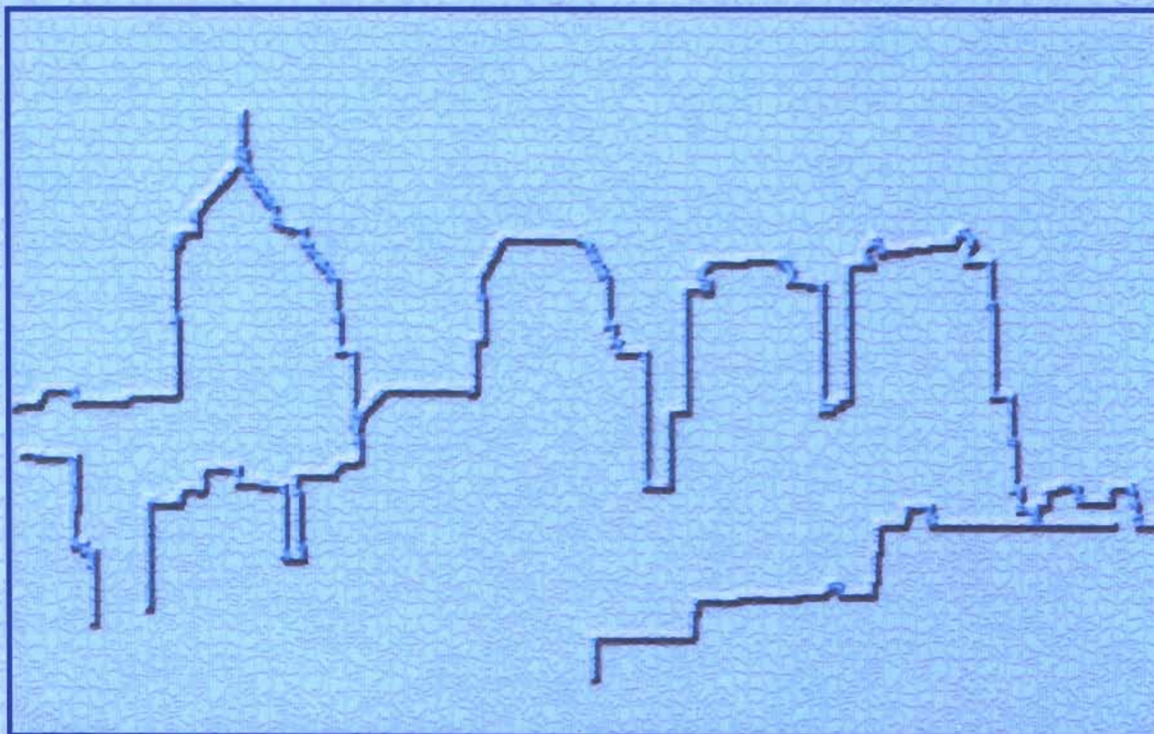
Supplemental Documentation
Volume 6

Stress Testing of the Northeast WPCP

Updated: September 1, 2009

FINAL REPORT



Stress Testing of the Northeast WPCP

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Prepared for

Philadelphia Water Department

Prepared by

CH2MHILL

December 2001

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SECTION 1

INTRODUCTION

1. Introduction

1.1 Project Objectives and Methodology

As part of its obligations under the Federal Clean Water Act and the Pennsylvania Clean Streams Law, the City of Philadelphia Water Department (PWD) has initiated a program with an objective to minimize the impact of combined sewer overflows (CSOs) on local receiving waters. One of the proposed strategies for reducing the CSO volume is to maximize flow to be treated by the water pollution control plants (WPCPs) during periods of wet weather. To implement this strategy effectively, the PWD needs to have a clear understanding of the factors that affect how much flow each of the three WPCPs can effectively treat. With this knowledge, the PWD will be able to identify and prioritize plant upgrades and other system modifications that will allow it to meet their CSO minimization objectives in the most environmentally-sound and cost-effective manner.

The PWD contracted CH2M HILL to conduct stress testing at the three wastewater treatment plants that are owned and operated by the City. The objective of the stress testing was to determine the reliable maximum capacity of the existing facilities and identify cost-effective methods of increasing the ability of these facilities to treat peak hydraulic flows associated with wet weather conditions. The major tasks performed during the project are briefly described below.

Historical Data and Operations Review. The objective of the historical data and operations review was to evaluate the physical condition, current loading, and treatment efficiency provided by the existing unit processes. A tour of the plant was conducted, and the process equipment and facilities were examined. Operating records, design information, and engineering drawings were studied to develop a strong understanding of the operations and constraints. Technical Memorandum 1 – Historical Data Review was produced to summarize the results of the site visit and historical data analysis.

Short-Term Stress Test. CH2M HILL performed a series of capacity and diagnostic tests to determine the loading versus performance characteristics of specific unit processes at each facility. The short-term stress testing focused on determining the response of the primary and secondary clarifiers to increased hydraulic loading under different operating conditions. The short-term stress testing at the Northeast WPCP (NEWPCP) included primary clarifier stress tests, secondary clarifier stress tests, secondary clarifier dye tests, and flow meter calibration. The results of each test are summarized in a test description report in Technical Memorandum 2 – Short-Term Test Results.

Long-Term Stress Test (Online Monitoring). Online monitoring equipment was installed to quantify the dynamic load/response characteristics of the secondary treatment system to naturally-occurring storm events. The equipment was also used to monitor the effect that increased flows had on the solids inventory in the system and the secondary effluent quality. Online monitoring included total plant flow, return activated sludge (RAS) flow, mixed liquor suspended solids (MLSS) concentration, sludge blanket levels, and secondary effluent total suspended solids (TSS) concentration. The equipment was in place from March

1 to June 30, 1999 and recorded data on a 10-minute interval. The results of the long-term stress test are summarized in Technical Memorandum 3 – Long-Term Online Monitoring Results. The detailed online monitoring data and instrument calibration records are provided under separate cover.

Hydraulic Throughput Capacity Assessment. WinHYDRO, a computer model that facilitates complex analysis of plant hydraulics, was used to evaluate the hydraulic throughput capacity of the Northeast WPCP. Hydraulic and energy grade lines from the headworks to the plant outfall were developed for the average and peak flow conditions. Hydraulic bottlenecks, which limit the hydraulic throughput capacity of the existing facilities, and flow distribution problems were identified and evaluated. The hydraulic throughput capacity of each unit process was determined. The results of the hydraulic modelling performed are summarized in Technical Memorandum 4 – Hydraulic Throughput Capacity of Existing Facilities.

Evaluation of Potential Improvements. Based upon results on stress testing and hydraulic modeling, major bottlenecks that limit plant capacity were identified and potential solutions developed to increase peak instantaneous capacity. Budgetary cost estimates were developed for each potential solution. The results of this analysis are summarized in Technical Memorandum 5 – Budgetary Cost Estimates for Potential Plant Improvements.

1.2 Report Organization

The project notebook consists of a final report and a series of attachments. The main body of the report contains a summary of the results from the stress testing, plant data analysis, and the evaluation of process improvements and upgrade options. The detailed results from the historical data review, short-term testing (stress tests, dye tests and flow meter calibration), online monitoring, and hydraulic throughput capacity assessment are included in the project notebook as attachments. Tables describing the design criteria, scope of work, estimated capital costs for the potential process modifications and capital upgrades, and the current National Pollution Discharge Elimination System (NPDES) discharge permit for the site are also included as attachments.

Section 2

Current Performance

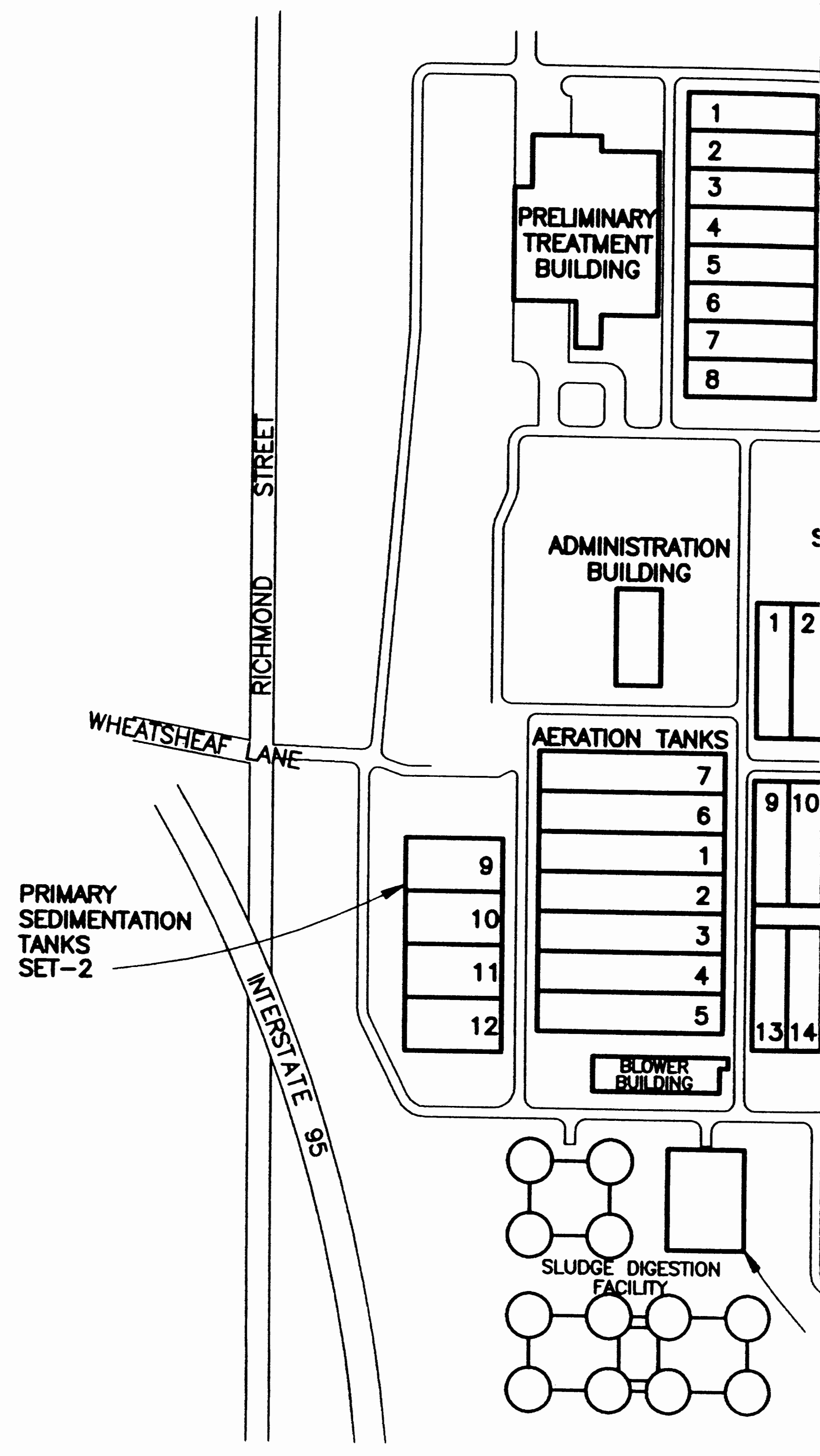
2. Current Performance

2.1 Description of Facilities

Figure 2.1 presents a flow schematic and Table 2.1 summarizes the existing unit processes at the NEWPCP.

TABLE 2.1
NORTHEAST WPCP - SUMMARY OF UNIT PROCESSES

Unit Process	Number	Description
Bar Screens	7	Width = 8 ft, single-rake front cleaned, 1-in. opening
	1	Width = 8 ft, multiple-rake front cleaned, 5/8-in. opening
Low-Level Pumps	6	Centrifugal pumps Q = 85 mgd, at 55-ft head
Grit Removal	4	Rectangular detritors Length = 55 ft, width = 55 ft, SWD = 7.5 ft, volume = 22,690 ft^3 (each)
Influent Flow Meter	2	Venturi – 48 inch – Set 1 primary clarifiers
	1	Venturi – 66 inch – Set 2 primary clarifiers
Primary Clarifiers	8 (Set 1)	Length = 240 ft, width = 65 ft, SWD = 10 ft Surface area = 15,600 ft^2, weir length = 450 ft (each) C and F sludge mechanism, influent end hopper
	4 (Set 2)	Length = 250 ft, width = 125 ft, SWD = 10 ft Surface area = 31,250 ft^2, weir length = 900 ft (each) C and F sludge mechanism, influent end hopper
Aeration Basin	7	Four-pass – through flow only Length = 371 ft, width = 87 ft, SWD = 15 ft, volume = 3.286 mg (each) Operate with selector
Aeration System		
Blowers	4	Centrifugal Q = 35,000 acfm
	2	Centrifugal Q = 27,000 acfm
Diffusers	Fine bubble	Ceramic; 12,000 per tank
Secondary Settling Tanks	8 (Set 1)	Length = 214 ft, width = 75 ft, SWD = 11 ft Surface area = 16,100 ft^2, weir length = 860 ft (each) Gould-type central hopper, C&F sludge mechanism
	8 (Set 2)	Length = 231 ft, width = 70 ft, SWD = 13 ft Surface area = 16,200 ft^2, weir length = 860 ft (each) Gould-type central hopper, C and F sludge mechanism
Chlorine Contact Chamber	2	Three-pass serpentine flow Length = 300 ft, width = 84 ft, SWD = 11 ft, volume = 2.06 mg Chlorine gas solution feed
Sludge Thickening	12	Dissolved air flotation Length = 90 ft, width = 20 ft, SWD = 12 ft
Anaerobic Digesters	8 (Set 1)	Digesters - Diameter = 110 ft, SWD = 30 ft, volume = 300,000 ft^3 (each)
	2	Sludge transfer tanks Volume = 1.5 mg (each) Diameter = 96 ft, SWD = 26 ft


PRELIMINARY TREATMENT BUILDING
1
2
3
4
5
6
7
8
RICHMOND STREET
ADMINISTRATION BUILDING
WHEATSHEAF LANE
AERATION TANKS
7
6
1
2
3
4
5
PRIMARY SEDIMENTATION TANKS SET-2
9
10
11
12
INTERSTATE 95
BLOWER BUILDING
SLUDGE DIGESTION FACILITY
1
2
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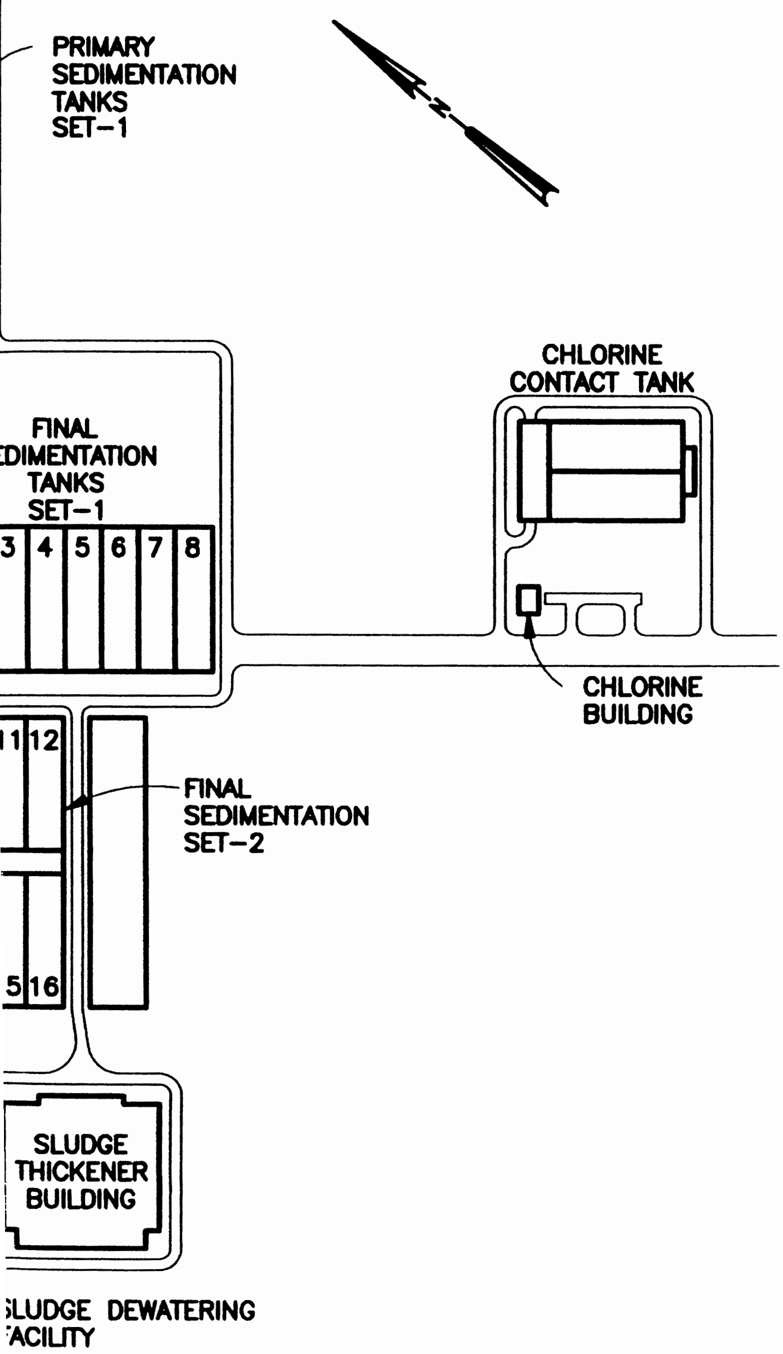

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WATERLOO ONTARIO
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FIGURE 2-1
FLOW SCHEMATIC
NORTHEAST WPCP

CITY OF PHILADELPHIA WATER DEPARTMENT

2.1.1 Preliminary Treatment

The NEWPCP receives wastewater from the Frankford high-level sewer and the Frankford, Somerset, and Delaware low-level sewers. The Frankford high-level sewer flows by gravity through the high-level screens to preliminary treatment and provides approximately 28 percent of the raw sewage flow to the facility. The remaining 72 percent of the raw sewage flows via gravity through the low-level screens into the raw sewage pump station where it is pumped to detritor tanks. The low-level screens are susceptible to blinding during high loadings (autumn leaf litter) due largely to the long travel time of the single rake mechanism. A new screen, with multiple rakes, has been installed and is not performing satisfactorily.

There are six raw sewage pumps with a rated capacity of 85 mgd at 55 of feet head, each equipped with variable speed drive. The pump operation is manually controlled based on the level in the pump station wet well. The maximum water surface level (WSL) in Junction Chamber "A" (before overflows could occur in the collection system) is 18.5 ft. Operators control the raw sewage pump operations to ensure the pump wet well remains below this level. The level in Junction Chamber "A" is maintained between 8 to 10 feet with the influent gate in the fully open position. Either modifying the influent gate position or allowing the water surface level in Junction Chamber "A" to increase above 18.5 feet is considered a flow restriction or flow throttling action. Flow restriction or throttling incidences when the total flow is less than 420 mgd must be reported under the current NPDES requirements. THIS REPORTING MECHANISM IS TIED TO INFLUENT HGL NOT FLOW

The NEWPCP has four rectangular detritor grit removal tanks. Under certain flow conditions the WSL can back up into the grit tanks causing the tanks to overflow and recirculate back through the plant drain system. The hydraulic bottleneck is associated with the piping to the primary clarifiers and is discussed in more detail in Section 3.2.

2.1.2 Primary Treatment

There are two sets of primary clarifiers. The south (Set 2 or old) primary clarifiers consist of four 250 by 125 feet rectangular basins with a side wall depth of 10 feet. Each tank has seven chain and flight mechanisms that move the primary sludge to the influent end of the basin. The tank influent channel has openings at the bottom of the channel. A venturi meter located between the grit tanks and clarifiers measures flow to the south clarifiers. Due to a hydraulic restriction, the maximum flow to the south primary clarifiers is approximately 180 mgd.

The north (Set 1 or new) primary clarifiers consist of eight 240 by 65 feet rectangular basins with a side wall depth of 10 feet. Each tank has four chain and flight mechanisms that move the sludge to the influent end of the basin. There are four gates into each clarifier from the common influent channel located at the bottom of the influent channel. Two venturi meters located between the grit tanks and clarifiers measure flow to the north clarifiers. Due to a hydraulic restriction, the maximum flow to the north primary clarifiers is approximately 240 mgd.

420MGD
TO SECONDARY

2.1.3 Secondary Treatment

The NEWPCP has seven four-pass step-feed aeration basins. The original design of the facility was based on the SURFACT process that used a combination of suspended and attached growth by mounting a series of rotating biological contractor (RBC) units on top of each aeration basin. The RBCs are plagued with mechanical and operational problems and have been taken out of service.

The four-pass aeration basins can be operated in sludge re-aeration or step-feed mode. In addition, the NEWPCP has incorporated a selector zone at the beginning of B and C passes to improve the settling characteristics of the mixed liquor. The facility has been operating in re-aeration mode for several years. However, starting in mid-December 1998, the operations staff observed an increase in the final effluent five-day biochemical oxygen demand (BOD_5) concentration and a resultant decrease in the facility BOD_5 removal efficiency. The cause of the increased final BOD_5 was an inefficiency of the selector caused by an excessively high dissolved oxygen level in the zone. Modifications to the selector zone were made and the problem has been resolved.

The mixed liquor from the seven aeration basins flow into a common mixed liquor channel which feeds three sets of secondary clarifiers. The flow distribution between the sets of secondary clarifiers is not measured and therefore cannot be adequately controlled. There are a total of 16 rectangular secondary clarifiers. Each clarifier has chain and flight mechanisms that transport the sludge to a central hopper located at approximately the mid-length of the clarifier. The RAS rate is flow-paced and is currently operating at approximately 15 percent of the through flow based on the RAS flow meters output. Plant operations staff believe the existing RAS meters underestimate the RAS flow. Based on the measured ratio between the mixed liquor and RAS TSS concentration, the plant operations staff believe RAS is approximately 30 percent of the through flow.

Set 1 consists of eight 75 by 214 feet rectangular clarifiers, with a side wall depth of 11 feet and a common aerated influent (mixed liquor) channel. The flow distribution between the clarifiers in Set 1 is not measured and the operations staff suspects there are some hydraulic and solids loading imbalances between the eight clarifiers, with the downstream clarifiers receiving a larger portion of the overall flow.

Set 2 consists of eight 70 by 231 feet rectangular clarifiers, with a sidewall depth of 13 feet, and the set arranged into two banks of four clarifiers each. Each set of four clarifiers has a common non-aerated mixed liquor and a common final effluent channel. The common effluent channel for the Set 2 clarifiers is a hydraulic bottleneck and under high flow conditions the clarifier launders become flooded.

2.1.4 Disinfection

Disinfection is provided by chlorine solution injected at the upstream end of the chlorine contact chamber. Each basin provides a three-pass serpentine flow pattern and an overflow weir located at the end of the third-pass controls the WSL. The outfall conduits provide additional chlorine contact time for disinfection.

2.1.5 Solids Handling

The NEWPCP has twelve dissolved air floatation tanks (DAFs) to thicken the waste-activated sludge (WAS). The thickened sludge is pumped to the sludge-mixing chamber where it is combined with the primary sludge. The underflow from the DAF units is used as dilution water. Excess underflow is recycled to the head of the plant. Occasionally the DAF units are not able to float the WAS and the underflow from the DAF units has a very high solids concentration. Fortunately this does not occur very often.

The NEWPCP has eight anaerobic digesters with a total volume of 17.9 million gallons. The combined primary sludge and WAS is pumped to the anaerobic digesters sequentially. The digested solids are transported to the Biosolids Recycling Center for composting, beneficial reuse and landfilling.

2.2 Regulatory Requirements

The NEWPCP National Pollution Discharge Elimination System (NPDES) permit limits include effluent BOD_5 and TSS concentrations, mass discharges, and percent removal for daily, weekly (calendar), and monthly averages. Table 2.2 summarizes the NPDES permit criteria for the facility in effect during testing. Compliance is based on the flow measured by the three venturi flumes located upstream of the primary tanks and a 24-hour composite sample collected daily at the chlorine contact chamber outfall.

TABLE 2.2
NORTHEAST WPCP – NPDES PERMIT REQUIREMENTS

Parameter	Units	Monthly Average	Weekly Average	Maximum Day	Peak Instantaneous
BOD_5					
Concentration	mg/L	30	45	-	60
Mass Loading	lbs/day	42,000	63,600		
Percent Removal	%	86			
TSS					
Concentration	mg/L	30	45		60
Mass Lading	lbs/day	52,540	78,810	-	
Percent Removal	%	85			
Flow	mgd	210		315	420

PWD has negotiated a new NPDES permit for this facility effective July 2000. The modifications to the NPDES permit are summarized below. As part of PWD's long-term combined sewer overflow (CSO) control program, PWD will be reducing the frequency and volume of untreated sewage discharges through the CSOs. In order to account for the increased loading due to the combined sewage flows that exceed the treatment plant's rated hydraulic capacity, the following methods may be used for calculating and reporting mass loadings and effluent concentrations on the monthly discharge monitoring reports.

- If a calendar month includes one or more days where flow exceed 315 mgd, a value of 85 percent may be used for those days for the purpose of calculating average monthly TSS percent removal. The actual TSS percent removal associated with those days shall be reported on the appropriate space provided on the DMR.

- If a calendar month includes one or more days where flow exceed 315 mgd, a value of 86 percent may be used for those days for the purpose of calculating average monthly $cBOD_5$ percent removal. The actual $cBOD_5$ percent removal associated with those days shall be reported on the appropriate space provided on the DMR.
- When daily flows exceed 315 mgd, the average monthly and average weekly TSS and $cBOD_5$ mass loadings for those days may be calculated by using the lesser of the actual load or the permit's allowable average monthly and average weekly limit, respectively. The actual TSS and BOD_5 loadings associated with those days shall be reported on the appropriate space provided on the DMR.

PWD has requested that $cBOD_5$ data be used to establish compliance with permit requirements. Analysis of the data collected over the previous permit cycle indicated that there is relatively little variation in the $cBOD_5/BOD_5$ ratio in the plant influent. Therefore, calculating the theoretical $cBOD_5$ loading based on historical BOD_5 data can be used to develop $cBOD_5$ limits for the site. The suggested $cBOD_5$ permit requirements for NEWPCP are:

	Concentration mg/L	**Mass Loading lbs/day**	**Percent Removal %**
Average Monthly	25	36,430	86
Average Weekly	40	54,645	
Instantaneous Maximum	50		

A copy of the new NPDES is located in the project notebook.

2.3 Current Loading and Performance Achieved

2.3.1 Unit Process Loading

Table 2.3 presents a summary of the current unit process loading over a three-year period from July 1995 to July 1998. The average and maximum daily flows were 199 mgd and 380 mgd, respectively. The maximum instantaneous flow was 430 mgd.

On September 16, 1999, the total plant flow was greater than 315 mgd from 4:30 a.m. to 10:00 a.m. the following morning. The peak flow was greater than 420 mgd for approximately 13 hours over that timeframe. The water surface level in Junction Chamber "A" was greater than 12 feet starting at 7:00 a.m. on September 16. However, the influent sluice gate was not throttled to restrict the flow to the plant.

TABLE 2.3
NORTHEAST WPCP – SUMMARY OF CURRENT UNIT PROCESS LOADINGS

Unit Process	Units	Current Loadings		Typical Values	Notes
		Average	Maximum		
Loading					
Hydraulic	mgd	199	430		1
Organic					
BOD	lbs/day	217,682	291,207		2
TSS	lbs/day	291,855	442,469		2
Grit Tanks					
Volume (total)	ft^3	90,760			
Area (total)	ft^2	12,100			
HRT	minutes	4.9	2.3	3 – 5	3
Primary Clarifiers					
Area (total)	ft^2	249,800			
Weir Length (total)	ft	7,200			
Surface Overflow Rate	gpd/ft^2	797	1,721	1,000 – 3,000	3
Removal Efficiency					
BOD	%	37		35	
TSS	%	62		60	
Aeration Basins					
Volume (total)	mg	23			
BOD Loading	$lbs/day/1,000\ ft^3$	46	59	20 – 40	2, 3
HRT	hours	2.8	1.3		4, 3
MLSS	mg/L	1,126	2,379		
SVI	mL/g	99		100 – 150	
ISV	ft/hr	15	25		
SRT	day	1.86			3
F/M	1/day	0.82			3
Secondary Clarifiers					
Area (total)	ft^2	258,400			
Weir Length	ft	13,760			
Surface Overflow Rate	gpd/ft^2	770	1,664	600 – 1,500	3
Solids Loading Rate	$lbs/hr/ft^2$	8.8	19.6	20 – 40	3, 5
Chlorination					
Volume	mg	4.12			
HRT	minutes	30	14	15	6

Notes: [1]Maximum hydraulic loading based on instantaneous flow
[2]Maximum loading based on 95th percentile
[3]Based on all units in service
[4]Based on through flow only
[5]Based on RAS flow rated of 34 percent
[6]Including volume of outfall

The average raw sewage TSS and BOD_5 concentrations are 177 mg/L and 133 mg/L, respectively. The average organic loading to the treatment plant, calculated based on the raw sewage TSS and BOD_5 concentrations and the average flow for each day was 291,855 lbs/day and 217,282 lbs/day, respectively.

2.3.2 Primary Treatment Performance

The average and peak surface overflow rates (SORs) for the primary clarifiers were approximately 800 gpd/ft^2 and 1,700 gpd/ft^2, respectively. Typical overflow rates for rectangular clarifiers are between 1,000 gpd/ft^2 to 3,000 gpd/ft^2. The primary clarifiers at the NEWPCP are operating below their expected capacity based on typical surface overflow rates.

The removal efficiencies are slightly lower than expected considering the low hydraulic loading. The average TSS removal efficiency in the primary clarifiers was 61 percent and 63 percent, respectively for Sets 1 and 2. The Set 2 clarifiers performed slightly better than the Set 1 clarifiers given the hydraulic loading on Set 1 clarifiers was higher due to the hydraulic restriction between the Set 1 clarifiers and the preliminary treatment building. This difference in performance can be attributed to this hydraulic restriction. The BOD_5 removal efficiency in the primary clarifiers was 37 percent and 40 percent, respectively for Sets 1 and 2.

2.3.3 Secondary Treatment Performance

The average primary effluent TSS and BOD_5 concentrations were 87 mg/L and 96 mg/L, respectively. The average and 95th percentile total BOD_5 loadings to the secondary treatment system, calculated based on the primary effluent BOD_5 concentration and the average flow for each day were 142,600 lbs/day and 180,825 lbs/day, respectively.

The aeration basins are currently operating with a solids residence time (SRT) of 1.9 days. The food to microorganisms (F:M) ratio in the aeration basins averaged 0.82 day $^{-1}$. The F:M is slightly lower in the late summer/early fall due to a higher mixed liquor suspended solids (MLSS) concentration over this period. The average sludge volume index (SVI) between January 1998 and January 1999 was 99 mL/g. This is low for an activated sludge plant, indicating there are few filamentous organisms in the biomass. Operations created a selector zone in the beginning of B and C passes by controlling the air supply. The target SVI during the transition was 80 to 100 mL/g. Typically, the mixed liquor values for a well-settled activated sludge are between 100 mL/g and 150 mL/g. The aeration basin selector reduces the number of filamentous organisms in the mixed liquor and thereby improves the settling characteristics of the sludge. Operational staff reported that the effluent has been turbid in the winter months because of the absence of the "sweeping action" associated with filaments. Improvements to the selector zone being operated has not resulted in a reoccurrence of these turbid events. Current SVI's range from 80 to 100 mL/g.

Using average values, a mass balance around the secondary clarifiers was performed to check the reliability of the solids inventory data. The measured RAS flow was approximately 15 percent of the total plant flow. The error difference between the measured solids in, and the measured solids out of the secondary clarifier was approximately 194 percent. The expected level of accuracy for this type of analysis is +/- 10 percent. Based on the mass balance calculation, the RAS flow is approximately 34 percent of the flow into the aeration basin.

The average and peak SORs for the secondary clarifiers were approximately 770 gpd/ft^2 and 1,660 gpd/ft^2, respectively. Typical SORs for rectangular Gould-type clarifiers are between 800 gpd/ft^2 to 1,500 gpd/ft^2. The secondary clarifiers at the NEWPCP are operating at or beyond the expected maximum hydraulic capacity based on typical SORs.

The average and peak solids loading rates (SLRs) for the secondary clarifiers were approximately 9 lbs/day/ft^2 and 20 lbs/day/ft^2 based on RAS flows of 34 percent (result of mass balance calculation). Typical peak SLRs for rectangular Gould-type clarifiers are between 20 lbs/day/ft^2 and 40 lbs/day/ft^2. The secondary clarifiers at the NEWPCP are operating below the expected maximum hydraulic capacity based on typical solids loading rates.

The secondary clarifiers at the NEWPCP achieve a very good quality final effluent even though the hydraulic loading rates are close to the expected maximum capacity. The daily TSS and BOD_5 concentrations were below the NPDES criteria of 60 mg/L except for one day in October 1995 and three days in January 1996 when the TSS concentrations exceeded the discharge limit. Based on a 30-day running average, the final effluent TSS load to the receiving water and percent removal did not exceed the NPDES criteria of 52,540 lbs/day and 85 percent removal. However, the BOD_5 load to the receiving water and percent removal did exceed the NPDES criteria on one occasion in January 1996. The NPDES permit is based on the calendar month.

SECTION 3
CURRENT CAPACITY

3. Current Capacity

3.1 Treatment Capacity

The reliable treatment capacity of the unit processes at the NEWPCP was estimated using a combination of manufacturers information, standard engineering design loading and performance criteria, operations staff observations of previous performance, and field testing of specific unit processes.

The field testing conducted at the NEWPCP included the following:

Online Monitoring Data

- Secondary clarifier 7
- Plant flow, RAS flow, mixed liquor TSS, sludge blanket level, and effluent TSS from March 1 to June 30, 1999

Primary Clarifier Stress Tests

- Primary clarifier 12 – Set 2 clarifiers
- Primary clarifier 1 – Set 1 clarifiers normal sludge pumping operation
- Primary clarifier 1 – increased sludge pumping

Secondary Clarifier Stress Tests

- Secondary clarifier 2 – current mixed liquor concentration (approximately 1,000 mg/L)
- Secondary clarifier 2 – increased mixed liquor concentration (approximately 2,000 mg/L)

Secondary Clarifier Dye Tests

- Secondary clarifier 2 – Set 1 clarifiers
- Secondary clarifier 12 – Set 2 clarifiers
- Secondary clarifier 15 – installed longitudinal baffle and sludge hopper hat
- Secondary clarifier 16 – installed longitudinal baffle

Table 3.1 summarizes the estimated treatment capacity for each unit. The basis of the estimated capacity is discussed below. The detailed field test results are presented in Technical Memorandum 2 – Short-Term Test Results and Technical Memorandum 3 – Long-Term Online Monitoring Results.

TABLE 3.1
NORTHEAST WWTP TREATMENT CAPACITY ASSESSMENT

Unit Process	Estimated Capacity (mgd)	Criteria
Pumping and Screening	500 mgd – screening and raw sewage pumping capacity	
	Low-level interceptor[1] – 375 mgd	Observed capacity of pumps
	High-level interceptor – 125 mgd	Observed maximum flow
Grit Removal	525 mgd – grit removal [2]	SOR – 58,000 gpd/ft^2
Primary Treatment		Based on allowable SOR
	460 mgd – existing	SOR – 2,500 gpd/ft^2
	505 mgd – modified inlet baffle	SOR – 2,800 gpd/ft^2
	567 mgd – improved sludge pumping	SOR – 3,500 gpd/ft^2
	710 mgd – potential	
	Set 1[3] – 273 mgd (existing)	2,500 gpd/ft^2 – test results
	Set 2[3] – 187 mgd (existing)	2,000 gpd/ft^2 – test results
	Set 2 – 235 mgd (modified inlet baffle)	2,500 gpd/ft^2 – test results
Aeration Basins	N/A – no change to organic loading patterns	
Secondary Clarifiers	270 – 380 mgd – existing condition	Long-term monitoring results
	440 mgd – improved flow/solids distribution between clarifiers	Based on allowable SOR – 1,800 gpd/ft^2
	322 mgd – mixed liquor concentration 2,000 mg/L	Based on allowable SLR – 30 lbs/day/ft^2
Chlorine Contact Chamber	430 mgd – meeting disinfection requirements at current flows	
	800 mgd – volume of chlorine basin and plant outfall	HRT – 15 minutes

[1]Based on one pump and one screen out of service
Rated capacity of raw sewage pumps – 85 mgd at 55 feet TDH, Observed maximum capacity 75 mgd
Channel velocity of screens – 0.41 ft/s at 5 ft channel depth
[2]Based on removal of 60 mesh (0.25 mm) particles
[3]Based on one clarifier out of service

3.1.1 Preliminary Treatment

The estimated treatment capacity of the preliminary treatment system is 500 mgd. This is based on the observed capacity of 75 mgd of the existing pumps with five of the six pumps in service, plus an estimated capacity of 125 mgd for the Frankford high-level sewer. For peak flow conditions, the face velocity for the bar screens will vary from 0.2 ft/s to 0.4 ft/s. The face velocity is determined by the pump wet well level that controls the water depth through the bar screen channel.

The estimated treatment capacity of the grit removal tanks is 525 mgd. This is based on three of the four grit detritors being in service, with an allowable SOR of 58,000 gpd/ft^2. The expected removal efficiency of the grit removal system under peak flow conditions is 90 percent of particles greater than 60 mesh (25 mm).

3.1.2 Primary Treatment

Six primary stress tests were conducted at the three wastewater treatment plants owned and operated by the PWD. Table 3.2 summarizes the physical characteristics of the clarifiers at each site and the stress tests performed. The primary clarifiers at all three plants are hydraulically similar. Differences in behaviour are the result of differences in influent characteristics and minor differences in influent and effluent structures.

TABLE 3.2
PRIMARY CLARIFIERS STRESS TEST PERFORMED

Site	SEWPCP	SWWPCP	NEWPCP	
Clarifier dimension			**Set 1**	**Set 2**
# of clarifiers	4	5	8	4
Type	Rectangular	Rectangular	Rectangular	Rectangular
Length (ft)	250	250	240	250
Width (ft)	125	125	65	125
SWD (ft)	12	12	10	10
Sludge Removal				
Hopper location	Influent end	Influent end	Influent end	
Sludge collection	Chain & flight	Chain & flight	Chain & flight	
Pumping freq.	Once every two days	Once per day	Three times per day	
Influent structure				
Channel	Common	Common	Common	Common
Clarifier openings	Orifice and weirs	Orifice	Orifice	Orifice
Openings/clarifier	8 Orifices and 14 weirs	8	4	12
Location	Surface and mid-level	mid SWD	Bottom SWD	Surface and Bottom SWD
Baffling	Yes	Yes	yes	Yes
Effluent structure				
Type	Lateral launders	Finger launders	Finger launders	Finger launders
Orientation	Cross flow	Longitudinal	Longitudinal	Longitudinal
Weir length (ft)	193	307	137	274
Launders	3	21	12	24
Test performed	1	2	2	1
Target SOR (range) gpd/ft^2	1,000-2,400	1,000-3,500	1,000-3,000	750-2,800

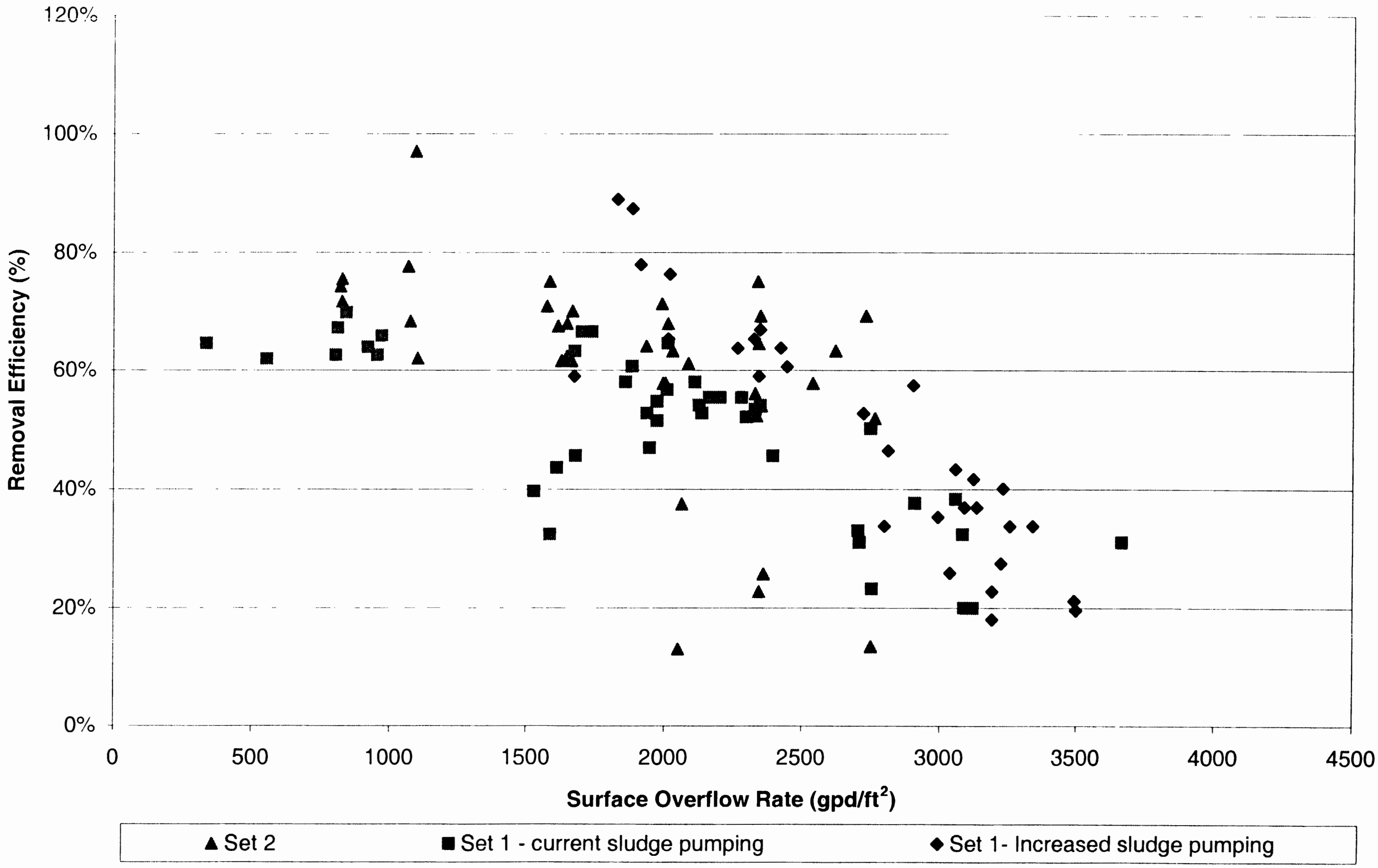
Three stress tests were performed on the primary clarifiers at NEWPCP. Figure 3-1 presents the measured TSS removal efficiency as a function of the SOR observed during the three stress tests. The test procedures and detailed results are described in Technical Memorandum 2; the main findings are summarized below.

Set 2 Primary Clarifiers. The stress test on primary clarifier 12 indicated that the clarifier performance began to deteriorate at a SOR of 2,000 gpd/ft^2, with an increase in effluent suspended solids and removal efficiency of less than 60 percent. At a SOR of 2,400 gpd/ft^2, the solids in the cross-collection channel were re-suspended, resulting in a short-term catastrophic failure of the clarifier. Clouds of black solids were observed in the influent end of the clarifier and the primary effluent TSS concentrations were greater than 100 mg/L for approximately 45 minutes. Catastrophic failure occurred again at a SOR of 2,700 gpd/ft^2. The sludge blanket in the clarifier rose throughout the test.

Set 1 Primary Clarifiers. The stress test on primary clarifier 1 indicated that the clarifier performance began to deteriorate at a SOR of 2,500 gpd/ft^2, with a TSS removal efficiency of less than 50 percent. The sludge blanket in the clarifier remained relatively constant through the test, rising slightly at the effluent end of the clarifier at the end of the test period. The re-suspension of solids from the cross-collection channel was not observed during this test. A second stress test on primary clarifier 1 was performed to quantify the improvement that could be achieved by increasing the primary sludge removal rate. The primary sludge pumps were operated for five out of every 20 minutes to simulate an underflow rate of 250 gpm for the test period. The TSS removal efficiency improved at all SORs tested. The removal efficiency was greater than 60 percent for a SOR of up to 2,800 gpd/ft^2. The clarifier performance deteriorated significantly at a SOR of 3,200 gpd/ft^2. The sludge blanket level remained below one foot throughout the test.

The estimated treatment capacity of the primary clarifiers is 460 mgd. This is based on two clarifiers being out of service (one clarifier in each set) and an allowable SOR of 2,500 gpd/ft^2 and 2,000 gpd/ft^2 for the Set 1 and Set 2 clarifiers, respectively. Modifications to the Set 2 clarifier inlet openings to direct the flow upward and away from the influent sludge hopper would result in an increase in primary treatment capacity of 505 mgd. Increasing the primary sludge pumping rate from the clarifiers would increase the primary treatment capacity to over 550 mgd. The primary stress test at SWWPCP indicated that these clarifiers are able to achieve 60 percent TSS removal efficiency at a SOR of 3,500 gpd/ft^2 with modifications to the inlet structures and improved solids removal. The potential maximum capacity of the primary clarifiers at the NEWPCP is 710 mgd with two clarifiers out of service based on an allowable SOR of 3,500 gpd/ft^2.

Figure 3-1
Comparison of Primary Clarifier Performance
TSS Removal Efficiency versus Surface Overflow Rate (SOR)



3.1.3 Secondary Treatment

Six secondary clarifier stress tests were conducted at the three wastewater treatment plants owned and operated by the PWD. Table 3.3 summarises the physical characteristics of the clarifiers at each site and the secondary clarifier stress tests performed. The secondary clarifiers at all three plants are very similar and performed similarly. Differences in performance were largely the result of differences in mixed liquor settling characteristics and solids loading during the tests.

TABLE 3.3
PHYSICAL CHARACTERISTICS OF THE SECONDARY CLARIFIERS TESTED

Site	SEWPCP	SWWPCP	NEWPCP	
Clarifier dimension			**Set 1**	**Set 2**
# of clarifiers	12	20	8	8
Type	Gould	Gould	Gould	Gould
Length (ft)	214	260	214	231
Width (ft)	68	75	75	70
SWD (ft)	11	11	11	13
Sludge Removal				
Hopper location	mid length	mid length	mid length	
Sludge collection	Chain & flight	Chain & flight	Chain & flight	
RAS removal	Gravity to sump	Pump per clarifier	Common pump	
RAS rate	30%	35%	15-30%	
MLSS	1,300	2,100	1,100	
Influent structure				
Channel	Common to 6	Common to 10	Common to 8	Common to 4
Clarifier openings	Adjustable weir	Orifice	Overflow Weir	Overflow Weir
Number per clarifier	4	4	4	4
Location	Top	Surface	Surface	Surface
Baffling	Yes	Yes	No	Yes
Effluent structure				
Type	Finger Launders	Finger Launders	Finger Launders	Finger Launders
Orientation	Longitudinal	Longitudinal	Longitudinal	Longitudinal
Weir length (m)	784	816	850	850
Number of Launders/	24	12	24	24

TABLE 3.3
PHYSICAL CHARACTERISTICS OF THE SECONDARY CLARIFIERS TESTED

Site	SEWPCP	SWWPCP	NEWPCP	
Test performed				
Stress test	2	1	0	3
Target SOR (range) gpd/ft^2	860-2,000	600-2,100		1,000-2,100
Dye tests	1	0	3	1

Three stress tests were performed on the Set 1 secondary clarifiers. The test procedures and results are described in Technical Memorandum 2; the main findings are summarized below. Stress tests were not performed on the Set 2 clarifiers because of the difficulty in measuring flow to the test tank.

Four dye tests were performed on the secondary clarifiers. The dye tests included secondary clarifier 2 (Set 1), secondary clarifier 12 (Set 2), secondary clarifier 15 (with longitudinal baffle), and secondary clarifier 16 (longitudinal baffle plus sludge hopper hat). The test procedures and results are described in Technical Memorandum 2; the main findings are summarized below.

The performance of the secondary clarifier 7 was monitored over a four-month period using online instrumentation to quantify the dynamic performance of the clarifiers to naturally-occurring storm events. The online instrumentation recorded total plant flow, set 1 RAS flow, mixed liquor TSS concentration, sludge blanket levels, and effluent TSS concentration. The results of the online monitoring are summarized below; more detailed results are presented in Technical Memorandum 3.

Stress Test Results. Three stress tests were conducted on secondary clarifier 2. Figure 3-2 presents the effluent TSS concentration as a function of the SOR. The first test was conducted in the summer at current mixed liquor concentration. The second and third stress tests were conducted in September at current and elevated mixed liquor concentrations. The mixed liquor concentration of the Set 1 clarifiers was increased by modifying the RAS distribution to the aeration basins. Aeration basins 6 and 7 preferentially feed the Set 1 secondary clarifiers.

The stress tests conducted at current mixed liquor concentrations (Tests 1 and 2) indicated that the clarifier performance began to deteriorate at a SOR of 1,800 gpd/ft^2. The effluent TSS concentration remained below 25 mg/L throughout the test and catastrophic failure of the clarifier was not observed. The mixed liquor concentration and SVI during test 1 was 890 mg/L and 151 mL/g. The mixed liquor concentration and SVI during Test 2 were 970 mg/L and 103 mL/g, respectively. The clarifier performed slightly better during the second test. The SVI range corresponds to the range normally experienced at the facility. The mixed liquor concentrations were approximately 20 percent lower than the average mixed liquor for the facility.

The stress tests conducted at elevated mixed liquor concentrations (Test 3) indicated that the clarifier deteriorates rapidly at a SOR of 1,600 gpd/ft^2. Catastrophic failure of the clarifier was observed and the sludge blanket increased under the effluent launders and started to washout. The failure mechanism was a solids-flux-type failure and the test was terminated once failure was achieved. The mixed liquor concentration and SVI during Test 1 were 1,930 mg/L and 95 mL/g. The mixed liquor concentration was approximately 70 percent higher than the average mixed liquor for the facility.

Figure 3-3 presents the effluent TSS concentration as a function of solids loading rate (SLR) for the three stress tests conducted. The secondary clarifier failed at a SLR of approximately 30 lb/ft^2 per day. The estimated capacity of the secondary clarifiers will decrease with increasing mixed liquor concentrations.

Dye Test Results. Dye tests were used to evaluate the hydraulic efficiency of the secondary clarifiers. Four clarifier dye tests were performed; one dye test for each clarifier type and baffling configuration used at the facility. The test results from clarifiers 2 and 12 indicated that the hydraulic characteristics of the Set 1 and Set 2 clarifiers are very similar. The stress test results from clarifier 2 can be used to estimate the performance of the Set 2 clarifiers.

The test results from clarifiers 15 and 16 indicated that the longitudinal baffle does not improve the hydraulic characteristics of the clarifier. A more pronounced sludge density current was observed in the baffled clarifiers than in the unbaffled clarifiers.

Online Monitoring Results. The online monitoring recorded the response of secondary clarifier 7 to six storm events. Table 3.4 summarizes results of the online monitoring program. The secondary clarifier TSS concentration exceeded 60 mg/L for short periods of time during each storm. The effluent TSS concentration rose significantly at plant flow rates between 270 mgd to 380 mgd. The maximum SOR based on total plant flow and number of clarifiers in service during the storm events ranged from 1,310 gpd/ft^2 to 1,700 gpd/ft^2. This is significantly lower than the maximum allowable SOR observed during the secondary clarifier stress test. The difference between the stress test and long-term monitoring results indicates a significant imbalance in the flow and solids distribution between the secondary clarifiers.

TABLE 3.4
RESULTS OF THE ONLINE MONITORING PROGRAM

Date	SVI	MLSS	Q	Q Peak	SOR	SOR Peak	TSS Effluent Peak
March 3	95	998	270	340	1,040	1,310	80
March 6[1]	2*	1,643	300	388	1,160	1,500	93
March 6 and 7[1]	2*	1,240	325	370	1,250	1,430	93
March 21	94	1,219	300	410	1,240	1,700	153
April 9	133	1,117	360	394	1,490	1,630	191
April 11	2*	1,406	380	390	1,570	1,610	195
April 16	137	1,081	330	400	1,370	1.660	70

* Measurements were not taken on these days
[1] Same measured storm with difference in MLSS measured values

Figure 3-2
Northeast WPCP Secondary Clarifier 2 Stress Tests
Effluent Concentration versus Surface Overflow Rate (SOR)

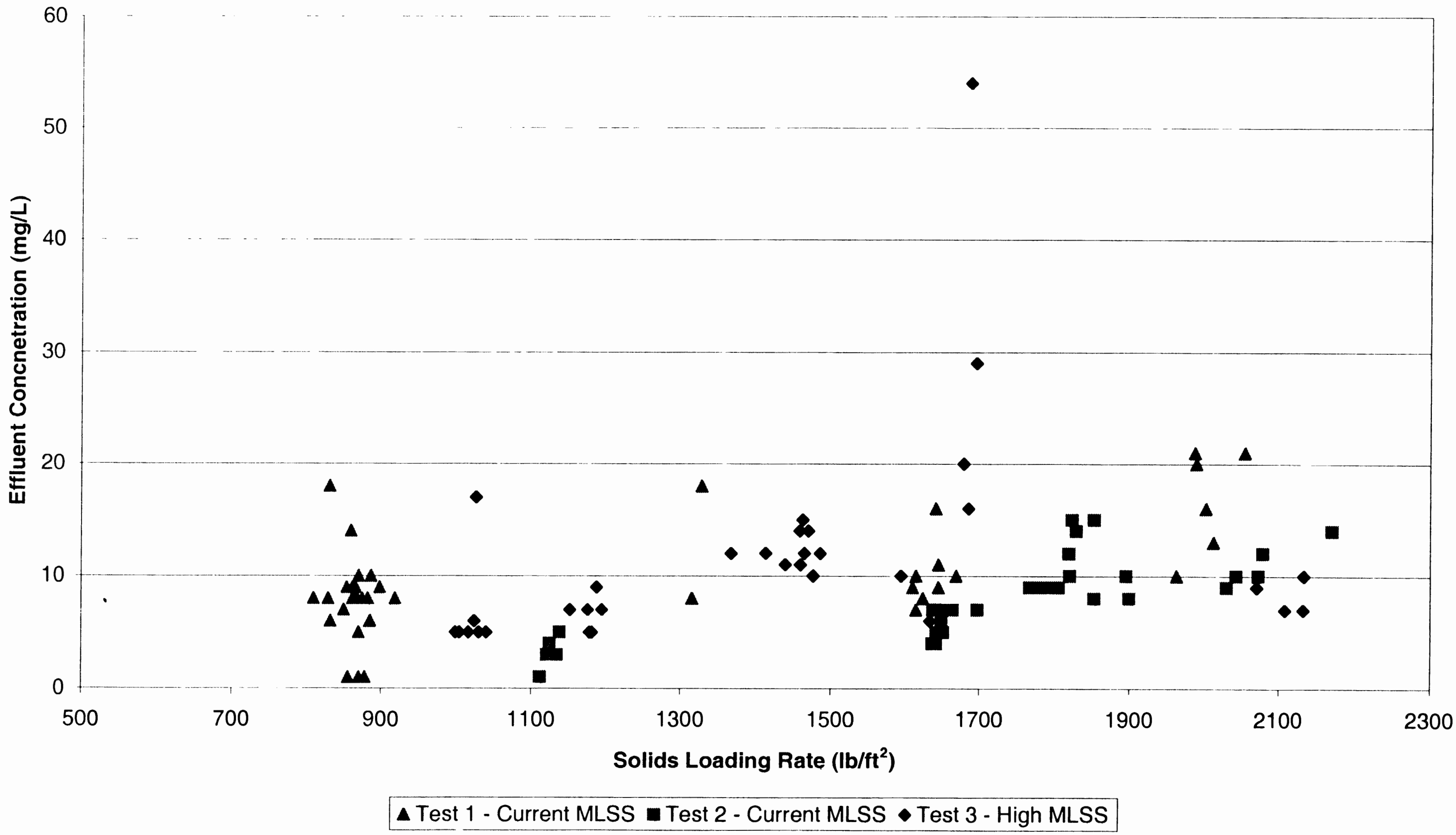


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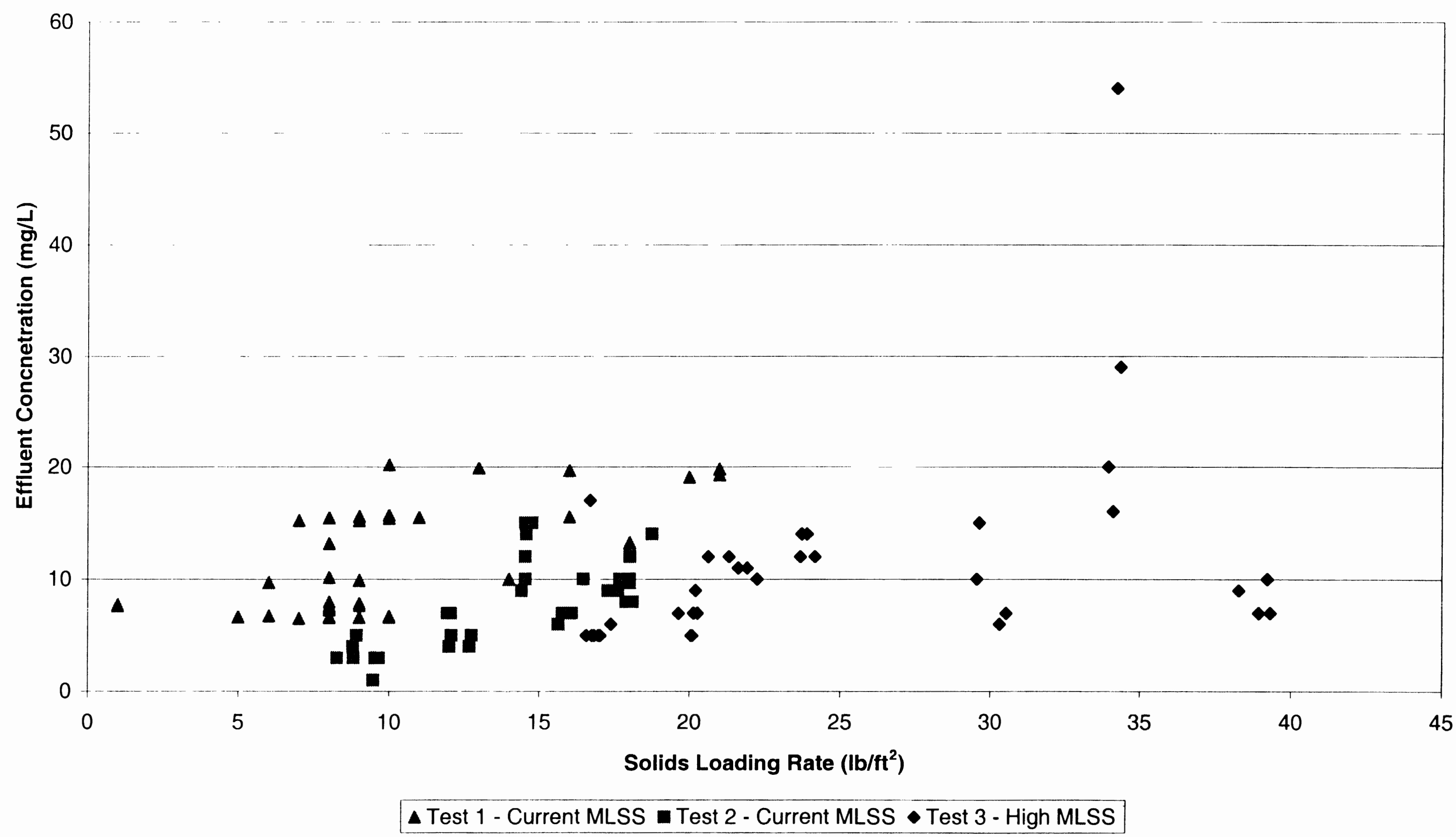
Figure 3-3
Northeast WPCP Secondary Clarifier 2 Stress Tests
Effluent Concentration versus Solids Loading Rate (SLR)



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3.2 Hydraulic Throughput Capacity

The hydraulic throughput capacity of the unit processes at the NEWPCP was estimated using WinHYDRO, a computer model that facilitates complex analysis of plant hydraulics. Hydraulic and energy gradelines from the headworks to the plant outfall were developed for a number of flow rates. The hydraulic throughput capacity of each unit process was developed based on the assumption that the downstream hydraulic bottlenecks had been resolved. Table 3.3 summarizes the estimated hydraulic throughput capacity for each unit process. The detailed hydraulic modelling results are presented in Technical Memorandum 4 – Hydraulic Throughput Capacity of Existing Facilities.

TABLE 3.3
NORTHEAST WWTP CURRENT HYDRAULIC THROUGHPUT CAPACITY

Unit Process	Estimated Capacity (mgd)	Basis of Capacity Estimate
Chlorine Contact Basin	>800	• Flow path – from the chlorine contact basin weir to the chlorine contact flow distribution chamber • Hydraulic control section – chlorine contact chamber weir • Both chlorine contact basins in service with the flow control gates fully open • Hydraulic exceedance – secondary clarifier overflow weir elevation
Secondary Effluent Channel – Set 1	300	• Flow path – from the chlorine contact basin weir to the secondary clarifier 1 overflow weir • Hydraulic control section – chlorine contact chamber weir • Both chlorine contact basins in service with the flow control gates fully open, 50/50 flow split between Set 1 and Set 2 secondary clarifiers; all secondary clarifiers in service • Hydraulic exceedance – secondary clarifier overflow weir elevation
Secondary Effluent Channel – Set 2	190	• Flow path – from the chlorine contact basin weir to the secondary clarifier 9 through 16 overflow weir • Hydraulic control section – chlorine contact chamber weir • Both chlorine contact basins in service with the flow control gates fully open, 50/50 flow split between Set 1 and Set 2 secondary clarifiers; all secondary clarifiers in service • Hydraulic exceedance – secondary clarifier overflow weir elevation
Primary Effluent Channel – Set 1	330	• Flow path – from the secondary clarifier overflow weir to the primary clarifier 1 overflow weir • Hydraulic control section – secondary clarifier overflow weir • A 50/50 flow split between Set 1 and Set 2 secondary clarifiers, 50/50 flow split between Set 1 and Set 2 primary clarifiers; six aeration basins in service • Hydraulic exceedance – primary secondary clarifier overflow weir elevation
Primary Effluent Channel – Set 2	250	• Flow path – from the secondary clarifier overflow weir to the primary clarifier 12 overflow weir • Hydraulic control section – secondary clarifier overflow weir • A 50/50 flow split between Set 1 and Set 2 secondary clarifiers, 50/50 flow split between Set 1 and Set 2 primary clarifiers: six aeration basins in service • Hydraulic exceedance – primary clarifier overflow weir elevation
Primary Clarifier – Set 1	250	• Flow path – from the primary clarifier overflow weir to the grit chamber collection channel • Hydraulic control section – primary clarifier overflow weir • All primary clarifiers in Set 1 in service, four detritors in service • Hydraulic exceedance – top of concrete in the grit removal building

TABLE 3.3
NORTHEAST WWTP CURRENT HYDRAULIC THROUGHPUT CAPACITY

Unit Process	Estimated Capacity (mgd)	Basis of Capacity Estimate
Primary Clarifier – Set 2	180	• Flow path – from the primary clarifier overflow weir to the grit chamber collection channel • Hydraulic control section – primary clarifier overflow weir • All primary clarifiers in service, four detritors in service, butterfly gate valve in the fully open position • Hydraulic exceedance – top of concrete in the grit removal building
Raw Sewage Pump Station Discharge Channel	Version A – 410 Version B – 440	• Flow path – from the Set 1 primary clarifier overflow weirs to the raw sewage pump station discharge channel • Hydraulic control section – primary clarifier Set 1 overflow weir • Version A – flow to Set 2 clarifiers limited to 180 mgd Version B – 50/50 flow split between Set 1 and Set 2 clarifiers • Hydraulic exceedance – top of concrete in the raw sewage pump station

The hydraulic throughput capacity of the NEWPCP is greater than 500 mgd except in the following locations:

- **Primary Clarifier Influent** – The hydraulic throughput capacity of the channel between the preliminary treatment building (grit tanks) and primary clarifiers set 2 is limited to 180 mgd. The headlosses occur in the 5 ft by 7 ft channel section between the set 2 flume (venturi meter) and the primary clarifier influent channel. The hydraulic throughput capacity of the channels between the preliminary treatment building (grit tanks) and the primary clarifiers set 1 is limited to 250 mgd. Therefore, the total hydraulic throughput capacity between the preliminary treatment and primary treatment is 430 mgd. At flow rates above 430 mgd the detritor floor and walkways become flooded. Additionally, at times, the detritor floor has flooded at flows less than 430 mgd for unknown reasons.

- **Secondary Clarifier Set 2 Effluent Channels** – The hydraulic throughput capacity of the set 2 secondary effluent channel is limited to 190 mgd with all secondary clarifiers in service. Excessive headlosses occur in the clarifier discharge channel and common effluent channel due to entrained air escaping through the bottom slots which connect the upper and lower channel sections. The hydraulic restriction contributes to the hydraulic imbalance between the set 1 and set 2 secondary clarifiers. The hydraulic restriction also contributes to flooding of the set 2 secondary clarifier weirs and premature failure of the clarifiers due to localized velocity gradients at the effluent weir.

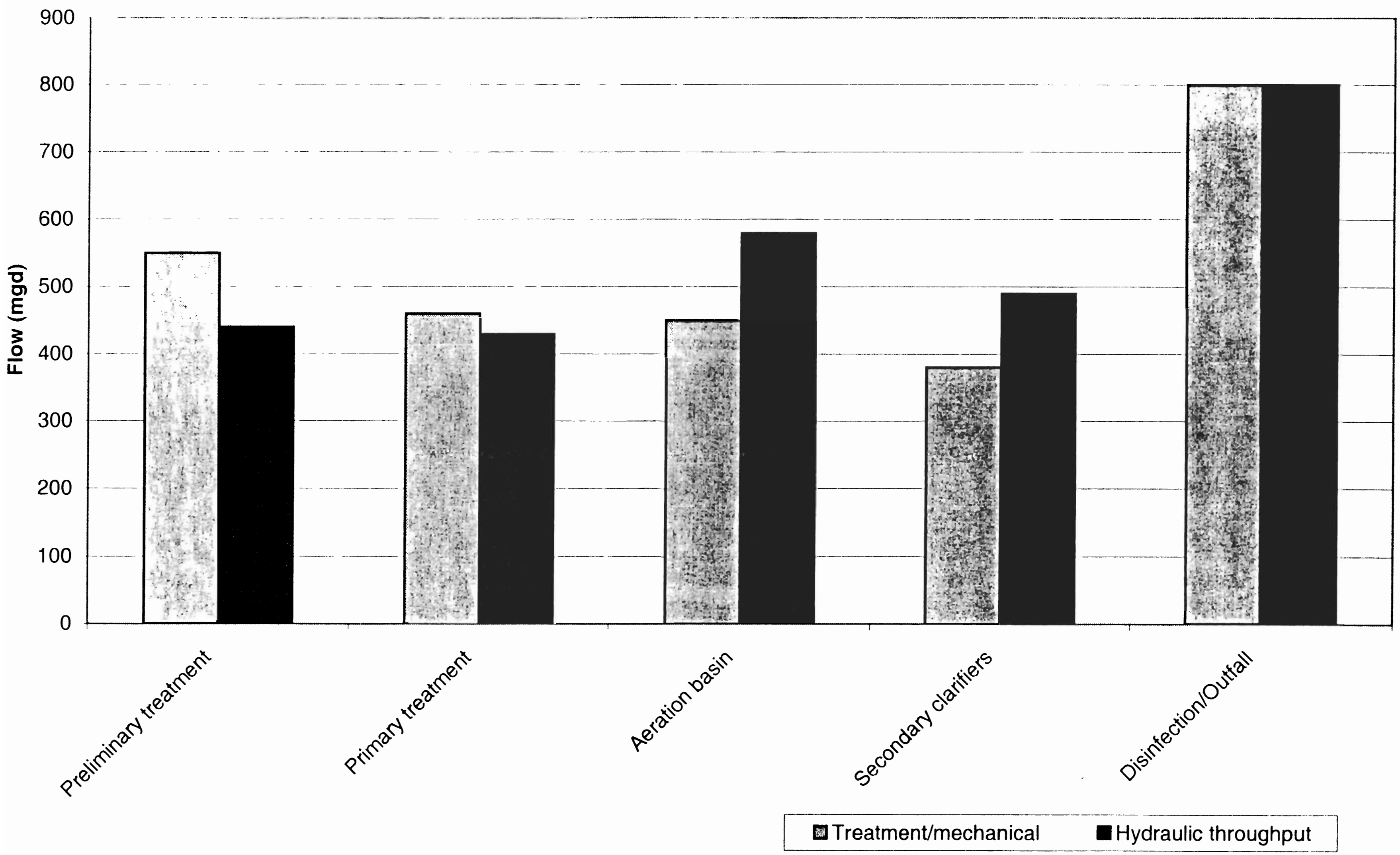
3.3 Capacity Limiting Factors

Figure 3-4 presents a summary of the estimated current capacity on a unit process basis for NEWPCP. The major capacity bottlenecks for the facility are:

- **Secondary Clarifiers** – The treatment capacity of the secondary clarifiers at the NEWPCP is reduced by the difficulties in controlling the hydraulic distribution between the set 1 and set 2 clarifiers and the hydraulic and solids loading between the clarifiers in each set.

- **Primary Clarifiers** – The hydraulic throughput capacity to the primary clarifiers limits the hydraulic throughput of the facility to 430 mgd. The hydraulic restriction between the set 2 primary clarifiers and the preliminary treatment building has a negative impact on the flow distribution between set 1 and set 2 primary clarifiers.
- **Primary Treatment** – The treatment capacity of the set 2 primary clarifiers is limited to 185 mgd due to high velocities caused by the inlet baffle resuspending solids in the clarifier cross collector channel.

Figure 3-4
Northeast WPCP - Estimated Current Capacity



SECTION 4

CURRENT SUSTAINABLE TREATMENT CAPACITY

4. Current Sustainable Treatment Capacity

4.1 Sustainable Treatment

The estimated treatment capacities summarized in section 3 of this report utilise maximum instantaneous limits currently in PWD's NPDES permits as the goal for the effluent quality. Since the maximum instantaneous and maximum daily limits are the same values, a process operation whose final effluent quality will meet the instantaneous maximum limits will also meet the daily maximum limits. However the current NPDES permits, based on expected performance for plants that intake substantial quantities of storm water, include maximum weekly and monthly limits which are significantly more stringent than the daily/instantaneous limits. Furthermore, strict compliance with maximum monthly concentration limits will not guarantee monthly compliance with other quality limits in the permit such as average monthly and weekly loading limits and percent removal requirements.

An important but difficult question remains regarding how long a facility (or process) can sustain high flows which allow effluent quality to meet all the permit effluent quality requirements.

The performance of the secondary clarifiers determines the final effluent quality from the NEWPCP. The data collected during the field-testing was used to predict final effluent quality as a function of flow rate. The predicted final effluent TSS and BOD_5 concentration for a given flow rate was used to determine the maximum flow which could be maintained for an infinite period of time with effluent quality meeting the monthly and weekly loading and percent removal requirements in the NPDES permit.

Secondary clarifier capacity is defined by either the clarification capacity, which is a function of surface overflow rate (SOR), or the solids flux capacity which is a function of solids loading rate (SLR). Clarifier performance as a function of both SOR and SLR was collected during the testing for a range of operating conditions. Data from the six secondary clarifier stress test was used to quantify the secondary clarifier performance as a function of hydraulic loading and to identify the maximum allowable solids loading rate for the clarifiers.

The historical data was used to determine the yield and mixed liquor concentrations required as a function of primary effluent quality. The data from the primary clarifier stress tests was used to determine the expected primary effluent quality as a function of flow rate. The mixer liquor required for the expected primary effluent quality determines the solids loading rate for the secondary clarifier.

4.2 Analysis Methodology

4.2.1 Predicting Secondary Effluent Quality as a Function of the SOR

In the stress tests of the secondary clarifiers, the TSS and BOD_5 concentrations in the secondary effluent were measured as a function of the surface overflow rate applied to the clarifiers. A linear regression was performed on the field testing data to establish the relationship between SOR and TSS and BOD_5 concentrations in the effluent. The intercept and slope values obtained for the regression were statistically analyzed to find the 95% confidence level associated with these two coefficients. Using the upper 95% confidence level interval provides a conservative description of the relationship between the SOR and effluent quality. The model is used to predict TSS or BOD_5 for a given SOR, the value generated using the linear regression will be lower than the actual value observed 95 out of 100 times.

The estimated effluent concentrations and discharge loads (which are equal to the effluent flow rate multiplied by the effluent concentration) can then be compared to permit levels to determine the sustainable treatment capacity of the facility on a SOR basis.

4.2.2 Effect of the SLR on Secondary Clarifier Performance

Failure of the secondary clarifiers may occur either due to clarification or thickening. An increase in the hydraulic loading to the primary clarifiers will result in an increase in organic loading to the aeration basin due to an increase in the amount of organic material entering the plant and deterioration in the primary clarifier performance. An increase in the organic loading to the aeration tanks results in an increase in the mixed liquor concentrations and therefore an increase in he solids loading for a given flow. Therefore the analysis done in terms of the SOR must be complemented with an analysis of the effect of influent flow rate versus SLR.

Stress tests were performed on the primary clarifiers and removal efficiencies as a function of the surface overflow rate in the primary clarifiers were documented. The data was used to predict the quality of the primary effluent as a function of the influent flow rate. This analysis, combined with analysis of historical data on solids production, was used to estimate the SLR as a function of flow, taking into account both the performance of the primary clarifiers and the increase in the organic loading associated with augmented flows.

The stress tests on the secondary clarifiers indicated that the maximum SLR that could be maintained before thickening failure occurs is 35 lb/(ft^2.day). The flow at which these solids loading rates are achieved are the maximum sustained flow that can be maintained in the plant before thickening failure occurs.

4.3 Analysis Results

4.3.1 Predicting Maximum Flows as a Function of the SOR

Figure 4.1 is a plot of the TSS in the secondary effluent and the SOR applied in the secondary clarifier from the six secondary clarifier stress tests conducted at the facilities owned and operated by PWD. The data from all six secondary clarifier stress tests were used in the preparation of this plot. Figure 4.2 presents the same analysis was done for the BOD_5 concentration in the secondary effluent.

The amount of TSS and BOD_5 discharged results from the product of the flow rate and the concentrations predicted by the 95% confidence level regressions. The discharge values were compared to the NPDES Permit values at the time of the test for the NEWPCP. The results of this analysis are presented in Table 4.1.

TABLE 4.1 NORTHEAST WPCP – TEST PERIOD NPDES PERMIT REQUIREMENTS AND RESULTS OF THE SUSTAINABLE FLOW ANALYSIS[1]

Parameter	Units	NPDES Limit	Maximum Sustainable Flow based on SOR		Maximum Sustainable Flow based on SLR
			TSS Limit	BOD5 Limit	
Maximum Day Limits	Mgd	420			375
Maximum Week Limits	Mgd		320	305	
BOD_5 Concentration	mg/L	45			
BOD5 Mass Loading	lbs/day	63,600			
TSS Concentration	mg/L	45			
TSS Mass Loading	lbs/day	78,810			
Maximum Monthly Limits	Mgd	210	260	235	
BOD_5 Concentration	mg/L	30			
BOD_5 Mass Loading	lbs/day	42,000			
BOD_5 Percent Removal	%	86			
TSS Concentration	mg/L	30			
TSS Mass Loading	lbs/day	52,540			
TSS Percent Removal	%	85			

[1] BOD_5 limits based on old permit, plant now monitors $cBOD_5$ for compliance.

The maximum sustainable flow at which the NEWPCP can meet the monthly NPDES TSS and BOD_5 effluent mass loading requirements are 260 and 235 mgd respectively. The maximum month sustainable capacities are slightly higher than the average design capacity of the facility.

Figure 4-1
Secondary Clarifier Stress Test - Effluent TSS Concentration as a Function of SOR

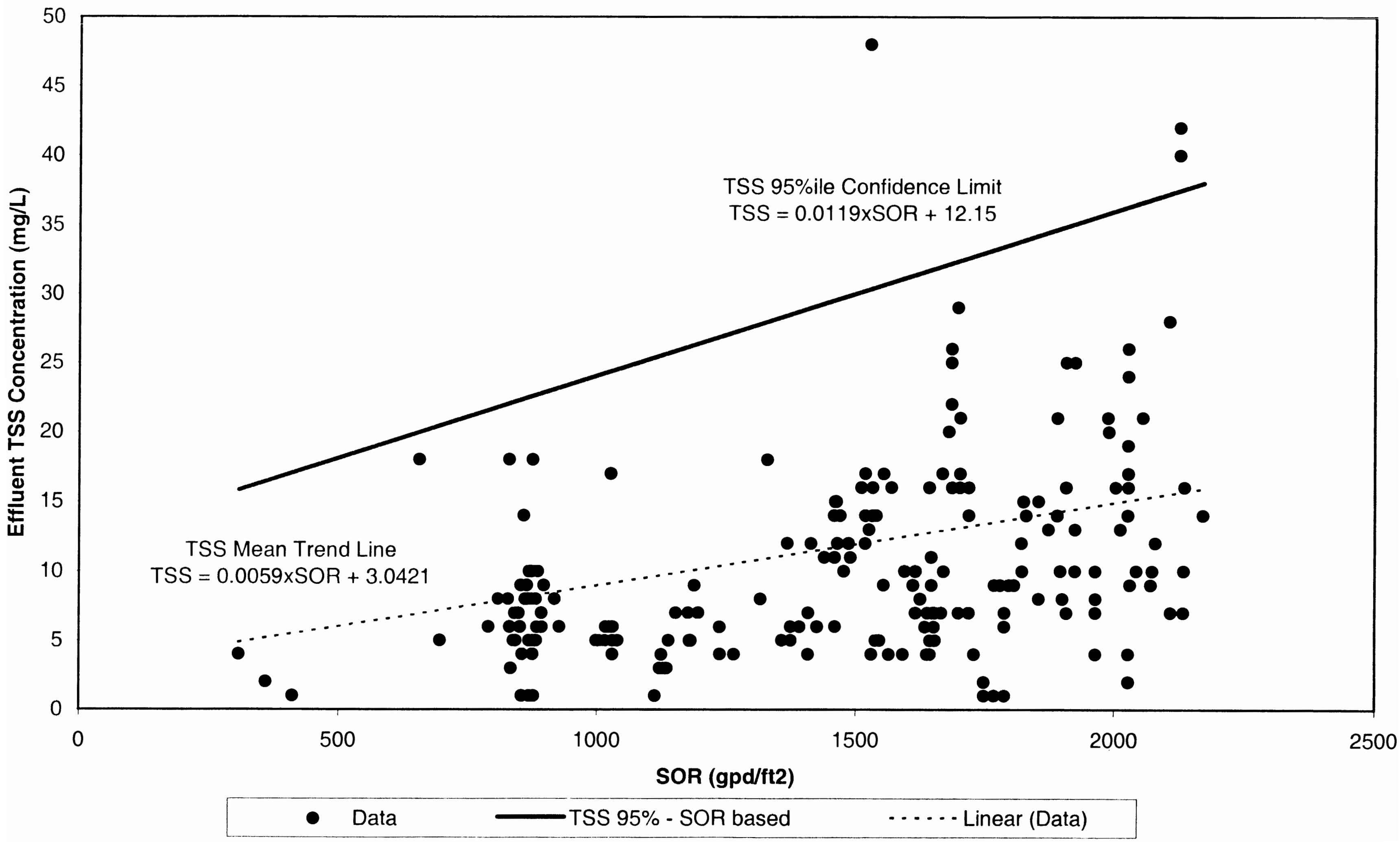
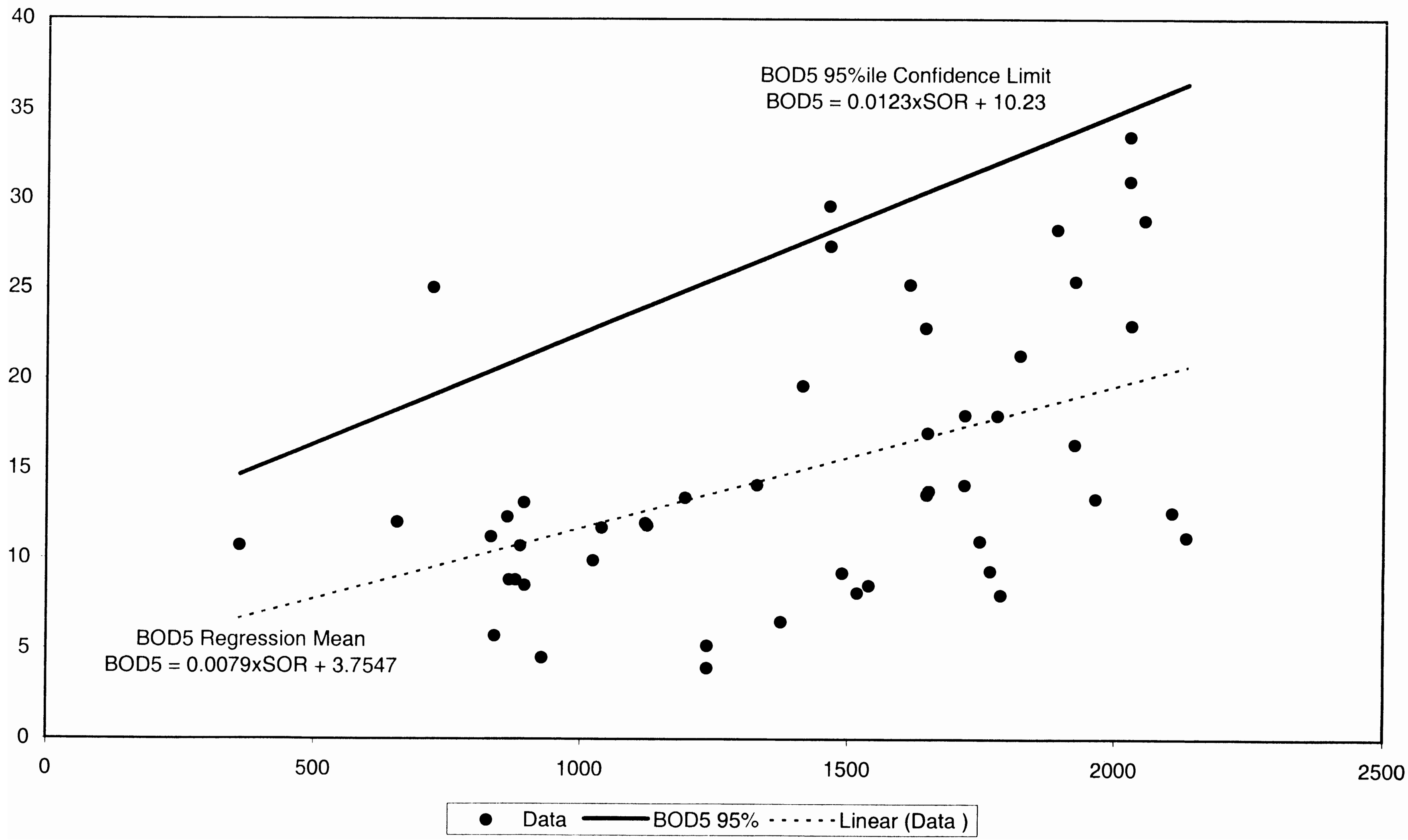


Figure 4-2
Secondary Clarifier Stress Test - Effluent BOD5 Concentration as a Function of SOR



4.3.2 Predicting Maximum Flows as a Function of SLR

The stress tests of the secondary clarifiers indicated that the maximum solids loading rate that could be sustained by the secondary clarifiers was 35 lb/(ft^2.day). The solids loading rate is a function of the MLSS concentration in the aeration basin and the influent and RAS flow rates. The MLSS concentration is dependent on the loading to the aeration basins, which in turn is dependent on the performance of the primary clarifiers as a function of the flow. The objective is to develop an overall correlation between the flow coming into the plant and the resulting solids loading rate into the secondary clarifiers.

The primary clarifier stress test results were used to determine the TSS percent removal in the primary clarifiers as a function of influent flow rate. A regression analysis of all stress test results performed in the primary clarifiers, except the test performed at the Southeast plant where the clarifier failed prematurely due to the hydraulic limitations of the launders, was performed and the lower 95% confidence levels associated with the regression parameters were calculated. Figure 4.3 presents the results of this analysis.

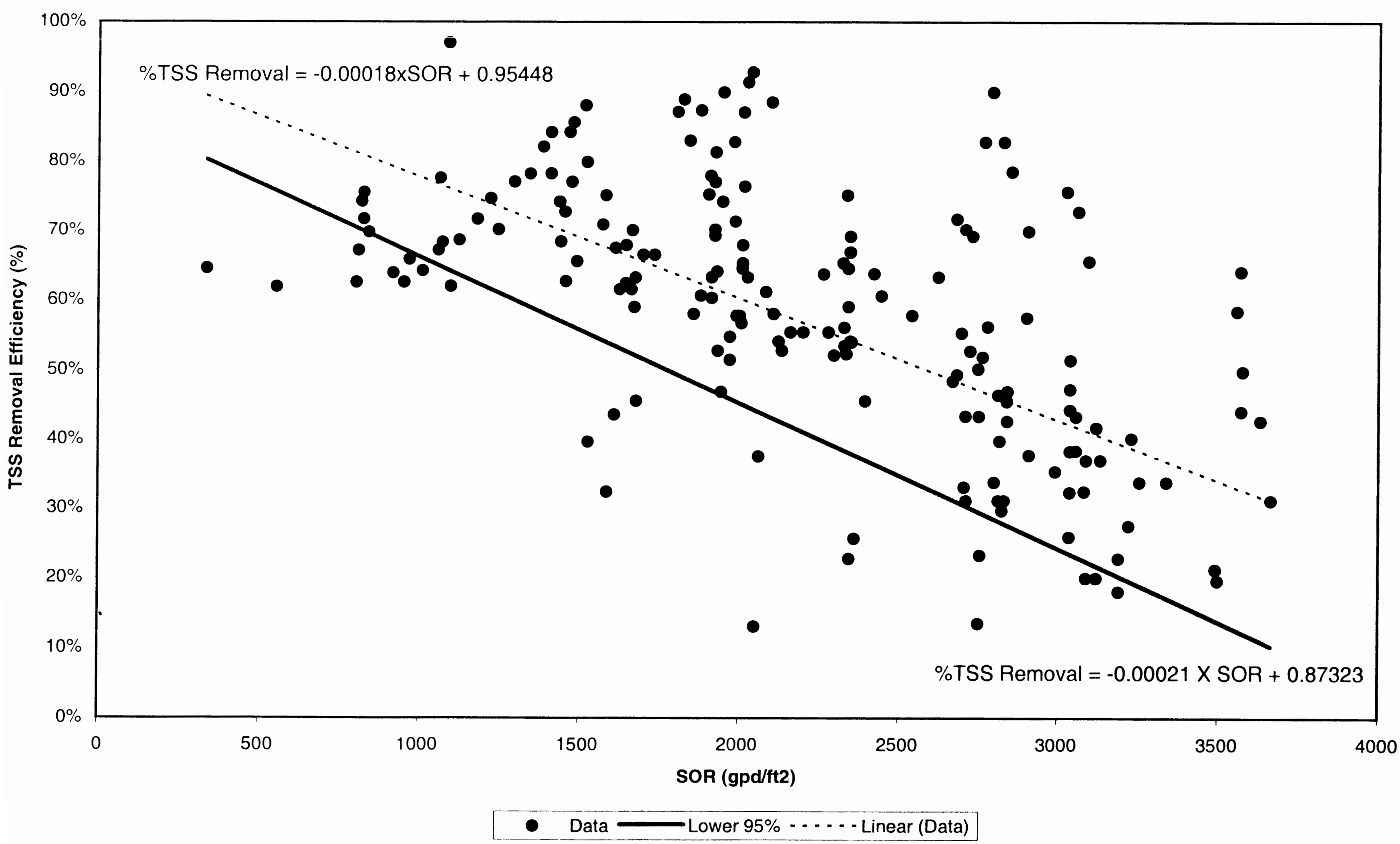
The yield for the NEWPCP was estimated based on the historical data of waste activated produced and the TSS and BOD_5 concentrations in the primary effluent. For the determination of the SLR limiting flow it was assumed that all of the primary clarifiers, secondary clarifiers and aeration basins are in service. This corresponds to current operating practice at the site.

The SLR becomes 35 lb(ft^2.day) at the NEWPCP when the sustained flow is equal to 375 mgd. At flow rates greater than 375 mgd thickening failure will occur unless measures are taken to reduce the solids loading rate to the secondary clarifiers. Preventative measures which can be readily implemented at the NEWPCP include modifing the step feed gate postions based on influent flow.

Improving the primary clarifier performance by providing "out of clarifier" primary sludge thickening or enhanced primary clarifier performance through chemical addition would also reduce the solids loading to the secondary clarifiers. These alternatives would require capital expenditure for additional facilities.

Improving the solids removal efficiency of the secondary clarifiers would effectively increase the allowable solids loading rate to the clarifier. This would require modifications to the existing RAS system.

Figure 4-3
Primary Clarifier Stress Test – Percent TSS Removal Efficiency as a Function of SOR



Upgrades to Increase Capacity of Secondary Treatment to 450 MGD

Currently NEWPCP secondary system capacity is limited to 430 mgd. A slight increase to this secondary treatment capacity could be achieved by modifying the Set 2 secondary effluent channel "double decker" structure to improve hydraulics and some modifications to the existing RAS collection and pumping system. Capital costs for these improvements are estimated at $2,410,000.

Increase Wet Weather Treatment Capacity

The NEWPCP has four unused secondary clarifiers on site. These tanks could be modified to provide stormwater treatment equivalent to primary treatment for an additional 100 mgd of flow. The estimated capital cost to modify these tanks is between $5,000,000 and $10,000,000. The estimated capital cost to increase the raw sewage pumping and preliminary treatment by 150 mgd is between $20,000,000 and $24,000,000.

The potential primary treatment capacity at the NEWPCP is 710 mgd. Increased primary sludge pumping would be required to achieve the additional primary treatment capacity. The estimated capital cost for primary sludge thickeing is $12,254,000. The estimated capital cost to increase the raw sewage pumping from 500 to 800 mgd to take advantage of all available tankage on site is between $36,000,000 and $40,000,000.

COST TO TAKE THICKENING/SLUDGE CAPACITY TO 550 MGD = ?

4.4 Control of High Flow Duration

Discussions with PWD managers directing PWD 's CSO program indicated that current CSO in line storage and draw down plans expect that stored combined sewerage would be released to the plant over a 12 hour period following a storm event. This is a volume of combined sewerage that PWD's plants have not received in the past. Furthermore, there is flexibility in the draw down strategy since the primary objective of the effort would be to return the storing sewer back to its original condition prior to the next storm event. It was clear that this is only a current plan and it would change should PWD be required in the future to provide additional combined sewerage storage to meet receiving water quality objectives.

From the wastewater treatment plants perspective, there are a number of factors that influence the ability of a plant to achieve weekly or monthly limits when the plant is being stressed by storm induced high influent flows. The number and distribution of rain events during the week/month together with plant effluent quality during non-rain event periods rank high on the list of influences. PWD's revised permit language provides effluent quality relief but only when the daily plant flow exceeds the permitted maximum daily flows currently stated in the permits. No such relief occurs for flows below the maximum daily flow limits.

Since the impact of stored combined sewerage on the NEWPCP performance is an unchartered experience, it is recommended that the duration of storage be no greater than a 24-hour period for each storm event. Should the CSO program's strategy for stored combined sewerage change beyond this 24 hour period, the issue of plant compliance for all monthly and weekly effluent quality requirements should be reviewed.

SECTION 5

POTENTIAL UPGRADES

5. Potential Upgrades

A list of potential upgrades was developed to increase the capacity or improve the performance of the NEWPCP. The potential improvements are based on the results of stress tests on unit process, long-term monitoring of the plant, and hydraulic modelling.

Each upgrade option has been prioritized based upon the following criteria:

- **Priority A – Existing Facilities Optimization.** Improvements that are easily implemented, low cost, high benefit, and will have an immediate positive impact upon normal operations. These are options that can be included in short-term capital budgets.
- **Priority B – Proactive Improvements.** Improvements that are moderate in cost and will have a small impact on plant capacity. This category also includes improvements that are necessary to maintain existing capacity for increased mixed liquor suspended solids (MLSS) in the aeration tanks. These are options that should be included in a long-term improvement plan.
- **Priority C – Improvements to Increase the Solids Handling Capacity of the Secondary Clarifier.** The stress tests identified that the solids handling capacity of the secondary clarifiers is very limited. This category includes improvements that are necessary to increase the secondary clarifier capacity with current mixed liquor concentration and/or to maintain exisitng capacity if increased mixed liquor suspended solids are required in the future.
- **Priority D - Capacity De-bottlenecking.** Improvements that have large costs associated with them and will greatly increase capacity above the current permitted peak flow. These options should be considered in an overall long-term wet-weather flow control program and in the long-term improvement plan if significantly more treatment capacity is required at the facility.

The list of potential upgrades, budgetary cost estimate, and their associated prioritization are summarized in Table 5.1 below. Detailed descriptions of each upgrade are presented in Technical Memorandum 5 – Budgetary Cost Estimates for Potential Plant Improvements.

The cost estimates shown here are based on preliminary costs and are for use as "budgetary" values only. The cost estimates are Class "C" cost estimates (order of magnitude costs) as defined by the American Association of Cost Engineers. The level of accuracy of the Class "C" cost estimates is +50 percent to –30 percent of the actual cost of construction. These costs can be used for decision-making to select those options that are most feasible from both a design and cost perspective for more detailed analysis.

TABLE 5.1
POTENTIAL UPGRADE OPTIONS AT NORTHEAST WPCP

Option No.	Description	Priority Classification	Estimated Conceptual Cost
1	Improve mixing in mixed liquor channel to secondary clarifiers 9 through 16	A	$472,000
2	Polymer addition on Set 1 secondary clarifiers to maintain effluent quality	B	$22,000
3	Separate flow measurement of secondary effluent from sets 1 and 2	C	Currently undetermined
4	Automation of step feed operation for aeration tanks	A/B	$161,000
5	Modify Set 2 secondary effluent channels to reduce hydraulic restrictions under high flow conditions	B/D	$223,000
6	Modify the existing RAS system in the secondary clarifiers	C	$2,183,000
7	Provide a second conduit to the Set 2 primary clarifiers to convey additional flow to Set 2 Primary tanks	D	$3,312,000
8	Reduce losses and increase capacity between the grit tanks and Set 1 clarifiers by installing another conduit and venturi meter	D	$707,000
9	Provide a bypass from the primary effluent channels to the chlorine contact chamber	D	$8,291,000
10	Provide separate primary sludge thickening	D	$12,254,000
11	Reuse abandoned ABCD tanks as wet weather treatment facility	C	$5.0 – 10.0 million
12	Increase raw sewage pumping and screening	D	
	A - by 50 mgd	D	$10.0 – 12.0 million
	B - by 150 mgd		$20.0 – 24.0 million
	C - by 300 mgd		$36.0 – 40 million

Table 5.1 includes the final estimated cost for each improvement. Table 5.2 below presents a summary of the overall cost for improvements at the Northeast plant, broken down into alternatives that are dependant upon one another for an increase in capacity at the plant.

TABLE 5.2
SUMMARY OF BUDGETARY COSTS FOR POTENTIAL IMPROVEMENTS AT NORTHEAST WPCP

Improvement Alternatives	Total Costs for Improvements (Million $)	Cumulative Costs for Improvements (Million $)	Plant Peak Capacity (mgd)	New Plant Peak Capacity (MGD)		
				Primary	Secondary	Stormwater
Process optimization (Options 1,2, 4)	0.64	0.64	430	430	430	0
Upgrades required to increase capacity of the primary treatment to 550 mgd with secondary bypassing (Options 7, 8, 9, 12A)	23.31	23.95	550	550	430	0
Upgrades required to increase capacity of secondary treatment to 450 mgd (Options 5, 6)	2.41	26.36	550	550	450	0
Increase wet weather treatment capacity						
(Options 11, 12B)	34.00	49.36	650	550	450	100
(Options 10, 12C)	52.25	77.61	800	700	450	100

Process Optimization

The objective of this plan is to improve the performance of the NEWPCP under current wet weather flow conditions by implementing modest capital imrovements and operational changes.

The secondary clarifiers at the NEWPCP are susceptible to solids loading failure under high flow conditions. This project identified upgrades that improve the hydraulic and solids loading distribution between the clarifiers by improving the mixing in the mixed liquor channel and improving flow measurement between sets of clarifiers. Implementing step feed during high flow conditions will reduce the solids loading on the secondary clarifiers and therfore improve performance. The estimated capital cost of these upgrades is $640,000.

Upgrades to Increase Primary Capacity to 550 MGD with Secondary Bypassing

The NEWPCP has additional primary treatment capacity that is unavailable because of hydraulic limitations between the preliminary treatment building and the primary clarifiers. This bottleneck can be resolved by adding a new conduit and venturi meter, as well as a new conduit to the Set 2 primary clarifiers. A bypass channel from the primary effluent to the chlorine contact chamber will be required for the additional flow. The estimated capital cost to increase the primary treatment capacity from 430 to 550 mgd, including secondary bypassing and upgrade to the raw sewage pumping, is $23,310,000. ? WHY