l)	4.044	66	5.10	11810.00	S	100.0
1DFT predicted limits		68	5.40	12045.00	S	100.0
		70	6.60	12276.00	S	100.0
		72	16.00	12464.00	S	99.8
Maximun flux [kg/(m ² .h)]	9.54	72.25	19.70	12488.00	S	99.8
Overflow rate (m/h)	1.76	72.5	24.70	12500.00	S	99.7
Influent flow (m ³ /h)	1156.9	72.75	26.30	12554.00	S	100.0
		73	38.80	12469.00	S	99.3
Flux ratings		73.25	41.90	12475.00	S	99.2
		73.5	47.20	12480.00	S	99.1
Flux load factor [Vo/(n.Xf)] (m/h)	6.17	73.75	52.20	12489.00	F	99.0
		74	58.80	12487.00	F	98.9
Simulation Data		76	122.50	12415.00	F	97.6
		78	154.40	12488.00	F	97.0
Recycle flow (m ³ /h)	397.2	100	820.00	11797.00	F	89.7
Area (m ²)	658.78					

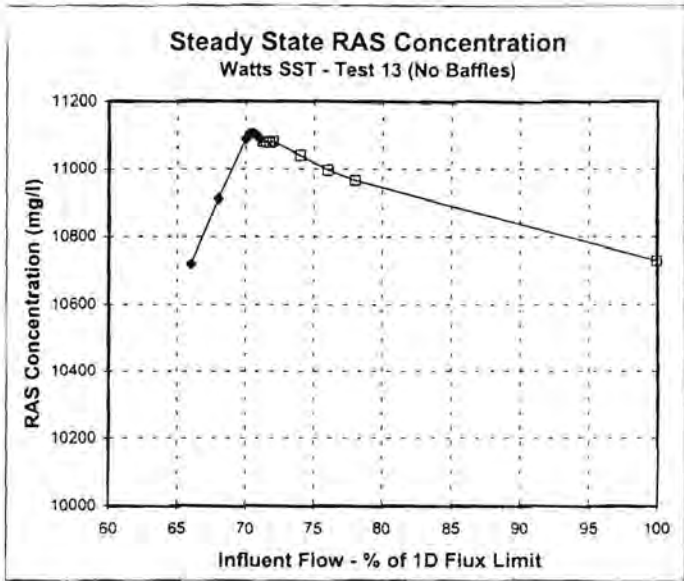
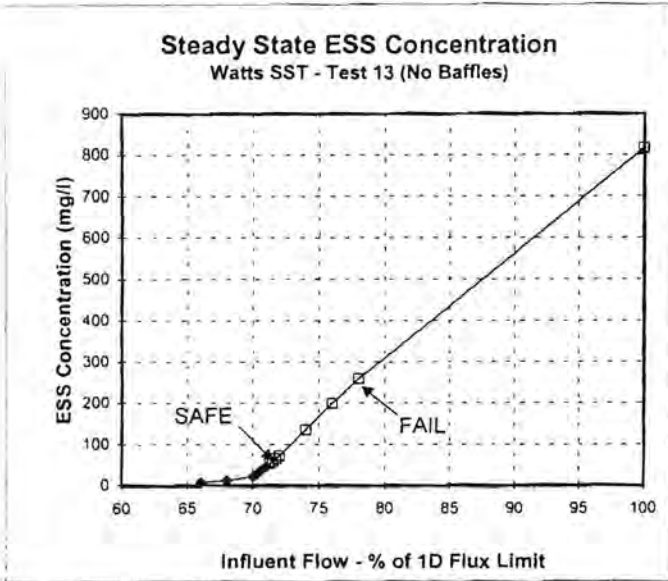


Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

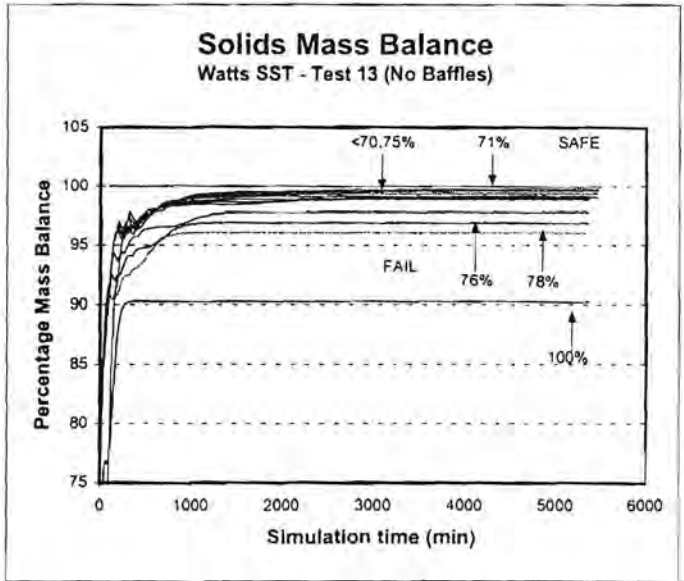
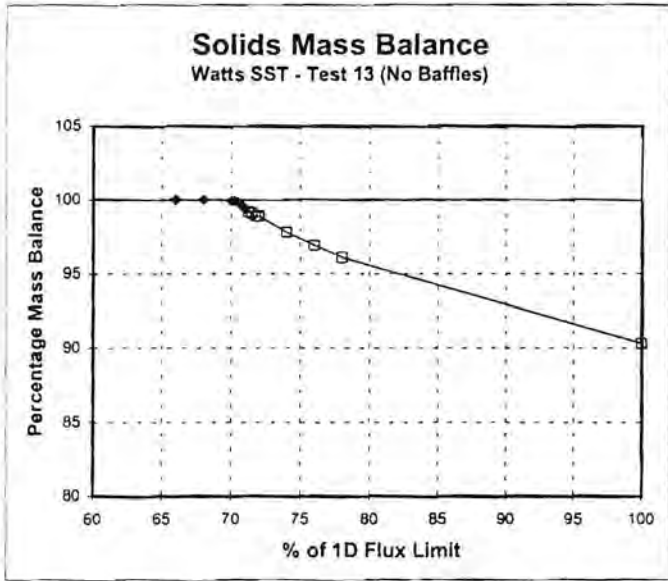


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 12 simulation on the Watts SST - No Baffles

Test 12 - Normal No Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.62	66	6.90	11592.00	S	100.0
n (l/g)	0.3055	66	6.90	11592.00	S	100.0
Xf (g/l)	3.444	68	7.40	11833.00	S	100.0
1DFT predicted limits		70	14.30	12062.00	S	100.0
		70.25	14.80	12093.00	S	100.0
Maximun flux [kg/(m ² .h)]	9.55	70.5	15.40	12121.00	S	100.0
Overflow rate (m/h)	2.17	70.75	16.10	12151.00	S	100.0
Influent flow (m ³ /h)	1428.6	71	17.10	12178.00	S	100.0
Flux ratings		71.25	17.90	12204.00	S	99.9
		71.5	50.20	11889.00	F	97.8
		71.75	94.90	11844.00	F	98.1
Flux load factor [Vo/(n.Xf)] (m/h)	7.24	72	102.80	11838.00	F	98.0
		74	152.60	11813.00	F	97.0
Simulation Data		76	203.00	11790.00	F	96.1
		78	248.40	11787.00	F	95.3
Recycle flow (m ³ /h)	397.7	100	676.60	11725.00	F	89.5
Area (m ²)	658.78					



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 13 simulation on the Watts SST - No Baffles

Test 13 - Normal No Baffles

Vo (m/h) 7.62
 n (l/g) 0.3055
 Xf (g/l) 3.987

1DFT predicted limits

Maximum flux [kg/(m².h)] 11.98
 Overflow rate (m/h) 2.16
 Influent flow (m³/h) 1423.6

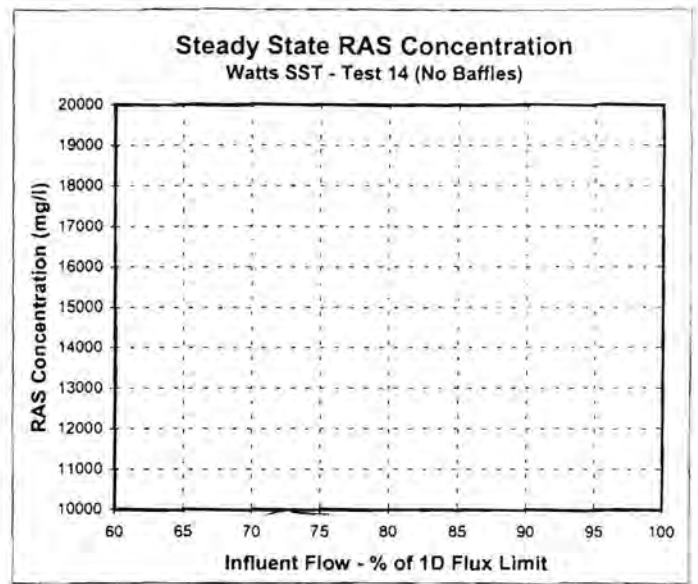
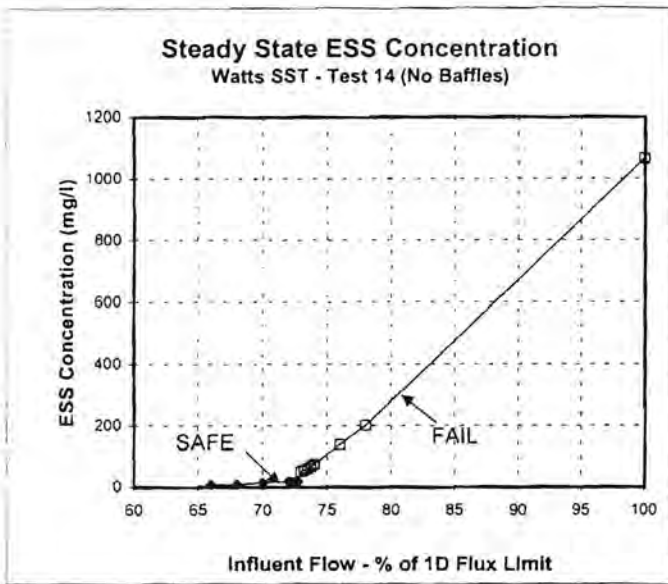
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 6.26

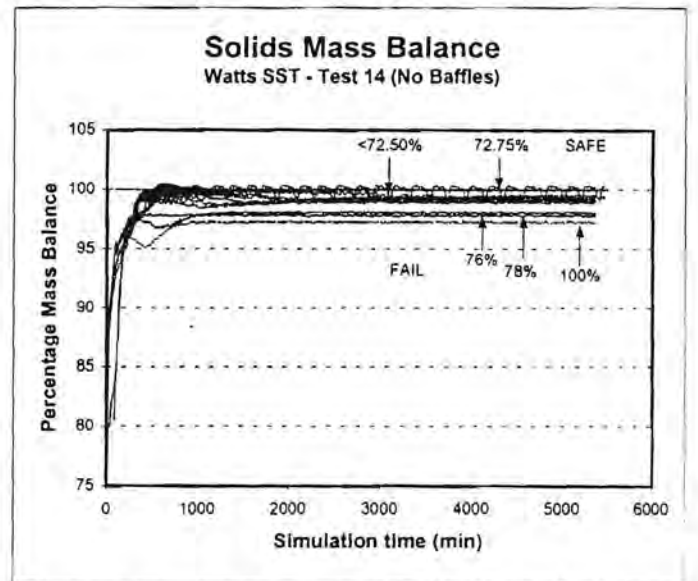
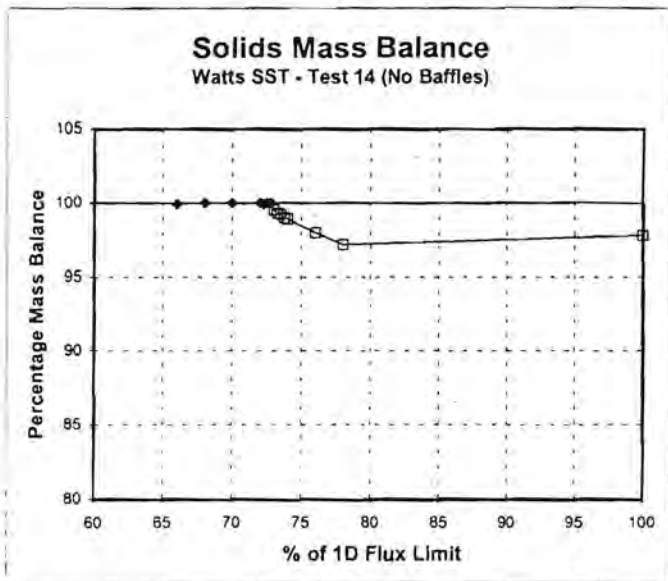
Simulation Data

Recycle flow (m³/h) 555.6
 Area (m²) 658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
66	6.90	10719.00	S	100.0
66	6.90	10719.00	S	100.0
68	11.00	10911.00	S	100.0
70	21.70	11088.00	S	99.9
70.25	26.40	11104.00	S	99.9
70.5	33.00	11106.00	S	99.8
70.75	39.50	11100.00	S	99.6
71	45.20	11088.00	S	99.4
71.25	52.00	11080.00	F	99.2
71.5	57.40	11080.00	F	99.1
71.75	64.80	11077.00	F	98.9
72	72.30	11081.00	F	98.9
74	134.70	11040.00	F	97.8
76	199.77	10997.00	F	96.9
78	259.00	10967.00	F	96.1
100	815.70	10729.00	F	90.3



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 14 simulation on the Watts SST - No Baffles

Test 14 - Normal No Baffles

Vo (m/h) 7.62
 n (l/g) 0.3055
 Xf (g/l) 3.983

1DFT predicted limits

Maximun flux [kg/(m².h)] 13.31
 Overflow rate (m/h) 2.26
 Influent flow (m³/h) 1486.9

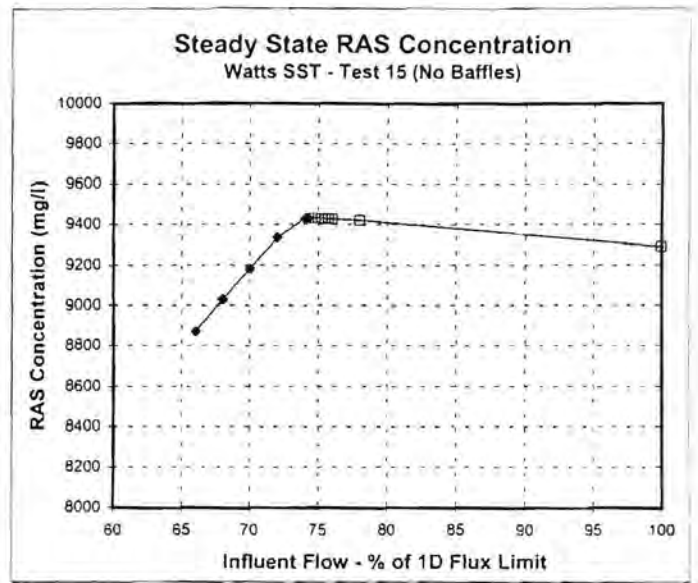
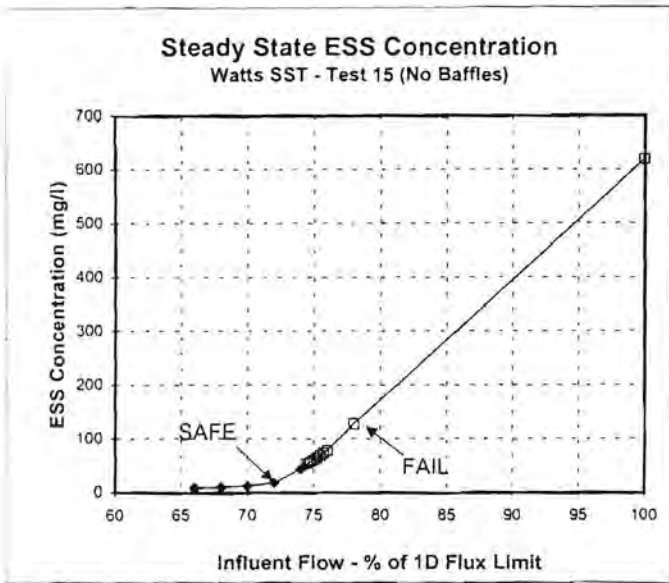
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 6.26

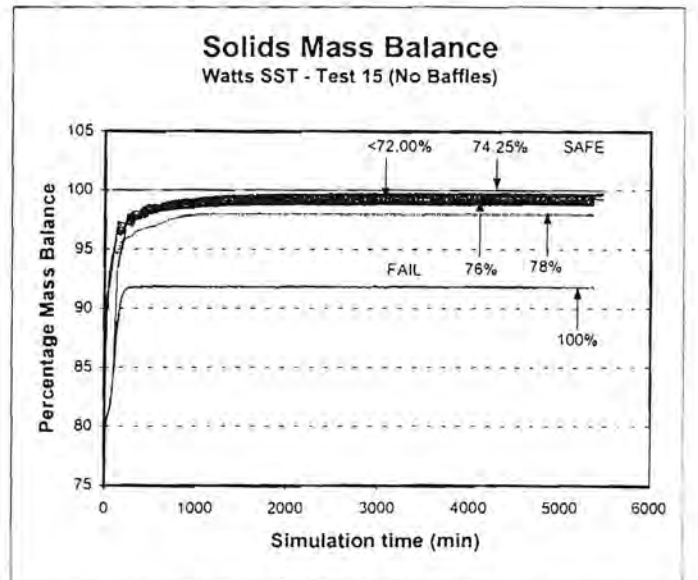
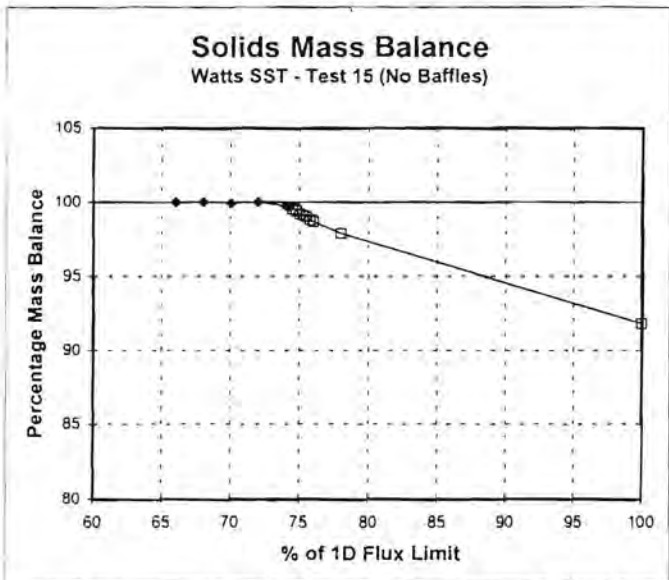
Simulation Data

Recycle flow (m³/h) 714
 Area (m²) 658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
66	6.90	9443.00	S	99.9
66	6.90	9443.00	S	99.9
68	8.50	9609.00	S	100.0
70	13.40	9767.00	S	100.0
72	17.20	9935.00	S	100.0
72.25	16.70	9941.00	S	99.9
72.5	16.60	9969.00	S	100.0
72.75	17.50	9987.00	S	100.0
73	50.50	9911.00	F	99.5
73.25	55.10	9907.00	F	99.3
73.5	60.80	9904.00	F	99.2
73.75	67.80	9898.00	F	99.0
74	75.30	9894.00	F	98.9
76	139.30	9865.00	F	98.0
78	201.10	9838.00	F	97.2
100	1064.70	9786.00	F	97.8



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 15 simulation on the Watts SST - No Baffles

Test 15 - Normal No Baffles

Vo (m/h) 7.62
 n (l/g) 0.3055
 Xf (g/l) 3.618

1DFT predicted limits

Maximum flux [kg/(m².h)] 13.27
 Overflow rate (m/h) 2.52
 Influent flow (m³/h) 1662.3

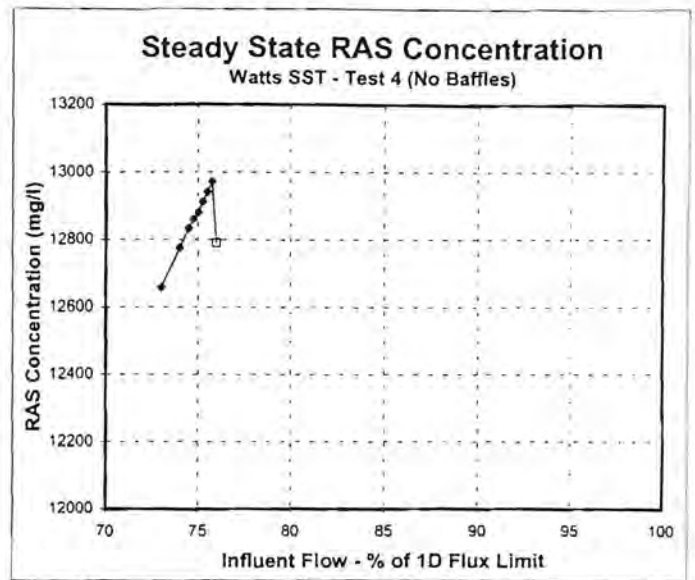
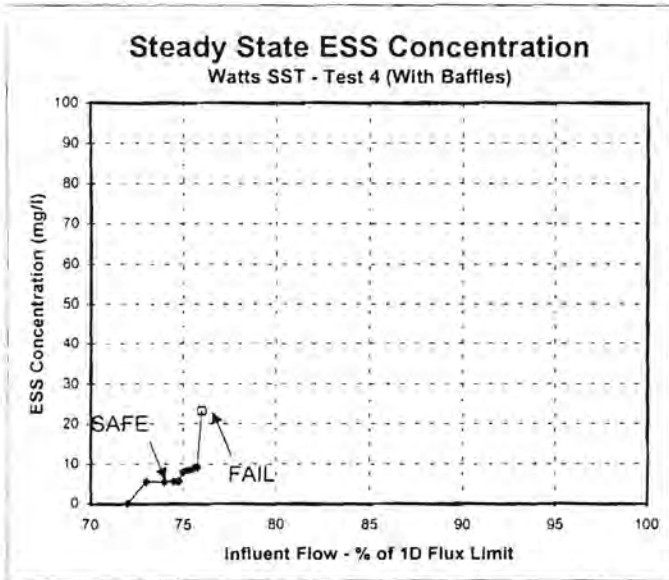
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 6.89

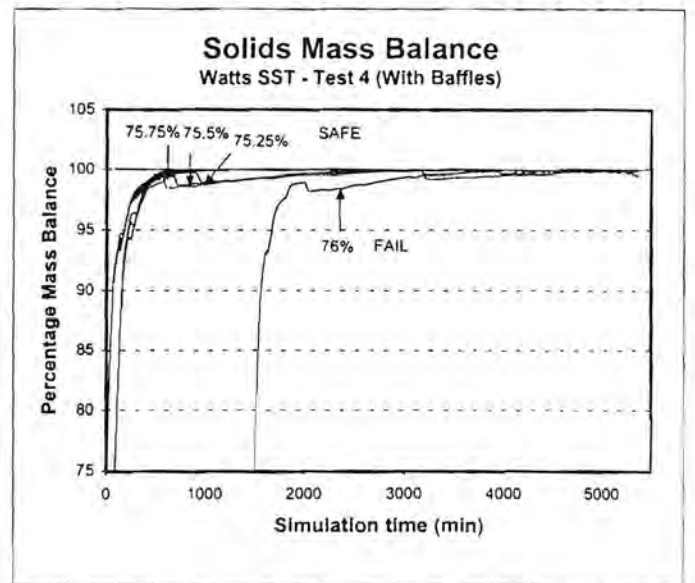
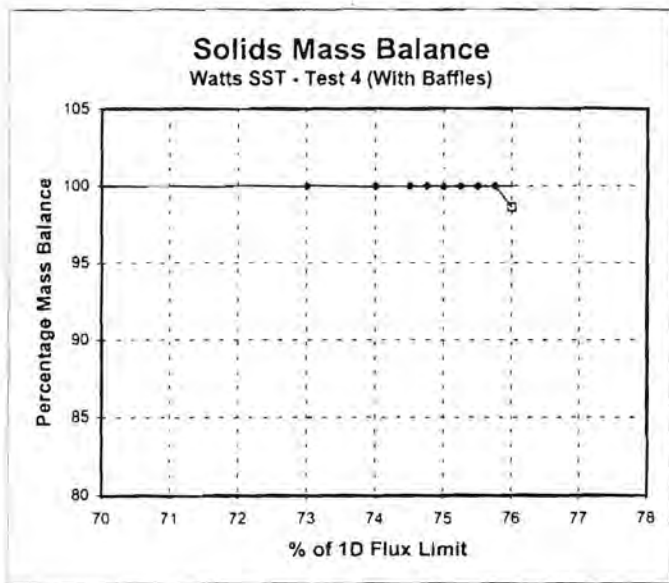
Simulation Data

Recycle flow (m³/h) 753.5
 Area (m²) 658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
66	8.11	8872.00	S	100.0
66	8.11	8872.00	S	100.0
68	9.10	9029.00	S	100.0
70	11.50	9182.00	S	99.9
72	16.80	9335.00	S	100.0
74	43.20	9430.00	S	99.7
74.25	48.10	9433.00	S	99.7
74.5	52.60	9432.00	F	99.5
74.75	56.60	9432.00	F	99.4
75	60.30	9432.00	F	99.2
75.25	64.20	9431.00	F	99.1
75.5	69.10	9430.00	F	99.0
75.75	73.80	9430.00	F	98.8
76	78.50	9429.00	F	98.7
78	127.40	9422.00	F	97.9
100	618.30	9290.00	F	91.8



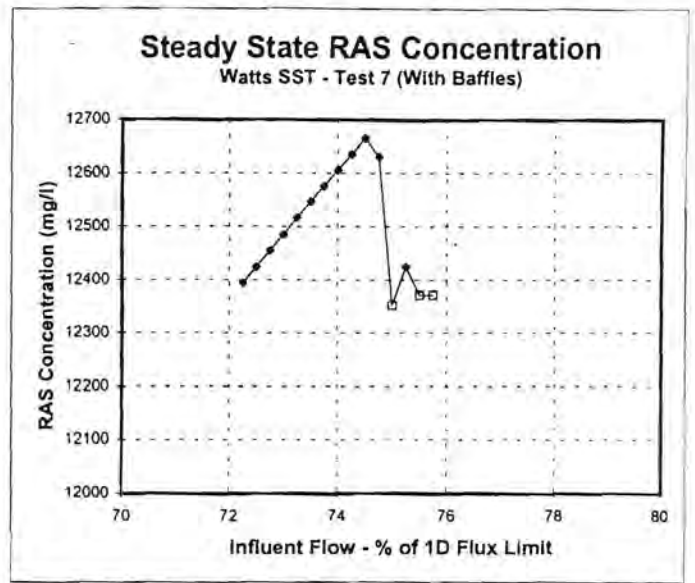
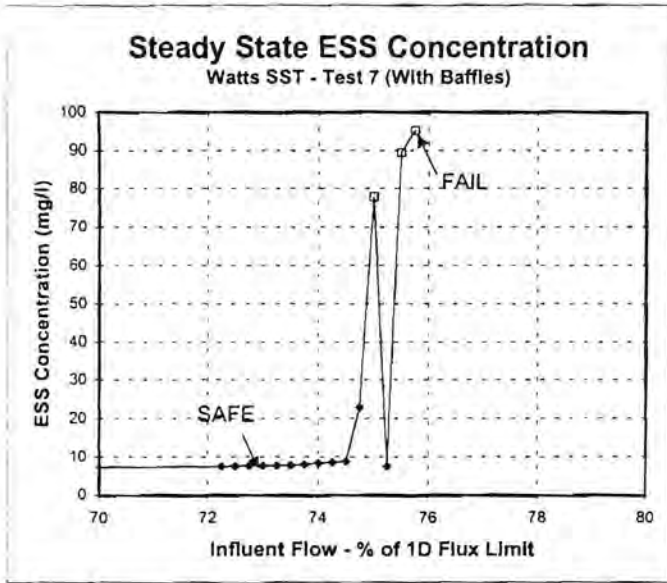
Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



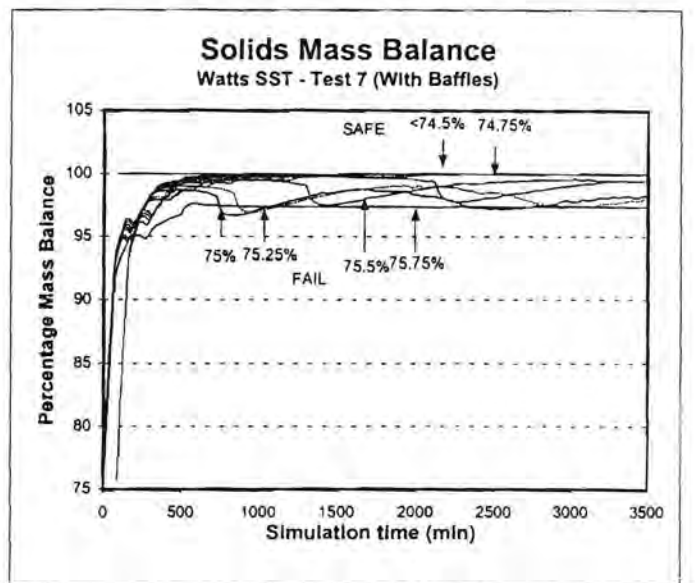
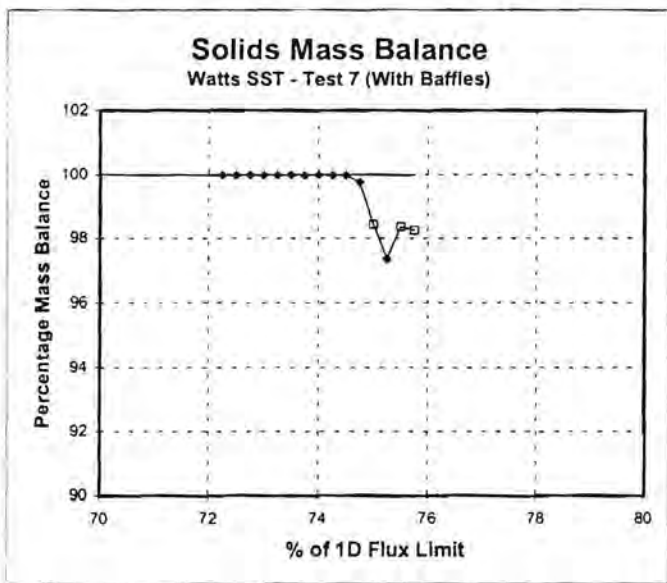
Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the Watts SST - With Baffles

Test 4 - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.62	0	0.00	0.00	S	0.0
n (l/g)	0.3055	0	0.00	0.00	S	0.0
Xf (g/l)	4.13	0	0.00	0.00	S	0.0
1DFT predicted limits		0	0.00	0.00	S	0.0
		0	0.00	0.00	S	0.0
Maximun flux [kg/(m ² .h)]	9.54	0	0.00	0.00	S	0.0
Overflow rate (m/h)	1.71	72	0.00	0.00	S	0.0
Influent flow (m ³ /h)	1124.2	73	5.40	12657.28	S	100.0
		74	5.38	12774.64	S	100.0
		74.5	5.46	12832.85	S	100.0
		74.75	5.52	12861.02	S	100.0
Flux ratings		75	7.92	12881.06	S	100.0
		75.25	8.31	12910.93	S	100.0
Flux load factor [Vo/(n.Xf)] (m/h)	6.04	75.5	8.66	12940.13	S	100.0
		75.75	9.12	12971.48	S	100.0
Simulation Data		76	23.40	12789.52	F	98.6
Recycle flow (m ³ /h)	396.9					
Area (m ²)	658.78					

Note: Failure is indicated at a ESS concentration of 23.40 mg/l. This is because the SettlerCAD model could not simulate the run any longer then 7500 min. An evaluation of the ESS vs time showed that the ESS concentration was increasing and that failure would have occurred if the SettlerCAD model could simulate the run longer



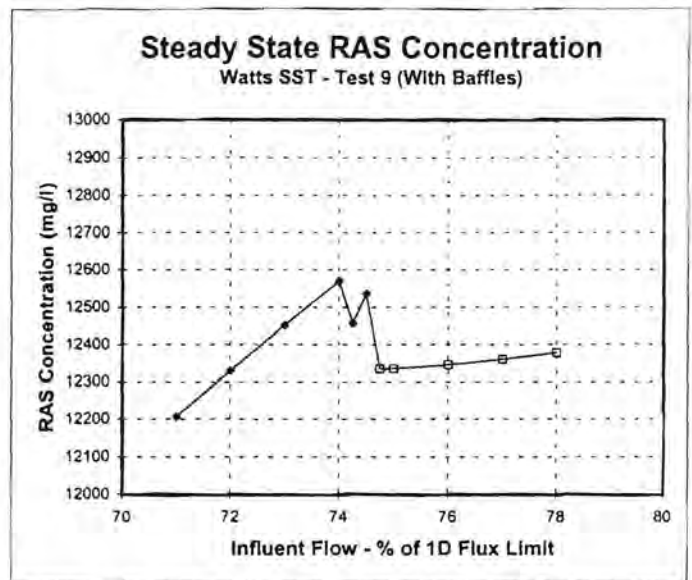
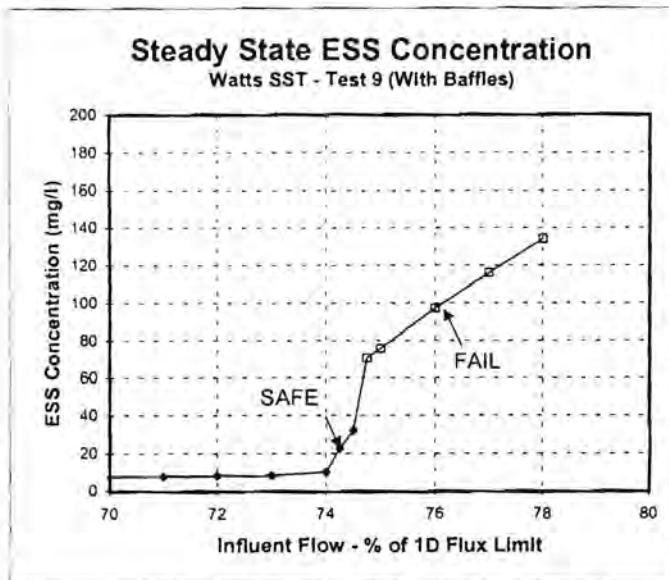
Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



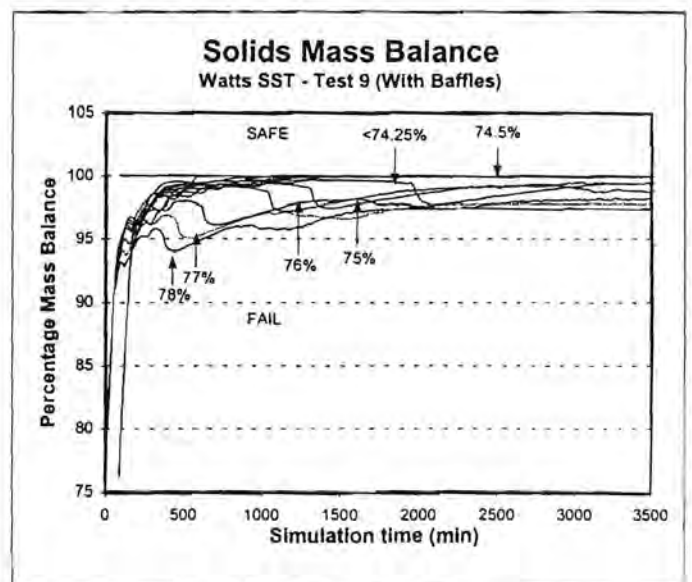
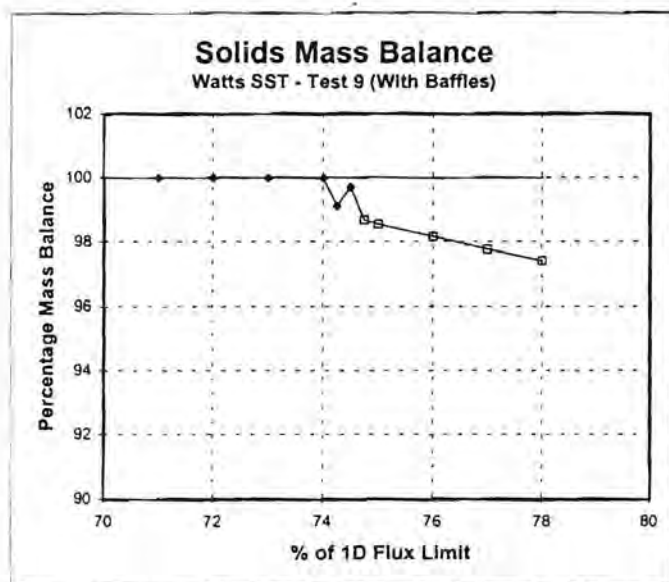
Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 7 simulation on the new SST - With Baffles

Test 7 - With Baffles		Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
Vo (m/h)	7.62					
n (l/g)	0.3055	0	0.00	0.00	S	0.0
Xf (g/l)	3.56	72.25	7.44	12393.82	S	100.0
		72.5	7.48	12424.65	S	100.0
1DFT predicted limits		72.75	7.56	12455.32	S	100.0
		73	7.62	12485.04	S	100.0
Maximun flux [kg/(m ² .h)]	9.55	73.25	7.67	12516.67	S	100.0
Overflow rate (m/h)	2.08	73.5	7.77	12547.28	S	100.0
Influent flow (m ³ /h)	1369.1	73.75	7.90	12575.00	S	100.0
		74	8.36	12606.06	S	100.0
Flux ratings		74.25	8.51	12635.66	S	100.0
		74.5	8.79	12665.20	S	100.0
Flux load factor [Vo/(n.Xf)] (m/h)	7.01	74.75	22.85	12631.67	S	99.8
		75	77.86	12352.62	F	98.4
Simulation Data		75.25	7.47	12425.08	S	97.4
		75.5	89.54	12371.99	F	98.4
Recycle flow (m ³ /h)	397.7	75.75	95.11	12371.95	F	98.3
Area (m ²)	658.78					

Note: The SettlerCAD simulation crashed for the simulation that is 75.25 % of the 1DFT limit



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 9 simulation on the new SST - With Baffles

Test 9 - With Baffles

Vo (m/h)	7.62
n (l/g)	0.3055
Xf (g/l)	3.444

1DFT predicted limits

Maximum flux [kg/(m ² .h)]	9.55
Overflow rate (m/h)	2.17
Influent flow (m ³ /h)	1428.6

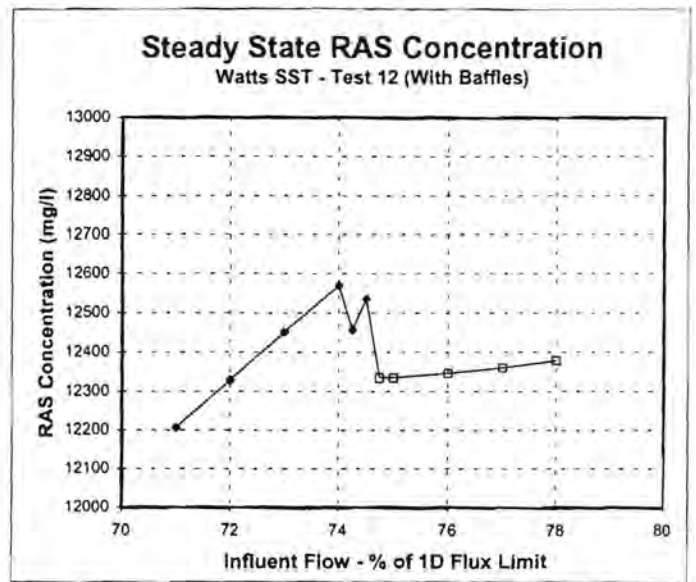
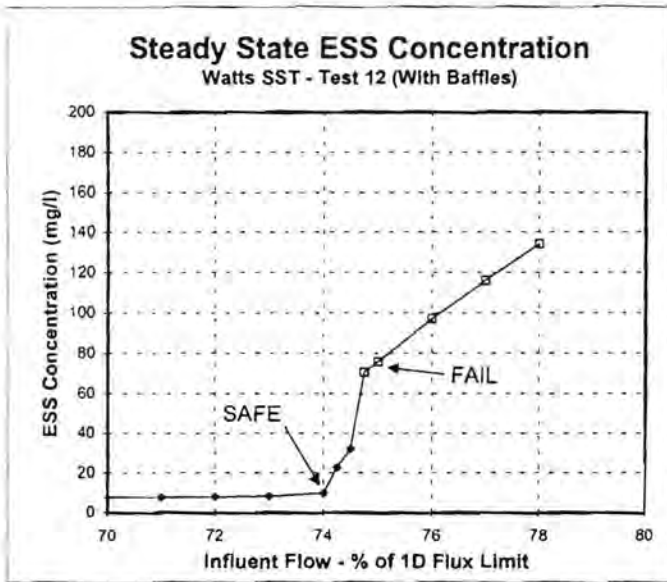
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	7.24
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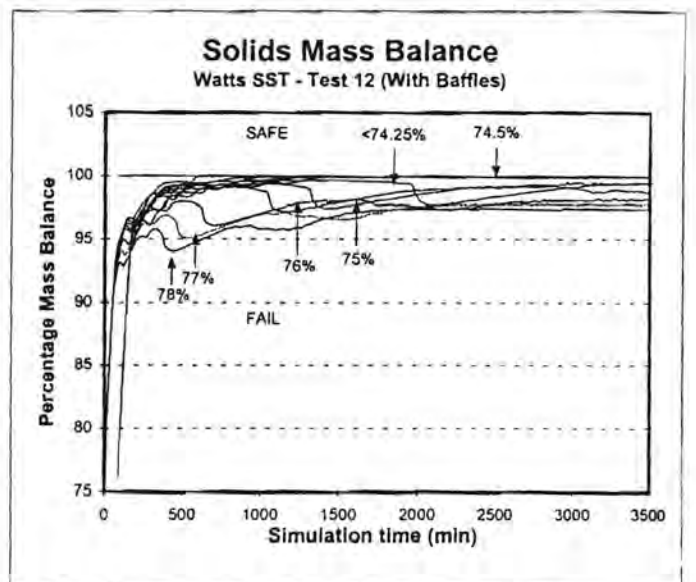
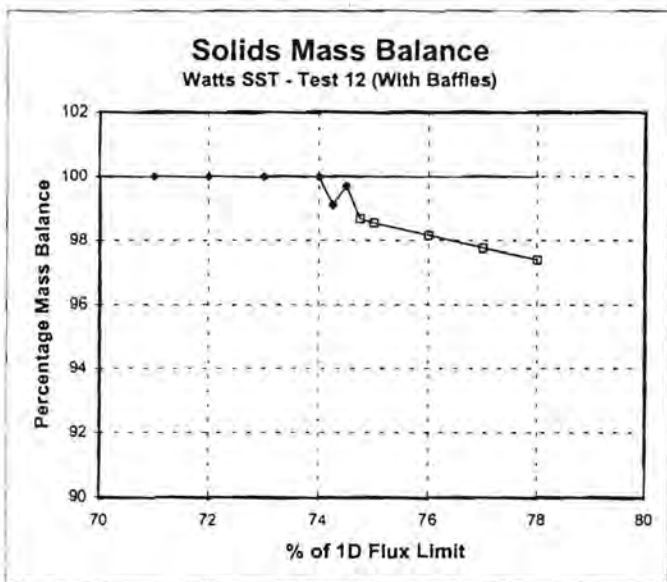
Simulation Data

Recycle flow (m ³ /h)	397.7
Area (m ²)	658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
0	0.00	0.00	S	0.0
71	7.79	12206.25	S	100.0
71	7.79	12206.25	S	100.0
71	7.79	12206.25	S	100.0
71	7.79	12206.25	S	100.0
71	7.79	12206.25	S	100.0
72	8.03	12329.05	S	100.0
73	8.33	12451.15	S	100.0
74	9.87	12570.05	S	100.0
74.25	22.66	12457.00	S	99.1
74.5	32.21	12536.53	S	99.7
74.75	70.60	12334.19	F	98.7
75	75.72	12334.37	F	98.6
76	97.10	12345.34	F	98.2
77	116.09	12359.58	F	97.8
78	134.33	12377.63	F	97.4



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 12 simulation on the new SST - With Baffles

Test 12 - With Baffles

Vo (m/h)	7.62
n (l/g)	0.3055
Xf (g/l)	3.444

1DFT predicted limits

Maximum flux [kg/(m ² .h)]	9.55
Overflow rate (m/h)	2.17
Influent flow (m ³ /h)	1428.6

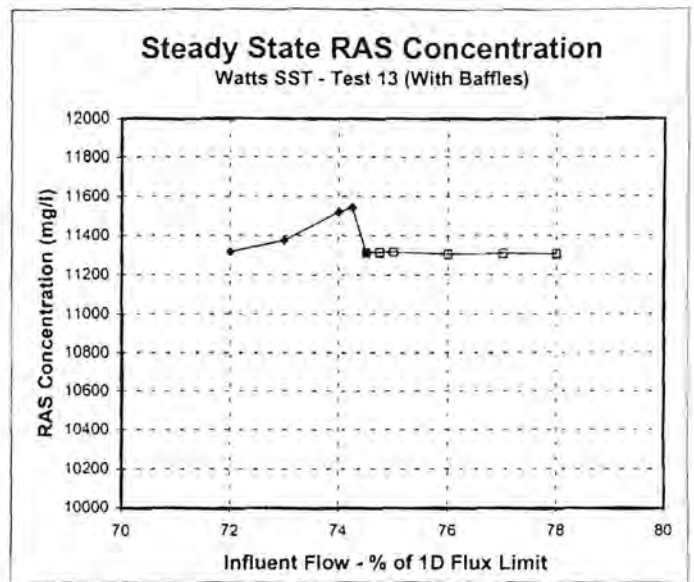
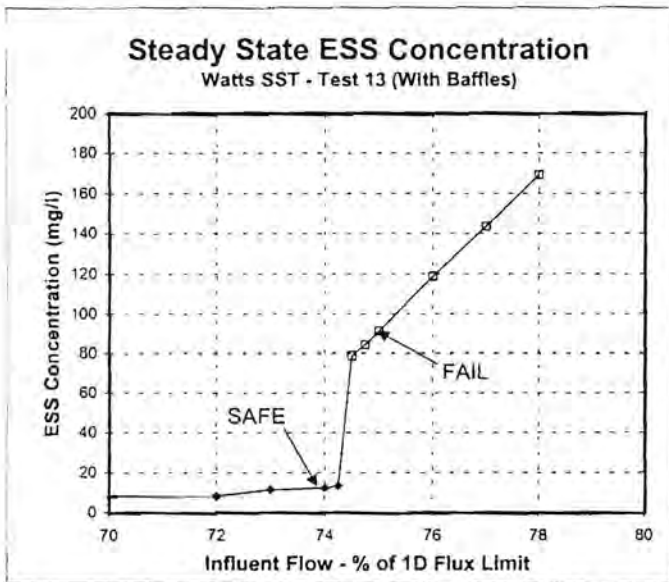
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	7.24
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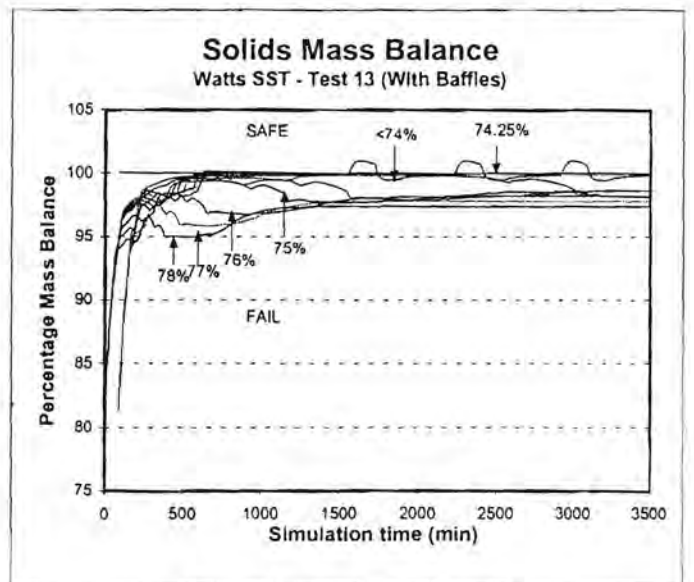
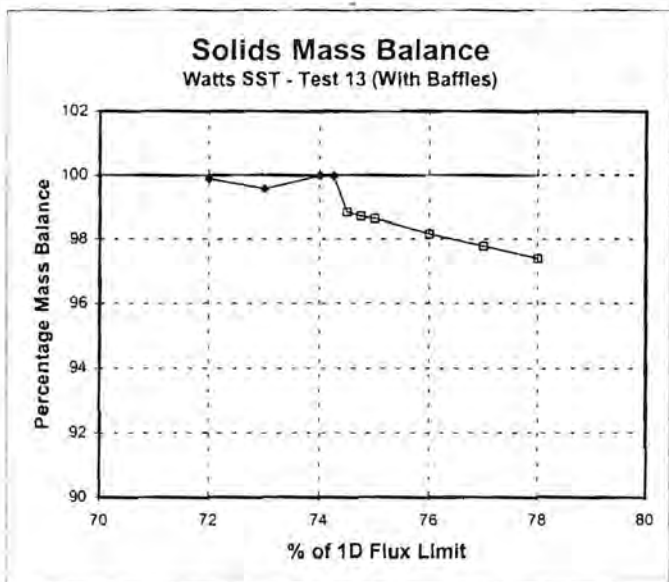
Simulation Data

Recycle flow (m ³ /h)	397.7
Area (m ²)	658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
0	0.00	0.00	S	0.0
71	7.79	12206.25	S	100.0
71	7.79	12206.25	S	100.0
71	7.79	12206.25	S	100.0
71	7.79	12206.25	S	100.0
71	7.79	12206.25	S	100.0
72	8.03	12329.05	S	100.0
73	8.33	12451.15	S	100.0
74	9.87	12570.05	S	100.0
74.25	22.66	12457.00	S	99.1
74.5	32.21	12536.53	S	99.7
74.75	70.60	12334.19	F	98.7
75	75.72	12334.37	F	98.6
76	97.10	12345.34	F	98.2
77	116.09	12359.58	F	97.8
78	134.33	12377.63	F	97.4



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)

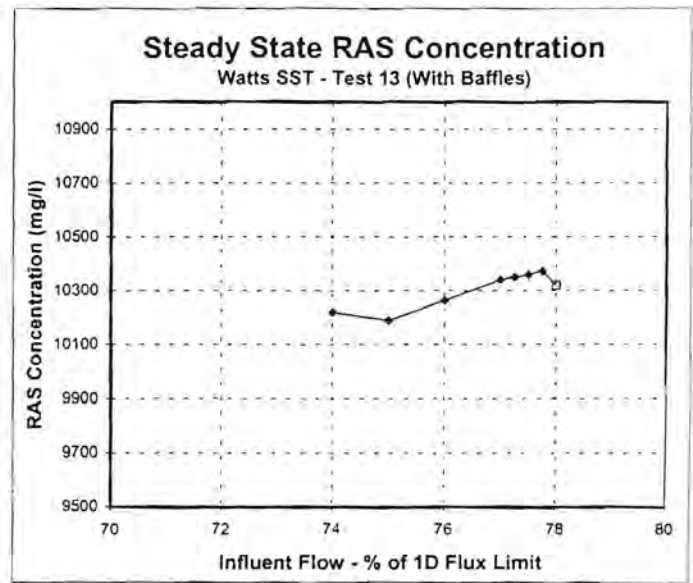
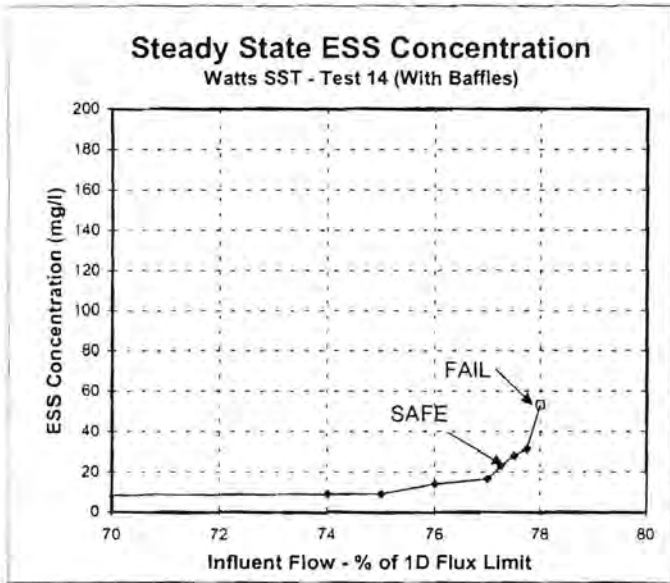


Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 13 simulation on the new SST - With Baffles

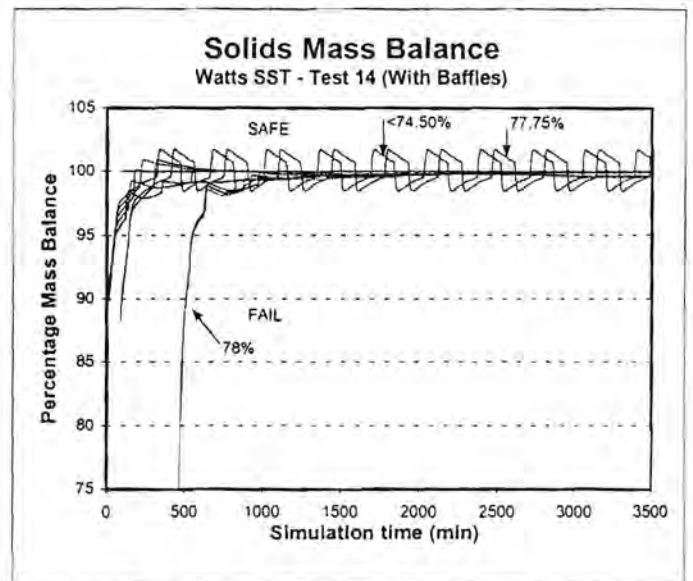
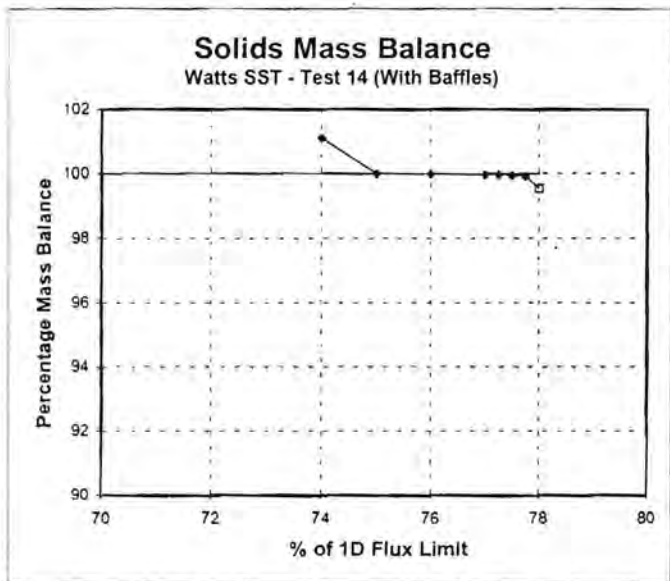
Test 13 - With Baffles

Vo (m/h)	7.62
n (l/g)	0.3055
Xf (g/l)	3.987
1DFT predicted limits	
Maximun flux [kg/(m ² .h)]	11.98
Overflow rate (m/h)	2.16
Influent flow (m ³ /h)	1423.6
Flux ratings	
Flux load factor [Vo/(n.Xf)] (m/h)	6.26
Simulation Data	
Recycle flow (m ³ /h)	555.6
Area (m ²)	658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
0	0.00	0.00	S	0.0
72	8.09	11315.23	S	99.9
72	8.09	11315.23	S	99.9
72	8.09	11315.23	S	99.9
72	8.09	11315.23	S	99.9
72	8.09	11315.23	S	99.9
72	8.09	11315.23	S	99.9
73	11.26	11374.76	S	99.6
74	12.17	11521.56	S	100.0
74.25	13.20	11543.86	S	100.0
74.5	78.92	11312.45	F	98.8
74.75	84.39	11312.50	F	98.7
75	91.18	11315.70	F	98.6
76	118.76	11304.04	F	98.2
77	143.55	11307.37	F	97.8
78	169.50	11303.71	F	97.4



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 14 simulation on the new SST - With Baffles

Test 14 - With Baffles

Vo (m/h) 7.62
 n (l/g) 0.3055
 Xf (g/l) 3.983

1DFT predicted limits

Maximun flux [kg/(m².h)] 13.31
 Overflow rate (m/h) 2.26
 Influent flow (m³/h) 1486.9

Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h) 6.26

Simulation Data

Recycle flow (m³/h) 714
 Area (m²) 658.78

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
0	0.00	0.00	S	0.0
74	8.62	10219.99	S	101.1
74	8.62	10219.99	S	101.1
74	8.62	10219.99	S	101.1
74	8.62	10219.99	S	101.1
74	8.62	10219.99	S	101.1
74	8.62	10219.99	S	101.1
74	8.62	10219.99	S	101.1
74	8.62	10219.99	S	101.1
74	8.62	10219.99	S	101.1
75	8.74	10189.35	S	100.0
76	13.77	10263.11	S	100.0
77	16.43	10339.78	S	100.0
77.25	23.09	10348.96	S	100.0
77.5	28.01	10359.65	S	99.9
77.75	31.50	10372.86	S	99.9
78	53.32	10318.73	F	99.5

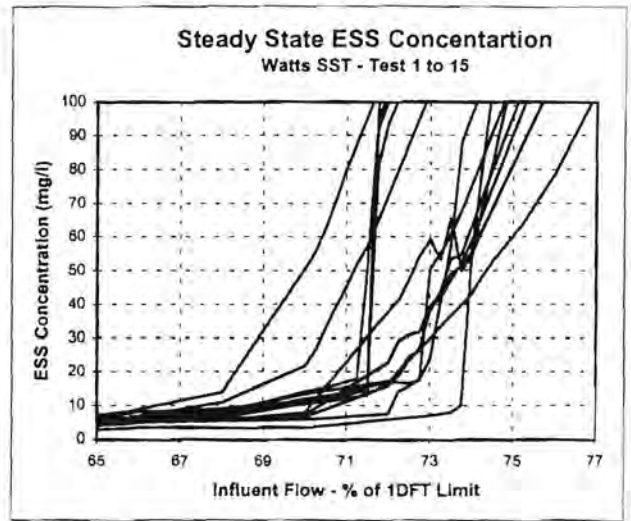
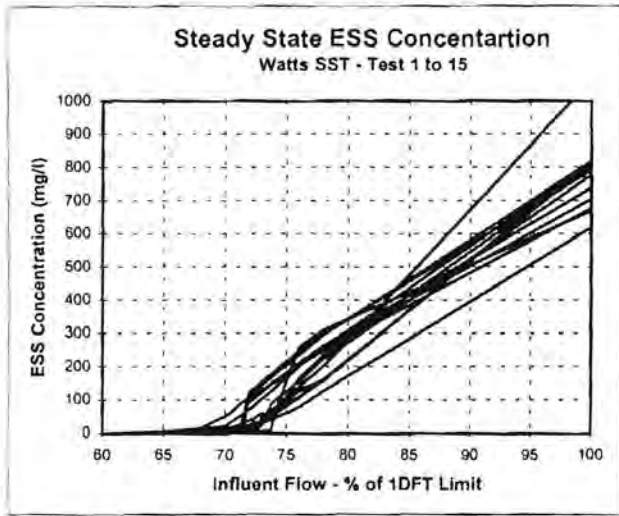


Fig a and b: SettlerCAD predicted ESS concentration versus influent flow (as a % of 1DFT limit) for Test 1 to 15 on the Watts SST

APPENDIX C

STOWa Results (Rijen)

SettlerCAD Predicted Failure Results

PARAMETER	STOWa# Rijen Test #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14
		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6a	Test 6b	Test 7	Test 8	Test 9	Test 10	Test 11	Test 11	Test 12
Flux Factor [Vo/(n.X _F) - m/h		5.91	4.47	6.43	3.11	3.76	5.39	4.03	2.61	2.89	4.42	4.56	5.55	4.32	5.75
Influent Flow (m3/h) for 1 SST		1461.8	1396.9	959.7	749.1				564.4			1180.7			
% of 1DFT maximum Q _i		69.75	63	65	63				62			65			
Overflow Rate (m/h)		0.90	0.86	0.59	0.46				0.35			0.73			
Recycle Flow (m ³ /h)		531.8	1009.9	287.5	530.1				530.1			533.4			
Underflow Rate (m/h)		0.327	0.621	0.176	0.326				0.326			0.328			
Recycle Ratio		0.36	0.72	0.30	0.71				0.94			0.45			
Applied Flux (kg SS)/(m ² .h)		3.33	5.05	1.92	2.52				2.57			2.70			
% of 1DFT maximum flux		75.9	74.6	70.7	74.4				76.0			72.9			
Actual Retention Time (h)		2.4	1.9	3.8	3.7				4.3			2.7			
Duration of Run (min)		4000	4000	4000	4000				4000			4000			
Duration of Run (# of Rha)		28.4	34.2	17.7	18.2				15.6			24.4			
Sim time Step (min)		2.5	2.5	2.5	2.5				2.5			2.5			
Sim time Step (%Rha)		1.77	2.14	1.11	1.14				0.97			1.52			
ESS (mg/l)*		63.8	50.9	52.7	50.7				85.8			54.7			
Recycle Conc (mg/l)*		9494	8037	9942	7551				7672			7989.7			
Mass Balance (%)*		94.8	99.8	93	98.7				98.4			98.6			
Test Result (ESS>50mg/l)		Fail	Fail	Fail	Fail				Fail			Fail			

* Mean over the last 2 R_{av} values

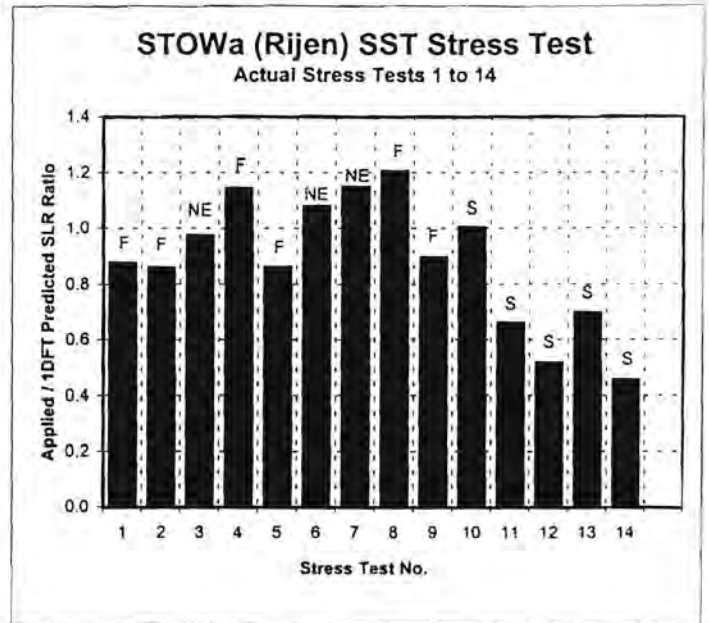
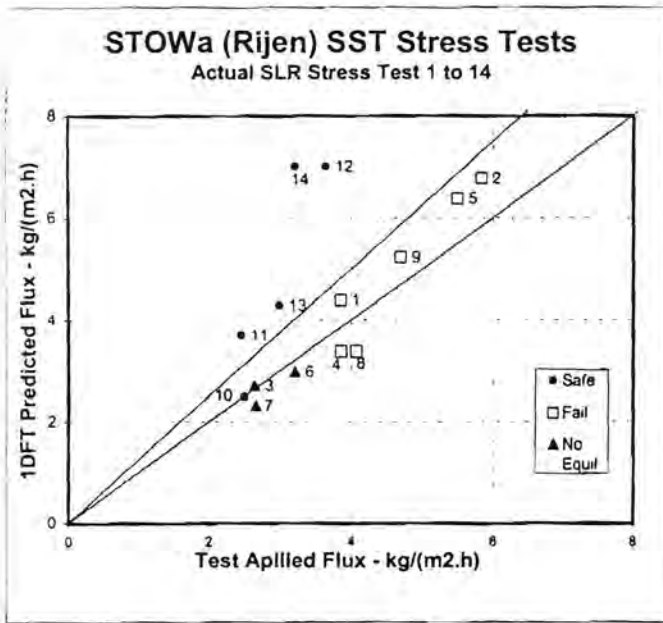
Summary of the SettlerCAD simulation results for the SettlerCAD influent flow limit of Test 1 to 14 for the STOWa (Rijen) results

SettlerCAD Prediction of Actual SLR Tests

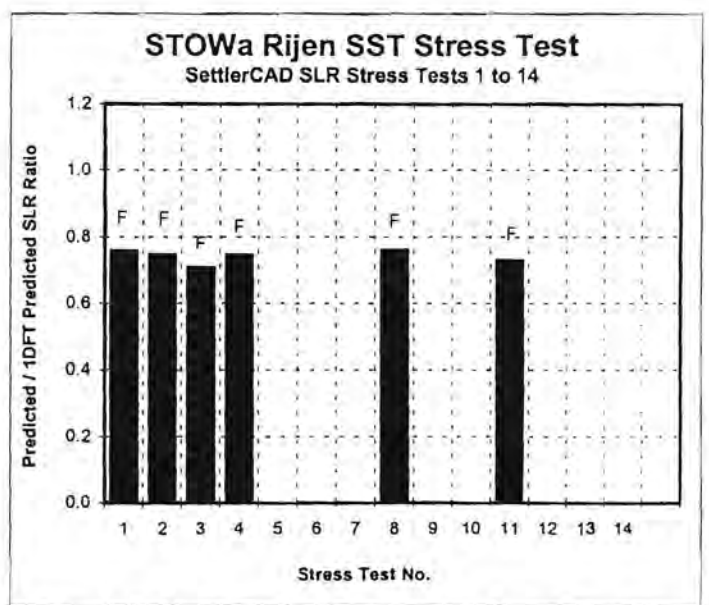
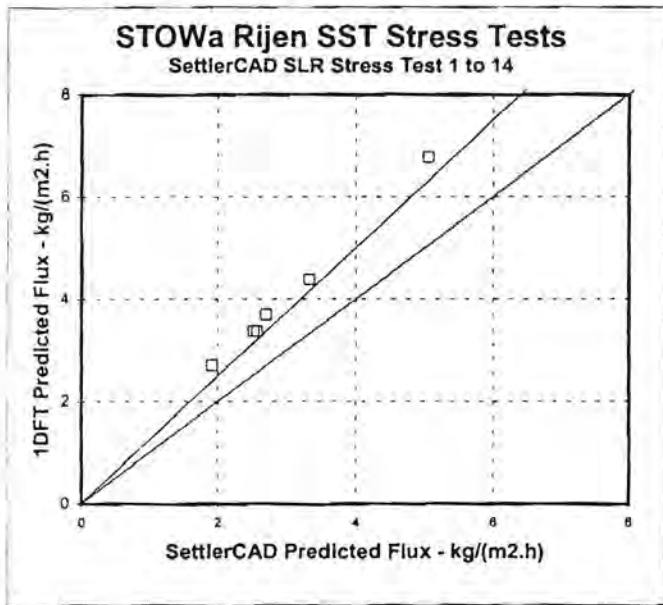
PARAMETER	STOWa# Rijen Test #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14
		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6a	Test 6b	Test 7	Test 8	Test 9	Test 10	Test 11	Test 11	Test 12
Flux Factor [Vo/(n.X _F) - m/h		5.91	4.47	6.43	3.11	3.76	5.39	4.03	2.61	2.89	4.42	4.56	5.55	4.32	5.75
Influent Flow (m3/h) for 1 SST		1772.5	1772.5	1431.0	1431.0	1431.0	1203.4	1203.4	1203.4	1203.4	1024.5	1024.5	1024.5	845.6	845.6
% of 1DFT maximum Q _i		84.6	79.9	96.9	120.4	78.5	109.7	119.2	132.2	82.4	100.3	56.4	35.1	58.8	27.7
Overflow Rate (m/h)		1.09	1.09	0.88	0.88	0.88	0.74	0.74	0.74	0.74	0.63	0.63	0.63	0.52	0.52
Recycle Flow (m ³ /h)		533.3	1008.3	287.5	529.2	1016.7	287.5	287.5	529.2	1012.5	287.5	533.3	1016.7	533.3	1016.7
Underflow Rate (m/h)		0.33	0.62	0.18	0.33	0.63	0.18	0.18	0.33	0.62	0.18	0.33	0.62	0.33	0.62
Recycle Ratio		0.300	0.570	0.200	0.370	0.710	0.241	0.241	0.441	0.841	0.279	0.521	0.990	0.631	1.200
Applied Flux (kg SS)/(m ² .h)		3.85	5.83	2.64	3.86	5.49	3.21	2.66	4.07	4.69	2.50	2.45	3.64	2.99	3.20
% of 1DFT maximum flux		87.7	86.2	97.4	114.1	86.2	107.7	114.9	120.3	89.6	100.3	66.3	51.9	70.0	45.7
Actual Retention Time (h)		2.0	1.7	2.7	2.4	1.9	3.1	3.1	2.7	2.1	3.6	3.0	2.3	3.4	2.5
Duration of Run (min)		4000	4000	4000	4000				6000			4000			
Duration of Run (# of Rha)		32.8	39.6	24.4	27.9				37.0			22.2			
Sim time Step (min)		2.5	2.5	2.5	2.5				2.5			2.5			
Sim time Step (%Rha)		2.05	2.47	1.53	1.74				1.54			1.39			
ESS (mg/l)*		503.5	399	581.4	1271.3				6.1			1761.2			
Recycle Conc (mg/l)*		9258.9	8317.2	10591.5	7369.1				9137.8			7501			
Mass Balance (%)*		92.8	96	90	91.2				100			92.1			
Test Result (ESS > 50 mg/l)		Fail	Fail	Fail	Fail				Fail			Fail			
Observed Result		Fail	Fail	No Equil	Fail	Fail	No Equil	No Equil	Fail	Fail	Safe	Fail	Safe	Safe	Safe

* Mean over the last 2 R_{av} values

Summary of the SettlerCAD simulation results for the actual Test 1 to 14 of the STOWa (Rijen) results



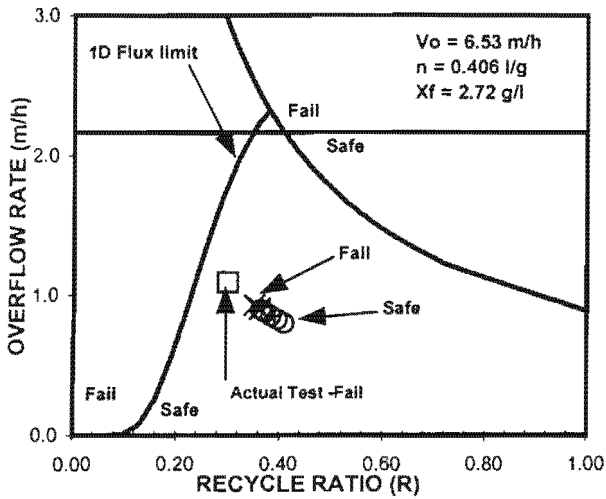
Figs a and b: Calculated 1DFT maximum SLR versus test applied SLR (Fig a, left) and test applied to 1DFT calculated maximum SLR ratios (Fig b, right) for the 14 Stress test reported by STOWa (1981) on the Rijen SST



Figs a and b: 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Figs a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig b, right) for the 14 stress tests reported by STOWa (1981) on the Rijen SST

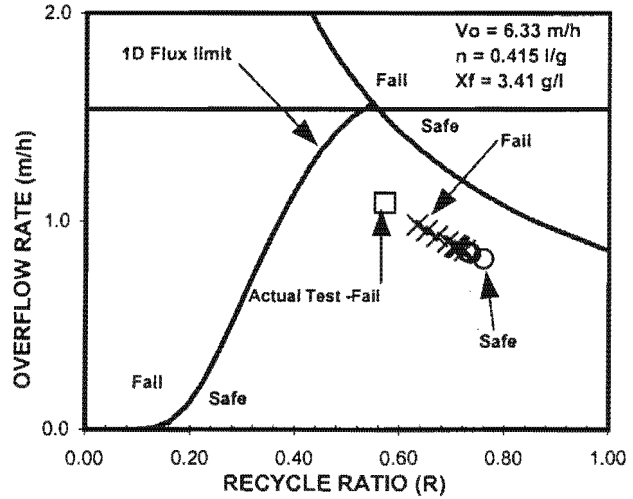
Rijen Test 1 - STOWa Test 1

1D Flux Theory (no correction)



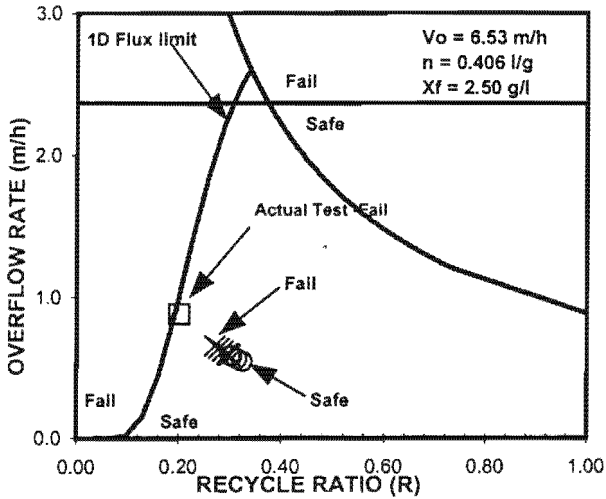
Rijen Test 2 - STOWa Test 2

1D Flux Theory (no correction)



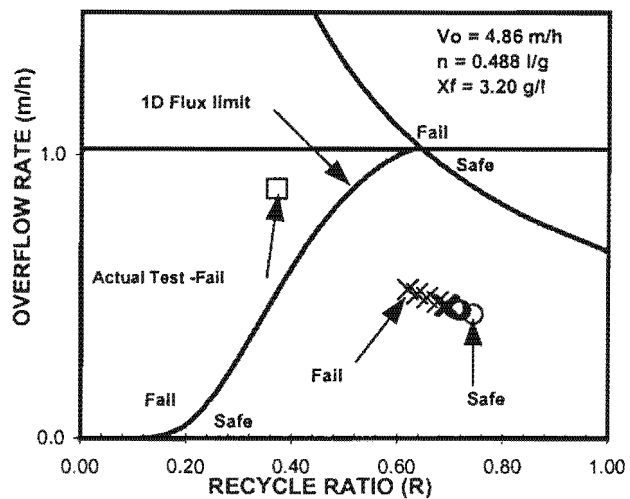
Rijen Test 3 - STOWa Test 3

1D Flux Theory (no correction)



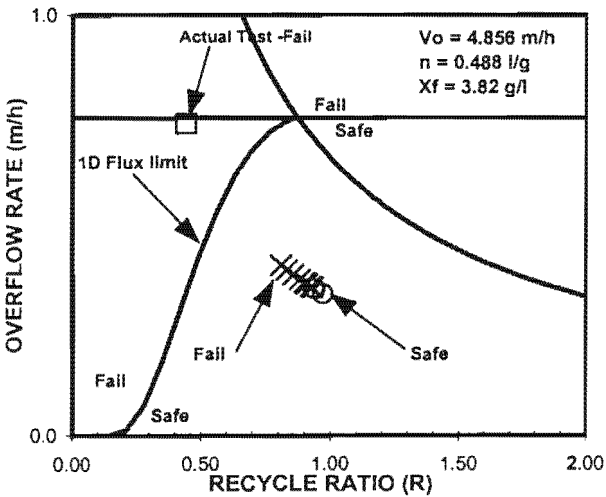
Rijen Test 4 - STOWa Test 4

1D Flux Theory (no correction)



Rijen Test 7 - STOWa Test 8

1D Flux Theory (no correction)



Rijen Test 10 - STOWa Test 6

1D Flux Theory (no correction)

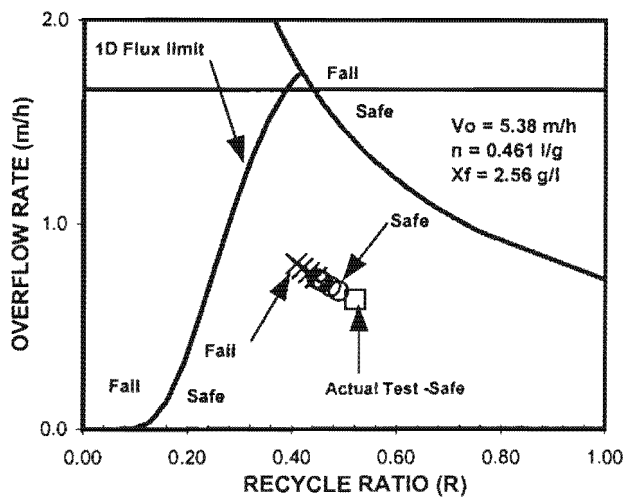


Fig a to f: 1DFT D&O charts showing the SST operating positions and results (Safe, Fail) of the SettlerCAD runs and actual tests

Construct D&O Chart chart: STOWa Test 1

Xf = 2.72 kgMLSS/m³
 Vo = 6.53 m/h
 n= 0.406 m³/kg
 Qr= 531.8 m³/h
 Qi (1D Flux Limit) 2095.8 m³/h
 A= 1626.18 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	531.8	0.00	0.00	0.00000	1.0000	0.0000	2.1643	88.3739
F	72	1509.0	531.8	0.93	0.35	0.03225	0.9417	0.0000	2.1643	27.4028
F	70	1467.1	531.8	0.90	0.36	0.06450	0.8835	0.0001	2.1643	13.7014
F	69.75	1461.8	531.8	0.90	0.36	0.09675	0.8249	0.0077	2.1643	9.1343
S	69.5	1456.6	531.8	0.90	0.37	0.12900	0.7656	0.0751	2.1643	6.8507
S	69.25	1451.3	531.8	0.89	0.37	0.16125	0.7050	0.2660	2.1643	5.4806
S	69	1446.1	531.8	0.89	0.37	0.19350	0.6425	0.5769	2.1643	4.5671
S	68.75	1440.9	531.8	0.89	0.37	0.22575	0.5770	0.9538	2.1643	3.9147
S	68.5	1435.6	531.8	0.88	0.37	0.25800	0.5071	1.3381	2.1643	3.4253
S	68.25	1430.4	531.8	0.88	0.37	0.29025	0.4303	1.6875	2.1643	3.0448
S	68	1425.1	531.8	0.88	0.37	0.32250	0.3416	1.9780	2.1643	2.7403
S	66	1383.2	531.8	0.85	0.38	0.35475	0.2270	2.1979	2.1643	2.4912
S	64	1341.3	531.8	0.82	0.40	0.36013	0.2024	2.2271	2.1643	2.4540
S	62	1299.4	531.8	0.80	0.41	0.36460	0.1795	2.2496	2.1643	2.4238
S	62	1299.4	531.8	0.80	0.41	0.36834	0.1580	2.2671	2.1643	2.3993
S	62	1299.4	531.8	0.80	0.41	0.37145	0.1377	2.2808	2.1643	2.3792
S	62	1299.4	531.8	0.80	0.41	0.37404	0.1183	2.2915	2.1643	2.3627
Actual (F)	84.6	1773.0	531.8	1.09	0.30	0.37620	0.0992	2.2998	2.1643	2.3491
						0.37800	0.0801	2.3064	2.1643	2.3379
						0.41025	#NUM!	#NUM!	2.1643	2.1542
						0.44250	#NUM!	#NUM!	2.1643	1.9972
						0.47475	#NUM!	#NUM!	2.1643	1.8615
						0.50700	#NUM!	#NUM!	2.1643	1.7431
						0.53925	#NUM!	#NUM!	2.1643	1.6388
						0.57150	#NUM!	#NUM!	2.1643	1.5464
						0.60375	#NUM!	#NUM!	2.1643	1.4638
						0.63600	#NUM!	#NUM!	2.1643	1.3895
						0.66825	#NUM!	#NUM!	2.1643	1.3225
						0.70050	#NUM!	#NUM!	2.1643	1.2616
						0.73275	#NUM!	#NUM!	2.1643	1.2061
						1.00000	#NUM!	#NUM!	2.1643	0.8837

Construct D&O Chart chart: STOWa Test 2

Xf = 3.41 kgMLSS/m³
 Vo = 6.33 m/h
 n = 0.415 m³/kg
 Qr = 1009.9 m³/h
 Qi (1D Flux Limit) 2217.3 m³/h
 A = 1626.18 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	1009.9	0.00	0.00	0.00000	1.0000	0.0000	1.5375	85.6672
F	72	1596.5	1009.9	0.98	0.63	0.03225	0.9548	0.0000	1.5375	26.5635
F	70	1552.1	1009.9	0.95	0.65	0.06450	0.9103	0.0000	1.5375	13.2817
F	68	1507.8	1009.9	0.93	0.67	0.09675	0.8664	0.0003	1.5375	8.8545
F	66	1463.4	1009.9	0.90	0.69	0.12900	0.8228	0.0063	1.5375	6.6409
F	64	1419.1	1009.9	0.87	0.71	0.16125	0.7794	0.0365	1.5375	5.3127
F	64.75	1435.7	1009.9	0.88	0.70	0.19350	0.7360	0.1102	1.5375	4.4272
F	64.5	1430.2	1009.9	0.88	0.71	0.22575	0.6924	0.2315	1.5375	3.7948
F	64.25	1424.6	1009.9	0.88	0.71	0.25800	0.6483	0.3898	1.5375	3.3204
F	63	1396.9	1009.9	0.86	0.72	0.29025	0.6034	0.5689	1.5375	2.9515
S	62.75	1391.4	1009.9	0.86	0.73	0.32250	0.5574	0.7528	1.5375	2.6563
S	62.5	1385.8	1009.9	0.85	0.73	0.35475	0.5098	0.9295	1.5375	2.4149
S	62.25	1380.3	1009.9	0.85	0.73	0.38700	0.4597	1.0907	1.5375	2.2136
S	62	1374.7	1009.9	0.85	0.73	0.42570	0.3950	1.2573	1.5375	2.0124
S	60	1330.4	1009.9	0.82	0.76	0.43215	0.3835	1.2820	1.5375	1.9823
S	60	1330.4	1009.9	0.82	0.76	0.43860	0.3718	1.3057	1.5375	1.9532
S	60	1330.4	1009.9	0.82	0.76	0.44505	0.3598	1.3286	1.5375	1.9249
Actual (F)	79.9	1771.6	1009.9	1.09	0.57	0.47730	0.2946	1.4289	1.5375	1.7948
						0.50955	0.2142	1.5060	1.5375	1.6812
						0.54180	0.0820	1.5587	1.5375	1.5812
						0.57405	#NUM!	#NUM!	1.5375	1.4923
						0.60630	#NUM!	#NUM!	1.5375	1.4130
						0.63855	#NUM!	#NUM!	1.5375	1.3416
						0.67080	#NUM!	#NUM!	1.5375	1.2771
						0.70305	#NUM!	#NUM!	1.5375	1.2185
						0.73530	#NUM!	#NUM!	1.5375	1.1651
						0.76755	#NUM!	#NUM!	1.5375	1.1161
						0.79980	#NUM!	#NUM!	1.5375	1.0711
						0.83205	#NUM!	#NUM!	1.5375	1.0296
						0.86430	#NUM!	#NUM!	1.5375	0.9912
						1.00000	#NUM!	#NUM!	1.5375	0.8567

Construct D&O Chart chart: STOWa Test 3

Xf = 2.5 kgMLSS/m³
 Vo = 6.53 m/h
 n = 0.406 m³/kg
 Qr = 287.5 m³/h
 Qi (1D Flux Limit) 1476.5 m³/h
 A = 1626.2 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	287.5	0.00	0.00	0.00000	1.0000	0.0000	2.3665	88.3739
F	72	1063.1	287.5	0.65	0.27	0.03225	0.9364	0.0000	2.3665	27.4028
F	70	1033.6	287.5	0.64	0.28	0.06450	0.8725	0.0002	2.3665	13.7014
F	68	1004.0	287.5	0.62	0.29	0.09675	0.8077	0.0193	2.3665	9.1343
F	66	974.5	287.5	0.60	0.30	0.12900	0.7414	0.1491	2.3665	6.8507
F	65.75	970.8	287.5	0.60	0.30	0.16125	0.6729	0.4580	2.3665	5.4806
F	65.5	967.1	287.5	0.59	0.30	0.19350	0.6009	0.9019	2.3665	4.5671
F	65.25	963.4	287.5	0.59	0.30	0.22575	0.5236	1.3895	2.3665	3.9147
F	65	959.7	287.5	0.59	0.30	0.25800	0.4379	1.8447	2.3665	3.4253
S	64.75	956.0	287.5	0.59	0.30	0.29025	0.3369	2.2224	2.3665	3.0448
S	64.5	952.3	287.5	0.59	0.30	0.32250	0.1975	2.4996	2.3665	2.7403
S	64.25	948.7	287.5	0.58	0.30	0.32788	0.1641	2.5348	2.3665	2.6954
S	64	945.0	287.5	0.58	0.30	0.33235	0.1302	2.5612	2.3665	2.6590
S	62	915.4	287.5	0.56	0.31	0.33609	0.0932	2.5810	2.3665	2.6295
S	60	885.9	287.5	0.54	0.32	0.33920	0.0429	2.5955	2.3665	2.6054
S	60	885.9	287.5	0.54	0.32	0.34179	#NUM!	#NUM!	2.3665	2.5856
S	60	885.9	287.5	0.54	0.32	0.34395	#NUM!	#NUM!	2.3665	2.5694
Actual (NE)	96.9	1430.7	287.5	0.88	0.20	0.34575	#NUM!	#NUM!	2.3665	2.5560
						0.37800	#NUM!	#NUM!	2.3665	2.3379
						0.41025	#NUM!	#NUM!	2.3665	2.1542
						0.44250	#NUM!	#NUM!	2.3665	1.9972
						0.47475	#NUM!	#NUM!	2.3665	1.8615
						0.50700	#NUM!	#NUM!	2.3665	1.7431
						0.53925	#NUM!	#NUM!	2.3665	1.6388
						0.57150	#NUM!	#NUM!	2.3665	1.5464
						0.60375	#NUM!	#NUM!	2.3665	1.4638
						0.63600	#NUM!	#NUM!	2.3665	1.3895
						0.66825	#NUM!	#NUM!	2.3665	1.3225
						0.70050	#NUM!	#NUM!	2.3665	1.2616
						0.73275	#NUM!	#NUM!	2.3665	1.2061
						1.00000	#NUM!	#NUM!	2.3665	0.8837

Construct D&O Chart chart: STOWa Test 4

$X_f = 3.2 \text{ kgMLSS/m}^3$
 $V_o = 4.86 \text{ m/h}$
 $n = 0.488 \text{ m}^3/\text{kg}$
 $Q_r = 530.1 \text{ m}^3/\text{h}$
 $Q_i \text{ (1D Flux Limit)} = 1189 \text{ m}^3/\text{h}$
 $A = 1626.2 \text{ m}^2$

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Q_i (m^3/h)	Recycle Flow Q_r (m^3/h)	Overflow rate (m/d) Q_i/A	Recycle rate (m^3/d) $Q_r/Q_i = s$	Recycle ratio Q_r/Q_i s	alfa	Criterion 1 Thickening Q_i/A (m/d)	Criterion 2 Clarification Q_i/A (m/d)	Hyperbola Q_i/A (m/d)
	0	0.0	530.1	0.00	0.00	0.00000	1.0000	0.0000	1.0196	65.7729
F	72	856.1	530.1	0.53	0.62	0.03225	0.9592	0.0000	1.0196	20.3947
F	70	832.3	530.1	0.51	0.64	0.06450	0.9191	0.0000	1.0196	10.1974
F	68	808.5	530.1	0.50	0.66	0.09675	0.8798	0.0000	1.0196	6.7982
F	66	784.7	530.1	0.48	0.68	0.12900	0.8410	0.0015	1.0196	5.0987
F	64	761.0	530.1	0.47	0.70	0.16125	0.8027	0.0109	1.0196	4.0789
F	64.75	769.9	530.1	0.47	0.69	0.19350	0.7647	0.0384	1.0196	3.3991
F	64.5	766.9	530.1	0.47	0.69	0.22575	0.7268	0.0900	1.0196	2.9135
F	64.25	763.9	530.1	0.47	0.69	0.25800	0.6890	0.1649	1.0196	2.5493
F	63	749.1	530.1	0.46	0.71	0.29025	0.6510	0.2571	1.0196	2.2661
S	62.75	746.1	530.1	0.46	0.71	0.32250	0.6127	0.3590	1.0196	2.0395
S	62.5	743.1	530.1	0.46	0.71	0.35475	0.5738	0.4635	1.0196	1.8541
S	62.25	740.2	530.1	0.46	0.72	0.38700	0.5341	0.5650	1.0196	1.6996
S	62	737.2	530.1	0.45	0.72	0.42570	0.4849	0.6776	1.0196	1.5451
S	60	713.4	530.1	0.44	0.74	0.43215	0.4765	0.6951	1.0196	1.5220
S	60	713.4	530.1	0.44	0.74	0.43860	0.4680	0.7122	1.0196	1.4996
S	60	713.4	530.1	0.44	0.74	0.44505	0.4595	0.7289	1.0196	1.4779
Actual (F)	120.4	1431.6	530.1	0.88	0.37	0.47730	0.4152	0.8060	1.0196	1.3780
						0.50955	0.3679	0.8721	1.0196	1.2908
						0.54180	0.3160	0.9270	1.0196	1.2140
						0.57405	0.2566	0.9711	1.0196	1.1458
						0.60630	0.1821	1.0044	1.0196	1.0848
						0.63855	0.0422	1.0263	1.0196	1.0300
						0.67080	#NUM!	#NUM!	1.0196	0.9805
						0.70305	#NUM!	#NUM!	1.0196	0.9355
						0.73530	#NUM!	#NUM!	1.0196	0.8945
						0.76755	#NUM!	#NUM!	1.0196	0.8569
						0.79980	#NUM!	#NUM!	1.0196	0.8224
						0.83205	#NUM!	#NUM!	1.0196	0.7905
						0.86430	#NUM!	#NUM!	1.0196	0.7610
						1.00000	#NUM!	#NUM!	1.0196	0.6577

Construct D&O Chart chart: STOWa Test 8

Xf = 3.82 kgMLSS/m³
 Vo = 4.86 m/h
 n = 0.488 m³/kg
 Qr = 530.1 m³/h
 QI (1D Flux Limit) = 910.3 m³/h
 A = 1826.2 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	530.1	0.00	0.00	0.00000	1.0000	0.0000	0.7534	65.7729
F	72	655.4	530.1	0.40	0.81	0.07000	0.9272	0.0000	0.7534	9.3961
F	70	637.2	530.1	0.39	0.83	0.14000	0.8582	0.0003	0.7534	4.6981
F	68	619.0	530.1	0.38	0.86	0.21000	0.7922	0.0132	0.7534	3.1320
F	66	600.8	530.1	0.37	0.88	0.28000	0.7284	0.0699	0.7534	2.3490
F	64	582.6	530.1	0.36	0.91	0.35000	0.6661	0.1735	0.7534	1.8792
F	64.75	589.4	530.1	0.36	0.90	0.42000	0.6044	0.2990	0.7534	1.5660
F	64.5	587.1	530.1	0.36	0.90	0.49000	0.5425	0.4223	0.7534	1.3423
F	64.25	584.9	530.1	0.36	0.91	0.56000	0.4793	0.5294	0.7534	1.1745
F	63	573.5	530.1	0.35	0.92	0.63000	0.4131	0.6151	0.7534	1.0440
F	62.75	571.2	530.1	0.35	0.93	0.70000	0.3413	0.6788	0.7534	0.9396
F	62.5	568.9	530.1	0.35	0.93	0.77000	0.2580	0.7225	0.7534	0.8542
F	62.25	566.7	530.1	0.35	0.94	0.84000	0.1429	0.7480	0.7534	0.7830
F	62	564.4	530.1	0.35	0.94	0.85167	0.1144	0.7506	0.7534	0.7723
S	60	546.2	530.1	0.34	0.97	0.86139	0.0838	0.7522	0.7534	0.7636
S	60	546.2	530.1	0.34	0.97	0.86949	0.0450	0.7533	0.7534	0.7565
S	60	546.2	530.1	0.34	0.97	0.93949	#NUM!	#NUM!	0.7534	0.7001
Actual (F)	132.2	1203.4	530.1	0.74	0.44	1.00949	#NUM!	#NUM!	0.7534	0.6515
						1.07949	#NUM!	#NUM!	0.7534	0.6093
						1.14949	#NUM!	#NUM!	0.7534	0.5722
						1.21949	#NUM!	#NUM!	0.7534	0.5393
						1.28949	#NUM!	#NUM!	0.7534	0.5101
						1.35949	#NUM!	#NUM!	0.7534	0.4838
						1.42949	#NUM!	#NUM!	0.7534	0.4601
						1.49949	#NUM!	#NUM!	0.7534	0.4386
						1.56949	#NUM!	#NUM!	0.7534	0.4191
						1.63949	#NUM!	#NUM!	0.7534	0.4012
						1.70949	#NUM!	#NUM!	0.7534	0.3848
						1.77949	#NUM!	#NUM!	0.7534	0.3696
						1.84949	#NUM!	#NUM!	0.7534	0.3556
						2.00000	#NUM!	#NUM!	0.7534	0.3289

Construct D&O Chart chart: STOWa Test 11

$X_f = 2.56 \text{ kgMLSS/m}^3$
 $V_o = 5.38 \text{ m/h}$
 $n = 0.46 \text{ m}^3/\text{kg}$
 $Q_r = 533.4 \text{ m}^3/\text{h}$
 $Q_i \text{ (1D Flux Limit)} = 1816.4 \text{ m}^3/\text{h}$
 $A = 1626.2 \text{ m}^2$

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Q_i (m^3/h)	Recycle Flow Q_r (m^3/h)	Overflow rate (m/d) Q_i/A	Recycle rate (m^3/d) $Q_r/Q_i = s$	Recycle ratio Q_r/Q_i s	alfa	Criterion 1 Thickening Q_i/A (m/d)	Criterion 2 Clarification Q_i/A (m/d)	Hyperbola Q_i/A (m/d)
	0	0.0	533.4	0.00	0.00	0.00000	1.0000	0.0000	1.6571	72.8104
F	72	1307.8	533.4	0.80	0.41	0.03225	0.9455	0.0000	1.6571	22.5769
F	70	1271.5	533.4	0.78	0.42	0.06450	0.8912	0.0000	1.6571	11.2884
F	68	1235.2	533.4	0.76	0.43	0.09675	0.8369	0.0030	1.6571	7.5256
F	66	1198.8	533.4	0.74	0.44	0.12900	0.7822	0.0350	1.6571	5.6442
F	65.75	1194.3	533.4	0.73	0.45	0.16125	0.7269	0.1393	1.6571	4.5154
S	65.5	1189.7	533.4	0.73	0.45	0.19350	0.6703	0.3268	1.6571	3.7628
S	65.25	1185.2	533.4	0.73	0.45	0.22575	0.6119	0.5722	1.6571	3.2253
S	65	1180.7	533.4	0.73	0.45	0.25800	0.5508	0.8388	1.6571	2.8221
S	64.75	1176.1	533.4	0.72	0.45	0.29025	0.4857	1.0962	1.6571	2.5085
S	64.5	1171.6	533.4	0.72	0.46	0.32250	0.4143	1.3245	1.6571	2.2577
S	64.25	1167.0	533.4	0.72	0.46	0.35475	0.3325	1.5130	1.6571	2.0524
S	64	1162.5	533.4	0.71	0.46	0.38700	0.2286	1.6566	1.6571	1.8814
S	62	1126.2	533.4	0.69	0.47	0.39345	0.2023	1.6797	1.6571	1.8506
S	60	1089.8	533.4	0.67	0.49	0.39861	0.1786	1.6966	1.6571	1.8266
S	60	1089.8	533.4	0.67	0.49	0.40274	0.1574	1.7092	1.6571	1.8079
S	60	1089.8	533.4	0.67	0.49	0.40604	0.1381	1.7186	1.6571	1.7932
Actual (S)	56.4	1024.4	533.4	0.63	0.52	0.40868	0.1206	1.7256	1.6571	1.7816
						0.41080	0.1046	1.7310	1.6571	1.7724
						0.44305	#NUM!	#NUM!	1.6571	1.6434
						0.47530	#NUM!	#NUM!	1.6571	1.5319
						0.50755	#NUM!	#NUM!	1.6571	1.4346
						0.53980	#NUM!	#NUM!	1.6571	1.3489
						0.57205	#NUM!	#NUM!	1.6571	1.2728
						0.60430	#NUM!	#NUM!	1.6571	1.2049
						0.63655	#NUM!	#NUM!	1.6571	1.1438
						0.66880	#NUM!	#NUM!	1.6571	1.0887
						0.70105	#NUM!	#NUM!	1.6571	1.0386
						0.73330	#NUM!	#NUM!	1.6571	0.9929
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						1.00000	#NUM!	#NUM!	1.6571	0.7281

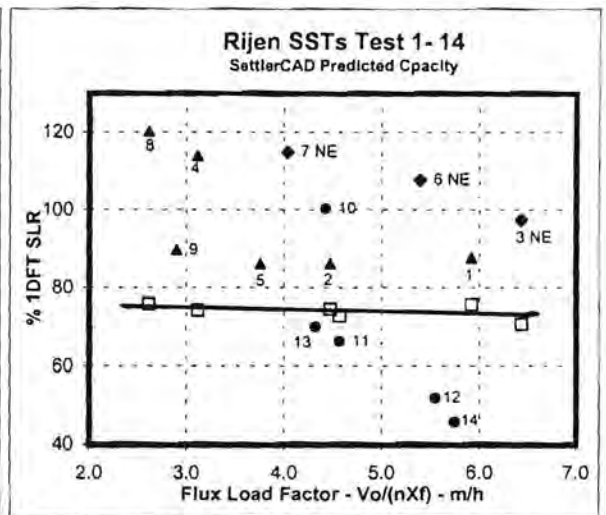
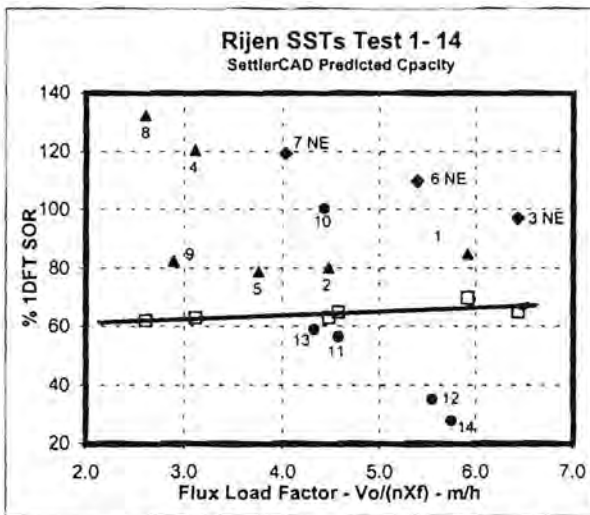
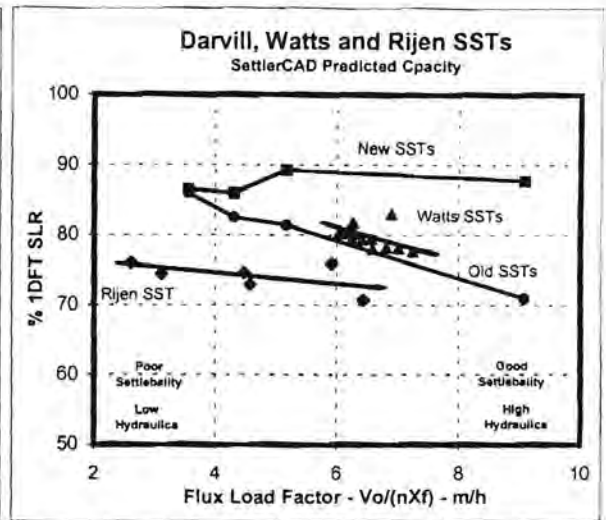
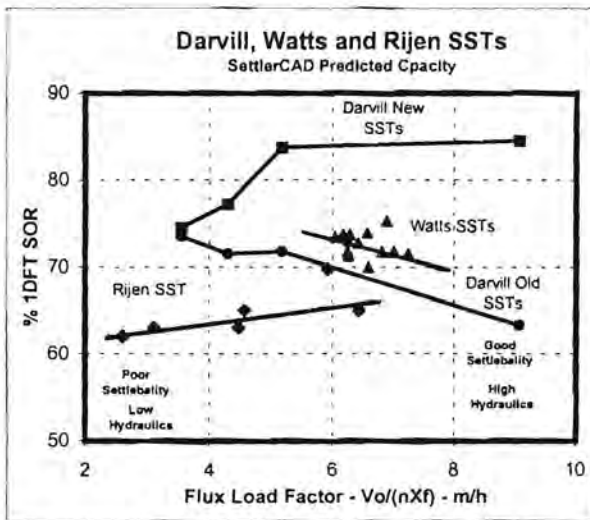


Fig a to d: SettlerCAD predicted capacity as % of the 1DFT maximum HLR (Figures on left) and SLR (Figures on the right) limits versus the flux load factor for Rijen Test 1 to 14 superimposed on the Darvill and Watts results (Fig a and b). Fig c and d shows a detail look at the Rijen results. The actual test positions and outcome is also shown in Fig c and d

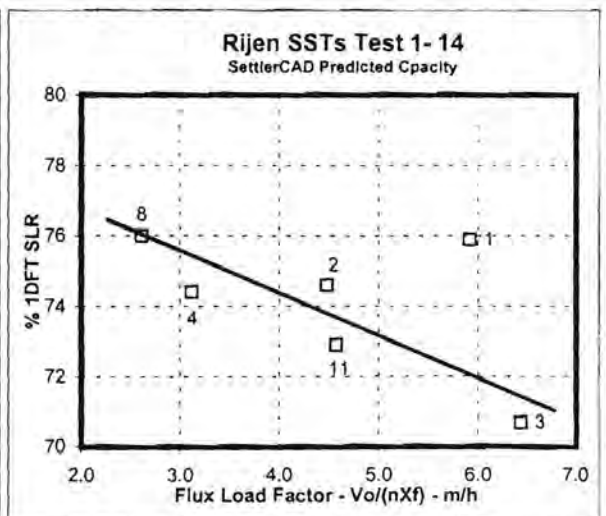
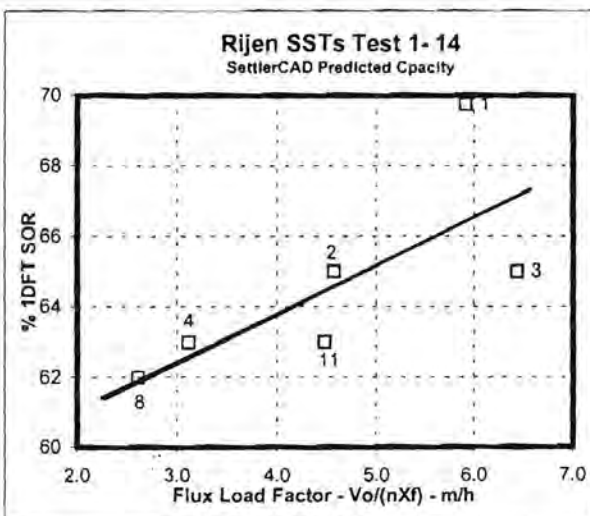


Fig e and f: SettlerCAD predicted maximum SOR (Fig e on left) and SLR (Fig f on right) as a % of the 1DFT limit values versus flux factor for the six tests simulated with SettlerCAD identified by number

Darvill	Test 2		Test 1		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Flux Constant V_0 (m/h)	7.83	7.83	7.71	7.71	8.00	8.00	9.08	9.08
Flux Constant n (m ³ /kgTSS)	0.513	0.513	0.39	0.39	0.43	0.43	0.29	0.29
Feed Conc. (g/l)	4.300	4.300	4.600	4.600	3.600	3.600	3.450	3.450
Flux Factor $V_0/(n \cdot X_F)$ - m/h	3.5	3.5	4.3	4.3	5.2	5.2	9.1	9.1

% of 1 DFT Overflow Rate	Test 2		Test 1		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Case 1 - Normal	74.50	73.50	77.25	71.50	83.75	71.75	84.50	63.25
Case 2 - No Baffles	74.30	76.25	80.00	74.50	87.30	75.80	89.00	65.00
Case 3 - Reverse Depth	67.50	82.50	63.00	78.25	63.75	82.75	68.00	81.25
Actual Test	92.10	92.10	78.50	78.50	65.60	65.60	89.10	89.10

% of 1 DFT SLR	Test 2		Test 1		Test 3		Test 4	
	New	Old	New	Old	New	Old	New	Old
Case 1 - Normal	86.5	86	86	82.5	89.3	81.4	87.7	70.9
Case 2 - No Baffles	86.4	87.5	87.7	84.3	91.6	84.1	91.3	72.3
Case 3 - Reverse Depth	82.8	90.8	77.3	86.6	76.1	88.6	74.67	85.2
Actual Test	95.8	95.8	86.8	86.8	77.3	77.3	91.4	91.4

Watts	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Flux Constant V_0 (m/h)	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62
Flux Constant n (m ³ /kgTSS)	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055	0.3055
Feed Conc. (g/l)	4.053	3.972	3.801	4.130	3.664	3.994	3.560	3.787	3.444	3.885	4.044	3.444	3.987	3.983	3.618
Flux Factor $V_0/(n \cdot X_F)$ - m/h	6.2	6.3	6.6	6.0	6.8	6.2	7.0	6.6	7.2	6.4	6.2	7.2	6.3	6.3	6.9

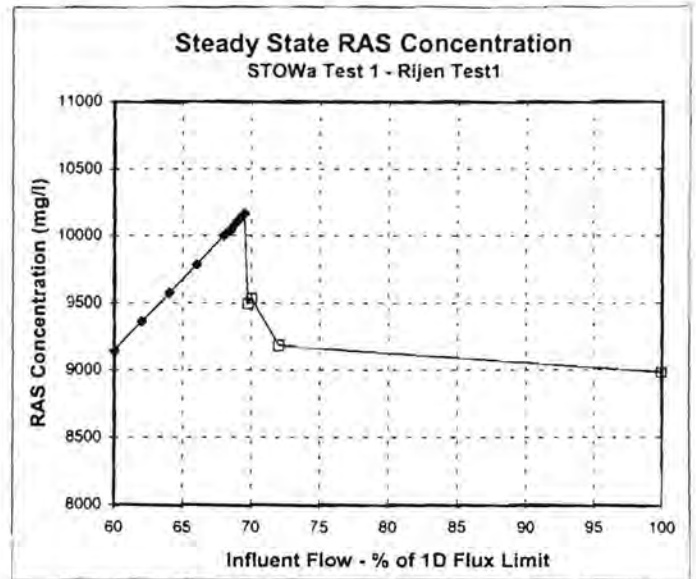
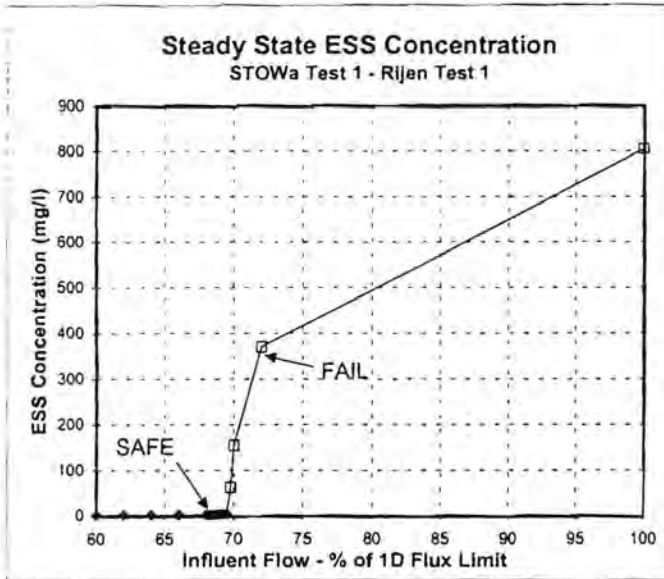
% of 1 DFT Overflow Rate	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Case 1 - Normal	73.5	73.75	74	73.5	71.75	71.75	71.75	70	71.5	72.75	73.75	71.5	71.25	73	75.25
Actual Test	41.2	52.5	87.7	69.5	59.4	60.1	68.2	51.4	71.2	63.3	88.3	76.7	71.8	68.8	60.7

% of 1 DFT SLR	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15
Case 1 - Normal	80.3	80.3	79.5	80.4	78.3	79.3	78.1	78	77.7	79.4	80.5	77.7	79.3	81.8	83
Actual Test	56.2	64.4	90.3	77.5	68.8	70.7	75.4	64.3	77.5	72.3	91.3	81.7	79.7	78.9	73

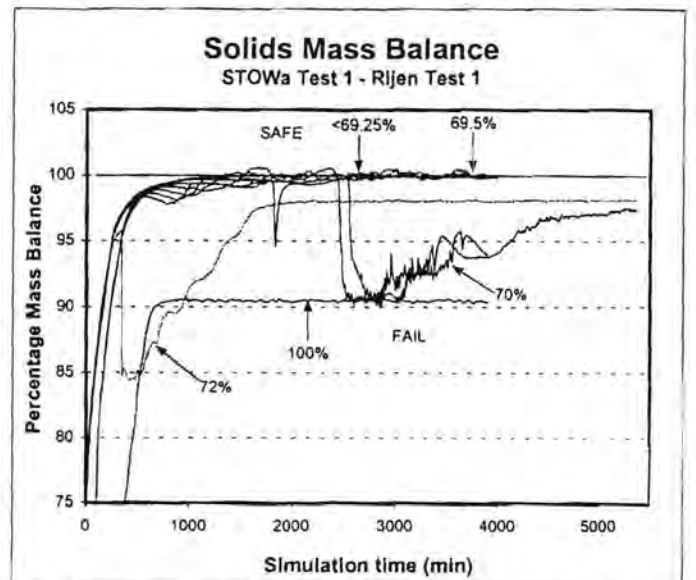
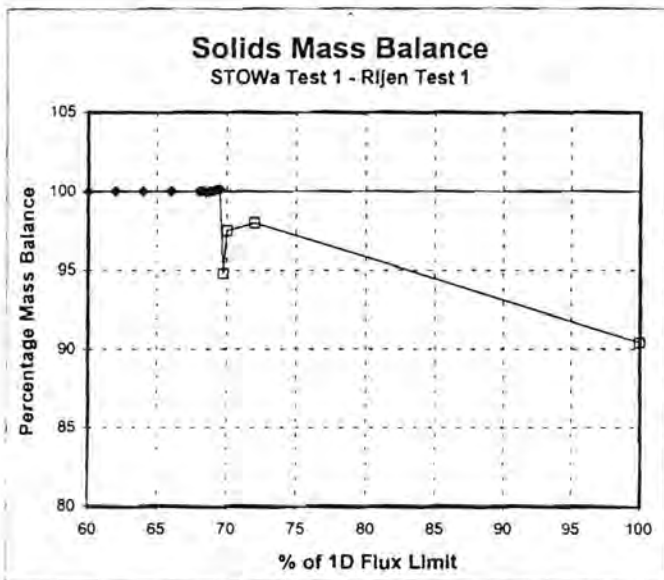
Rijen	STOWa #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14
	Rijen #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6a	Test 6b	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13
Flux Constant V_0 (m/h)	6.53	6.33	6.53	4.86	5.94	7.15	5.38	4.86	4.86	5.94	5.38	6.53	6.33	6.53	
Flux Constant n (m ³ /kgTSS)	0.406	0.415	0.406	0.488	0.433	0.379	0.46	0.488	0.488	0.433	0.46	0.406	0.415	0.406	
Feed Conc. (g/l)	2.720	3.410	2.500	3.200	3.650	3.500	2.900	3.820	3.44	3.1	2.56	2.9	3.53	2.8	
Flux Factor $V_0/(n \cdot X_F)$ - m/h	5.9	4.5	6.4	3.1	3.8	5.4	4.0	2.6	2.9	4.4	4.6	5.5	4.3	5.7	

% of 1 DFT SOR	STOWa #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14
	Rijen #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6a	Test 6b	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13
Normal	69.75	63.00	65.00	63.00	-	-	-	62.00	-	-	65	-	-	-	-
Actual Test	84.60	79.90	96.90	120.40	78.50	109.70	119.20	132.20	82.4	100.3	56.4	35.1	58.8	27.7	

% of 1 DFT SLR	STOWa #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14
	Rijen #	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6a	Test 6b	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13
Normal	75.9	74.6	70.7	74.4	-	-	-	76	-	-	72.9	-	-	-	-
Actual Test	87.7	86.2	97.4	114.1	86.2	107.7	114.9	120.3	89.6	100.3	66.3	51.9	70	45.7	



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 1 simulation on the Rijen SST

STOWa - Test 1

Vo (m/h)	6.53
n (l/g)	0.406
Xf (g/l)	2.72

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	4.39
Overflow rate (m/h)	1.29
Influent flow (m ³ /h)	2095.8

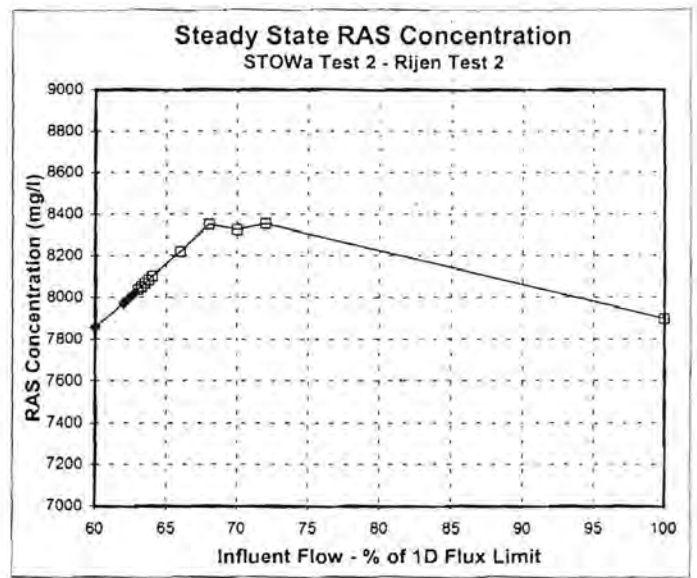
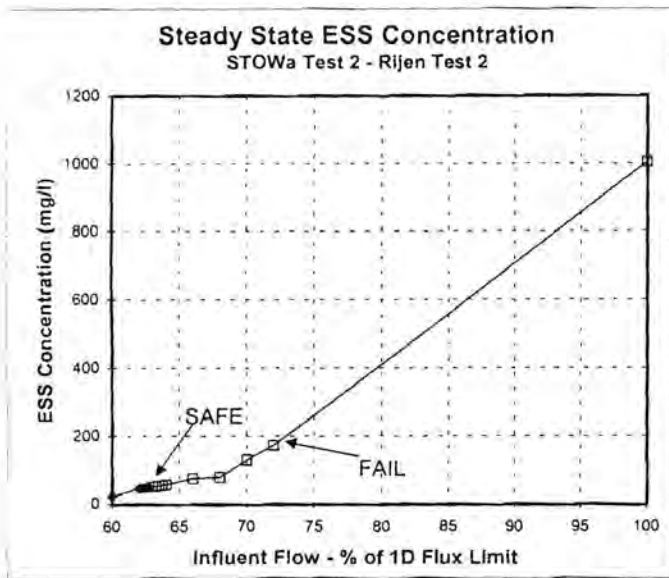
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	5.91
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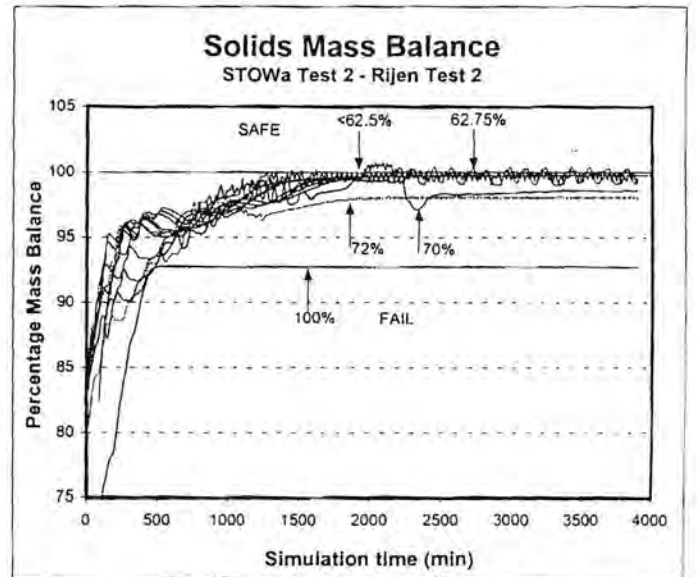
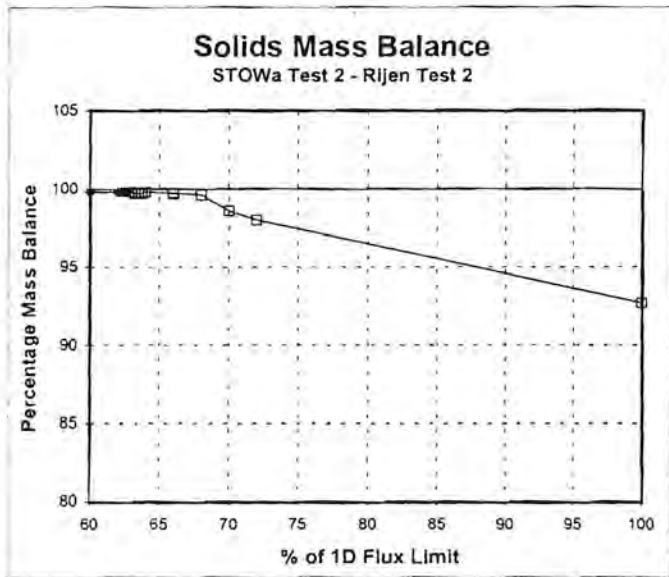
Simulation Data

Recycle flow (m ³ /h)	531.8
Area (m ²)	1626.2

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	2.00	9143.00	S	100.0
60	2.00	9143.00	S	100.0
62	2.20	9360.00	S	100.0
64	2.20	9571.00	S	100.0
66	2.50	9786.00	S	100.0
68	3.00	9999.00	S	100.0
68.25	3.10	10027.00	S	100.0
68.5	3.40	10039.00	S	99.9
68.75	3.90	10082.00	S	100.0
69	4.00	10109.00	S	100.0
69.25	4.00	10142.00	S	100.1
69.5	4.00	10166.00	S	100.1
69.75	63.80	9494.00	F	94.8
70	155.10	9533.00	F	97.5
72	370.70	9182.00	F	98.0
100	804.70	8984.00	F	90.4



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 2 simulation on the Rijen SST

STOWa - Test 2

Vo (m/h)	6.33
n (l/g)	0.415
Xf (g/l)	3.41

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	6.77
Overflow rate (m/h)	1.36
Influent flow (m ³ /h)	2217.3

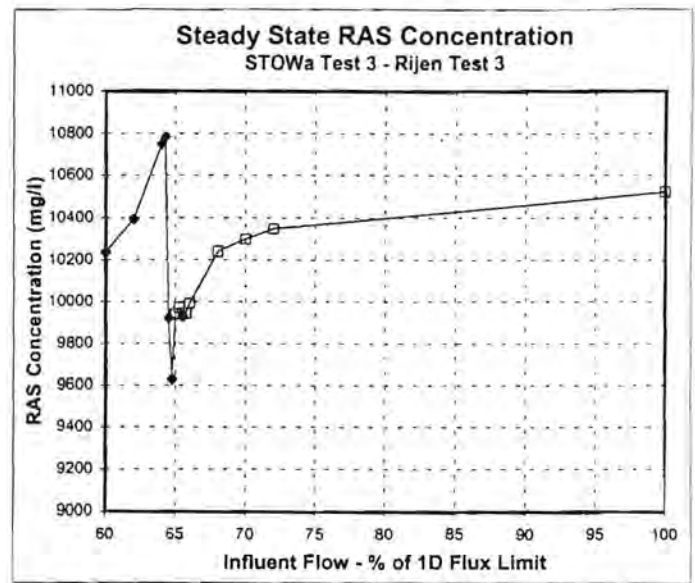
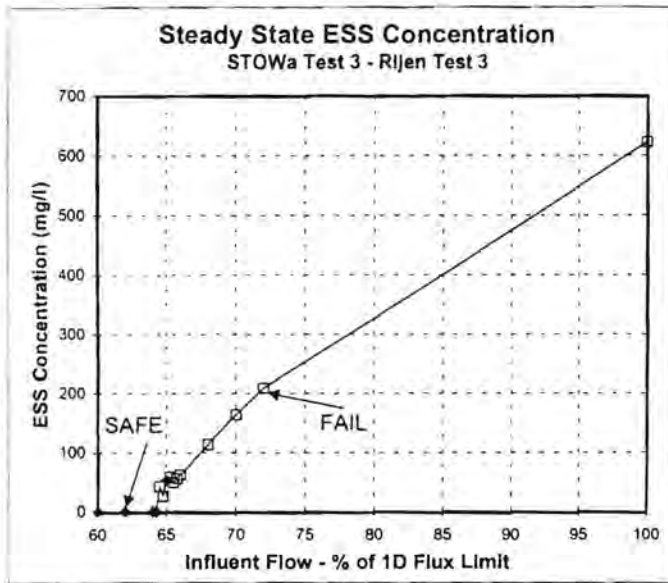
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	4.47
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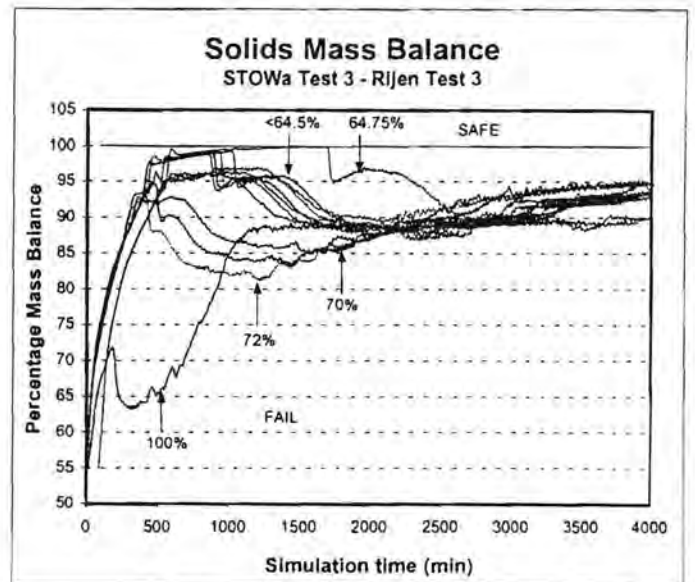
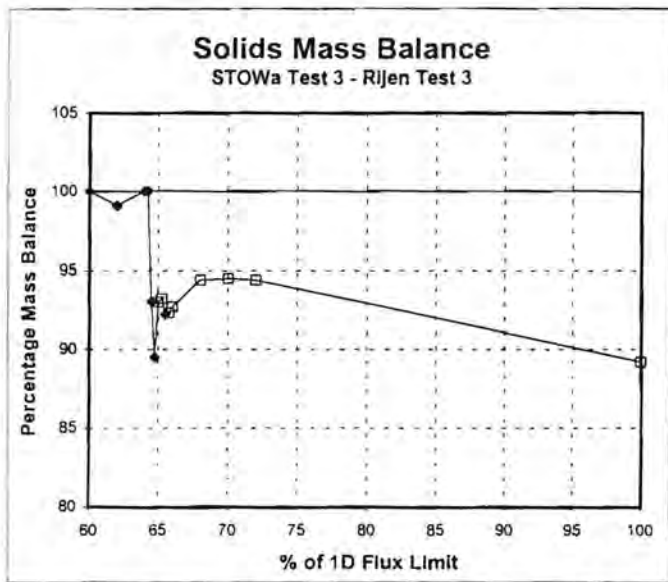
Simulation Data

Recycle flow (m ³ /h)	1009.9
Area (m ²)	1626.2

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	23.20	7859.00	S	99.8
60	23.20	7859.00	S	99.8
62	45.90	7973.00	S	99.8
62.25	47.00	7989.00	S	99.8
62.5	48.00	8005.00	S	99.8
62.75	49.40	8020.00	S	99.8
63	50.90	8037.00	F	99.8
63.25	52.30	8052.00	F	99.7
63.5	53.90	8068.00	F	99.7
63.75	55.40	8084.00	F	99.7
64	56.80	8102.00	F	99.8
66	74.90	8219.00	F	99.7
68	79.20	8351.00	F	99.6
70	130.50	8325.00	F	98.6
72	172.80	8355.00	F	98.0
100	1003.80	7899.00	F	92.7



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 3 simulation on the Rijen SST

STOWa - Test 3

Vo (m/h)	6.53
n (l/g)	0.406
Xf (g/l)	2.5

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	2.71
Overflow rate (m/h)	0.91
Influent flow (m ³ /h)	1476.5

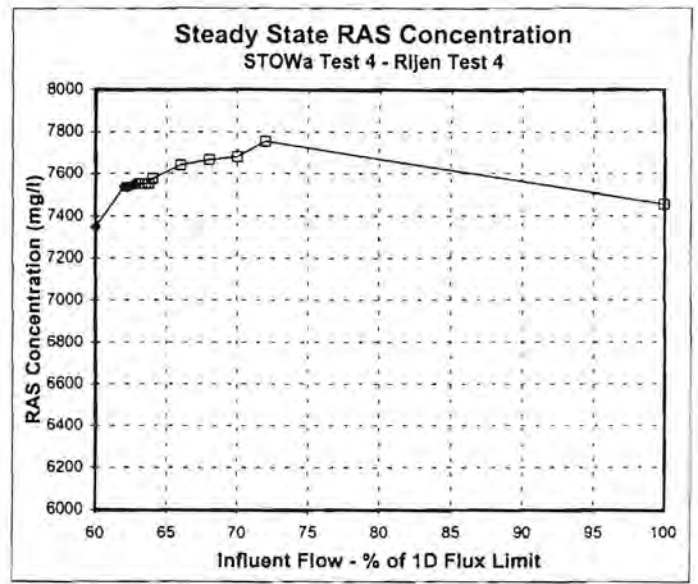
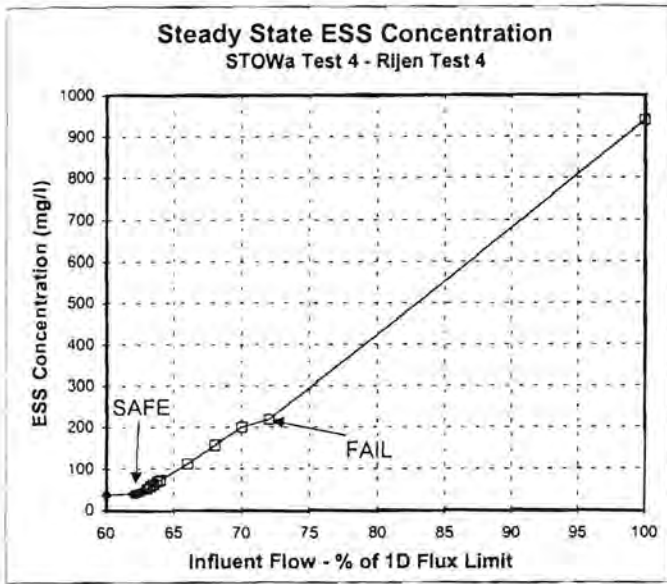
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	6.43
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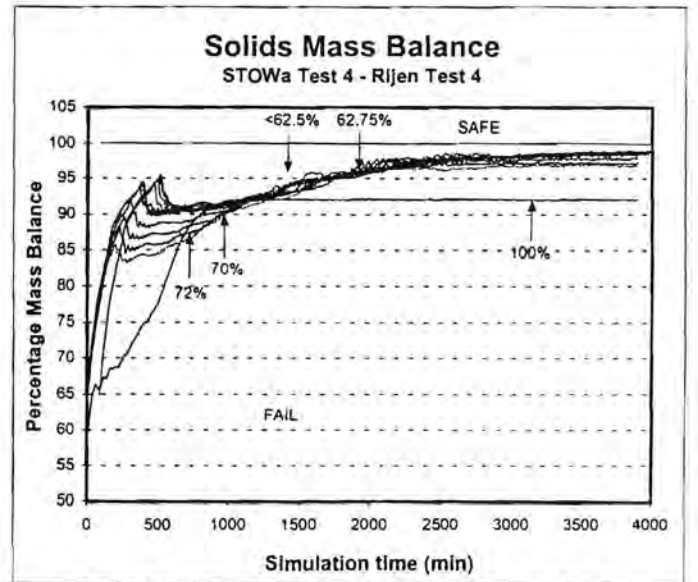
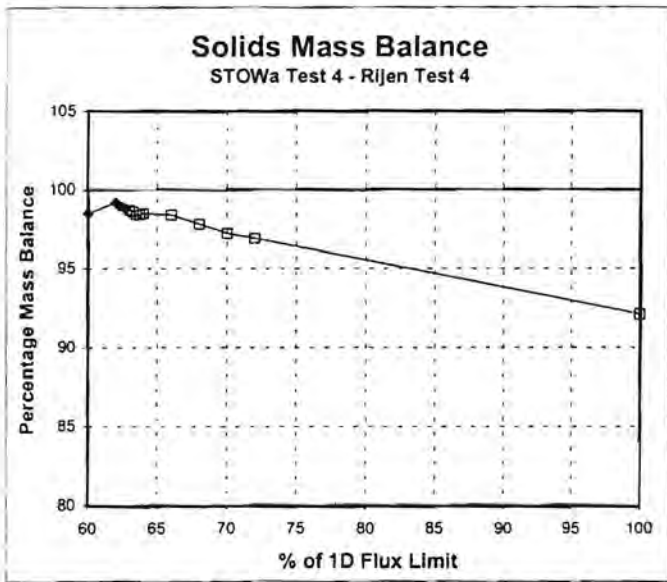
Simulation Data

Recycle flow (m ³ /h)	287.5
Area (m ²)	1626.2

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	0.80	10236.00	S	100.0
60	0.80	10236.00	S	100.0
62	1.10	10394.00	S	99.1
64	0.60	10750.00	S	100.0
64.25	0.60	10782.00	S	100.0
64.5	42.70	9924.00	S	93.0
64.75	26.20	9629.00	S	89.5
65	52.70	9942.00	F	93.0
65.25	58.80	9972.00	F	93.2
65.5	49.20	9932.00	S	92.2
65.75	55.90	9946.00	F	92.3
66	62.50	9992.00	F	92.7
68	113.80	10240.00	F	94.4
70	163.60	10298.00	F	94.5
72	208.50	10349.00	F	94.4
100	623.30	10523.00	F	89.2



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the Rijen SST

STOWa - Test 4

Vo (m/h)	4.86
n (l/g)	0.488
Xf (g/l)	3.2

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	3.38
Overflow rate (m/h)	0.73
Influent flow (m ³ /h)	1189

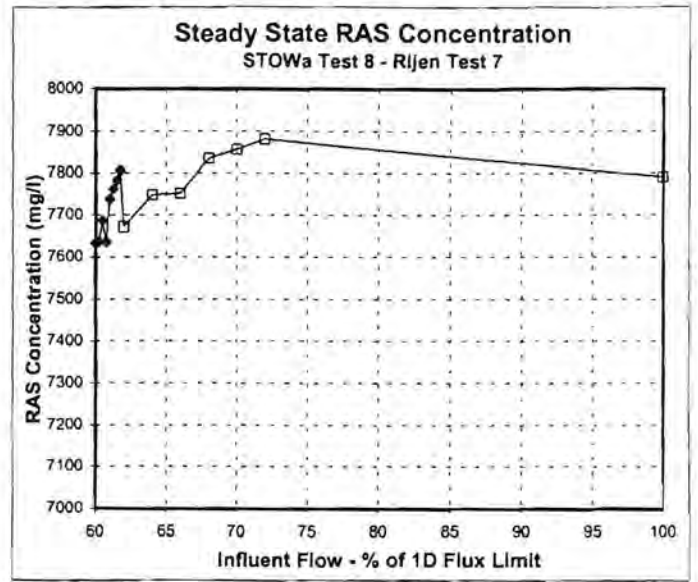
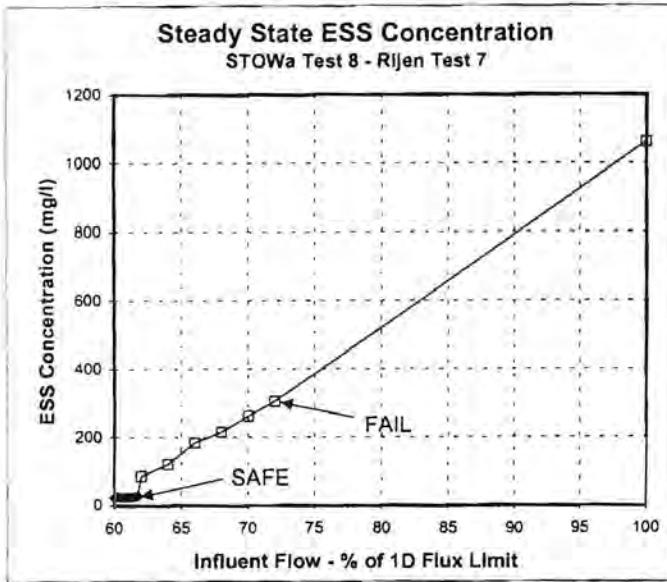
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	3.11
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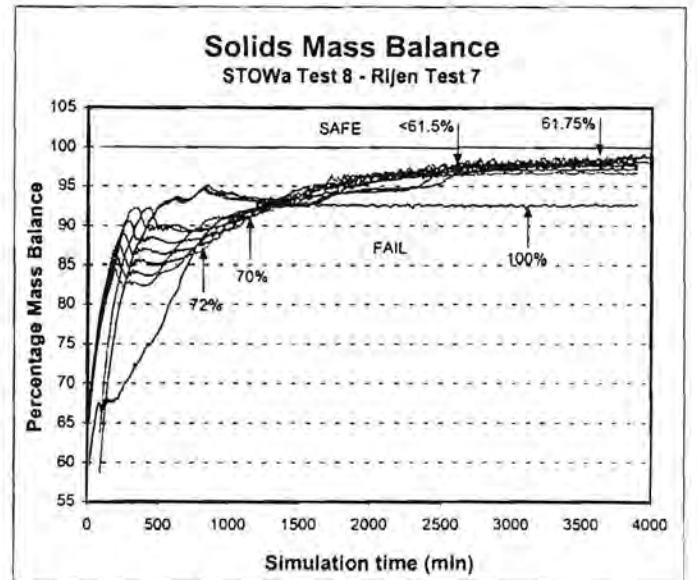
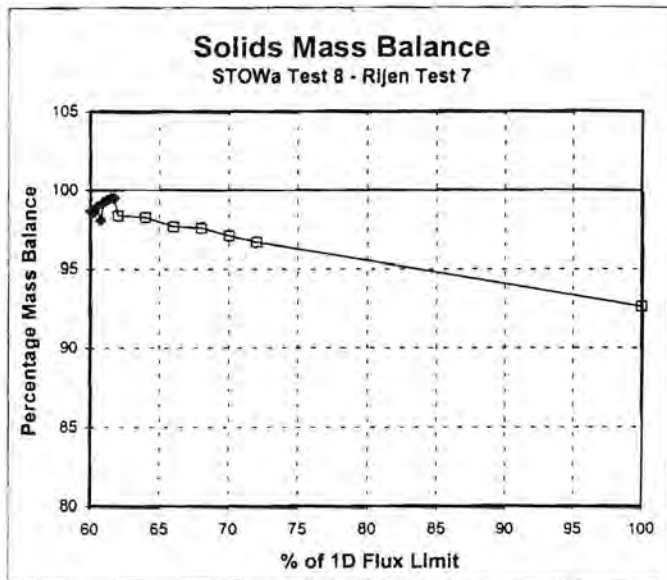
Simulation Data

Recycle flow (m ³ /h)	530.1
Area (m ²)	1626.2

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	35.80	7349.00	S	98.5
60	35.80	7349.00	S	98.5
62	38.20	7537.00	S	99.2
62.25	39.60	7535.00	S	99.0
62.5	41.80	7540.00	S	98.9
62.75	46.60	7548.00	S	98.8
63	50.70	7551.00	F	98.7
63.25	55.70	7550.00	F	98.6
63.5	61.10	7550.00	F	98.4
63.75	68.00	7552.00	F	98.4
64	72.10	7575.00	F	98.5
66	112.00	7641.00	F	98.4
68	156.40	7665.00	F	97.8
70	199.90	7679.00	F	97.2
72	218.90	7754.00	F	96.9
100	937.80	7456.00	F	92.1



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 8 simulation on the Rijen SST

STOWa - Test 8

Vo (m/h)	4.86
n (l/g)	0.488
Xf (g/l)	3.82

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	3.38
Overflow rate (m/h)	0.56
Influent flow (m ³ /h)	910.3

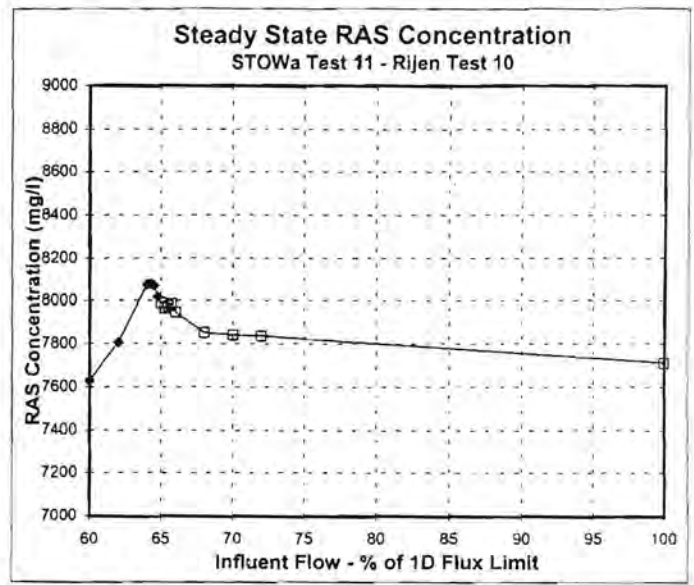
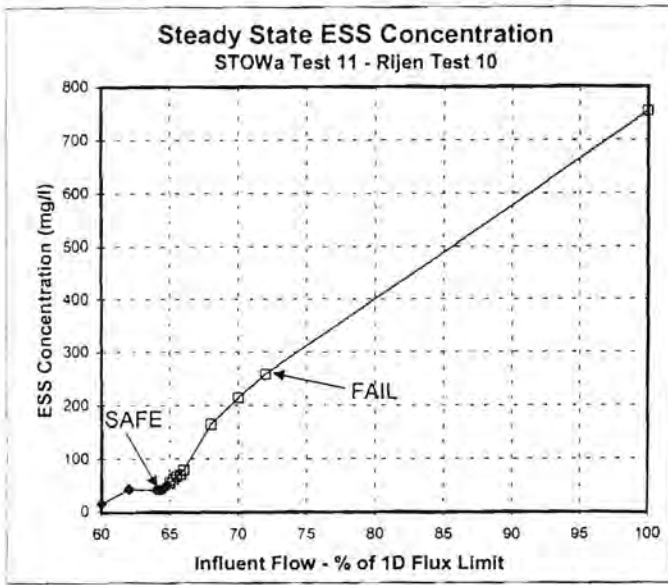
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	2.61
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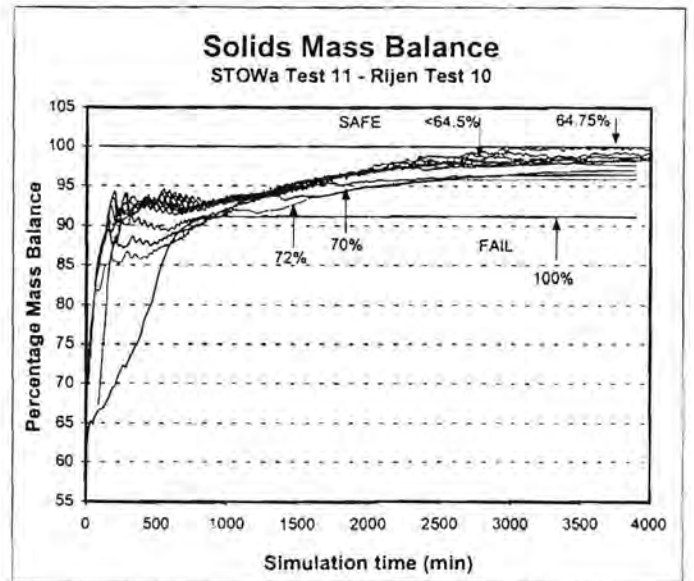
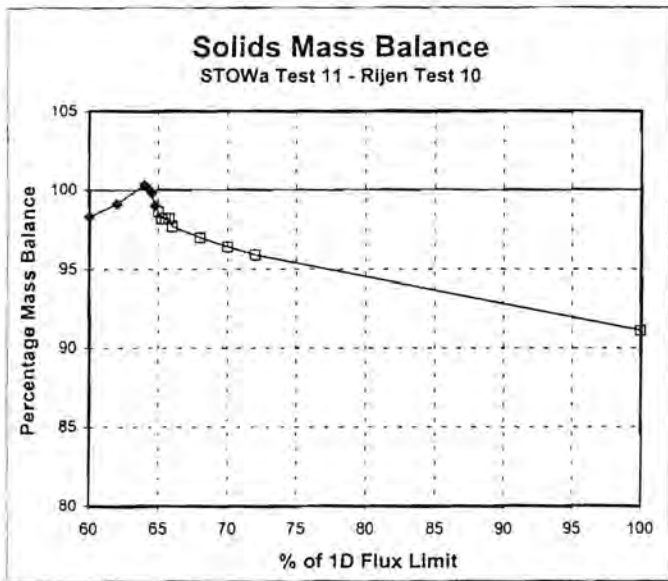
Simulation Data

Recycle flow (m ³ /h)	530.1
Area (m ²)	1626.2

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	23.30	7634.00	S	98.7
60	23.30	7634.00	S	98.7
60.25	25.90	7638.00	S	98.6
60.5	24.20	7687.00	S	99.0
60.75	23.10	7636.00	S	98.1
61	24.00	7738.00	S	99.3
61.25	24.90	7762.00	S	99.4
61.5	25.80	7784.00	S	99.5
61.75	27.30	7806.00	S	99.5
62	85.80	7672.00	F	98.4
64	120.20	7748.00	F	98.3
66	183.90	7752.00	F	97.7
68	214.80	7834.00	F	97.6
70	262.00	7856.00	F	97.1
72	305.20	7881.00	F	96.7
100	1062.00	7791.00	F	92.6



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 10 simulation on the Rijen SST

STOWa - Test 11

Vo (m/h)	5.38
n (l/g)	0.46
Xf (g/l)	2.56

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	3.7
Overflow rate (m/h)	1.12
Influent flow (m ³ /h)	1816.4

Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	4.57
------------------------------------	------

Simulation Data

Recycle flow (m ³ /h)	533.4
Area (m ²)	1626.2

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	15.40	7630.00	S	98.3
60	15.40	7630.00	S	98.3
62	42.90	7806.00	S	99.1
64	41.80	8075.00	S	100.3
64.25	41.50	8076.00	S	100.1
64.5	43.20	8070.00	S	99.8
64.75	49.00	8018.00	S	99.0
65	54.70	7990.00	F	98.6
65.25	60.60	7966.00	F	98.2
65.5	66.40	7977.00	F	98.2
65.75	70.90	7985.00	F	98.2
66	78.70	7948.00	F	97.7
68	165.30	7852.00	F	97.0
70	214.70	7842.00	F	96.4
72	259.20	7836.00	F	95.9
100	753.20	7711.00	F	91.1

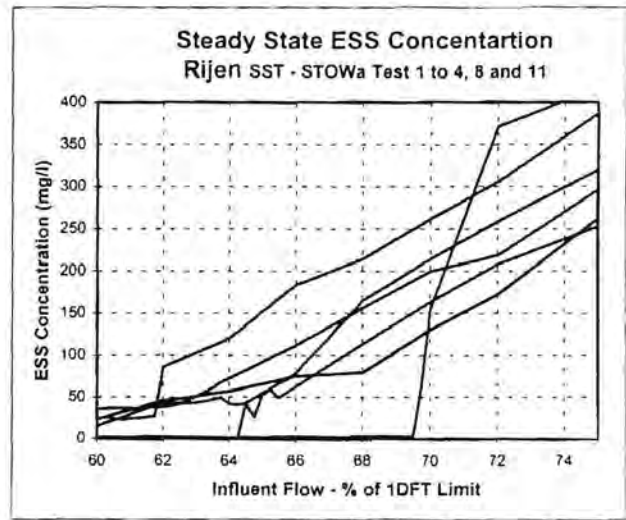
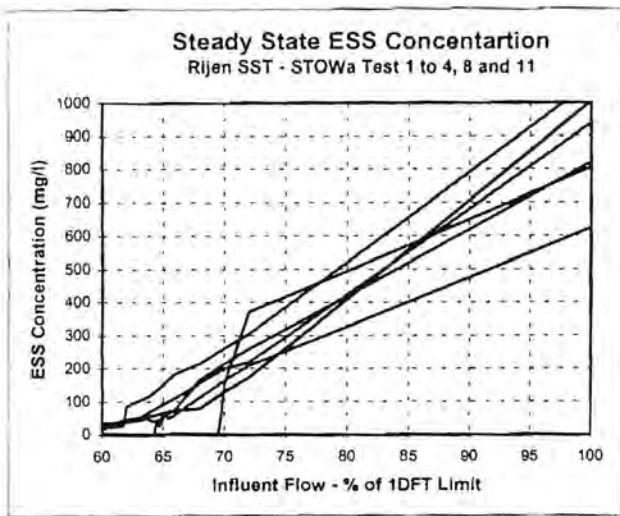


Fig a and b: SettlerCAD predicted ESS concentration versus influent flow (as a % of 1DFT limit) for Rijen SST - Stowa Tests 1, 2, 3, 4, 8 and 11

APPENDIX D
STOWa Results (Oss)



SettlerCAD Predicted Failure Results

PARAMETER	STOWa# Oss Test #	Test 15 Test 1	Test 16 Test 2	Test 17 Test 3	Test 18 Test 4	Test 19 Test 5	Test 20 Test 6	Test 21 Test 7	Test 22 Test 8	Test 23 Test 9	Test 24 Test 10
Flux Factor $[Vo/(n \cdot X_F) - m/h$		2.73	4.42	5.08	7.22	4.20	2.88	2.83	2.24	3.92	3.98
Influent Flow (m3/h) for 1 SST		382.7	1226.9	1204.8	2165.1	1027.3			410.8		
% of 1DFT maximum Q_i		60.25	63.00	66.00	60.50	63.75			61.75		
Overflow Rate (m/h)		0.28	0.89	0.88	1.58	0.75			0.30		
Recycle Flow (m ³ /h)		540.7	844.1	549.0	853.7	550.4			852.3		
Underflow Rate (m/h)		0.395	0.615	0.400	0.622	0.401			0.621		
Recycle Ratio		1.41	0.69	0.46	0.39	0.54			2.07		
Applied Flux (kg SS)/(m ² .h)		3.97	4.68	3.45	4.18	3.03			4.79		
% of 1DFT maximum flux		78.5	74.2	73.9	68.1	73.0			83.2		
Actual Retention Time (h)		3.8	1.7	2.0	1.2	2.2			2.8		
Duration of Run (min)		4000	4000	4000	4000	4000			4000		
Duration of Run (# of Rha)		17.4	39.0	33.0	56.8	29.7			23.8		
Sim time Step (min)		2.5	2.5	2.5	2.5	2.5			2.5		
Sim time Step (%Rha)		1.09	2.44	2.06	3.55	1.86			1.49		
ESS (mg/l)*		64.8	54.9	63.6	50.1	50.9			52.1		
Recycle Conc (mg/l)*		9949	7510	8350	6585	7456			7670		
Mass Balance (%)*		99.2	99.8	98.4	99.9	99.8			99.7		
Test Result (ESS>50mg/l)		Fail	Fail	Fail	Fail	Fail			Fail		

* Mean over the last 2 R_{ss} values

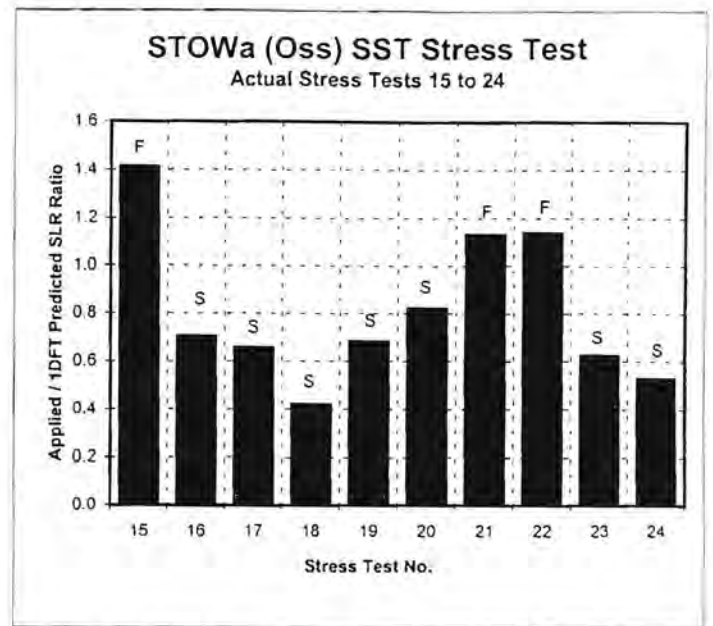
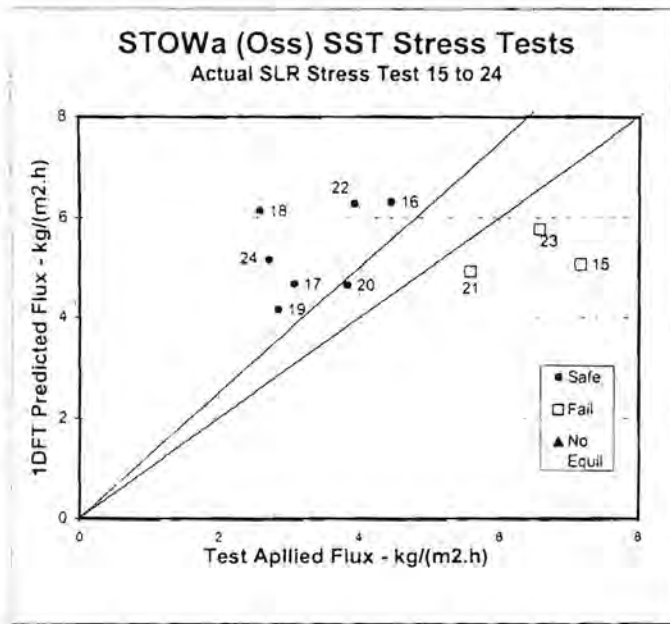
Summary of the SettlerCAD simulation results for the SettlerCAD influent flow limit of Test 15 to 24 for

SettlerCAD Prediction of Actual SLR Tests

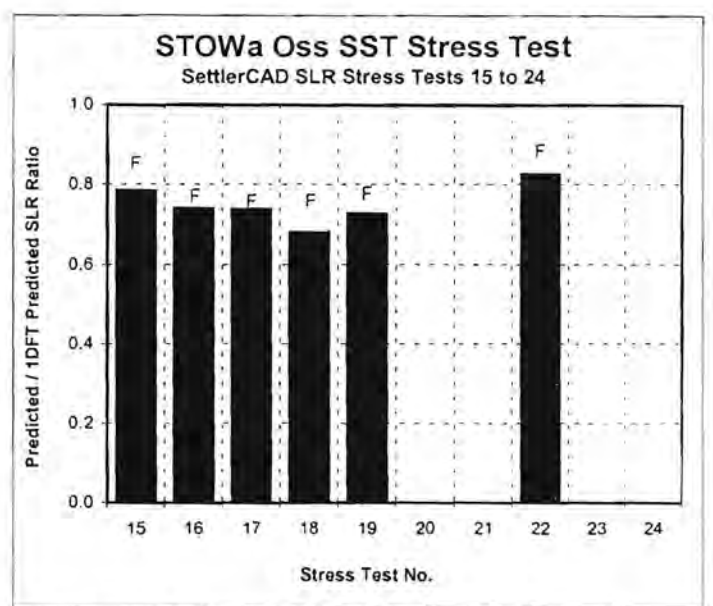
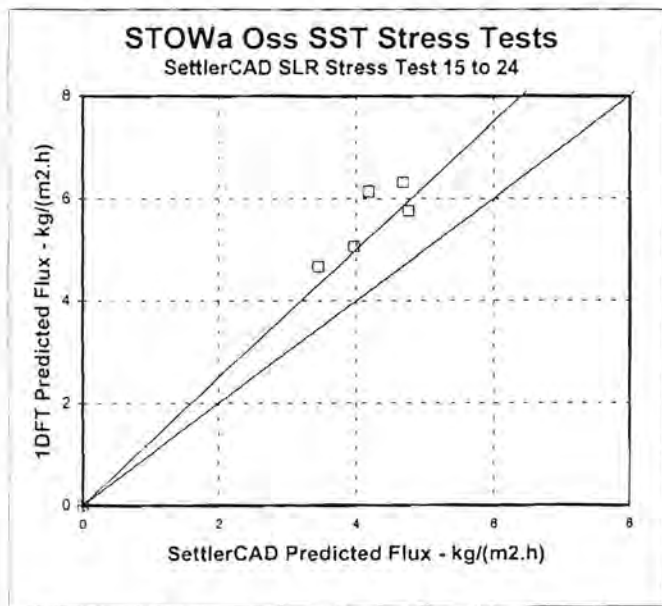
PARAMETER	STOWa# Oss Test #	Test 15 Test 1	Test 16 Test 2	Test 17 Test 3	Test 18 Test 4	Test 19 Test 5	Test 20 Test 6	Test 21 Test 7	Test 22 Test 8	Test 23 Test 9	Test 24 Test 10
Flux Factor $[Vo/(n \cdot X_F) - m/h$		2.73	4.42	5.08	7.22	4.20	2.88	2.83	2.24	3.92	3.98
Influent Flow (m3/h) for 1 SST		1125.4	1125.4	1015.6	1015.6	933.3	933.3	878.4	878.4	700.0	631.3
% of 1DFT maximum Q_i		177.2	57.8	55.6	28.4	57.9	71.1	123.1	132	43.1	32.1
Overflow Rate (m/h)		0.82	0.82	0.74	0.74	0.68	0.68	0.64	0.64	0.51	0.46
Recycle Flow (m ³ /h)		540.7	844.1	549.0	853.7	550.4	850.0	545.8	852.3	841.7	858.3
Underflow Rate (m/h)		0.394	0.615	0.400	0.622	0.401	0.619	0.397	0.621	0.612	0.626
Recycle Ratio		0.480	0.750	0.541	0.841	0.590	0.910	0.620	0.970	1.200	1.361
Applied Flux (kg SS)/(m ² .h)		7.16	4.45	3.08	2.59	2.85	3.83	5.58	6.57	3.93	2.72
% of 1DFT maximum flux		141.7	70.6	65.9	42.2	68.6	82.5	113.1	114.0	62.5	52.7
Actual Retention Time (h)		2.1	1.8	2.3	1.9	2.4	2.0	2.5	2.0	2.3	2.4
Duration of Run (min)		4000	4000	4000	4000	4000			4000		
Duration of Run (# of Rha)		31.4	37.1	29.5	35.2	27.9			32.6		
Sim time Step (min)		2.5	2.5	2.5	2.5	2.5			2.5		
Sim time Step (%Rha)		1.96	2.32	1.84	2.20	1.75			2.04		
ESS (mg/l)*		2768.1	6.3	2.8	0.9	7			2036.3		
Recycle Conc (mg/l)*		10929.8	6.3	7691	4159.4	7105.6			7926		
Mass Balance (%)*		91.8	100	100	100	100			94.8		
Test Result (ESS > 50 mg/l)		Fail	Safe	Safe	Safe	Safe			Fail		
Observed Result		Fail	Safe	Safe	Safe	Safe	Safe	Fail	Fail	Safe	Safe

* Mean over the last 2 R_{ss} values

Summary of the SettlerCAD simulation results for the actual Test 15 to 24 of the STOWa (Oss) results



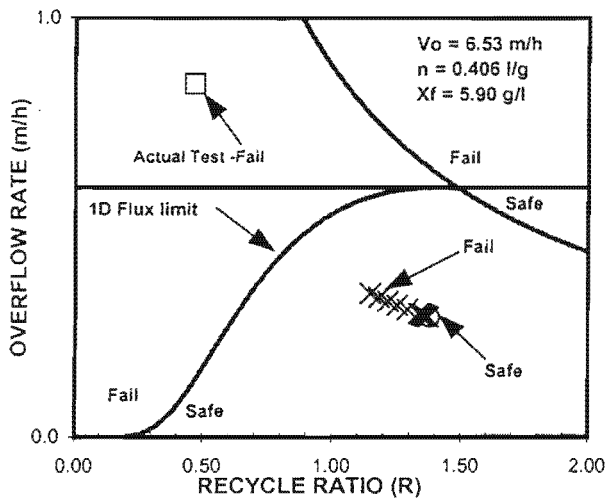
Figs a and b: Calculated 1DFT maximum SLR versus test applied SLR (Fig a, left) and test applied to 1DFT calculated maximum SLR ratios (Fig b, right) for the 10 Stress test reported by STOWa (1981) on the Oss SST



Figs a and b: 1DFT calculated maximum SLR versus SettlerCAD predicted maximum SLR (Figs a, left) and SettlerCAD predicted to 1DFT calculated maximum SLR ratios (Fig b, right) for the 10 stress tests reported by STOWa (1981) on the Oss SST

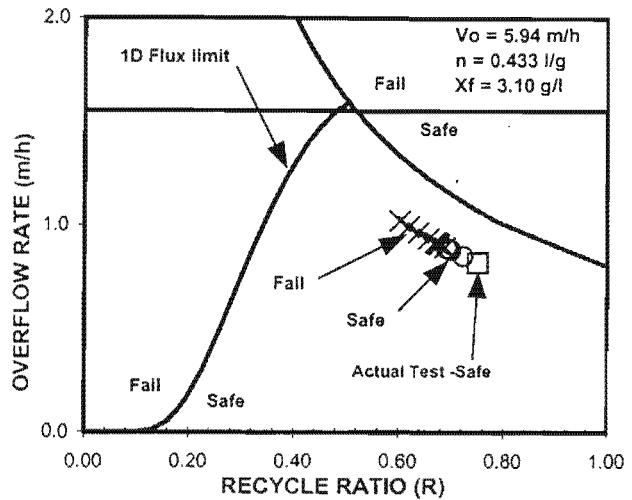
Oss Test 1 - STOWa Test 15

1D Flux Theory (no correction)



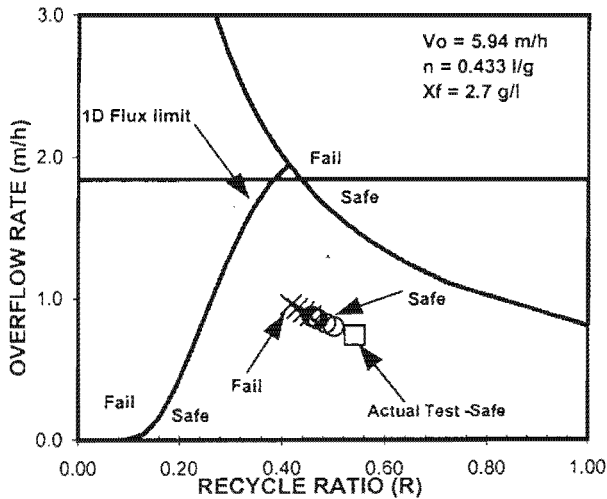
Oss Test 2 - STOWa Test 16

1D Flux Theory (no correction)



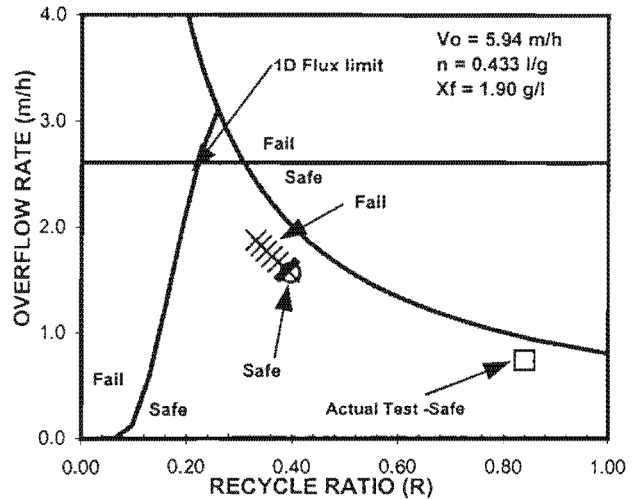
Oss Test 3 - STOWa Test 17

1D Flux Theory (no correction)



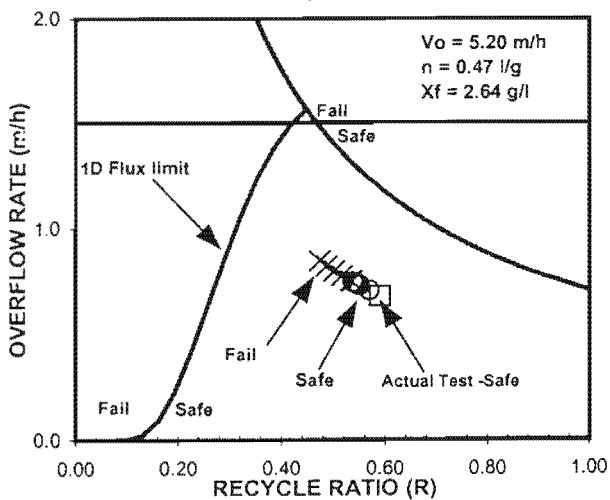
Oss Test 4 - STOWa Test 18

1D Flux Theory (no correction)



Oss Test 5 - STOWa Test 19

1D Flux Theory (no correction)



Oss Test 8 - STOWa Test 22

1D Flux Theory (no correction)

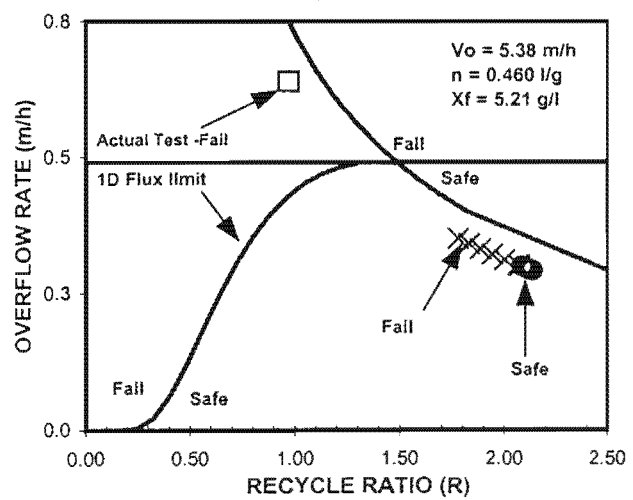


Fig a to f: 1DFT D&O charts showing the SST operating positions and results (Safe, Fail) of the SettlerCAD runs and actual tests

Xf = 5.9 kgMLSS/m³
 Va = 6.53 m/h
 n= 0.406 m³/kg
 Qr= 540.7 m³/h
 Qi (1D Flux Limit) 853.3 m³/h
 A= 1372.0 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	540.7	0.00	0.00	0.00000	1.0000	0.0000	0.5951	88.3739
F	72	470.4	540.7	0.34	1.15	0.06452	0.9480	0.0000	0.5951	13.6980
F	70	457.3	540.7	0.33	1.18	0.12903	0.8995	0.0000	0.5951	6.8490
F	68	444.2	540.7	0.32	1.22	0.19355	0.8539	0.0005	0.5951	4.5660
F	66	431.2	540.7	0.31	1.25	0.25806	0.8108	0.0062	0.5951	3.4245
F	64	418.1	540.7	0.30	1.29	0.32258	0.7699	0.0262	0.5951	2.7396
F	62	405.0	540.7	0.30	1.33	0.38710	0.7307	0.0645	0.5951	2.2830
F	61.75	403.4	540.7	0.29	1.34	0.45161	0.6932	0.1178	0.5951	1.9569
F	61.5	401.8	540.7	0.29	1.35	0.51613	0.6569	0.1796	0.5951	1.7122
F	61.25	400.1	540.7	0.29	1.35	0.58065	0.6218	0.2437	0.5951	1.5220
F	61	398.5	540.7	0.29	1.36	0.64516	0.5875	0.3054	0.5951	1.3698
F	60.75	396.9	540.7	0.29	1.36	0.70968	0.5539	0.3620	0.5951	1.2453
F	60.5	395.2	540.7	0.29	1.37	0.77419	0.5209	0.4119	0.5951	1.1415
F	60.25	393.6	540.7	0.29	1.37	0.83871	0.4882	0.4548	0.5951	1.0537
S	60	392.0	540.7	0.29	1.38	0.90323	0.4555	0.4907	0.5951	0.9784
S	60	392.0	540.7	0.29	1.38	0.96774	0.4228	0.5202	0.5951	0.9132
S	60	392.0	540.7	0.29	1.38	1.03226	0.3896	0.5437	0.5951	0.8561
Actual (F)	177.2	1157.6	540.7	0.84	0.47	1.09677	0.3557	0.5620	0.5951	0.8058
						1.16129	0.3206	0.5757	0.5951	0.7610
						1.22581	0.2835	0.5854	0.5951	0.7209
						1.29032	0.2434	0.5915	0.5951	0.6849
						1.35484	0.1981	0.5946	0.5951	0.6523
						1.41935	0.1426	0.5949	0.5951	0.6226
						1.48387	0.0492	0.5926	0.5951	0.5956
						1.54839	#NUM!	#NUM!	0.5951	0.5707
						1.61290	#NUM!	#NUM!	0.5951	0.5479
						1.67742	#NUM!	#NUM!	0.5951	0.5268
						1.74194	#NUM!	#NUM!	0.5951	0.5073
						1.80645	#NUM!	#NUM!	0.5951	0.4892
						1.87097	#NUM!	#NUM!	0.5951	0.4723
						2.00000	#NUM!	#NUM!	0.5951	0.4419

Construct D&O Chart chart: STOWa Test 16

Xf = 3.1 kgMLSS/m³
 Vo = 5.94 m/h
 n = 0.433 m³/kg
 Qr = 844.1 m³/h
 Qi (1D Flux Limit) = 1947.4 m³/h
 A = 1372 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	844.1	0.00	0.00	0.00000	1.0000	0.0000	1.5518	80.3892
F	72	1402.1	844.1	1.02	0.60	0.03225	0.9523	0.0000	1.5518	24.9269
F	70	1363.2	844.1	0.99	0.62	0.06450	0.9052	0.0000	1.5518	12.4634
F	68	1324.2	844.1	0.97	0.64	0.09675	0.8586	0.0006	1.5518	8.3090
F	66	1285.3	844.1	0.94	0.66	0.12900	0.8121	0.0106	1.5518	6.2317
F	64	1246.3	844.1	0.91	0.68	0.16125	0.7656	0.0546	1.5518	4.9854
F	64.75	1260.9	844.1	0.92	0.67	0.19350	0.7189	0.1525	1.5518	4.1545
F	64.5	1256.1	844.1	0.92	0.67	0.22575	0.6717	0.3030	1.5518	3.5610
F	64.25	1251.2	844.1	0.91	0.67	0.25800	0.6236	0.4892	1.5518	3.1159
F	63	1226.9	844.1	0.89	0.69	0.29025	0.5741	0.6905	1.5518	2.7697
S	62.75	1222.0	844.1	0.89	0.69	0.32250	0.5228	0.8893	1.5518	2.4927
S	62.5	1217.1	844.1	0.89	0.69	0.35475	0.4687	1.0731	1.5518	2.2661
S	62.25	1212.3	844.1	0.88	0.70	0.38700	0.4105	1.2345	1.5518	2.0772
S	62	1207.4	844.1	0.88	0.70	0.42570	0.3320	1.3936	1.5518	1.8884
S	60	1168.4	844.1	0.85	0.72	0.43215	0.3175	1.4163	1.5518	1.8602
S	60	1168.4	844.1	0.85	0.72	0.43860	0.3024	1.4378	1.5518	1.8329
S	60	1168.4	844.1	0.85	0.72	0.44505	0.2867	1.4583	1.5518	1.8063
Actual (S)	57.8	1125.6	844.1	0.82	0.75	0.47730	0.1929	1.5434	1.5518	1.6842
						0.48730	0.1538	1.5639	1.5518	1.6497
						0.49730	0.1013	1.5811	1.5518	1.6165
						0.50730	#NUM!	#NUM!	1.5518	1.5846
						0.53955	#NUM!	#NUM!	1.5518	1.4899
						0.57180	#NUM!	#NUM!	1.5518	1.4059
						0.60405	#NUM!	#NUM!	1.5518	1.3308
						0.63630	#NUM!	#NUM!	1.5518	1.2634
						0.66855	#NUM!	#NUM!	1.5518	1.2024
						0.70080	#NUM!	#NUM!	1.5518	1.1471
						0.73305	#NUM!	#NUM!	1.5518	1.0966
						0.76530	#NUM!	#NUM!	1.5518	1.0504
						0.79755	#NUM!	#NUM!	1.5518	1.0080
						1.00000	#NUM!	#NUM!	1.5518	0.8039

Construct D&O Chart chart: STOWa Test 17

Xf = 2.7 kgMLSS/m³
 Vo = 5.94 m/h
 n = 0.433 m³/kg
 Qr = 549 m³/h
 Qi (1D Flux Limit) = 1825.5 m³/h
 A = 1372 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	549	0.00	0.00	0.00000	1.0000	0.0000	1.8452	80.3892
F	72	1314.4	549	0.96	0.42	0.03225	0.9450	0.0000	1.8452	24.9269
F	70	1277.9	549	0.93	0.43	0.06450	0.8903	0.0000	1.8452	12.4634
F	68	1241.3	549	0.90	0.44	0.09675	0.8356	0.0036	1.8452	8.3090
F	66	1204.8	549	0.88	0.46	0.12900	0.7804	0.0413	1.8452	6.2317
S	65.75	1200.3	549	0.87	0.46	0.16125	0.7245	0.1622	1.8452	4.9854
S	65.5	1195.7	549	0.87	0.46	0.19350	0.6673	0.3770	1.8452	4.1545
S	65.25	1191.1	549	0.87	0.46	0.22575	0.6082	0.6556	1.8452	3.5610
S	65	1186.6	549	0.86	0.46	0.25800	0.5462	0.9563	1.8452	3.1159
S	64.75	1182.0	549	0.86	0.46	0.29025	0.4799	1.2447	1.8452	2.7697
S	64.5	1177.4	549	0.86	0.47	0.32250	0.4070	1.4988	1.8452	2.4927
S	64.25	1172.9	549	0.85	0.47	0.32788	0.3939	1.5369	1.8452	2.4518
S	64	1168.3	549	0.85	0.47	0.33235	0.3828	1.5676	1.8452	2.4188
S	62	1131.8	549	0.82	0.49	0.33609	0.3733	1.5925	1.8452	2.3919
S	60	1095.3	549	0.80	0.50	0.33920	0.3652	1.6127	1.8452	2.3700
S	60	1095.3	549	0.80	0.50	0.34179	0.3584	1.6292	1.8452	2.3520
S	60	1095.3	549	0.80	0.50	0.34395	0.3527	1.6427	1.8452	2.3372
Actual (S)	55.6	1015.0	549	0.74	0.54	0.34575	0.3478	1.6538	1.8452	2.3251
						0.37800	0.2479	1.8252	1.8452	2.1267
						0.41025	0.0684	1.9403	1.8452	1.9595
						0.44250	#NUM!	#NUM!	1.8452	1.8167
						0.47475	#NUM!	#NUM!	1.8452	1.6933
						0.50700	#NUM!	#NUM!	1.8452	1.5856
						0.53925	#NUM!	#NUM!	1.8452	1.4908
						0.57150	#NUM!	#NUM!	1.8452	1.4066
						0.60375	#NUM!	#NUM!	1.8452	1.3315
						0.63600	#NUM!	#NUM!	1.8452	1.2640
						0.66825	#NUM!	#NUM!	1.8452	1.2030
						0.70050	#NUM!	#NUM!	1.8452	1.1476
						0.73275	#NUM!	#NUM!	1.8452	1.0971
						1.00000	#NUM!	#NUM!	1.8452	0.8039

Construct D&O Chart chart: STOWa Test 18

Xf = 1.9 kgMLSS/m³
 Vo = 5.94 m/h
 n= 0.433 m³/kg
 Qr= 853.7 m³/h
 Qi (1D Flux Limit) 3578.7 m³/h
 A= 1372 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	853.7	0.00	0.00	0.00000	1.0000	0.0000	2.6091	80.3892
F	72	2576.7	853.7	1.88	0.33	0.03225	0.9209	0.0000	2.6091	24.9269
F	70	2505.1	853.7	1.83	0.34	0.06450	0.8399	0.0040	2.6091	12.4634
F	68	2433.5	853.7	1.77	0.35	0.09675	0.7557	0.1228	2.6091	8.3090
F	66	2361.9	853.7	1.72	0.36	0.12900	0.6667	0.5706	2.6091	6.2317
F	64	2290.4	853.7	1.67	0.37	0.16125	0.5700	1.2849	2.6091	4.9854
F	62	2218.8	853.7	1.62	0.38	0.19350	0.4601	2.0432	2.6091	4.1545
F	61.75	2209.8	853.7	1.61	0.39	0.22575	0.3233	2.6781	2.6091	3.5610
F	61.5	2200.9	853.7	1.60	0.39	0.25800	0.0534	3.0974	2.6091	3.1159
F	61.25	2192.0	853.7	1.60	0.39	0.29025	#NUM!	#NUM!	2.6091	2.7697
F	61	2183.0	853.7	1.59	0.39	0.32250	#NUM!	#NUM!	2.6091	2.4927
F	60.75	2174.1	853.7	1.58	0.39	0.35475	#NUM!	#NUM!	2.6091	2.2661
F	60.5	2165.1	853.7	1.58	0.39	0.38700	#NUM!	#NUM!	2.6091	2.0772
S	60.25	2156.2	853.7	1.57	0.40	0.42570	#NUM!	#NUM!	2.6091	1.8884
S	60	2147.2	853.7	1.57	0.40	0.43215	#NUM!	#NUM!	2.6091	1.8602
S	60	2147.2	853.7	1.57	0.40	0.43860	#NUM!	#NUM!	2.6091	1.8329
S	60	2147.2	853.7	1.57	0.40	0.44505	#NUM!	#NUM!	2.6091	1.8063
Actual (S)	28.4	1016.4	853.7	0.74	0.84	0.47730	#NUM!	#NUM!	2.6091	1.6842
						0.50955	#NUM!	#NUM!	2.6091	1.5777
						0.54180	#NUM!	#NUM!	2.6091	1.4837
						0.57405	#NUM!	#NUM!	2.6091	1.4004
						0.60630	#NUM!	#NUM!	2.6091	1.3259
						0.63855	#NUM!	#NUM!	2.6091	1.2589
						0.67080	#NUM!	#NUM!	2.6091	1.1984
						0.70305	#NUM!	#NUM!	2.6091	1.1434
						0.73530	#NUM!	#NUM!	2.6091	1.0933
						0.76755	#NUM!	#NUM!	2.6091	1.0473
						0.79980	#NUM!	#NUM!	2.6091	1.0051
						0.83205	#NUM!	#NUM!	2.6091	0.9662
						0.86430	#NUM!	#NUM!	2.6091	0.9301
						1.00000	#NUM!	#NUM!	2.6091	0.8039

Construct D&O Chart chart: STOWa Test 19

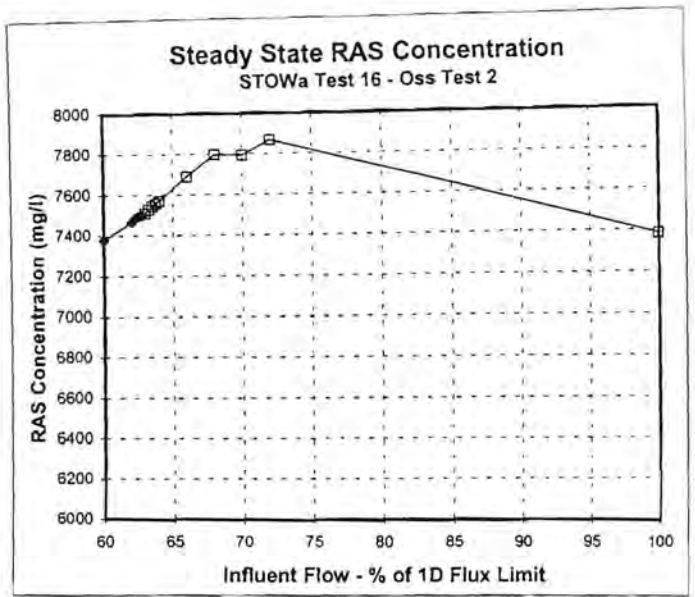
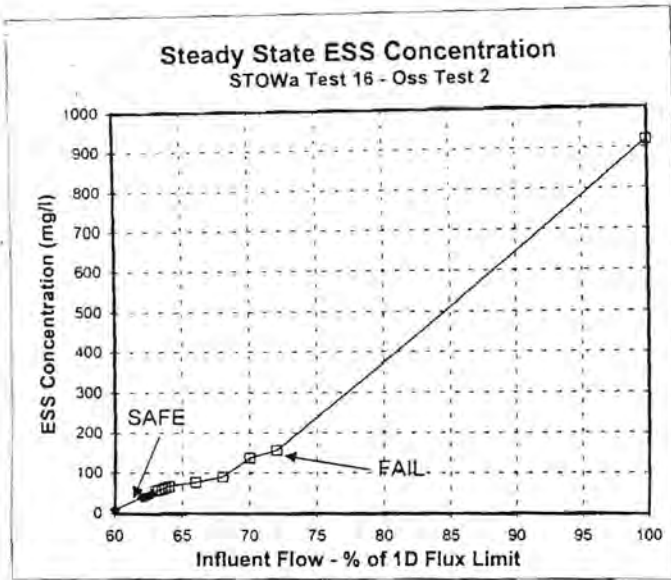
Xf = 2.64 kgMLSS/m³
 Vo = 5.20 m/h
 n = 0.47 m³/kg
 Qr = 550.4 m³/h
 Qi (1D Flux Limit) 1611.5 m³/h
 A = 1372 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	550.4	0.00	0.00	0.00000	1.0000	0.0000	1.5036	70.3743
F	72	1160.3	550.4	0.85	0.47	0.03225	0.9483	0.0000	1.5036	21.8215
F	70	1128.1	550.4	0.82	0.49	0.06450	0.8970	0.0000	1.5036	10.9108
F	68	1095.8	550.4	0.80	0.50	0.09675	0.8459	0.0015	1.5036	7.2738
F	66	1063.6	550.4	0.78	0.52	0.12900	0.7948	0.0207	1.5036	5.4554
F	64	1031.4	550.4	0.75	0.53	0.16125	0.7432	0.0907	1.5036	4.3643
F	63.75	1027.3	550.4	0.75	0.54	0.19350	0.6909	0.2277	1.5036	3.6369
S	63.5	1023.3	550.4	0.75	0.54	0.22575	0.6374	0.4185	1.5036	3.1174
S	63.25	1019.3	550.4	0.74	0.54	0.25800	0.5821	0.6369	1.5036	2.7277
S	63	1015.2	550.4	0.74	0.54	0.29025	0.5242	0.8576	1.5036	2.4246
S	62.75	1011.2	550.4	0.74	0.54	0.32250	0.4625	1.0624	1.5036	2.1822
S	62.5	1007.2	550.4	0.73	0.55	0.35475	0.3948	1.2403	1.5036	1.9838
S	62.25	1003.2	550.4	0.73	0.55	0.38700	0.3170	1.3858	1.5036	1.8185
S	62	999.1	550.4	0.73	0.55	0.41925	0.2184	1.4964	1.5036	1.6786
S	60	966.9	550.4	0.70	0.57	0.42925	0.1784	1.5232	1.5036	1.6395
S	60	966.9	550.4	0.70	0.57	0.43925	0.1270	1.5461	1.5036	1.6021
S	60	966.9	550.4	0.70	0.57	0.44025	0.1208	1.5482	1.5036	1.5985
Actual (S)	57.9	933.1	550.4	0.68	0.59	0.44125	0.1142	1.5502	1.5036	1.5949
						0.44225	0.1071	1.5522	1.5036	1.5913
						0.48225	#NUM!	#NUM!	1.5036	1.4593
						0.52225	#NUM!	#NUM!	1.5036	1.3475
						0.56225	#NUM!	#NUM!	1.5036	1.2517
						0.60225	#NUM!	#NUM!	1.5036	1.1685
						0.64225	#NUM!	#NUM!	1.5036	1.0957
						0.68225	#NUM!	#NUM!	1.5036	1.0315
						0.72225	#NUM!	#NUM!	1.5036	0.9744
						0.76225	#NUM!	#NUM!	1.5036	0.9232
						0.80225	#NUM!	#NUM!	1.5036	0.8772
						0.84225	#NUM!	#NUM!	1.5036	0.8356
						0.88225	#NUM!	#NUM!	1.5036	0.7977
						1.00000	#NUM!	#NUM!	1.5036	0.7037

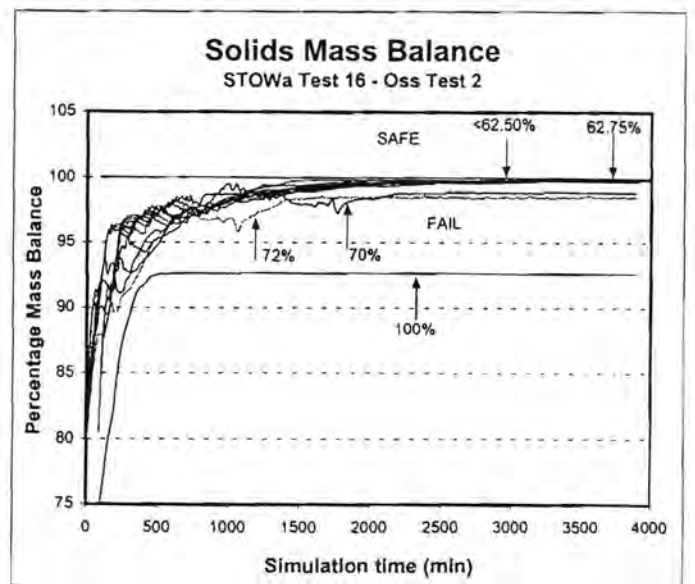
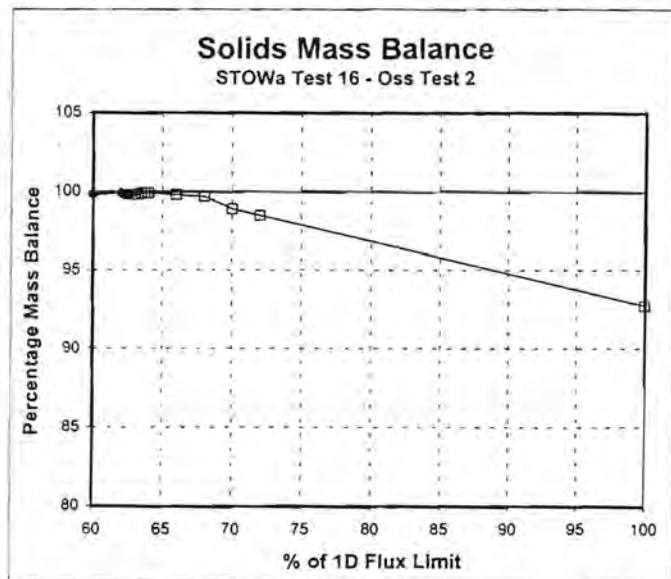
Construct D&O Chart chart: STOWa Test 22

Xf = 5.21 kgMLSS/m³
 Vo = 5.38 m/h
 n = 0.46 m³/kg
 Qr = 852.3 m³/h
 Qi (1D Flux Limit) = 665.3 m³/h
 A = 1372 m²

SettlerCAD Results	% of 1D Flux Limit (%)	Influent Flow Qi (m ³ /h)	Recycle Flow Qr (m ³ /h)	Overflow rate (m/d) Qi/A	Recycle rate (m ³ /d) Qr/Qi = s	Recycle ratio Qr/Qi s	alfa	Criterion 1 Thickening Qi/A (m/d)	Criterion 2 Clarification Qi/A (m/d)	Hyperbola Qi/A (m/d)
	0	0.0	852.3	0.00	0.00	0.00000	1.0000	0.0000	0.4897	72.8104
F	72	479.0	852.3	0.35	1.78	0.08065	0.9357	0.0000	0.4897	9.0285
F	70	465.7	852.3	0.34	1.83	0.16129	0.8765	0.0000	0.4897	4.5142
F	68	452.4	852.3	0.33	1.88	0.24194	0.8215	0.0031	0.4897	3.0095
F	66	439.1	852.3	0.32	1.94	0.32258	0.7700	0.0215	0.4897	2.2571
F	64	425.8	852.3	0.31	2.00	0.40323	0.7214	0.0629	0.4897	1.8057
F	62	412.5	852.3	0.30	2.07	0.48387	0.6751	0.1216	0.4897	1.5047
F	61.75	410.8	852.3	0.30	2.07	0.56452	0.6307	0.1871	0.4897	1.2898
S	61.5	409.2	852.3	0.30	2.08	0.64516	0.5878	0.2510	0.4897	1.1286
S	61.25	407.5	852.3	0.30	2.09	0.72581	0.5460	0.3084	0.4897	1.0032
S	61	405.8	852.3	0.30	2.10	0.80645	0.5049	0.3570	0.4897	0.9028
S	60.75	404.2	852.3	0.29	2.11	0.88710	0.4641	0.3967	0.4897	0.8208
S	60.5	402.5	852.3	0.29	2.12	0.96774	0.4233	0.4278	0.4897	0.7524
S	60.25	400.8	852.3	0.29	2.13	1.04839	0.3818	0.4514	0.4897	0.6945
S	60	399.2	852.3	0.29	2.14	1.12903	0.3390	0.4684	0.4897	0.6449
S	60	399.2	852.3	0.29	2.14	1.20968	0.2938	0.4799	0.4897	0.6019
S	60	399.2	852.3	0.29	2.14	1.29032	0.2443	0.4867	0.4897	0.5643
Actual (F)	132	878.2	852.3	0.64	0.97	1.37097	0.1869	0.4896	0.4897	0.5311
						1.45161	0.1084	0.4889	0.4897	0.5016
						1.46161	0.0948	0.4886	0.4897	0.4982
						1.47161	0.0791	0.4883	0.4897	0.4948
						1.48161	0.0594	0.4878	0.4897	0.4914
						1.49161	0.0288	0.4873	0.4897	0.4881
						1.50161	#NUM!	#NUM!	0.4897	0.4849
						1.51161	#NUM!	#NUM!	0.4897	0.4817
						1.52161	#NUM!	#NUM!	0.4897	0.4785
						1.60226	#NUM!	#NUM!	0.4897	0.4544
						1.68290	#NUM!	#NUM!	0.4897	0.4326
						1.76355	#NUM!	#NUM!	0.4897	0.4129
						1.84419	#NUM!	#NUM!	0.4897	0.3948
						2.50000	#NUM!	#NUM!	0.4897	0.2912



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 2 simulation on the Oss SST

STOWa - Test 16

Vo (m/h)	5.94
n (l/g)	0.433
Xf (g/l)	3.1

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	6.31
Overflow rate (m/h)	1.42
Influent flow (m ³ /h)	1947.4

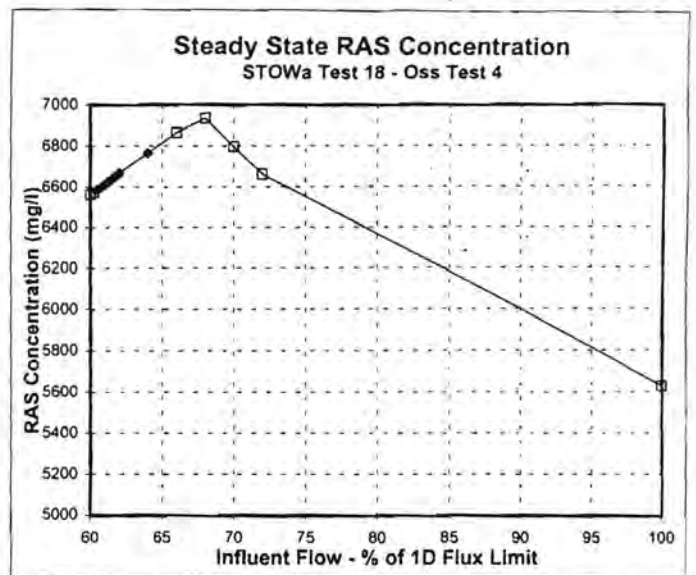
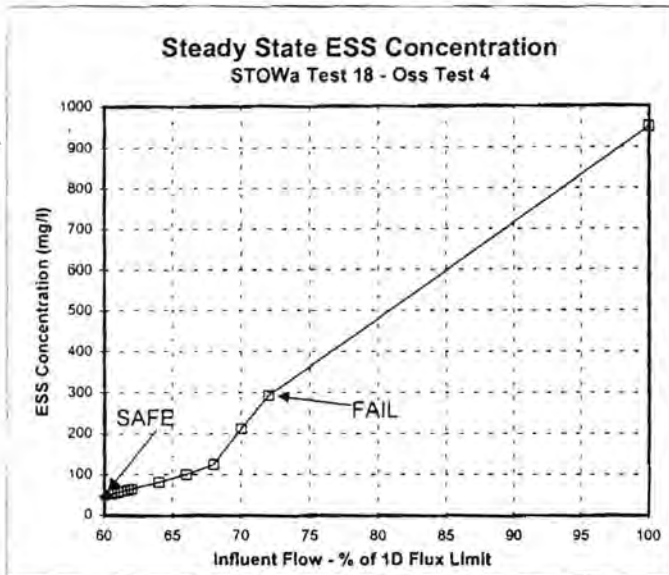
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	4.43
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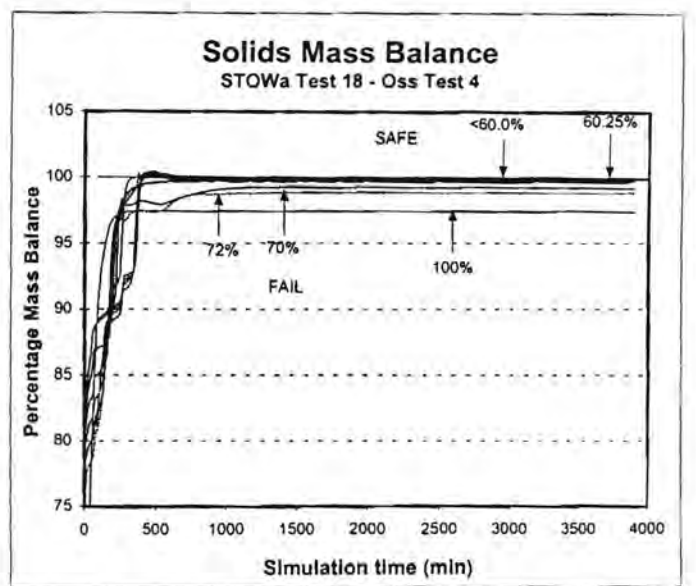
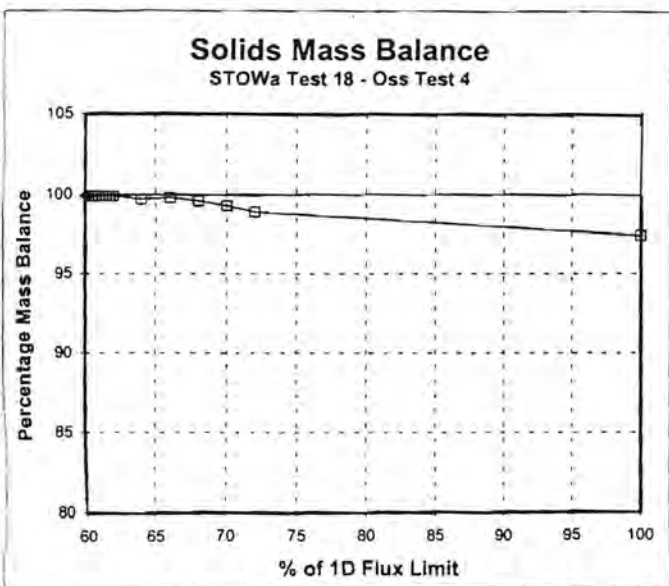
Simulation Data

Recycle flow (m ³ /h)	844.1
Area (m ²)	1372

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	9.20	7377.00	S	100.0
60	9.20	7377.00	S	99.8
62	39.50	7466.00	S	99.9
62.25	41.30	7483.00	S	99.8
62.5	44.00	7495.00	S	99.8
62.75	48.80	7499.00	S	99.8
63	54.90	7510.00	F	99.8
63.25	57.60	7528.00	F	99.8
63.5	60.00	7544.00	F	99.9
63.75	63.00	7557.00	F	99.9
64	66.70	7569.00	F	99.9
66	76.60	7689.00	F	99.8
68	90.20	7797.00	F	99.7
70	137.10	7794.00	F	98.9
72	155.90	7869.00	F	98.5
100	918.70	7382.00	F	92.7



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 4 simulation on the Oss SST

STOWa - Test 18

Vo (m/h)	5.94
n (l/g)	0.433
Xf (g/l)	1.9

1DFT predicted limits

Maximum flux [kg/(m ² .h)]	6.14
Overflow rate (m/h)	2.61
Influent flow (m ³ /h)	3578.7

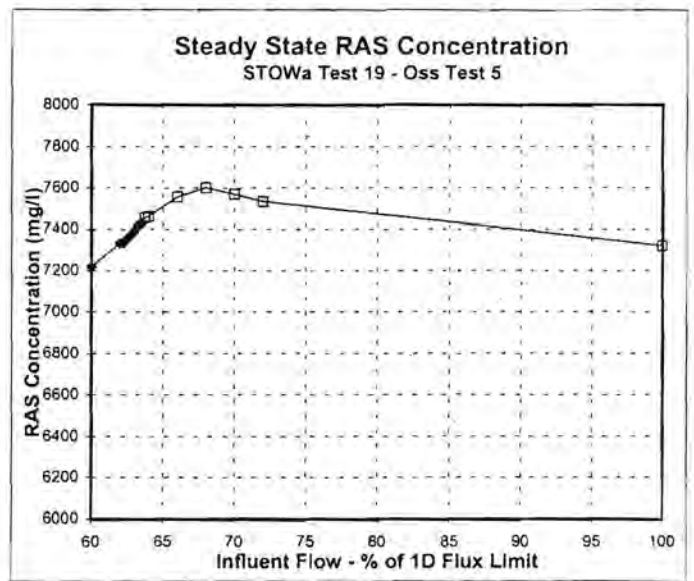
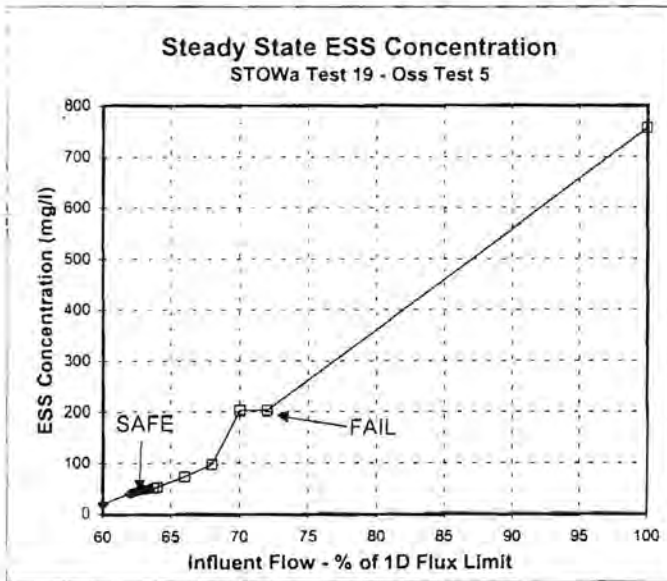
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	7.22
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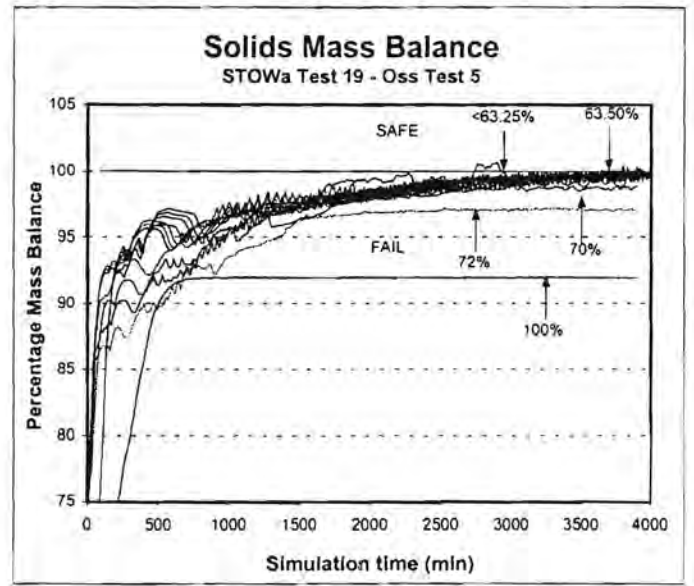
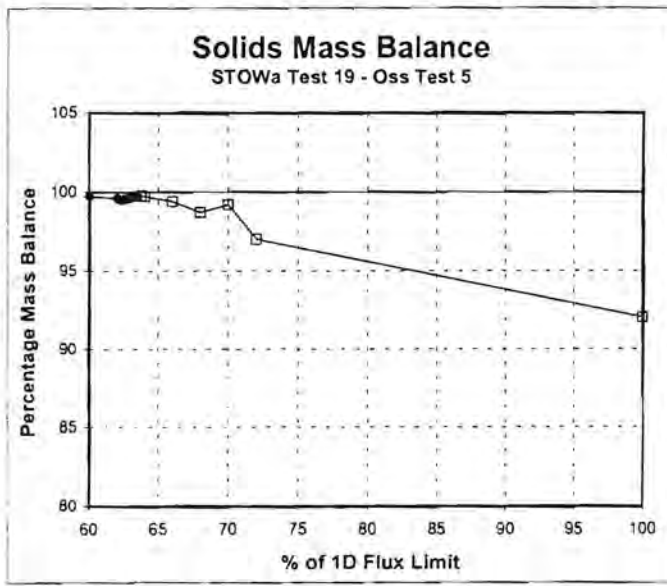
Simulation Data

Recycle flow (m ³ /h)	853.7
Area (m ²)	1372

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	44.40	6562.00	S	99.9
60	44.40	6562.00	S	99.9
60.25	47.40	6572.00	S	99.9
60.5	50.10	6585.00	F	99.9
60.75	52.70	6597.00	F	99.9
61	54.90	6610.00	F	99.9
61.25	57.10	6624.00	F	99.9
61.5	59.10	6638.00	F	99.9
61.75	61.60	6651.00	F	99.9
62	63.50	6665.00	F	99.9
64	80.30	6763.00	F	99.7
66	100.20	6864.00	F	99.8
68	125.10	6933.00	F	99.6
70	212.80	6796.00	F	99.3
72	293.20	6663.00	F	98.9
100	949.40	5630.00	F	97.4



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 5 simulation on the Oss SST

STOWa - Test 19

Vo (m/h)	5.2
n (l/g)	0.47
Xf (g/l)	2.64

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	4.16
Overflow rate (m/h)	1.17
Influent flow (m ³ /h)	1611.5

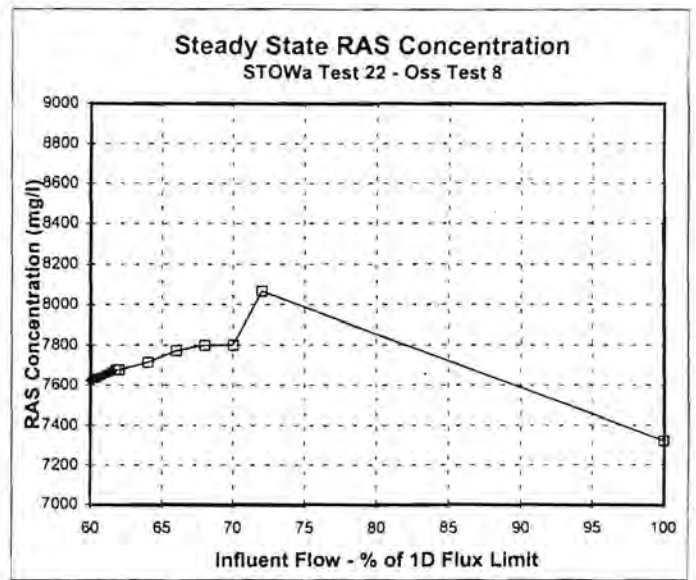
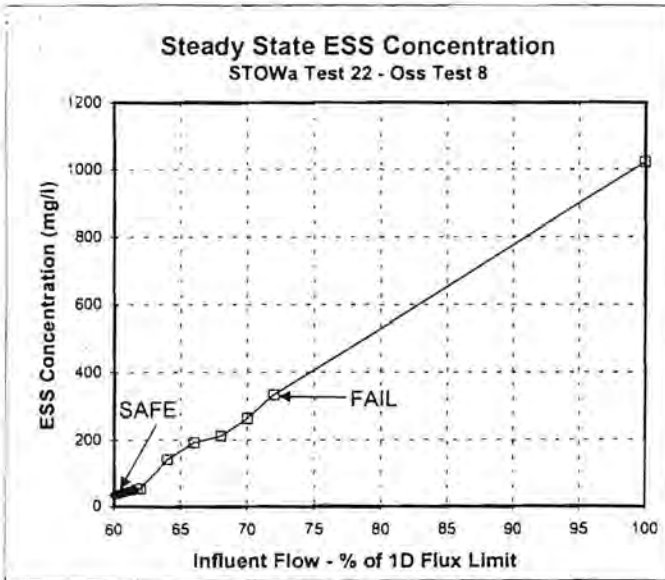
Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	4.19
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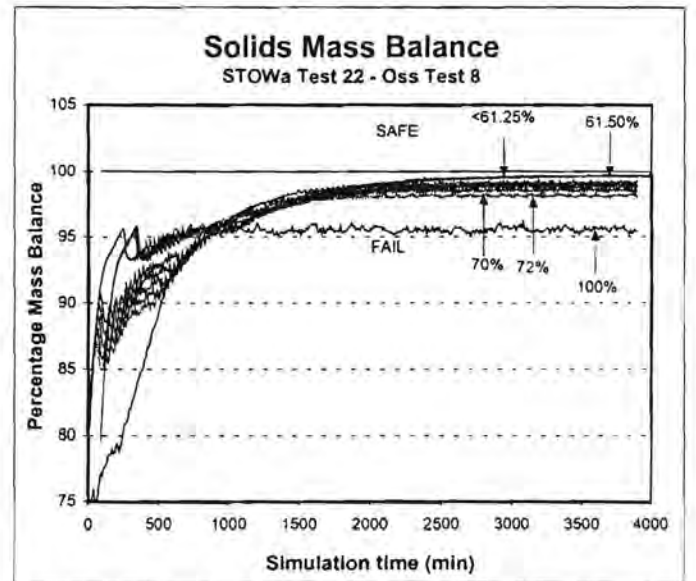
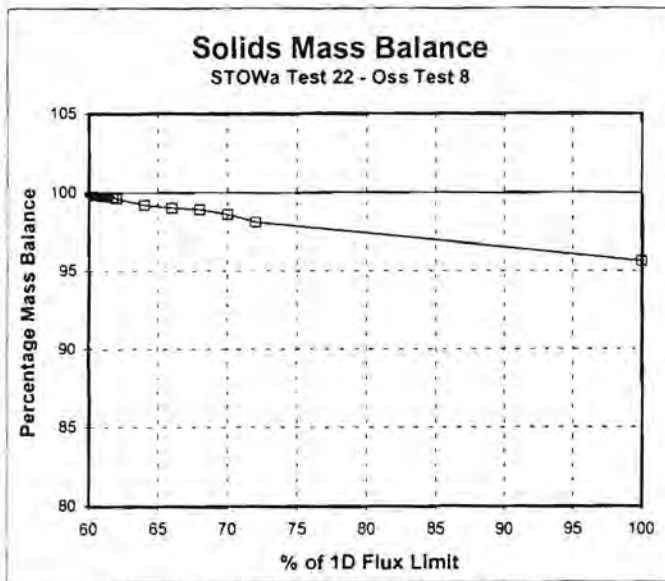
Simulation Data

Recycle flow (m ³ /h)	550.4
Area (m ²)	1372

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	19.00	7221.00	S	99.7
60	19.00	7221.00	S	99.7
62	39.80	7334.00	S	99.6
62.25	41.70	7336.00	S	99.5
62.5	44.10	7356.00	S	99.5
62.75	46.30	7373.00	S	99.6
63	47.90	7393.00	S	99.6
63.25	47.60	7420.00	S	99.7
63.5	49.30	7431.00	S	99.7
63.75	50.90	7456.00	F	99.8
64	52.80	7463.00	F	99.7
66	72.80	7557.00	F	99.4
68	97.20	7601.00	F	98.7
70	203.10	7570.00	F	99.2
72	203.10	7535.00	F	97.0
100	756.20	7321.00	F	92.0



Figs a and b: Final ESS and RAS concentrations (Figs a, left and Fig b, right) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares)



Figs c and d: % Mass balance (Figs c, left) versus influent flow as % 1DFT limit showing runs ended safe (colored in diamonds) and fail (empty squares) and % mass balance versus simulation time (Fig d, right) for the SettlerCAD Test 8 simulation on the Oss SST

STOWa - Test 22

Vo (m/h)	5.38
n (l/g)	0.46
Xf (g/l)	5.21

1DFT predicted limits

Maximun flux [kg/(m ² .h)]	5.76
Overflow rate (m/h)	0.48
Influent flow (m ³ /h)	665.3

Flux ratings

Flux load factor [Vo/(n.Xf)] (m/h)	2.24
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Simulation Data

Recycle flow (m ³ /h)	852.3
Area (m ²)	1372

Influent Flow as % of 1DFT Limit	Final ESS (mg/l)	Final RAS (mg/l)	Test Result	% Mass Balance
60	35.50	7626.00	S	99.9
60	35.50	7625.00	S	99.9
60.25	37.70	7633.00	S	99.8
60.5	40.00	7637.00	S	99.8
60.75	42.40	7644.00	S	99.7
61	45.50	7654.00	S	99.7
61.25	47.60	7662.00	S	99.7
61.5	49.60	7670.00	S	99.7
61.75	52.10	7675.00	F	99.7
62	53.80	7677.00	F	99.6
64	141.40	7715.00	F	99.2
66	192.00	7772.00	F	99.0
68	211.00	7798.00	F	98.9
70	263.20	7800.00	F	98.6
72	333.50	8067.00	F	98.1
100	1022.00	7321.00	F	95.6

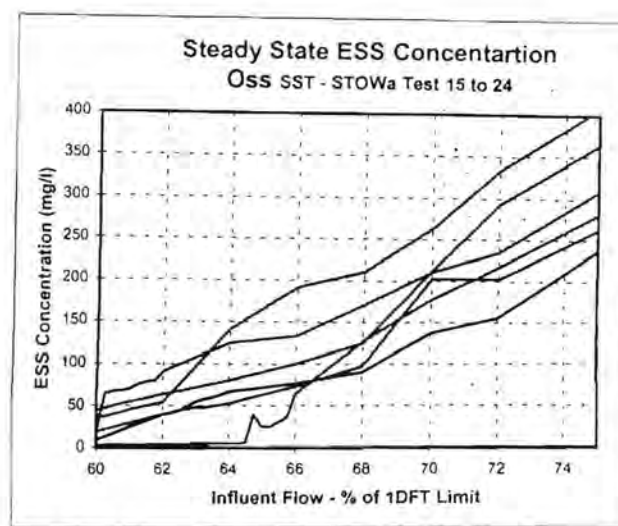
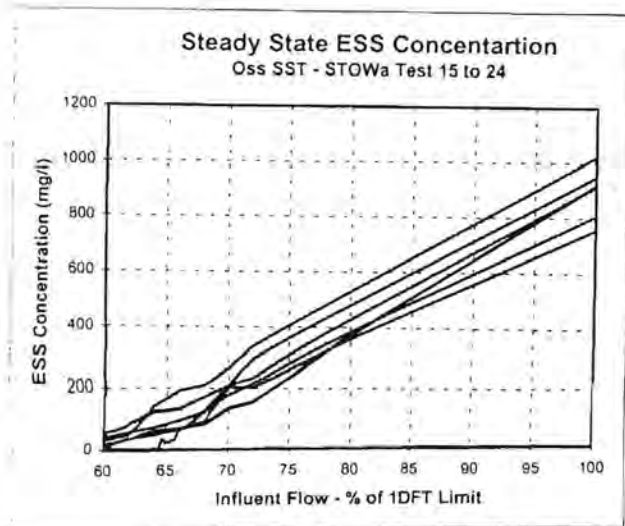


Fig a and b: SettlerCAD predicted ESS concentration versus influent flow (as a % of 1DFT limit) for Oxs SST - Stowa Tests 15 to 24