ACTIVATED SLUDGE PLANT FIELD & MODEL CAPACITY EVALUATION

Ricky Garrett, PE, Mike Jupe (TCEQ "A" Certified Wastewater Operator) and
Daniel Christodoss, PE, PhD
City of Waco Water Utility Services
P.O. Box 2570
Waco, TX 76702-2570

ABSTRACT

This paper presents results from the model capacity evaluation of an activated sludge plant at a large municipal wastewater treatment plant. The plant capacity evaluation (stress test) was performed to evaluate treatment process capacity and efficiencies as a part of the continuous improvement of the treatment plant for process optimization and maximization of flow through the plant.

The stress test was performed for 3 months mainly during dry weather with a few wet weather events that caused equivalent inflows higher than the existing rating of 37.8 mgd.

The stress test was conducted by diverting the entire flow proportionally through 3 of the 5 aeration basins and 3 of the 4 final clarifiers. Since normal operation of the plant is with 5 aeration basins, in terms of true plant capacity, a flow of 28 mgd through these 3 aeration basins during the stress test equates to 22.68 mgd x 5 basins/3 basins = **37.8 mgd** during normal operations (with 5 aeration basins in service). Similarly, a flow of 28.35 mgd through 3 final clarifiers during this stress test is equivalent to 37.8 mgd through 4 final clarifiers during normal operations.

On any given day, the stress tests lasted several hours during periodic, relatively stable, flow conditions. System performance was evaluated by measuring influent and effluent BOD, ammonia, and TSS.

The major conclusion is that the plant can treat more than 20% of current permitted flow effectively, which was established by the stress test and the mathematical model as shown in Tables 1.

Table 1 - Stress test June thru August 2005

	Plant Flow (mgd)	Flow EQUIV (mgd)	Inf. BOD_5 (mg/L)	Inf. TSS (mg/L)	Inf. NH_3 (mg/L)	Eff. $CBOD_5$ (mg/L)	Eff. TSS (mg/L)	Eff. NH_3 (mg/L)	LBS-BOD (entering)	Aeration Detention, (hrs)
Average	23.165	38.43	220.140	224.721	16.884	1.413	1.366	0.164	42,177	5.32
Max	37.781	52.33	587.000	614.000	23.000	3.730	4.500	2.220	106,155	6.20
Min	19.641	32.74	62.000	116.000	10.700	0.590	0.000	0.042	12,444	3.88

KEYWORDS

activated sludge, aeration, stress test, model capacity, final clarifiers, waste water treatment, nitrification, biological oxygen demand, total suspended solids, ammonia, anoxic zone, oxygen transfer, operations and maintenance, treated effluent

INTRODUCTION

This field and model capacity evaluation was performed at a time when the plant capacity was being down-rated from 37.8 MGD down to 31 MGD. The potential for down-rating raised the following concerns:

- Significant *loss in capacity*
- *Funding* needed to construct additional facilities ($40-$70 million)
- *Timing* for the downgrade invoking an unrealistic accelerated schedule

The operational history of the plant that led to the potential down-rating is described below.

PLANT COMPONENTS

Features of the WMARSS system include:

1. Primary clarifiers capable of efficient capture of suspended solids, grit and scum from plant inflows including high short term peak flows.
2. Biological activated sludge treatment using:
    a) 5 aeration basins which are designed to facilitate operation in plug flow with tapered aeration, step aeration (step feeding), or complete mix. The aeration basins produce a waste activated sludge which is as easy to separate and dispose of as possible
    b) Final clarifiers capable of removing activated sludge and scum promptly and efficiently, and dividing it into desired return activated sludge (RAS) and Waste Activated Sludge (WAS) flows
3. Thickeners for combined primary and waste activated sludges, with DAF thickeners chosen specifically for the mixed sludge involved.
4. Two-stage anaerobic digestion of mixed sludges for effective stabilization and yield of by-product methane.
5. Two Engine/Generators capable of producing half the plant's power needs.
6. Anaerobically digested sludge filter pressed to a cake of 18% solids. The cake is heat dried and pelletized (with heat from the furnace) into a commercial sized pellet with nutritional and soil conditioning value at slow release. The methane gas from the digestors powers the furnace to the drier unit and is blended with natural gas to conserve energy.

OPERATIONAL HISTORY

The conventional activated sludge Wastewater Treatment Plant for the Waco Metropolitan Area Regional Sewerage System (WMARSS):

- was constructed in **1983** and
- started operation in **1984** under an operating permit which restricted flow to a maximum 30-day average of 37.8 MGD daily average, 47.9 mgd daily max, 83.2 mgd, 2 hour peak flow, at treated effluent limits of 20 mg/L BOD, and 20mg/L TSS.
- won an EPA award in **1993**, for plants treating 10 mgd and higher
- had a change in the effluent limits in **1995** to 10 mg/L BOD, 15 mg/L TSS and 3 mg/L NH-3 single stage nitirification at which time, a pellet drying facility was added to the plant to treat digested sludge. When the ammonia permit was issued, the fifth aeration basin was constructed to provide the biological treatment and retain the 37.8 mgd annual average influent, at 250mg/L BOD and 250mg/L TSS.
- was being considered for down-rating in **2000-2004** based on performance issues compounded by design and operational constraints

EPA's DEFINITION OF PLANT CAPACITY

True *capacity* of a plant is a function of design, process optimization and management. In the original **1984** Operations and Maintenance (O&M) Manual, EPA's findings on 287 plants were quoted as follows:

> a) *Plant performance depends on the quality of the original design, the caliber of the plant's administrators, the effectiveness of the operators and the quality of the maintenance program.*
>
> b) *Every treatment plant has its own performance-limiting problems (foul-ups). This was found whether or not a plant was meeting permit. And if these problems can be sorted out and defined, then they can be cured, or made less severe, or (if nothing else) watched constantly.*

DESIGN AND OPERATIONAL CONSTRAINTS

EPA's findings cited above held true for the WMARSS plant. In **1998**, the following operational problems were identified:

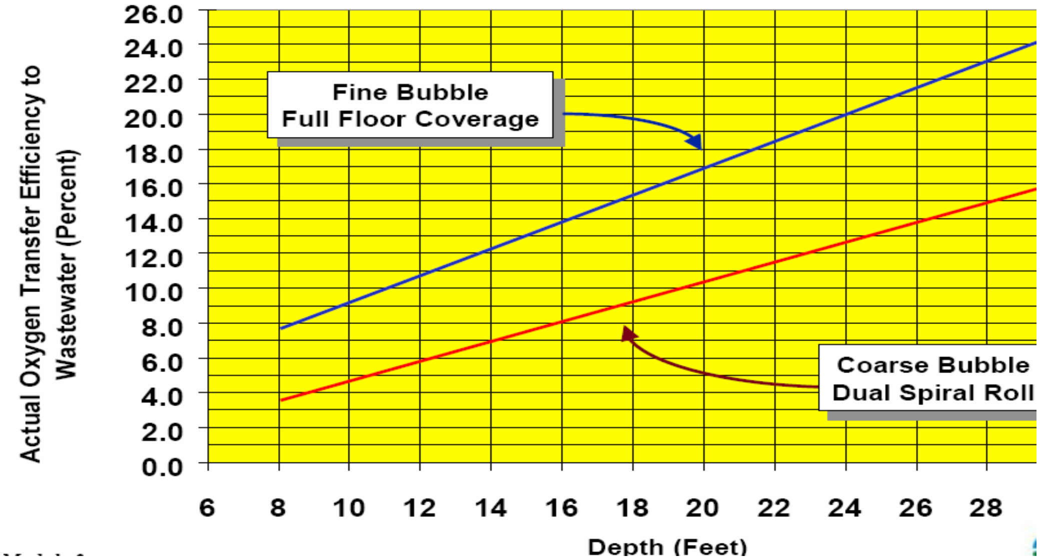
a) *There were inadequacies in communication between administration and plant personnel.*

b) *The plant side steams had adverse affects on the entire treatment train as a result of inadequate standard operating procedures to control the effects of the single stage nitrification cycle and the pellet building wastewater discharge.*

At this time, the WMARSS staff started evaluating the treatment system with EPA's findings in mind. The evaluation resulting in the following findings:

1. The oxygen transfer efficiency in the aeration basins was inadequate to supply the oxygen needed for single stage nitrification. The bubbles were coarse and there was not enough volume to achieve the desired treatment. Following graph depicts how bubble size affects oxygen transfer.

Figure 1 – Bubble Size vs. Oxygen Transfer Efficiency



2. The anoxic zones were not mixed nor utilized effectively to reduce the oxygen demand through BOD reduction utilizing nitrate as the substrate and alkalinity savings. Following is an introduction to nitrification and de-nitrification for clarification.

Nitrogen appears in organic wastes in various forms. In wastewater, four types of nitrogen are common: organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. These different forms constitute the total nitrogen content. The predominant forms of nitrogen in wastewater are organic nitrogen and ammonia (NH_3). Organic nitrogen is converted to ammonia in the first step of the nitrogen cycle. In order to remove nitrogen from wastewater, ammonia must be oxidized to nitrate (NO_3). This process is commonly referred to as nitrification. An oxic environment must be maintained for sufficient period of time to promote nitrification.

The overall reaction of nitrification is:
$NH_3 \rightarrow NO_2 \rightarrow NO_3$

Oxic conditions are maintained by a number of aerators. In the presence of dissolved oxygen, the microorganisms convert stored BOD (biochemical oxygen demand) to CO_2, water, and increased cell mass. Biological nitrification occurs, producing nitrite in an intermediate step and ultimately producing nitrate. Following nitrification, nitrogen can be removed from the wastewater by reducing the nitrate to nitrogen gas (N_2), which is released to the atmosphere. This process is commonly referred to as denitrification. Denitrification requires anoxic conditions, as well as an organic carbon source, to proceed.

NO_3^-	→	*NO_2*	→	*NO*	→	*N_2O*	→	*N_2*
nitrate		*nitrite*		*nitric oxide*		*nitrous oxide*		*nitrogen gas*

Introducing an anoxic zone into the flow scheme provides de-nitrification of nitrate in the return activated sludge from the clarifier. In this zone, operated with little to no dissolved oxygen (DO), the endogenous oxygen demand of mixed liquor suspended solids (MLSS) plus the carryover of BOD (biochemical oxygen demand) from the primary clarifier causes de-nitrification of the nitrate produced in the aerobic zone.

During anoxic conditions, dissolved oxygen is not available to the microorganisms for respiration. Because of this, the oxygen molecules are stripped from the nitrate, causing the production of nitrogen gas (N_2) . Carbon dioxide and water are also produced in the process, which results from the degradation of BOD. In addition, a portion of the alkalinity consumed during the nitrification process is restored through the de-nitrification process. When the mixed liquor flows to the secondary anoxic zones, there will be a relatively small concentration of extra cellular BOD in the wastewater. However, de-nitrification will still proceed since the microorganisms utilize internal storage products to reduce nitrate (endogenous de-nitrification). Secondary anoxic zones are not present at WMARSS.

Figure 2 – Process Schematics Showing Anoxic-Aeration and Clarifier Sequence

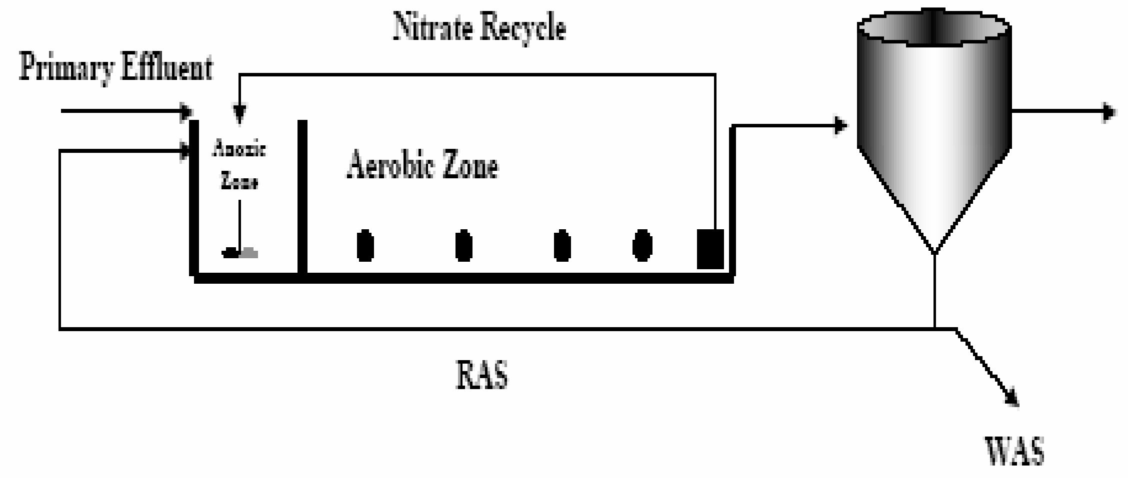
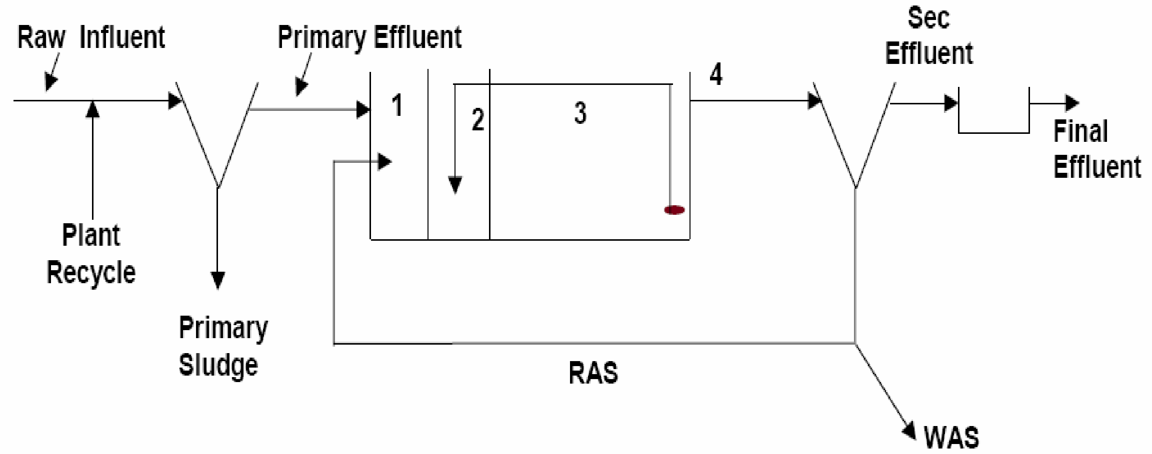


Figure 3 – System Schematics Influent to Effluent



3. The higher waste concentrations from the single stage nitrification had tendencies to overload the subsequent sludge thickening and anaerobic digestion process.

4. The inadequately controlled sludge thickening process adversely affected the single stage nitrification process and anaerobic digester process.
5. The pelletizing process discharged ammonia concentrations that caused fluctuation in the nitrification process, oxygen demand, chlorine demand and sulfur dioxide demand.
6. Inadequate screening of the plants influent and sludge flow adversely affected the sludge thickening process, digestion process and the pelletizing process.

The above six factors influence plant chemistry from an average BOD concentration of 250 mg/l to 350 mg/L, i.e. adding a 28 percent increase in plant BOD loading.

PERFORMANCE IMPROVEMENTS

To transition from re-treating plant foul-ups and collection system waste, the following improvements were made to optimize plant performance:

- Secondary Treatment Improvements.
  - ✓ Increased the Oxygen Transfer Efficiency in four aeration basins.
  - ✓ Automated the aeration zone valves to maintain the zones set D.O. level.
  - ✓ Automated three of the blowers to start-up with adjustable loading to satisfy the biological oxygen demand.
  - ✓ Installed Cipolletti weir aeration influent weirs to control and balance the aeration feed rate.
  - ✓ Improved the anoxic zone mixing efficiency.
  - ✓ Operated four aeration basins year round to obtain an average five-hour detention time.
  - ✓ Maintained a minimum 1.5 mg/L D.O. in first aeration zone to obtain optimal nitrifying growth rate.
  - ✓ Maintained a maximum .3 mg/L D.O. in anoxic zone to obtain optimal de-nitrifying growth rate.
  - ✓ Adjusted the aeration influent Cipolletti weir daily to balance and control the aeration basins feed rate.
  - ✓ Adjusted the wasting rates by the 10 percent rule.
  - ✓ Adjusted the activated sludge return rates lower to control the basins F/M ratio, pounds of nitrates to the anoxic zone with longer detention times.

- Solids Processing Improvements.
  - ✓ Started feeding polymer to the D.A.F. to increase the capture rate of the unit, thus lowering the sludge flow to the Digesters that increased their detention time along with lowering the BTU needed to heat the units and lowered the run time of the Dryer unit.
  - ✓ Redirected the D.A.F underflow to the solids side final clarifier underflow wet well, instead of the plants under drains.
  - ✓ Started up the second solids side final clarifier underflow pump to limit the amount of solids entering the plant under drains.

- ✓ Started one of the two side stream trickling filters to reduces the BOD re-entering the plants influent.
- ✓ Installed a two-millimeter opening fine screen in the sludge flow.
- ✓ Automated the digesters feed valves to balance the unit sludge feed flow.
- ✓ Redirected the belt press filtrate water to the solids side of the plant to reduce the ammonia concentration before entering the plants influent.

At this time, effective design and operational controls were introduced, and plant performance improved consistently, thereby eliminating the need for capacity down rating which was verified by the stress test which was performed to evaluate treatment process capacity and efficiencies as a part of the continuous improvement of the treatment plant for process optimization and maximization of flow through the plant.

The plants stress test was performed under the new standard operating procedures (SOP) developed from the in-house evaluation thereby validating the SOPs and EPA's Criteria for capacity evaluation.

The results of the stress test is now presented with comparison to plant data in 2002 where operational problems were noticeable.

Table 2 - Stress test June thru August 2005 (Duplicate of Table 1)

	Plant Flow	Inf. BOD$_5$ (mg/L)	Inf. TSS (mg/L)	Inf. NH$_3$ (mg/L)	Eff. CBOD$_5$ (mg/L)	Eff. TSS (mg/L)	Eff. NH$_3$ (mg/L)	LBS-BOD entering	Aeration Detention (hrs)	Flow EQ. 37.8
Average	23.165	220.140	224.721	16.884	1.413	1.366	0.164	42,177	5.32	38.43
Max	37.781	587.000	614.000	23.000	3.730	4.500	2.220	106,155	6.20	52.33
Min	19.641	62.000	116.000	10.700	0.590	0.000	0.042	12,444	3.88	32.74

Table 3 - Plant data from 2002

	Plant Flow	Inf. BOD$_5$ (mg/L)	Inf. TSS (mg/L)	Inf. NH$_3$ (mg/L)	Eff. CBOD$_5$ (mg/L)	Eff. TSS (mg/L)	Eff. NH$_3$ (mg/L)	LBS-BOD (entering)	Areation Detention
AVERAGE	25.446	322.58	419.56	15.78	2.81	3.06	1.446	68,087	6.58
MAX	66.004	644.00	1600.00	26.70	7.80	11.70	13.800	170,909	8.53
MIN	19.019	103.000	54.000	6.140	1.040	0.800	0.040	17,778	2.458

Comparing the data from the 2005 stress test chart to the 2002 chart there was a 38 percent reduction in BOD entering (re-entering) the plant. The stress test substantiates EPA's finding and validates the corrective measures taken at the WMARSS plant to bridge the gaps in communication, operations and process controls. The benefits from the teamwork far out weigh the effort since subsequent to the performance improvements, the plant's electrical usage dropped by 4.5 million kilowatts annually. Presently, the plant is much easier to operate and has dropped it's midnight shift under normal conditions (not including the pelletizing operations) but now operates an average of five day a week compared to the average six day weeks which equates to a 20% reduction in workload.

The major conclusion is that the plant can treat more than 20% design criteria permitted flow/single stage nitrification loading effectively, which was established by the stress test and the mathematical model.

STRESS TEST LOCATION AND METHODOLOGY

The site of the tests was a large 37.8 mgd Waste Water Treatment Plant designated the Waco Metropolitan Area Regional Sewer System (WMARSS). The system serves as the central plant to treat wastewater from member cities with a total population of about 175,000 residents: Waco, Bellmead, Hewitt, Woodway, Lacy-Lakeview and Robinson.

During the test, the stoichiometrical relationship of

- 1.1 lbs O_2 / lb BOD, and
- 4.6 lbs O_2 / lb ammonia

was maintained by adding diffusers in the 3 basins to meet the total aeration demands for influent BOD, ammonia and additionally, the mixed liquor. Average flows and BOD to these units varied from approximately 25 to 30 MGD and 250 mg/L respectively. This approach provided loadings and detention times comparable to the future average flows of 37.8 MGD under mean plus one standard deviation loads. Additional units were put online to deal with wet weather events. The stress test was conducted by diverting the entire flow proportionally through 3 of the 5 aeration basins and 3 of the 4 final clarifiers. Since normal operation of the plant is with 5 aeration basins, in terms of true plant capacity, a flow of 28 mgd through these 3 aeration basins during the stress test equates to 22.68 mgd x 5 basins/3 basins = **37.8 mgd** during normal operations (with 5 aeration basins in service). Similarly, a flow of 28.35 mgd through 3 final clarifiers during this stress test is equivalent to 37.8 mgd through 4 final clarifiers during normal operations. A dye-tracer study is also in progress to analyze the hydraulic characteristics of the clarifier and optimize its performance. On any given day, the stress tests lasted several hours during periodic, relatively stable, flow conditions. System performance was evaluated by measuring influent and effluent BOD, ammonia, and TSS.

SUMMARY OF THE RESULTS AND DISCUSSION

Graphs from the stress test data described previously are included below and support the conclusions provided next. The BOD converted to pounds per 1,000 cubic feet of the aeration unit is shown on Figure 4 and depicts fluctuations during the stress test. The actual pounds of BOD entering the plant during the stress test is shown on Figure 5. The influent BOD, TSS, ammonia and the flow equivalent is depicted on Figure 6 and compared to the effluent loading on Figure 7. The y-axis range is much smaller for Figure 7 than Figure 6 due to significant drop in influent values for measured parameters during treatment. The effluent loading model shown on Figure 8, derived from regression analysis of the stress test data shows consistency between the modeled and the actual data. To obtain the model, regression analysis was performed and model equations (Table 4) for effluent BOD, TSS and ammonia were derived as a function of influent parameters to calculate the model plot data.

Figure 4 – BOD in lbs per 1,000 cubic feet of the Aeration Unit

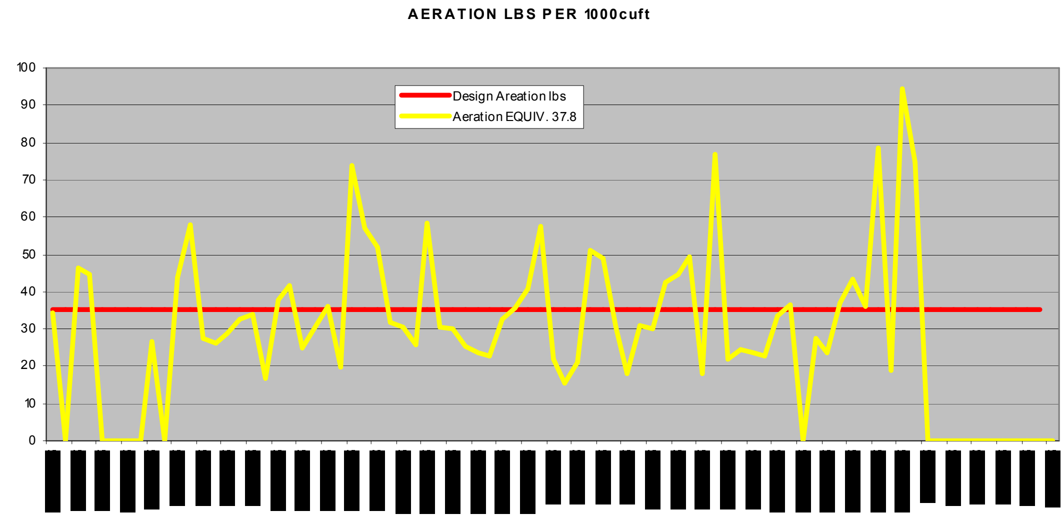


Figure 5 – lbs of BOD entering the plant from the collection system

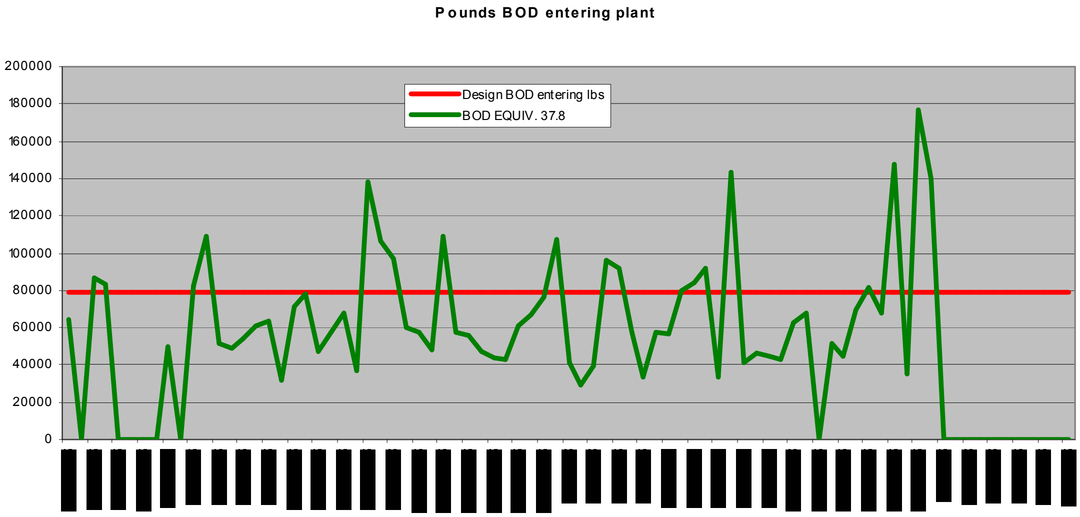


Figure 6 – Influent BOD, TSS, Ammonia and Flow Equivalent

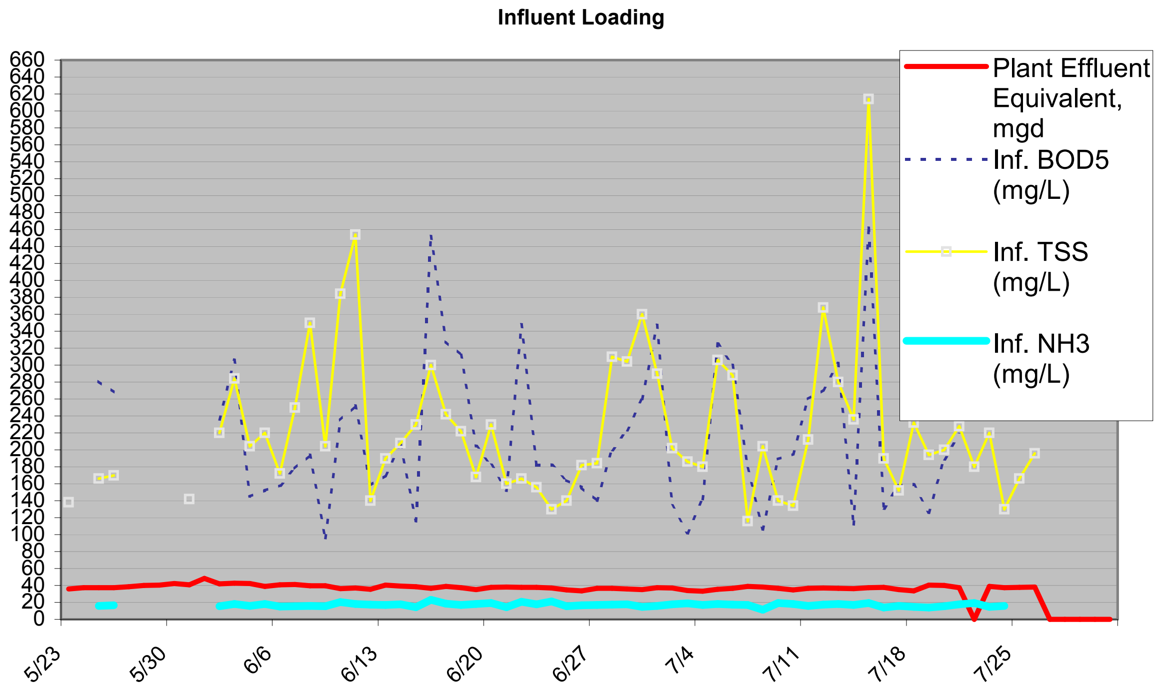


Figure 7 – Effluent BOD, TSS, Ammonia, Aeration Unit Detention

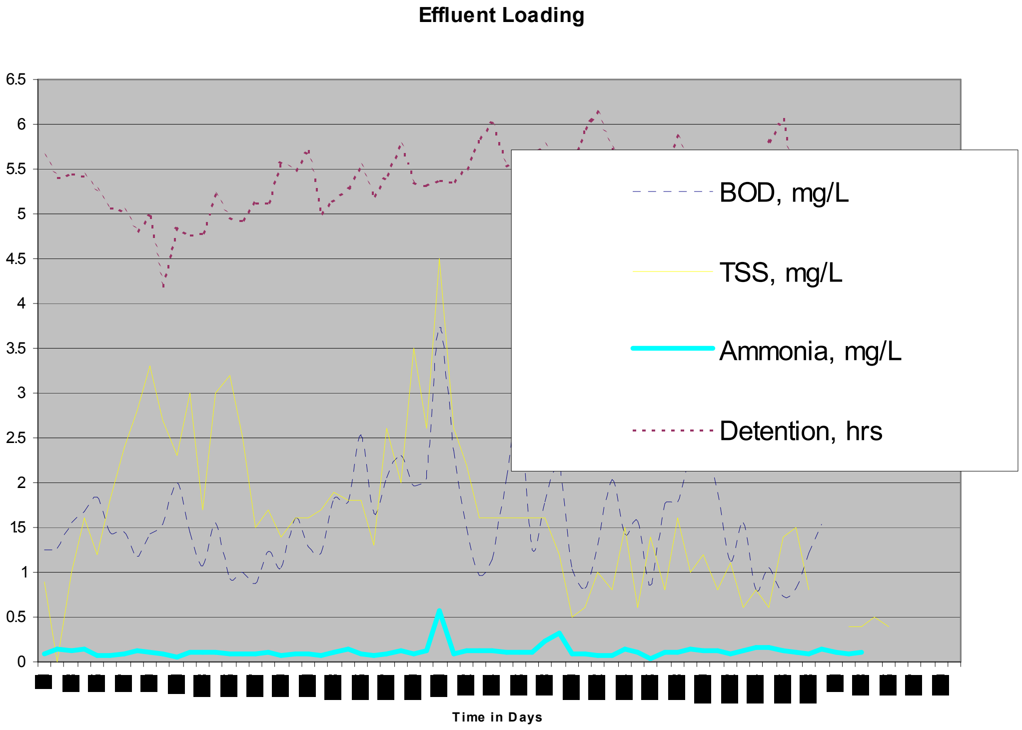


Figure 8 – Effluent Loading Plot Utilizing Model Equation Derived from Stress Test Data

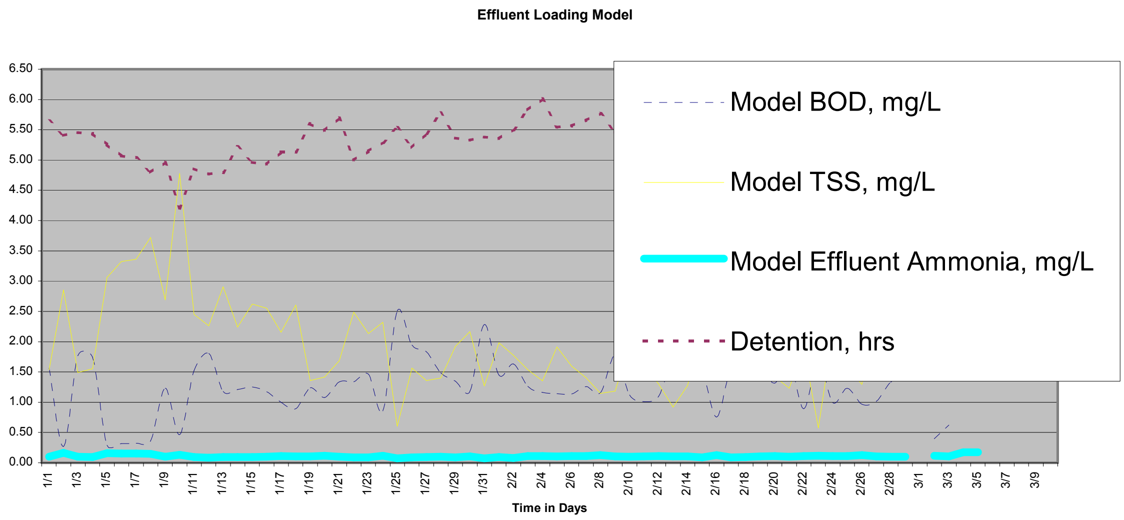


Table 4 – Effluent Concentrations Model

Effluent Ammonia Prediction Model

$$NH3_{eff} = 0.26728219604 + -0.0028310569243*MGD + -0.000041517607405*BOD_{inf} + -0.004190273598*NH3_{inf} + 0.0000891630116TSS_{inf}$$

MGD	**BOD_{inf}**	**$NH3_{inf}$**	**TSS_{inf}**	**$NH3_{eff}$**
35.925	214	16.8	138	0.086

Effluent TSS Prediction Model

$$TSS_{eff} = -3.732857302 + 0.17625048953*MGD + -0.0038607363102*BOD_{inf} + -0.010748551178*NH3_{inf} + -0.00044110484113*TSS_{inf}$$

MGD	**BOD_{inf}**	**$NH3_{inf}$**	**TSS_{inf}**	**TSS_{eff}**
35.925	214	16.8	138	1.53

Effluent BOD Prediction Model

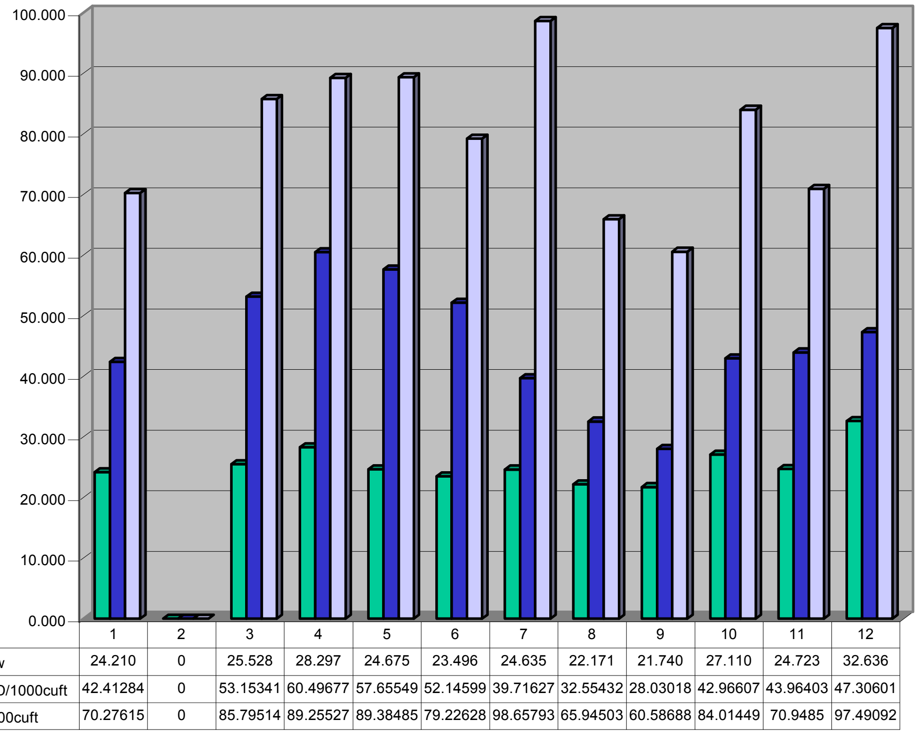
$$BOD_{eff} = -0.40045564232 + 0.017954249533*MGD + 0.0044010643804BOD_{inf} + 0.041444463095*NH3_{inf} + -0.00232059867*TSS_{inf}$$

MGD	**BODinf**	NH3inf	TSSinf	BODeff
35.925	214	16.8	138	1.56

CONCLUSION

The success of the stress test in demonstrating adequate capacity at the current permit limit of 37.8 mgd plus 20% though full scale data collection and mathematical modeling, is attributed to the introduction (over a 3-year period) of effective design and operational controls prior to the stress test, thereby eliminating the need for a down-rating. These performance improvements are demonstrated in decreasing effluent concentrations for the parameters monitored shown in the charts below:

Figure 9 – Monthly Average Loading in 2002 (Before Performance Improvements)

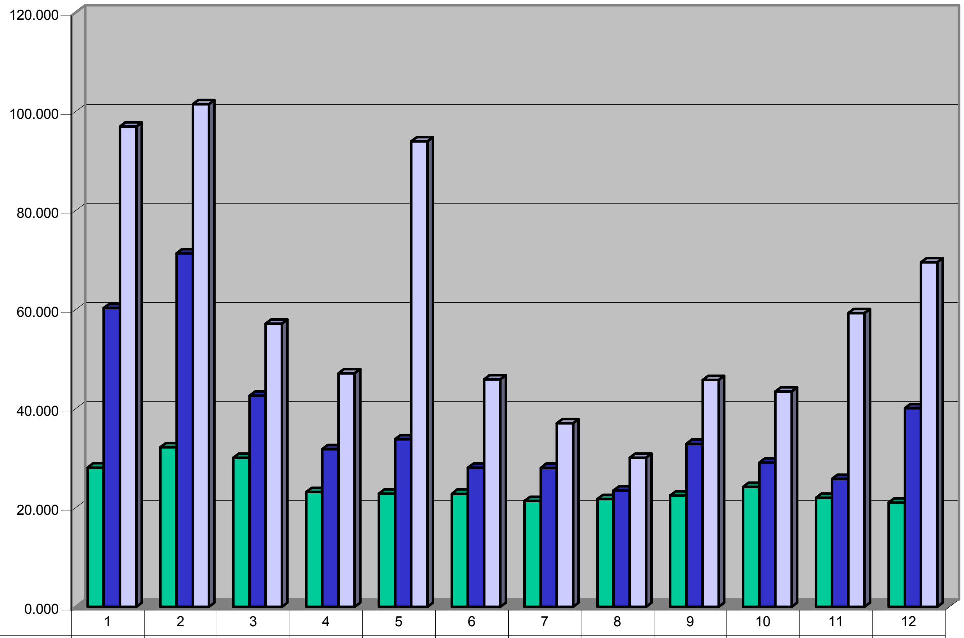


	1	2	3	4	5	6	7	8	9	10	11	12
🟩 Monthly average Flow	24.210	0	25.528	28.297	24.675	23.496	24.635	22.171	21.740	27.110	24.723	32.636
🟦 Monthly average BOD/1000cuft	42.41284	0	53.15341	60.49677	57.65549	52.14599	39.71627	32.55432	28.03018	42.96607	43.96403	47.30601
☐ Monthly Max bod/1000cuft	70.27615	0	85.79514	89.25527	89.38485	79.22628	98.65793	65.94503	60.58688	84.01449	70.9485	97.49092

1. This chart indicates that the plant was receiving high average aeration loading (8 months over 40 lbs per 1000 cuft and all the monthly max lbs per 1000 cuft were over 60 lbs)
2. The high aeration loadings were due to foul-ups at the plant. The chart demonstrates the negative impacts of the plant's deficient operational practices leading to where the pounds of BOD originated from. This brings us back to the EPA's findings part B related to "foul-ups", i.e., the WMARSS operational practices did not effectively process the plants solids thus contaminating the plant's side stream flows and leading to high aeration loadings.

3. The plant was not constantly meeting permit limits, but the cause was not from the influent loading; it was from the operational practices of the aeration process and low Oxygen Transfer Efficiency.

Figure 10 – Monthly Average Loading in 2003 (During Performance Improvements)



	1	2	3	4	5	6	7	8	9	10	11	12
🟩 Monthly average Flow	28.143	32.262	30.102	23.200	22.899	22.839	21.359	21.750	22.514	24.214	22.041	21.053
🟦 Monthly Average BOD/1000cuft	60.351	71.424	42.637	31.847	33.881	28.086	28.075	23.503	32.923	29.170	25.854	40.141
⬜ Monthly Max BOD/1000cuf	97.00582	101.54838	57.216447	47.182381	94.029532	45.942959	37.09399	30.131747	45.788252	43.516275	59.324426	69.614266

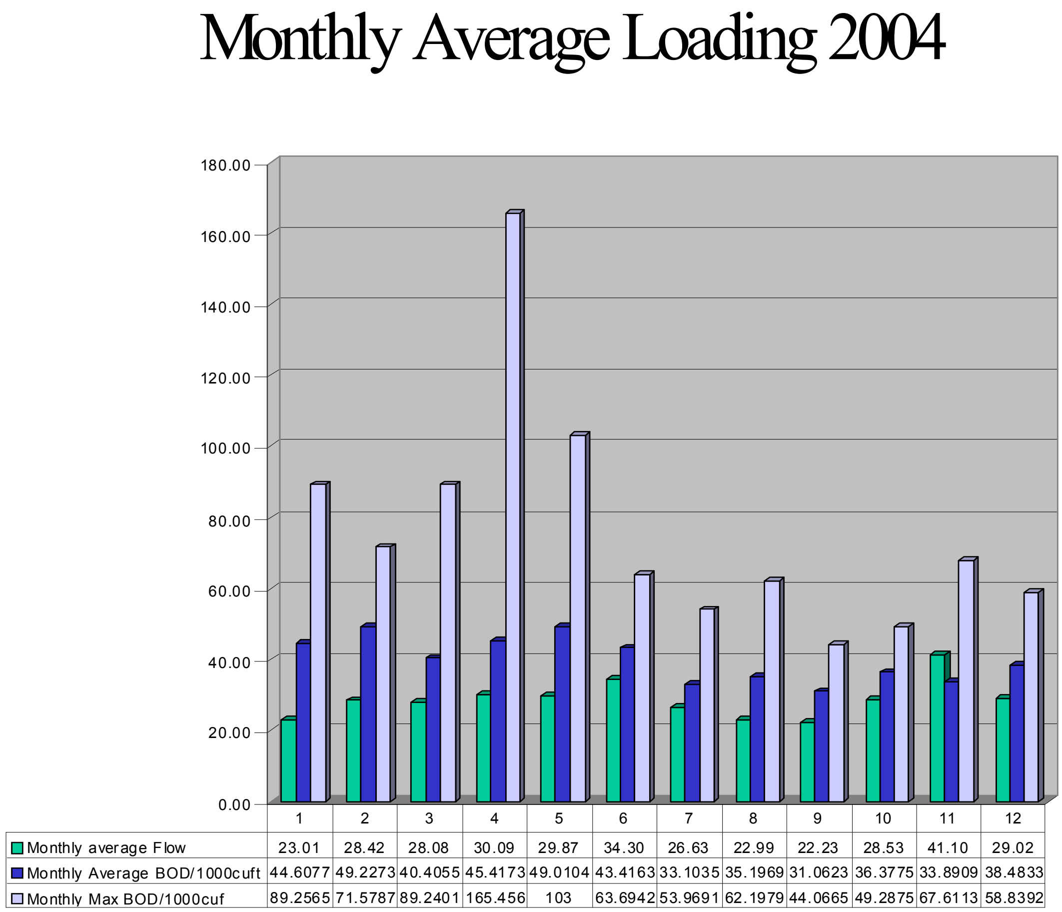
1. In 2003 the plant was still receiving high max aeration loading but reduced from 2002 (4 months of high loadings in 2003 vs. 12 months of high loadings over 60 lbs per 1000 cuft in 2002)
2. The average aeration loading was consistent and lower than 2002, indicating the plant personnel was properly processing the plants solids aided by implementation of the use of polymer at the Dissolved Air Floatation unit.
3. The plant also sustained max loading conditions with only 4/5 of the aeration capacity in service (5th aeration unit was not used) with no ammonia violations.

Improvements are more noticeable in Figure 10 which documents progressive improvements in 2004:

1. This chart indicates in 2004 the plant was still receiving high average aeration loading but reduced from 2002 (6 months in 2004 vs. 8 months over 40 lbs per 1000 cuft in 2002, and 8 months vs. 12 months over 60 lbs per 1000 cuft)

2. The high loading provided historical data that supports the 37.8 mgd rating, since the plant effectively treated 61,668 annual average pounds of BOD, which is 80% of the designed loading with only 4/5 of the aeration units in service.
3. So the plant was operating at 80% of its treatment capacity based on the original design and confirmed the EPA's Finding – A. The availability of an additional 20% capacity for emergencies over the 37.8 mgd as demonstrated in these charts indicate the new SOP's implemented in concert with mechanical enhancements have brought the plant closer to it's original design capacity.

Figure 11 – Monthly Average Loading in 2004 (After Performance Improvements)

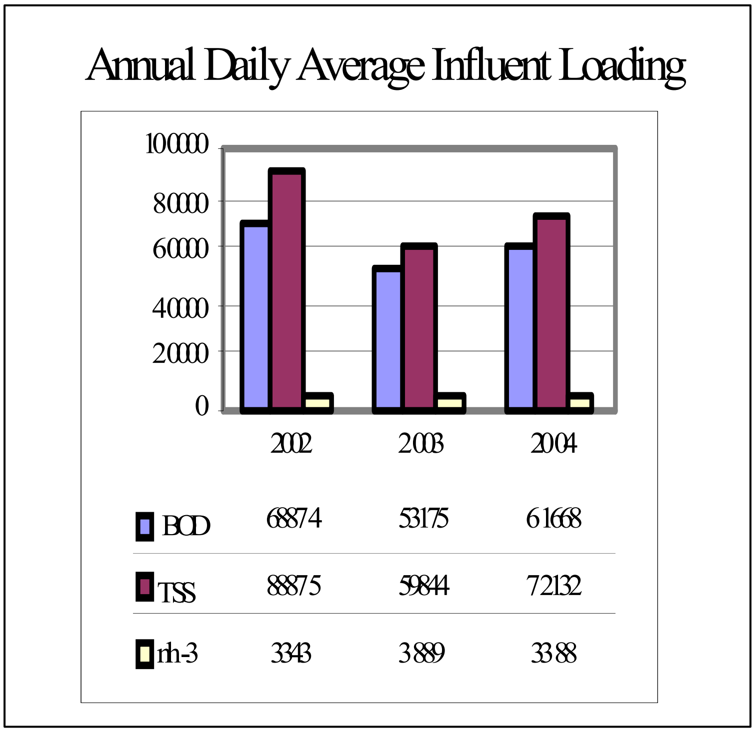


	1	2	3	4	5	6	7	8	9	10	11	12
🟩 Monthly average Flow	23.01	28.42	28.08	30.09	29.87	34.30	26.63	22.99	22.23	28.53	41.10	29.02
🟦 Monthly Average BOD/1000cuft	44.6077	49.2273	40.4055	45.4173	49.0104	43.4163	33.1035	35.1969	31.0623	36.3775	33.8909	38.4833
☐ Monthly Max BOD/1000cuf	89.2565	71.5787	89.2401	165.456	103	63.6942	53.9691	62.1979	44.0665	49.2875	67.6113	58.8392

Significant improvement in influent loadings are observed when the data from the 3 years are combined and reviewed side by side as in Figure 12. Following are the significant observations that are deduced from the Annual Daily Average Influent Loadings shown on Figure 12:

1. Controlling the side stream concentrations proved to improve the plants loadings and 2003 was the more effective year.
2. There is one other side stream that is not included in the influent loading, the Dryer units flow contains an average daily loading of 1,500lbs of ammonia that is treated in the aeration basins.
3. This additional ammonia loading is a 30% increase over the plants influent ammonia loading and this loading is not consistent, because the Dryer unit does not run 24/7 it operates 24/5.
4. Controlling all side streams in-effect at the plant has proven to be a beneficial operational practice that is continuing to enhance the operations and capacity of the aeration units.

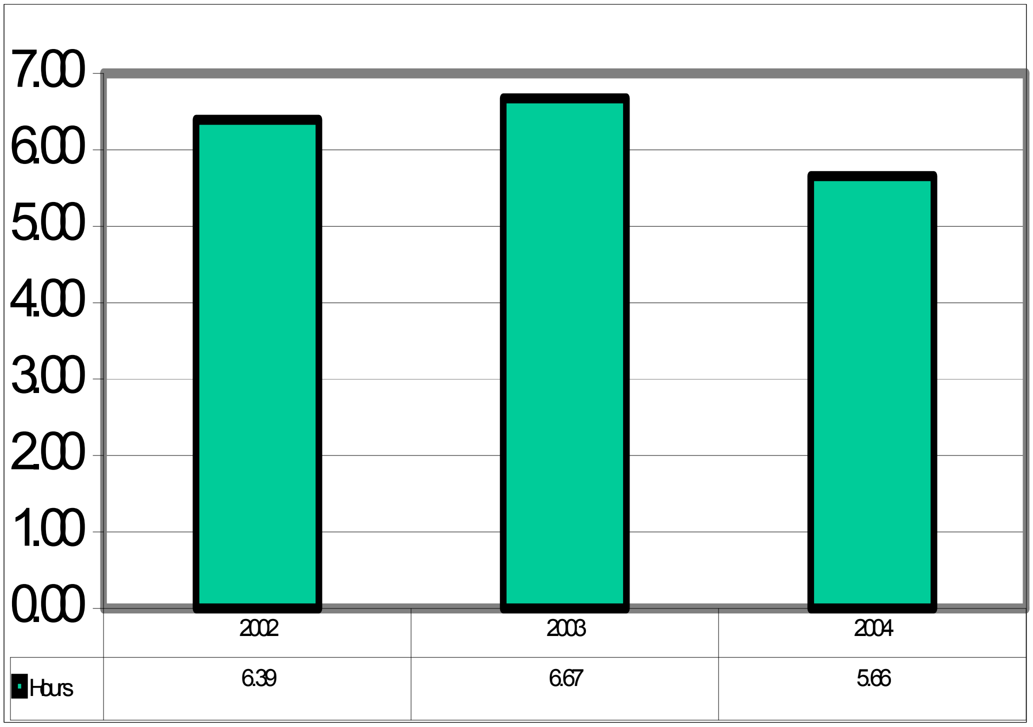
Figure 12 – Influent Loadings Decrease with Performance Improvements



Significant improvement in Detention Times are observed when the data from the 3 years are combined and reviewed side by side as in Figure 12. Following are the significant observations that are deduced from the Annual Average Detention Times shown on Figure 13:

1. Finally, in 2004 the plant was at 80% capacity with 80% treatment capacity in service, 20% additional available for emergencies, at an average detention time of 5.66 hour for the 4 aeration units in service and the annual average flow was at 78% of the 37.8 mgd design flow.
2. Looking at one specific month, especially June of 2004, the plant was at 76% capacity at 80% treatment capacity in service, at an average detention time of 5.2 hours at 90% of the 37.8 mgd design flow and still maintained effective treatment at an effluent NH-3 average of 0.15mg/L.
3. Further improvement was observed in Feb 05, when the plant was at 80% capacity at 80% treatment capacity in service, at an average detention time of 4.8 hours at 92% of the 37.8 mgd design flow with an effluent NH-3 of 0.13mg/L.

Figure 13 – Required Detention Times Decrease with Process Improvements

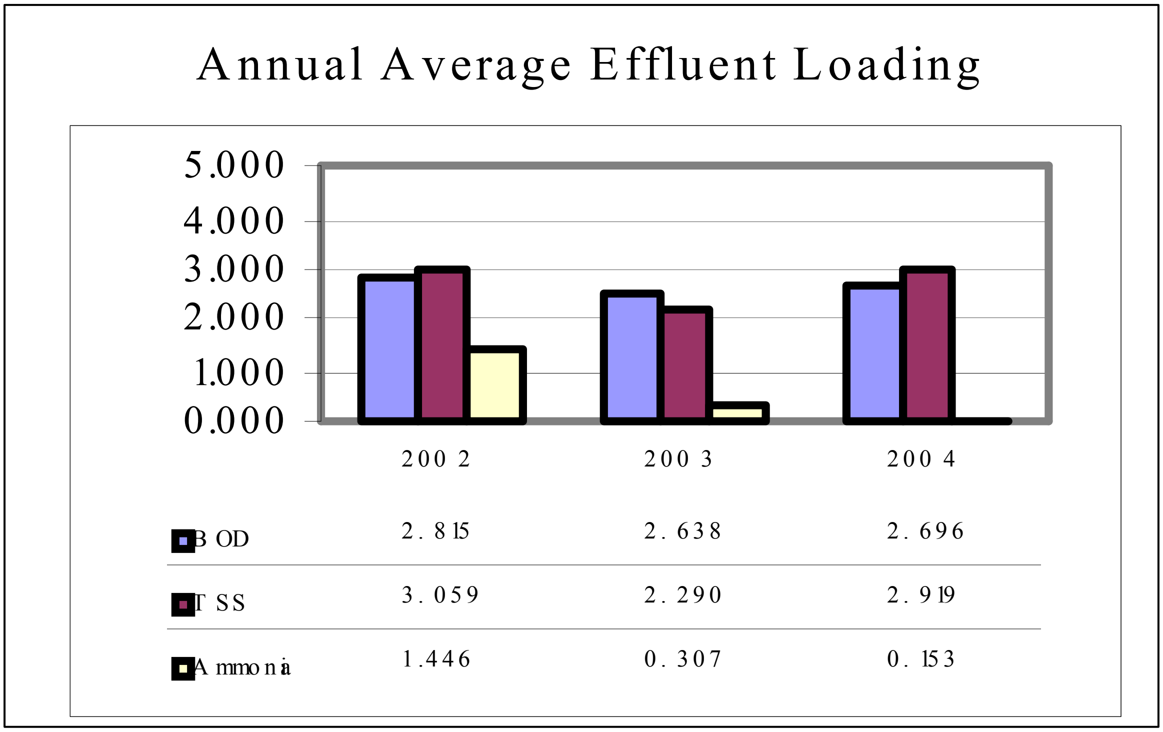


The significant drop in effluent ammonia, evident from the effectiveness of the anoxic and aeration zones and control of plant side streams are depicted on Figure 14 which compares effluent ammonia, TSS and BOD effluent loadings in 2002, 2003 and 2004. Following highlights are derived from Figure 14:

1. The plant has performed at monthly average detention times of 4.8 hours, with high aeration loading over 46 lbs/1000 cuft and still produced significantly low effluent NH-3 concentrations.

2. The year 2002 had many ammonia violations, but for the years 2003 and 2004 there were no ammonia violations and the average effluent NH-3 dropped from 1.446 to 0.153mg/L.
3. As mentioned before, the effluent quality is a result of the implementation of adjusted operational procedures on the aeration units, increased oxygen transfer efficiency and blower automation.
4. With the aeration unit operating efficiently biologically, the plant energy consumption (kwh) reduced 17% from 2002 to 2003 and an additional 6% in 2004. The automation of the blowers once again confirms the EPA's finding A and B on true treatment capacity because of the consistent treatment effectiveness observed during this period.

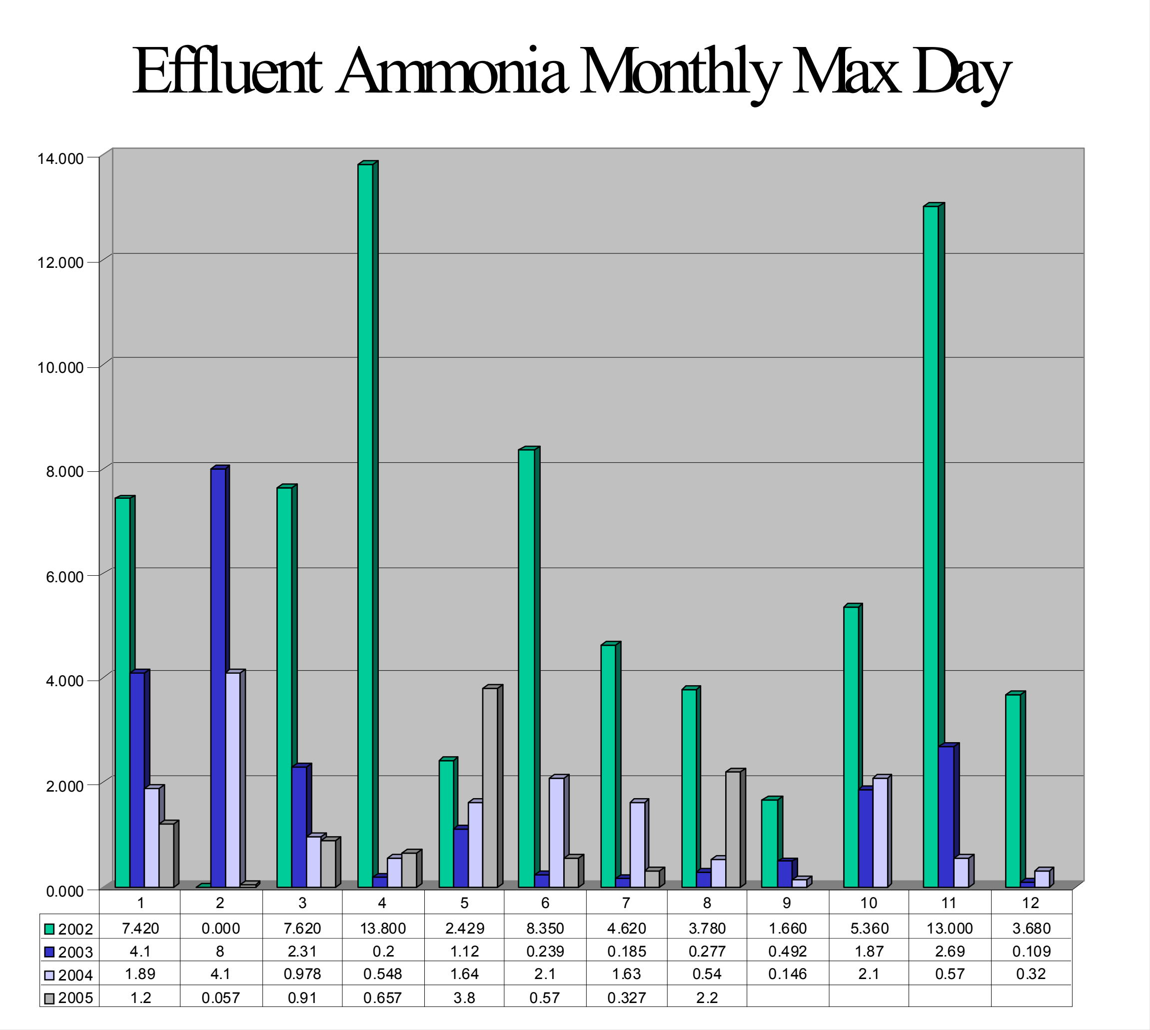
Figure 14 – Significant Drop in Effluent Ammonia with Improvements



	2002	2003	2004
🟦 BOD	2.815	2.638	2.696
🟥 TSS	3.059	2.290	2.919
🟨 Ammonia	1.446	0.307	0.153

More evidence of aeration basin effectiveness during the process improvements is observed in Figure 15 which shows the correlation. This chart indicates that in February 2002 the effluent average concentrations dropped to the minimum levels. This is due to the fact that this is the same month in which the WMARSS staff completed the installation of additional diffusers to the aeration basins to improve aeration characteristics for effective ammonia removal.

Figure 15 – Effluent Ammonia Monthly Max Day



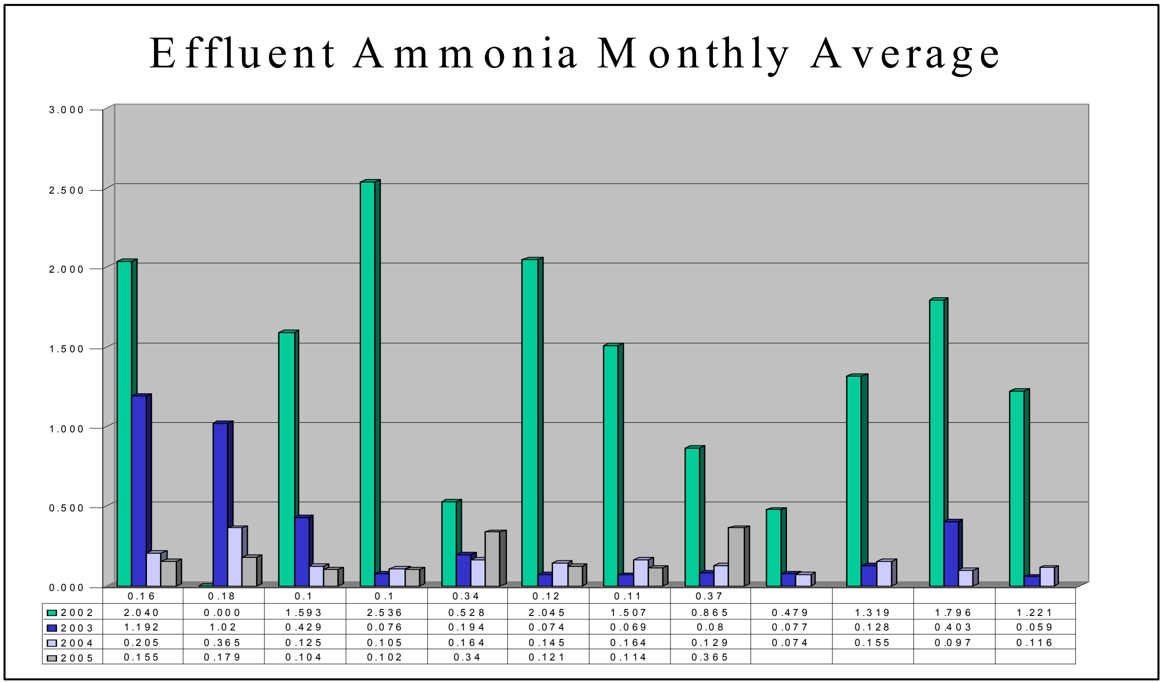
	1	2	3	4	5	6	7	8	9	10	11	12
🟩 2002	7.420	0.000	7.620	13.800	2.429	8.350	4.620	3.780	1.660	5.360	13.000	3.680
🟦 2003	4.1	8	2.31	0.2	1.12	0.239	0.185	0.277	0.492	1.87	2.69	0.109
☐ 2004	1.89	4.1	0.978	0.548	1.64	2.1	1.63	0.54	0.146	2.1	0.57	0.32
▨ 2005	1.2	0.057	0.91	0.657	3.8	0.57	0.327	2.2				

Average effluent ammonia concentrations are shown on Figure 16 for 2002. This chart also indicates that in February 2002 the effluent average concentrations dropped to the minimum levels which is correlated to the completion of the installation of additional diffusers at the aeration basins.

The conclusions discussed above only discussed average flow to the plant. Peak flow management is being addressed by the following:

- Peak Flow Storage Basin (one downstream of the highest I&I contributor)
- I&I Control in process (2 major I&I sites at the E. Bank have been remedied)
- Flow Diversion to Satellite Plant (Feasibility Study just completed)

Figure 16 – Effluent Ammonia Monthly Average



	0.16	0.18	0.1	0.1	0.34	0.12	0.11	0.37				
🟩 2002	2.040	0.000	1.593	2.536	0.528	2.045	1.507	0.865	0.479	1.319	1.796	1.221
🟦 2003	1.192	1.02	0.429	0.076	0.194	0.074	0.069	0.08	0.077	0.128	0.403	0.059
☐ 2004	0.205	0.365	0.125	0.105	0.164	0.145	0.164	0.129	0.074	0.155	0.097	0.116
▨ 2005	0.155	0.179	0.104	0.102	0.34	0.121	0.114	0.365				

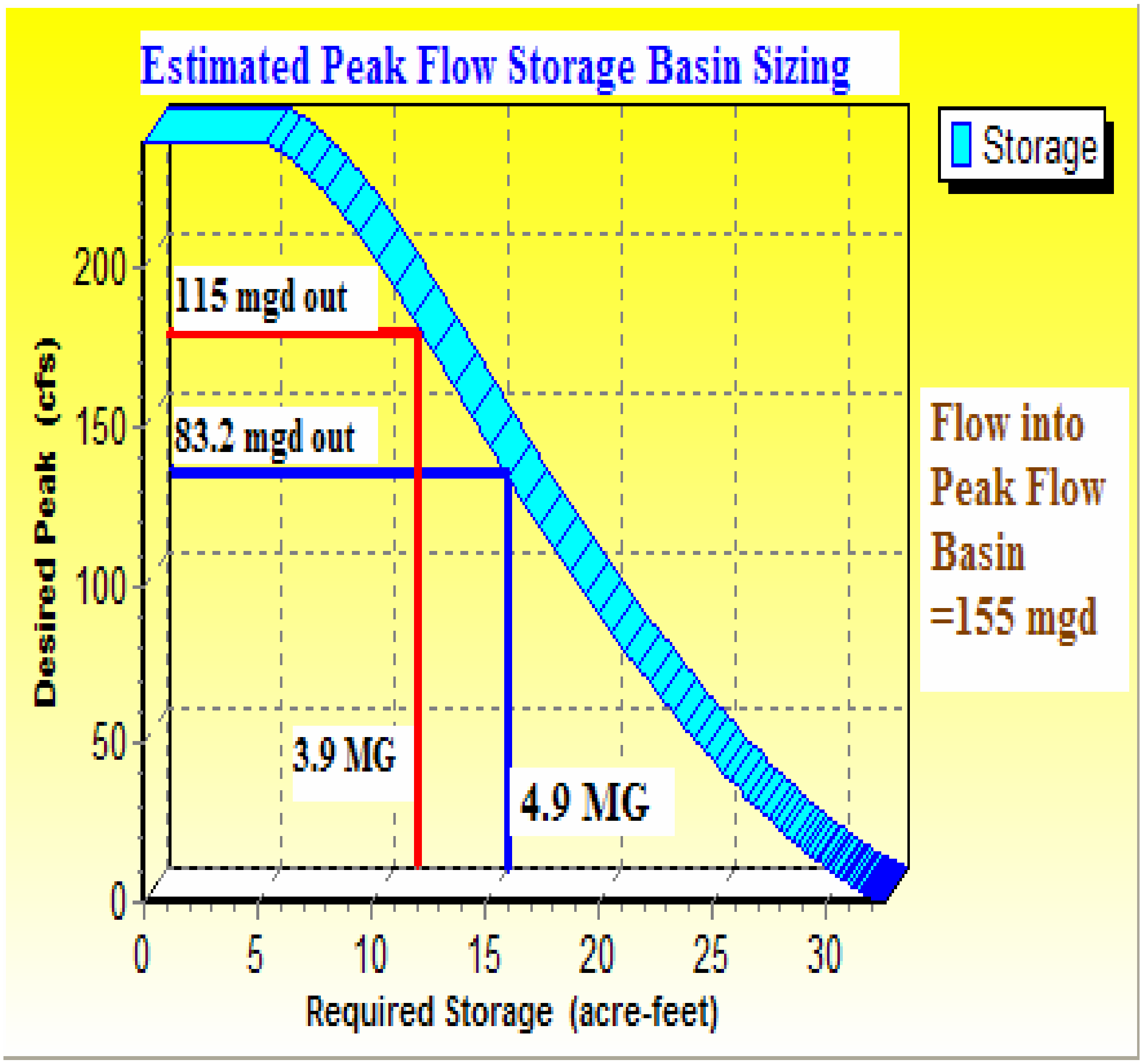
Peak flows during wet weather events are being addressed with the construction of a peak storage tank. The peak storage basin is important, since the limiting unit process in the treatment train is chlorination. Since it is not cost effective to construct additional chlorine contact basins, efforts are now focused on maximizing peak flow through WMARSS by raising the walls of the existing chlorine contact chamber in conjunction with the new peak storage basin construction. A preliminary hydraulic evaluation has indicated that raising the walls of the chlorine contact chamber by approximately 1 ft is feasible.

As part of the I&I Program, studies have been completed for two basins and evaluation is in process to consider planning for rehabilitation.

The feasibility study of the satellite plant has been completed. The study recommends two satellite plants at strategic locations to provide maximum benefit for flow diversion and capture as well as promote the potential for water reuse while providing new wastewater treatment infrastructure for selected cities in the watershed.

Output from Peak Flow Basin Modeling Calculations are shown on Figure 17.

Figure 17 – Peak Flow Basin Modeling Output Shown Graphically



When the flow into the peak flow basin is 155 mgd during wet weather events, a basin size of 3.9 million gallons (MG) and 4.9 MG will be needed to maintain a plant influent of 115 mgd and 83.2 mgd respectively. To lower the plant influent to the 83.2 mgd peak, a peak flow basin of 5 MG is required. By raising the walls of the Chlorine Contact Chamber, the flow into the plant can be increased, thereby reducing the required size of the peak flow basin.

ACKNOWLEDGEMENTS

The authors would like to thank all WMARSS employees for their tireless efforts in making this stress test feasible.

REFERENCES

WMARSS Operation and Maintenance Manual, January 1985