Environmental Protection Technology Series

PARALLEL EVALUATION OF CONSTANT AND DIURNAL FLOW TREATMENT SYSTEMS

Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

EPA-600/2-78-034
March 1978

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by

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DISCLAIMER

FOREWORD

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This report describes the results of studies performed to define the effects of diurnal flow variations on typical activated sludge system performance. These hourly fluctuations in wastewater strength and flow can adversely affect primary treatment as well as secondary treatment process units. The results are compared to data from a similar system operated at a constant flow.

Francis T. Mayo, Director
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ABSTRACT

Pilot plant studies were performed to evaluate the effects of an imposed diurnal flow pattern on a conventional activated sludge treatment plant. These results were compared against data generated on a similar system treating a constant flow. Effects on primary clarifier and final clarifier performance as well as soluble organic removals were evaluated. Other effects on general plant stability were noted.

There were essentially no differences between the diurnal and constant flow systems at the 1.5/1, 2.0/1, and 2.5/1 peak-to-average diurnal flows imposed. Intensive sampling over a 24 hour diurnal flow cycle did not alter this basic conclusion. General plant stability was not affected except for some sludge blanket level problems at the 2.5/1 peak-to-average flow phase.

This report was submitted in fullfillment of Task 02, program element 1BC611, SOS 2A. This report covers the period from January 20, 1974 to June 1, 1975 and work was completed June 1, 1975.

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ACKNOWLEDGEMENTS

Appreciation is extended to the following people for their efforts throughout the conduct of this project:

Burney N. Jackson supervised the operation of the pilot plant and the analytical laboratory and the compilation and reduction of project data.

Glenn R. Gruber, Leo J. Fichter, Mark C. Meckes, Mark C. Fischer, and Kevie A. Stahl operated and maintained the pilot plant on a 24-hour per day, 7 days per week basis. In addition, Ms. Stahl assisted Mr. Jackson in data compilation and reduction.

Robert N. Bloomhuff, William Chaney, and Harold L. Sparks performed daily laboratory analyses for all project samples.

Richard C. Brenner was the Project Officer during experimental data collection and also assisted in the review of this report.

SECTION 1

INTRODUCTION

Wastewater treatment facilities generally receive a dry-weather wastewater flow that varies in strength and volume at various hours of the day. These variations are related to water use in the community by both its private and industrial sectors. This daily cyclic nature of wastewater flows and strengths are known as diurnal variations. An example of the diurnal variation of a treatment plant wastewater flow is shown in Figure 1. The magnitude of the diurnal flow variation is related to the ratio of dry-weather peak-to-average flow. This is also defined by others as the ratio of the dry-weather peak flow to minimum flow.

To handle diurnal variations in flow, unit process design may be based on either average flows or peak flows. When the design is based on average flows, unit processes may have poor performance during peak flows. However, designs based on peak flows may result in substantially increased treatment plant costs for required increased reactor sizes.

When the magnitude of the diurnal flow variation is large, flow equalization may be an economical alternative for adequate treatment of the entire flow. Flow equalization dampens out flow fluctuations by providing storage during times of peak flows which are pumped through the plant during periods of less than average flows. This permits the design and operation of the treatment processes based on a more constant flow. Also, concentration fluctuations may be dampened, providing a more uniform loading of wastewater components to the treatment plant unit processes.

Several benefits have been attributed to the use of flow equalization.[1] Primary clarification, theoretically, should be improved since elimination of peak overflow rates would provide lower and more uniform effluent quality. LaBrega and Keenan[2] found that primary effluent suspended solids removal increased from 23 to 47 percent before and after flow equalization; however, organic removals across the primary were essentially the same. Activated sludge secondary clarifiers should also theoretically receive the same benefits. However, Boon and Burgess[3] and Foess et al.,[4] found that variations in sludge settleability had a greater effect on final clarifier performance than periods of peak flow. Other potential benefits include increased uniformity in concentration and mass flow of organics and nutrients to biological treatment units as well as dampening of any shock loads of toxic materials.

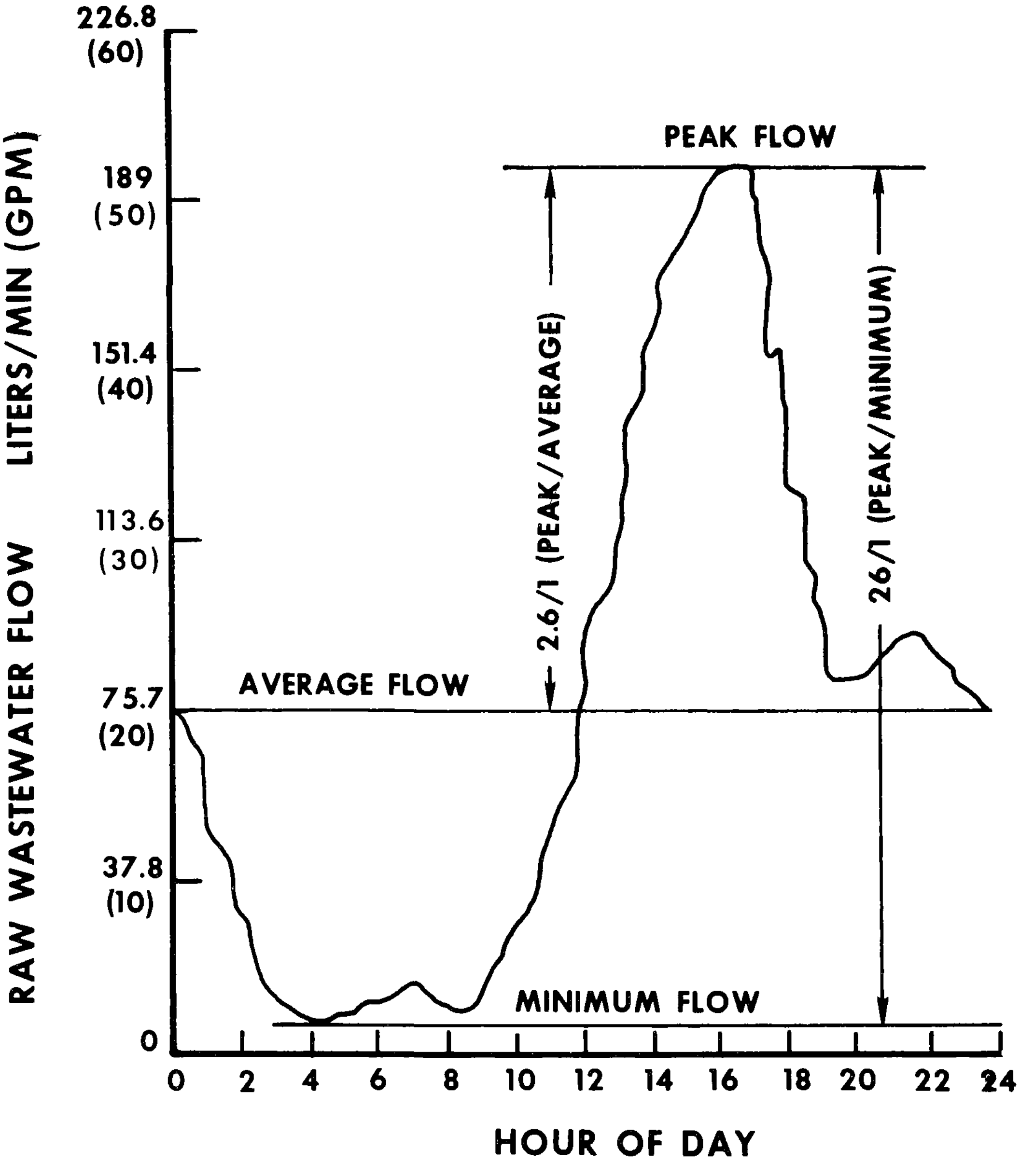

Figure 1. Typical influent wastewater diurnal flow pattern.

The purpose of this study was to evaluate the effects of imposing a diurnal flow to a pilot scale activated sludge wastewater treatment system. Variations in primary and secondary clarifier performance as well as soluble organic removals were evaluated against a similar system treating a constant wastewater flow. Secondary objectives were to evaluate the effects on general plant stability, ability to maintain dissolved oxygen (DO) in the aeration basins, and secondary clarifier sludge blanket levels during the diurnal cycle. During the three successive phases of the study, the effects of diurnal flow variations (peak/average) of 1.5/1, 2.0/1, and 2.5/1 were evaluated. The constant flow system was operated to simulate a flow-equalized plant. However, fluctuations in organic and nutrient loads were not dampened since the constant flow system received the same raw wastewater source as the diurnal flow system. Therefore, fluctuating organic and nutrient concentrations were received by the constant flow system which would have been dampened in a true flow equalization situation.

SECTION 2

CONCLUSIONS

1. At the diurnal flow variations examined in this study (1.5/1, 2.0/1, 2.5/1 peak-to-average), the constant and diurnal flow systems performed essentially the same.

2. There were no clear trends in primary clarifier performance between the constant and diurnal systems during any phase of this study.

3. Soluble organic removals were essentially the same for the two systems.

4. Final clarifier performance did not vary significantly between the diurnal and constant flow systems.

5. Intensive sampling over the 24 hr. diurnal flow cycles revealed no significant trends in system performance between the constant and diurnal flow systems.

6. No differences in treatment plant stability were observed between the two systems, although sludge blanket problems occurred periodically with the diurnally varied system during the 2.5/1 peak to average diurnal flow pattern.

7. Accurate flow proportioned sampling is essential to obtaining accurate results in diurnal flow studies. As the magnitude of the diurnal cycle increases, the lack of representative flow-proportioned samples will bias the evaluation in favor of the diurnal system.

SECTION 3

RECOMMENDATIONS

1. Additional pilot plant flow equalization studies should be performed incorporating in-line and/or side-line storage of incoming wastewater. The damping effect on mass loadings afforded by the storage technique represents a potential benefit of flow equalization which could not be evaluated in this project due to equipment limitations. The cumulative effect of hydraulic equalization and mass load damping could enhance the attractiveness of flow equalization from a process stability standpoint beyond the neutral position presented in this report.

SECTION 4

PLANT DESCRIPTION

All of the experimental work for this study was performed at the pilot plant in the Experimental Wing of the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, using two parallel activated sludge treatment systems and associated equipment.

Two sources of raw wastewater were utilized for this study. Phase I (1.5/1 peak-to-average flow) used a primarily domestic wastewater from the Mt. Washington area of Cincinnati, Ohio. This is a combined sewer system which at times produces a very weak wastewater. Phases II and III (2.0/1 and 2.5/1 peak-to-average flow, respectively) used a different wastewater source from another area of eastern Cincinnati with a large industrial contribution. Wide fluctuations in pH are characteristic of this wastewater. No pH control was provided.

The experimental pilot plant consists of the two parallel treatment systems shown schematically in Figure 2. Raw wastewater from one of the two sources described previously is comminuted and screened before being pumped to the primary clarifiers.

Raw wastewater flow control to the constant flow system (CFS) is provided by a Fischer and Porter* analog flow controller. The controller compares the flow signal from a Fischer and Porter magnetic flow meter to the controller set point which generates an error signal that is integrated over time by the controller. A diaphragm flow control valve is then adjusted by the controller to compensate for the error signal, thereby controlling flow.

The diurnal flow pattern was imposed with a Fischer and Porter flow programmer. This unit generates a 0-100 percent signal which can be programmed to alter the controller set-point with time. The flow is controlled at various set-points at various times of the day. The rest of the control loop is the same as the CFS.

Two identical primary clarifiers were used in parallel in the diurnal flow system (DFS). Each unit has a surface area of 1.1 m^2 (12 ft^2) and a volume of 3,975 1 (1,050 gal) providing a surface overflow rate (SOR) of 48.9 $m^3/day/m^2$ (1,200 gpd/ft^2) and a detention time of 1.75 hr., respectively, at an average unit influent flow rate of 37.8 1/min (10 gpm). The depth of

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*Fischer and Porter Company, Warminster, Pennsylvania

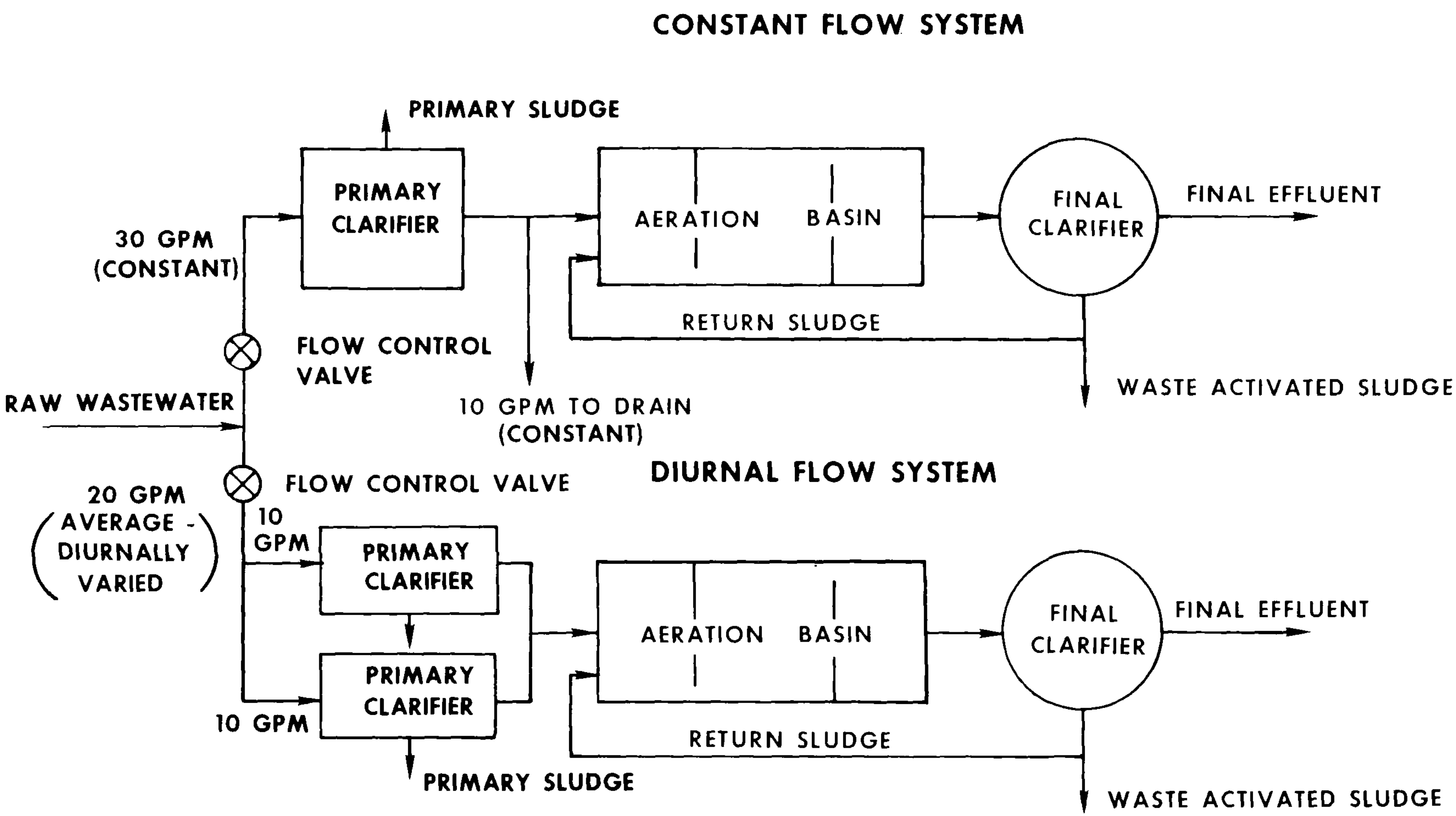

Figure 2. Schematic of parallel activated sludge pilot treatment systems.

these units are 3.96 m (13 ft.). Floating scum is removed manually in each unit. Mechanical sludge scraping is not provided in these primaries.

The CFS utilized one primary clarifier with a controlled influent flow of 113.5 l/min (30 gpm). This unit has a surface area of 3.3 m^2 (36 ft^2), providing an SOR of 48.9 m^3/day/m^2 (1,200 gpd/ft^2) at 113.5 l/min (30 gpm). The depth of the unit is 2.74 m (9 ft.). A liquid volume of 7,230 liters (1,910 gal.) yields a detention time of 1.06 hr. at 113.5 l/min (30 gpm). Only 75.7 l/min (20 gpm) of the effluent from this primary clarifier was needed as feed to the CFS aerator; the other 37.8 l/min (10 gpm) was wasted directly to drain. A 113.5 l/min (30 gpm) raw wastewater flow rate was employed to provide the same average primary clarifier overflow rate as imposed on the DFS primaries. This primary unit is equipped with mechanical sludge scraping and scum removal equipment.

The aeration systems are identical for both systems. Each aeration basin is a rectangular tank separated into three compartments. The total volume of each basin is 18,960 liters (5,010 gal.) with a 2.1 m (7 ft.) liquid depth. At the average system flow rate of 75.7 l/min (20 gpm), the nominal detention time of each aerator is 4.2 hr. Each basin contains non-clog, coarse-bubble air diffusers supplied with 376 l/min (15 scfm) of compressed air.

Each system has identical center-feed, peripheral-weir, circular final clarifiers. These units are 2.3 m (7.5 ft) in diameter with a 2.7 m (9 ft.) side water depth. With a usable surface area of 3.4 m^2 (36.6 ft^2) [20 cm (8 in.) of the 2.3 m (7.5 ft.) diameter is taken up by the peripheral weir], the SOR is 31.9 m^3/day/m^2 (785 gpd/ft^2) at the average flow of 75.7 l/min (20 gpm). Mechanical sludge scrapers are provided, but scum removal is manual.

Return sludge flow is accomplished by variable speed centrifugal pumps and measured with Fischer and Porter[R] magnetic flow meters. During this study, sludge recycle flow rates were varied manually between 30 to 50 percent of the raw wastewater flow to maintain mixed liquor suspended solids (MLSS) at about 3000 mg/l. Further, recycle rates on the DFS were adjusted manually throughout the day to maintain an approximate constant percentage of the diurnal influent flow pattern.

Both activated sludge systems were operated to maintain an F/M ratio of between 0.2 and 0.4 kg $TBOD_5$/day/kg MLVSS. Operational experience indicated that 3000 mg/l of MLSS would result in an F/M in the required range.

All raw wastewater, primary effluent, and final effluent samples were composited over each 24-hr. period. Each sample cycle was initiated by a flush of the sample lines to drain with the wastewater to be sampled. The sample flows were then diverted to refrigerated containers. Samples collected on the DFS were automatically proportioned to flow by actuating

*Fischer and Porter Company, Warminster, Pennsylvania the sampler solenoid valves once every 3,785 liters (1,000 gal.) of throughput rather than once every hour as was done on the CFS.

Analyses were performed by the operations staff of the pilot plant in accordance with Standard Methods.[5]

SECTION 5

RESULTS

This study was performed in three phases. A different peak to average diurnal flow variation was imposed during each phase on one of the treatment systems. During all three phases the other parallel treatment system received the same constant flow rate. Both systems treated the same total volume of wastewater daily. Each phase consisted of several months of operation. Periods of instability were encountered during each phase due to a combination of operating problems and slug loads of biological inhibitory materials in the wastewater. Therefore, a period of six to eight weeks was selected from each phase for presentation and evaluation when both systems were experiencing simultaneous stable operation.

PHASE I PEAK-TO-AVERAGE DIURNAL RATIO AT 1.5/1

A 1.5/1 peak to average (P/A) diurnal flow was imposed on the DFS during Phase I of this project. The flow pattern for this phase is shown in Figure 3.

Table 1 shows the averages for the various parameters measured during the 8 weeks of Phase I. The raw wastewater was weak with an average total suspended solids (TSS) of 98 mg/l, an average 5-day total biochemical oxygen demand ($TBOD_5$) of 106 mg/l and an average total chemical oxygen demand (TCOD) of 156 mg/l. Daily variations of the raw wastewater TSS and $TBOD_5$ are shown in Figures 4 and 5.

With a P/A of 1.5, the DFS primary clarifiers operated at an SOR of 48.9 $m^3/day/m^2$ (1,200 gpd/ft^2) at the average flow and 73.3 $m^3/day/m^2$ (1,800 gpd/ft^2) at the peak flow. The DFS produced an average primary effluent of 67 mg/l TSS, 84 mg/l $TBOD_5$, and a TCOD of 116 mg/l. The CFS during the same period produced an average primary effluent of 84 mg/l TSS, 93 mg/l $TBOD_5$, and 134 mg/l TCOD. Average removals across the diurnal primary clarifier were 12 percent higher for TCOD, 8 percent higher for $TBOD_5$, and 18 percent higher for TSS. Daily variations in primary effluent TSS for the CFS and DFS are shown in Figure 6. No explanation can be given the higher quality primary effluent produced by the DFS during Phase I.

The DFS final clarifiers during Phase I was operated at an SOR of 31.9 $m^3/day/m^2$ (785 gpd/ft^2) at the average flow and 48.1 $m^3/day/m^2$ (1,180 gpd/ft^2) at the peak flow. Final effluent from the DFS showed an average of 10 mg/l TSS, 16 mg/l $TBOD_5$, and 34 mg/l TCOD. The CFS final effluent showed an average TSS of 9 mg/l, $TBOD_5$ of 16 mg/l, and a TCOD of 31 mg/l.

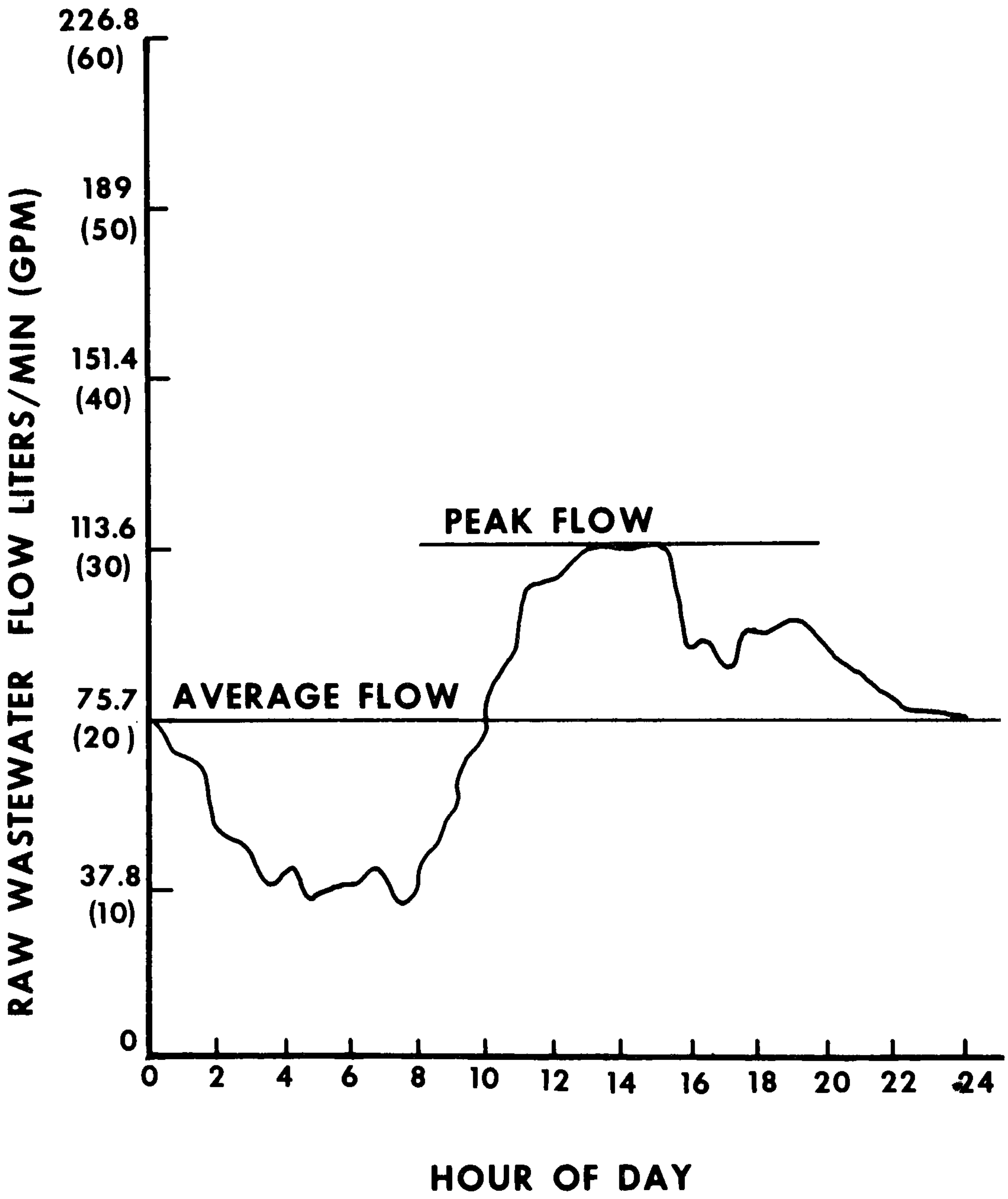

Figure 3. Diurnal flow pattern for Phase I;peak to average diurnal ratio at 1.5/1.

TABLE 1. AVERAGE PERFORMANCE VALUES FOR PHASE I: 1.5/1 PEAK-TO-AVERAGE FLOW (1-20-74 to 3-16-74)

	TOTAL COD (mg/l)	TOTAL COD REMOVED (%)	SOLUBLE COD (mg/l)	TOTAL BOD_5 (mg/l)	TOTAL BOD_5 REMOVED (%)	SOLUBLE BOD_5 (mg/l)	SOLUBLE BOD_5 REMOVED (%)	TOTAL SUSPENDED SOLIDS (mg/l)	TOTAL SUSPENDED SOLIDS REMOVED (%)	VOLATILE SUSPENDED SOLIDS (mg/l)	F/M $\frac{(k_g TBOD_5/day)}{(k_g MLVSS)}$
RAW WASTEWATER	156		55	106		26		98		77	
PRIMARY EFFLUENT DIURNAL SYSTEM	116	26+		84	20+			67	32+	50	
PRIMARY EFFLUENT CONSTANT SYSTEM	134	14+		93	12+			84	14+	64	
FINAL EFFLUENT DIURNAL SYSTEM	34	71* 78+	23	16	81* 85+	5	94^{o} 95$^{\Delta}$	10	85* 90+	8	0.26
FINAL EFFLUENT CONSTANT SYSTEM	31	77* 80+	24	16	83* 85+	5	95^{o} 95$^{\Delta}$	9	89* 91+	7	0.27

\+ Based on raw wastewater

* Based on primary effluent

^{o} Based on $TBOD_5$ of primary and $SBOD_5$ of final effluent

$^{\Delta}$ Based on $TBOD_5$ of raw wastewater and $SBOD_5$ of final effluent

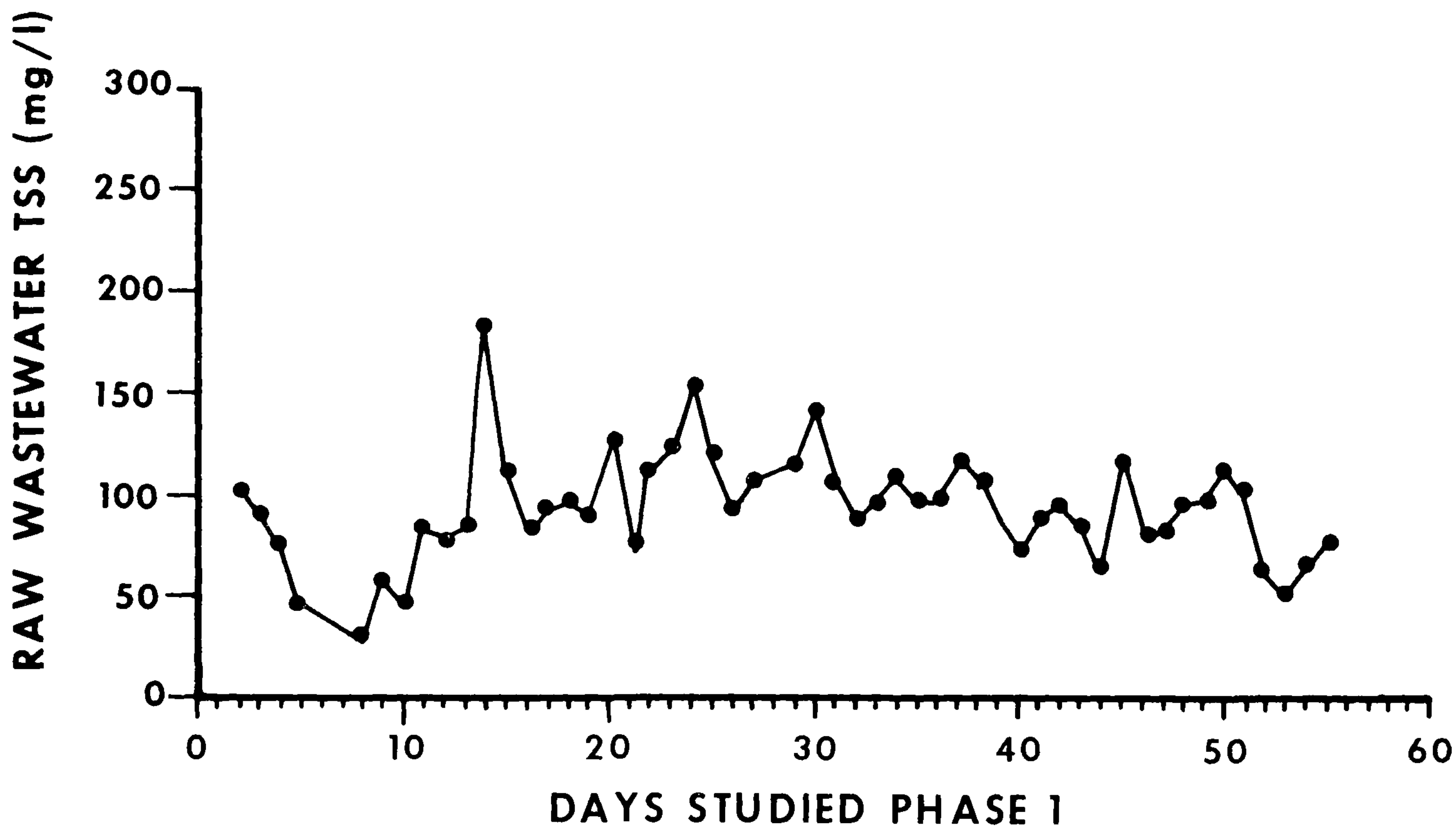

Figure 4. Daily variation of raw wastewater TSS for Phase I;peak to average diurnal ratio at 1.5/1.

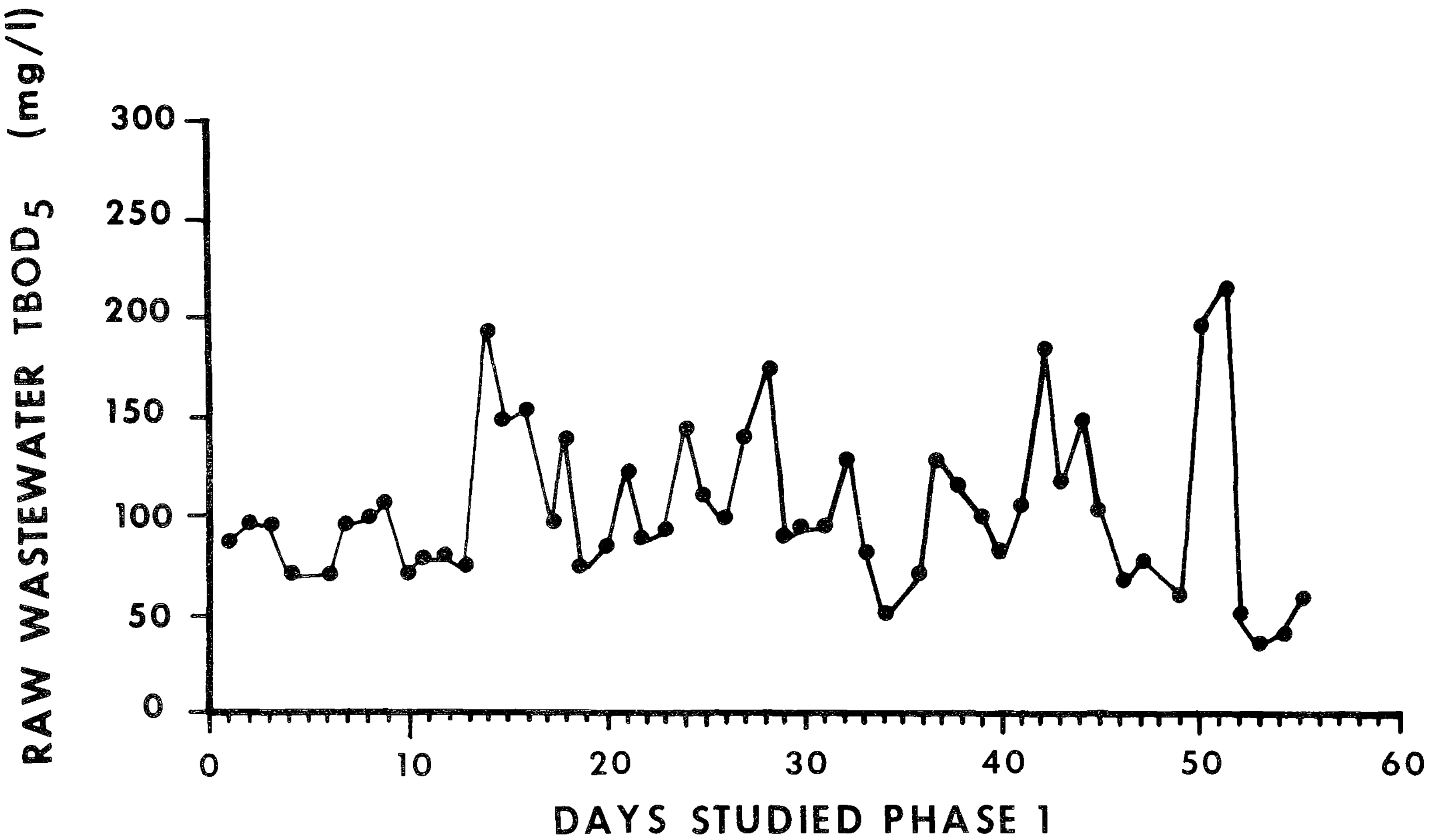

Figure 5. Daily variation of raw wastewater $TBOD_5$ for Phase I:peak to average diurnal ratio at 1.5/1.

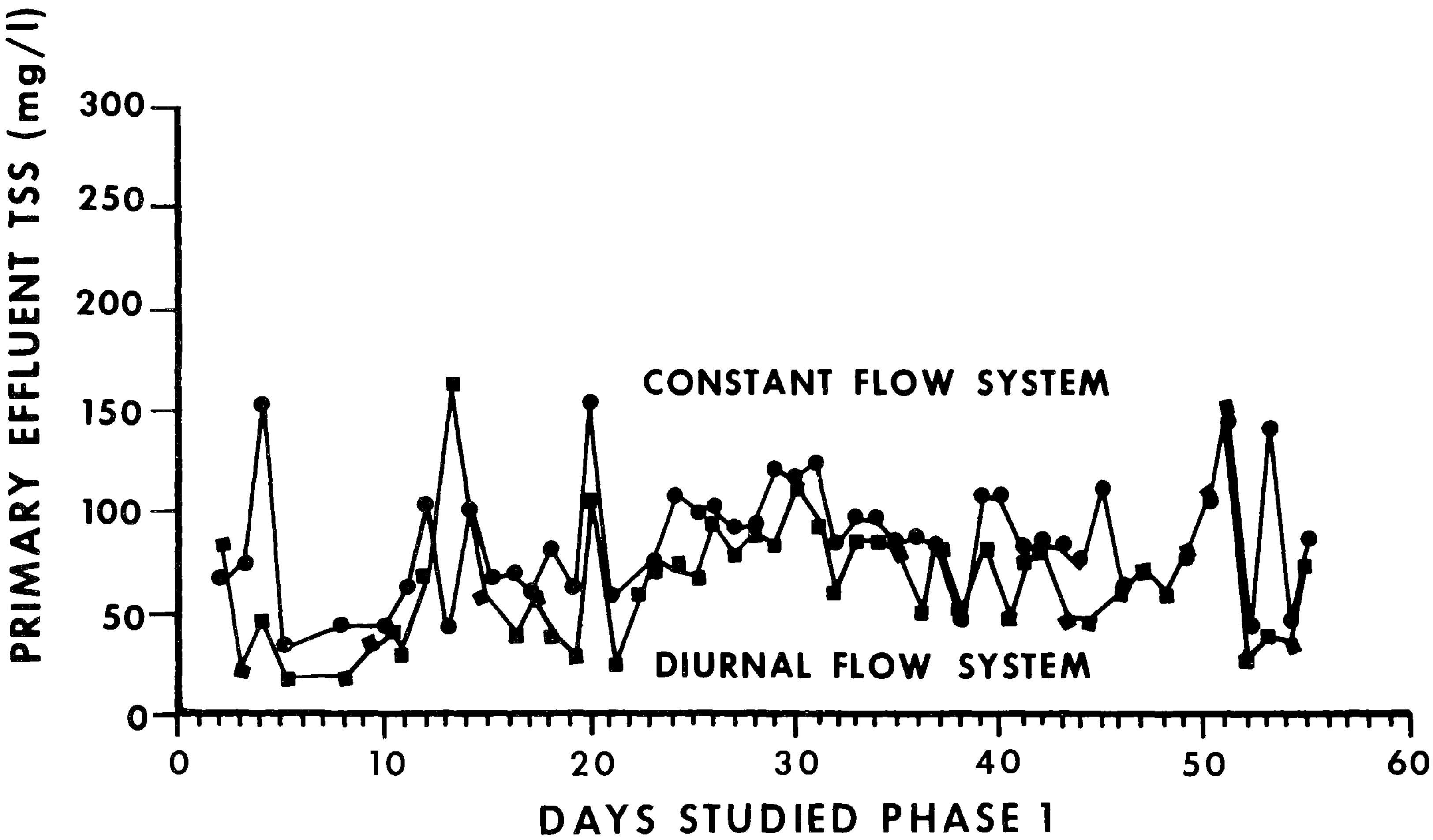

Figure 6. Daily variation of constant flow system primary effluent TSS for Phase I; peak to average diurnal ratio at 1.5/1.

Total plant removal efficiencies for these parameters were approximately equal for both systems. Even though the CFS aerator received a stronger primary wastewater than the DFS aerator the final effluent levels between the constant and diurnal systems were essentially the same. Final effluent soluble BOD_5 concentration for the DFS and CFS were identical and indicated a high degree of biological treatment efficiency. Both systems were operated at an average F/M of 0.26 kg $TBOD_5$/kg MLVSS/day. Figures 7 and 8 show the daily variations in final effluent TSS and $TBOD_5$, respectively.

Conclusions regarding comparison of secondary treatment performance are difficult to make since the primary effluent feed to each system was different. Based on the final effluent characteristics, both systems appear equal. However, the percentage of solids and organics removed through the constant flow activated sludge system averaged 2-6 percent higher than the diurnal flow secondary system. The differences in performance are not large enough to substantiate, on the average, any distinction between the constant and diurnal flow systems operations during the 1.5/1 P/A phase.

PHASE II PEAK-TO-AVERAGE DIURNAL RATIO AT 2.0/1

For Phase II, the imposed diurnal flow was increased to 2.0/1 peak-to-average as illustrated in Figure 9, while still maintaining an average influent flow over a 24 hr. period of 75.7 l/min. (20 gpm). The CFS continued to receive the same flow as in Phase I.

Table 2 summarizes the averages for the various parameters measured during the six weeks of Phase II. As mentioned previously, the raw wastewater source was changed at the beginning of Phase II from a primarily domestic wastewater to a combined industrial-domestic wastewater. Industrial contributions increased the magnitude and fluctuation in wastewater strength significantly for the rest of the study. Phase II raw wastewater averaged 244 mg/l TSS, 170 mg/l $TBOD_5$, and 354 mg/l TCOD. Figures 10 and 11 plot the daily variations in raw wastewater TSS and $TBOD_5$, respectively.

At a P/A diurnal flow ratio of 2.0/1, the DFS primary clarifiers were operated at an SOR OF 48.9 $m^3/day/m^2$ (1,200 gpd/ft^2) at the average flow of 75.7 l/min. (20 gpm) and 97.8 $m^3/day/m^2$ (2,400 gpd/ft^2) at the peak flow of 151.4 l/min. (40 gpm). DFS produced a primary effluent that averaged 200 mg/l TSS, 148 mg/l $TBOD_5$, and 330 mg/l TCOD. During this same period the CFS primary effluent averaged 203 mg/l TSS, 151 mg/l $TBOD_5$ and 342 mg/l TCOD.

Percent removals averaged 4 percent and 2 percent, respectively, for TCOD and $TBOD_5$ across the diurnal primary clarifier. TSS removal was 3 percent higher for the constant flow primary clarifier. These variations in removals between the systems are not as large as in Phase I but the removal efficiencies for both primaries were substantially lower. Figure 12 shows the daily variations in primary effluent TSS for the diurnal and constant flow systems during this 6 week period.

The daily fluctuations in primary clarifier performance show that the diurnal primary clarifiers at times produced a substantially higher quality effluent. Overall in Phase II, the DFS primary clariifers exhibit less daily

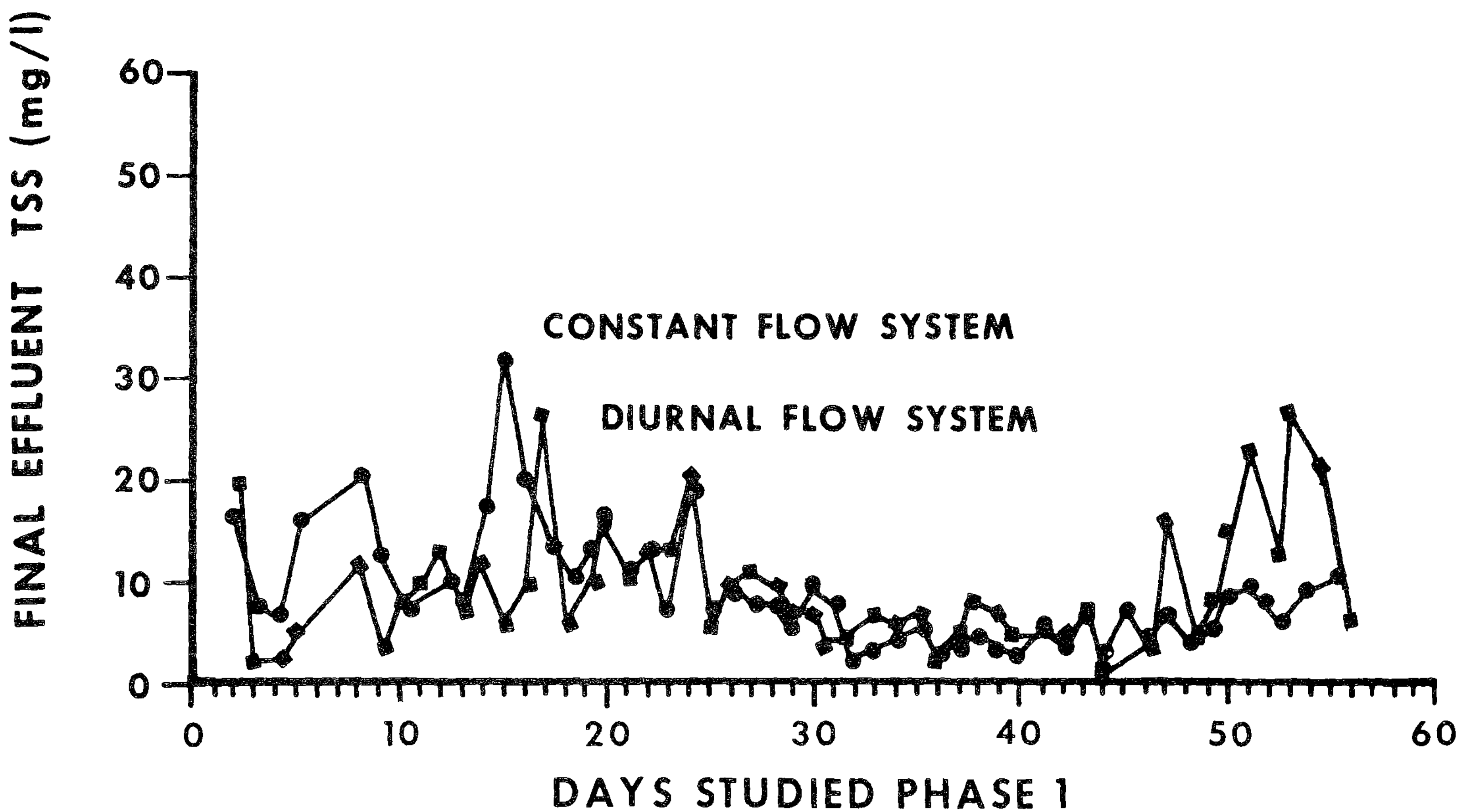

Figure 7. Daily variation of constant flow system and diurnal flow system final effluent TSS for Phase I;peak to average diurnal ratio at 1.5/1.

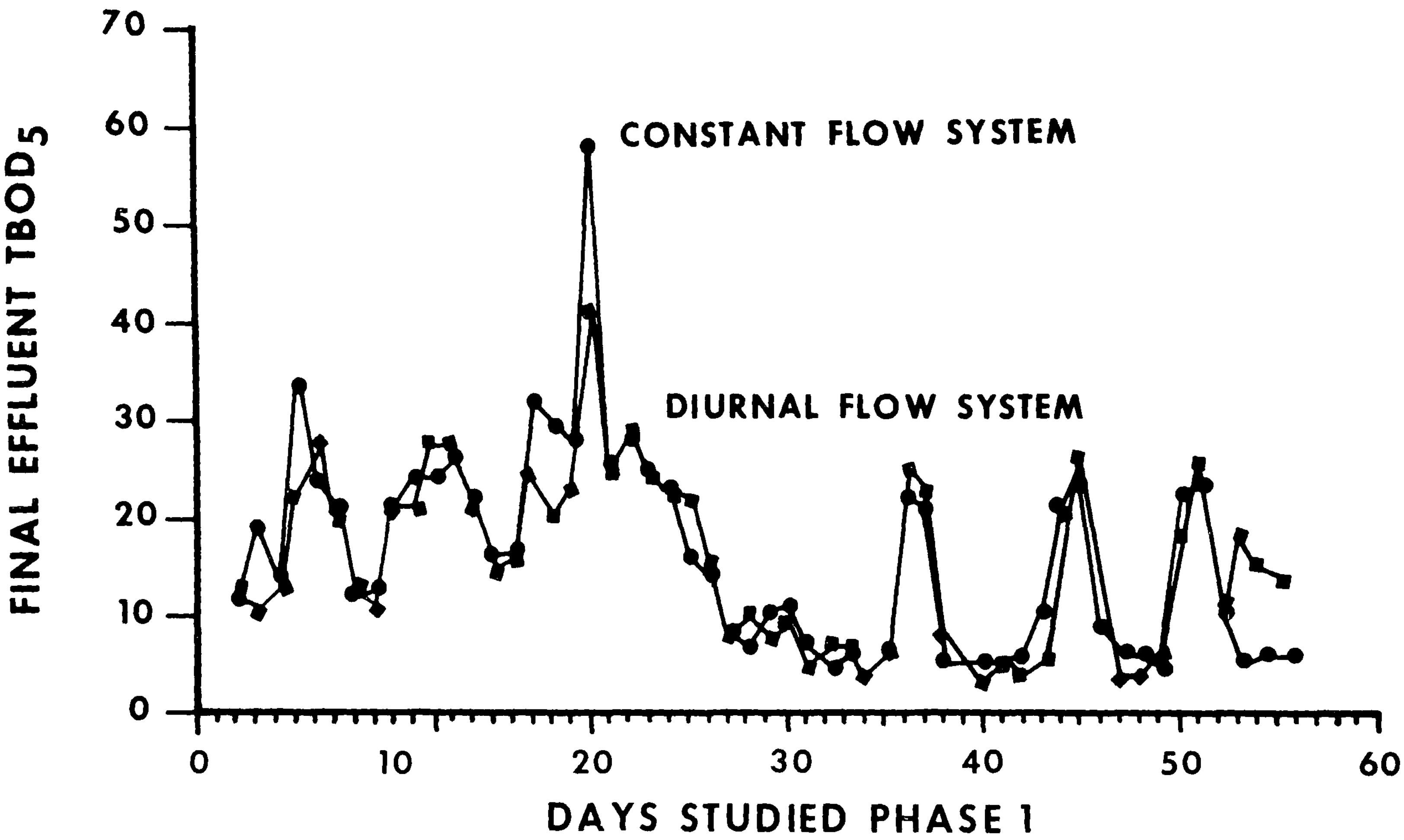

Figure 8. Daily variations of constant flow system and diurnal flow system final effluent $TBOD_5$ for Phase I;peak to average diurnal ratio at 1.5/1.

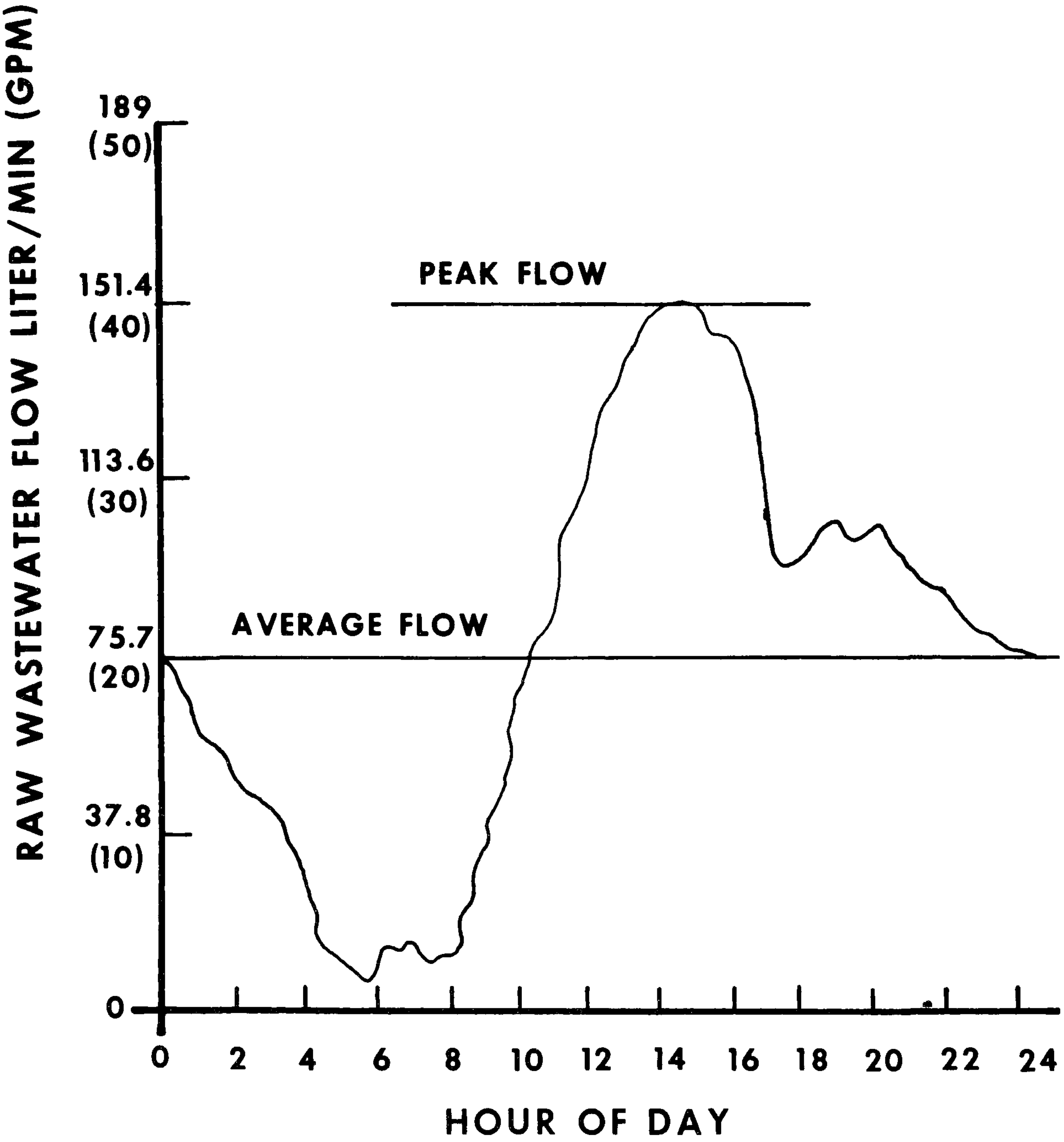

Figure 9. Diurnal flow pattern for Phase II;peak to average diurnal ratio at 2.0/1.

TABLE 2. AVERAGE PERFORMANCE VALUES FOR PHASE II: 2.0/1 PEAK-TO-AVERAGE FLOW (10-6-74 to 11-12-74)

	TOTAL COD (mg/l)	TOTAL COD REMOVED (%)	SOLUBLE COD (mg/l)	TOTAL BOD_5 (mg/l)	TOTAL BOD_5 REMOVED (%)	SOLUBLE BOD_5 (mg/l)	SOLUBLE BOD_5 REMOVED (%)	TOTAL SUSPENDED SOLIDS (mg/l)	TOTAL SUSPENDED SOLIDS REMOVED (%)	VOLATILE SUSPENDED SOLIDS (mg/l)	F/M $\frac{(k_g TBOD_5/day)}{(k_g MLVSS)}$
RAW WASTEWATER	354		131	170		67		244		191	
PRIMARY EFFLUENT DIURNAL SYSTEM	330	7+		148	13+			200	18+	142	
PRIMARY EFFLUENT CONSTANT SYSTEM	342	3+		151	11+			203	21+	152	
FINAL EFFLUENT DIURNAL SYSTEM	77	77* 78+	55	19	87* 89+	10	93^o 94^Δ	22	89* 91+	16	0.51
FINAL EFFLUENT CONSTANT SYSTEM	89	74* 74+	56	24	84* 86+	11	93^o 94^Δ	30	85* 88+	21	0.39

+ Based on raw wastewater

* Based on primary effluent

o Based on $TBOD_5$ of primary effluent and $SBOD_5$ of final effluent

Δ Based on $TBOD_5$ of raw wastewater and $SBOD_5$ of final effluent

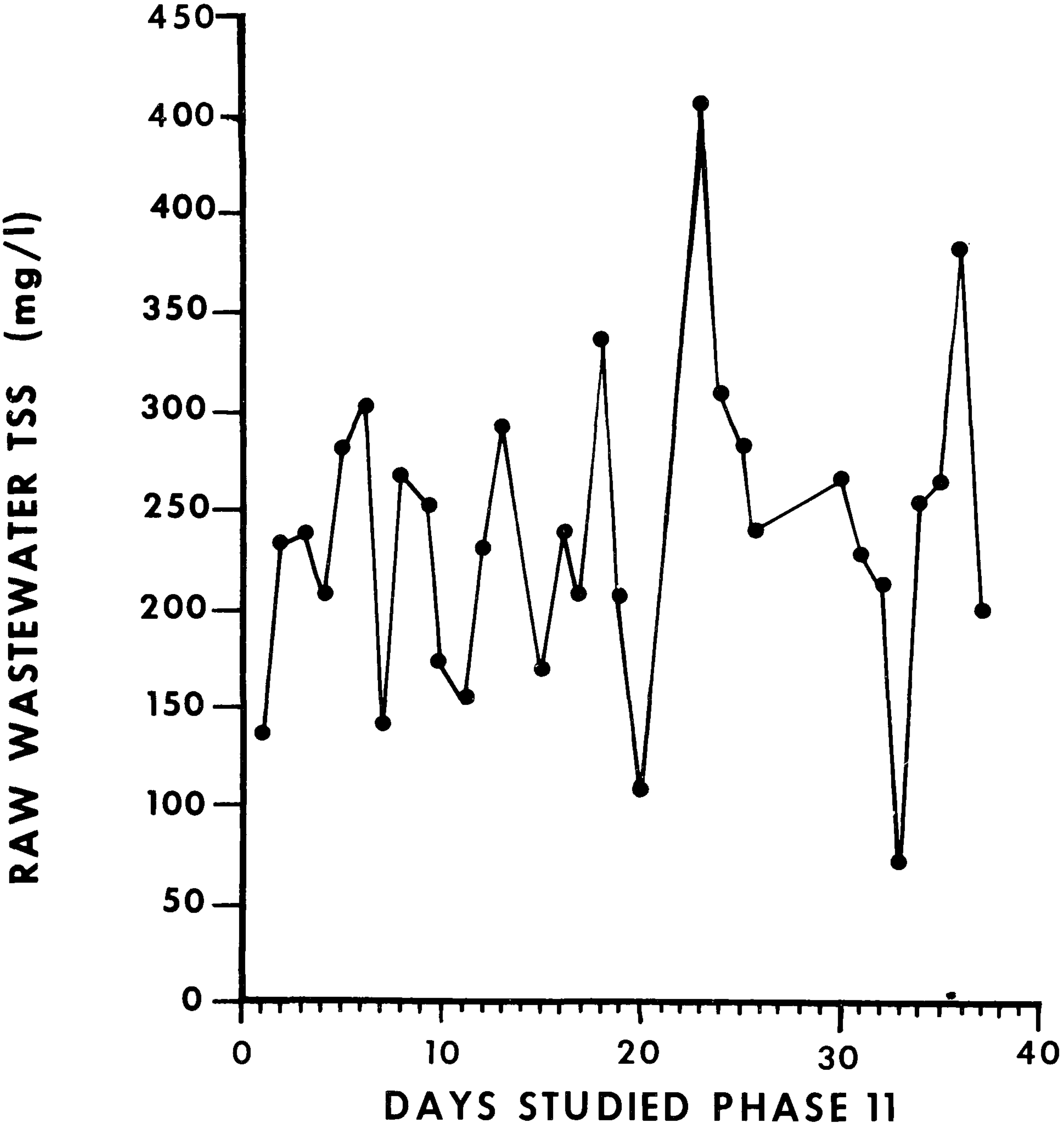

Figure 10. Daily variation of raw wastewater TSS for Phase II;peak to average diurnal ratio at 2.0/1.

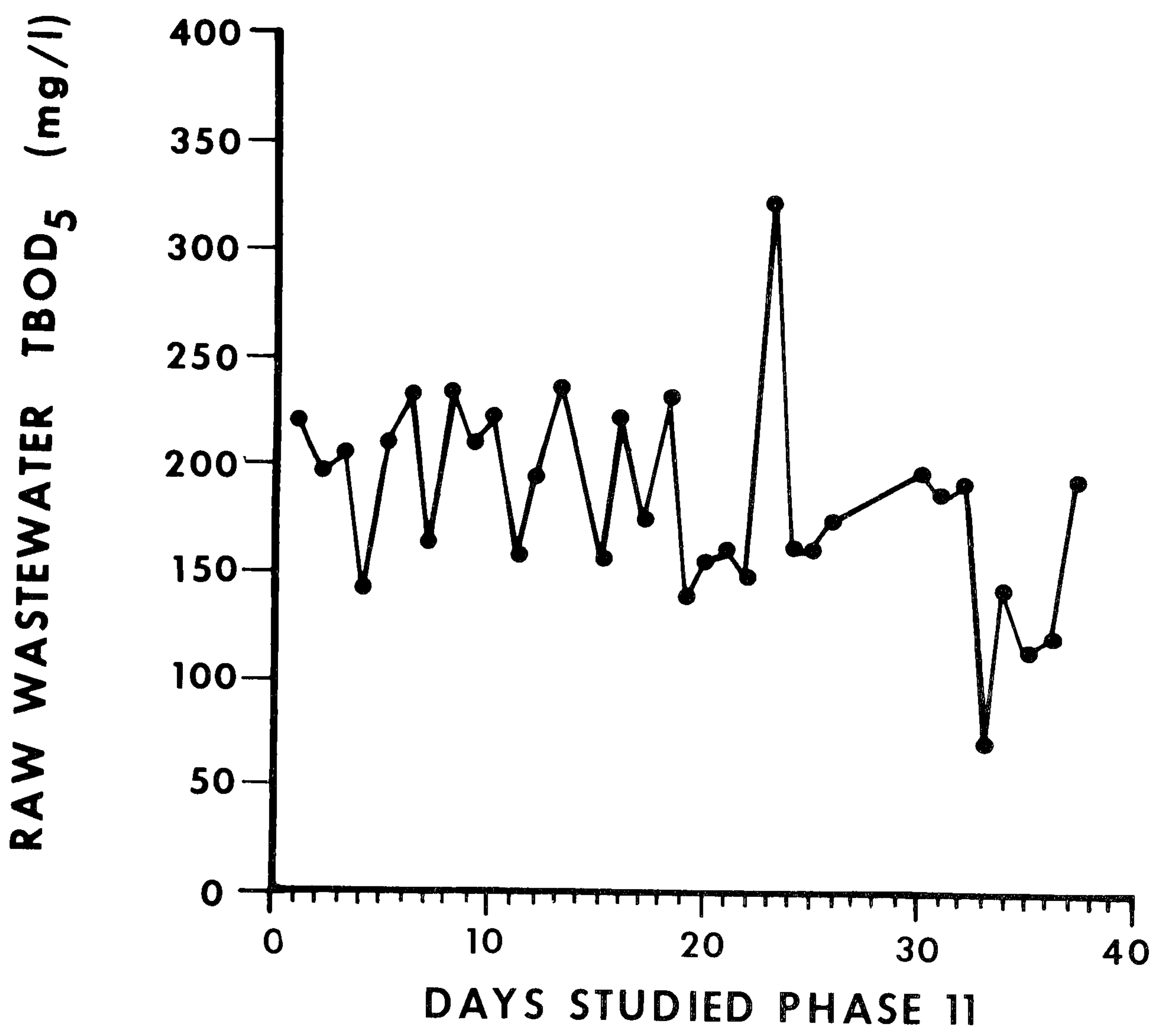

Figure 11. Daily variation of raw wastewater $TBOD_5$ for Phase II;peak to average diurnal ratio at 2.0/1.

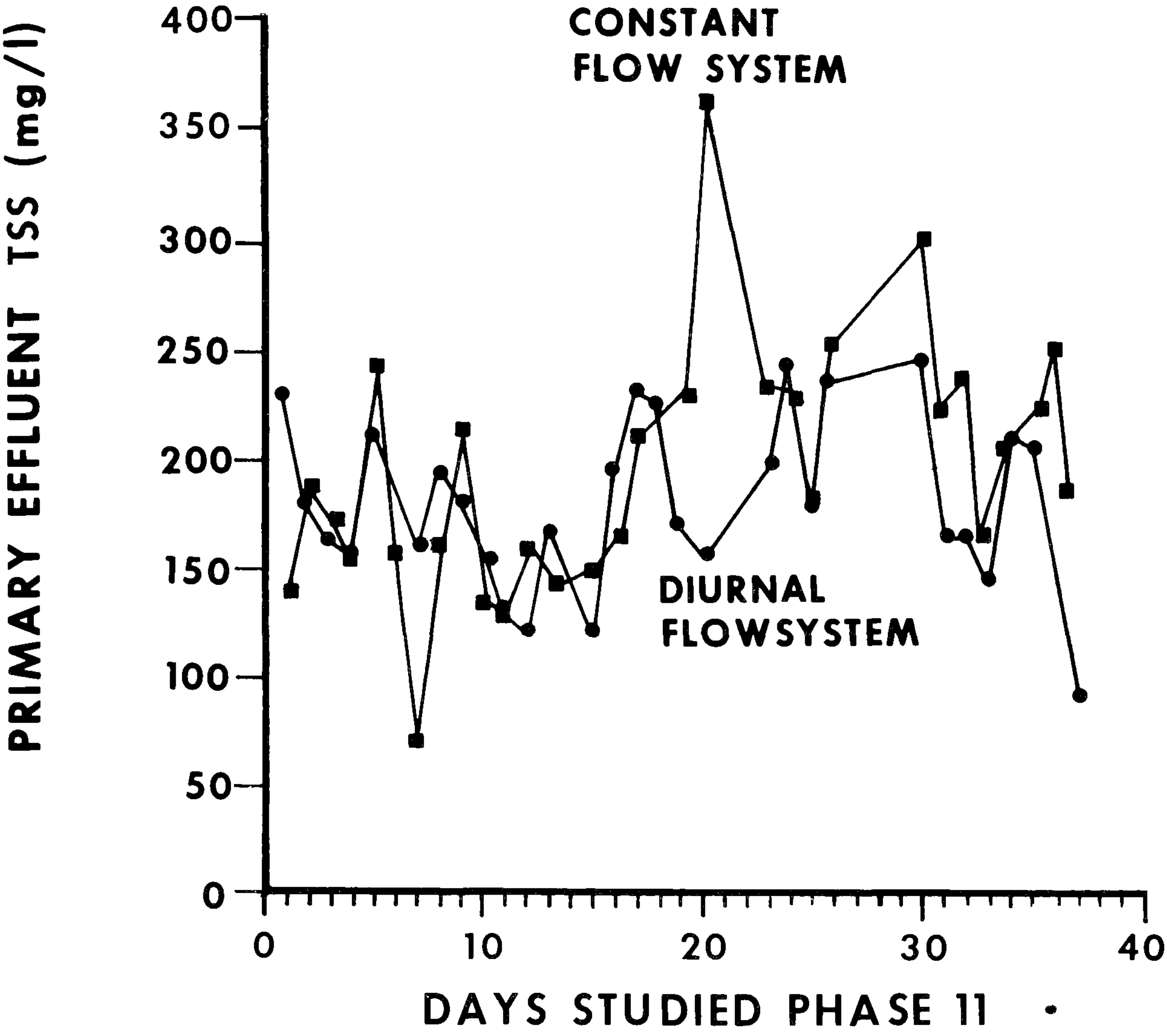

Figure 12. Daily variation of constant flow system and diurnal flow system primary effluent TSS for Phase II;peak to average diurnal ratio at 2.0/1.

performance variability than the single CFS primary clarifier. Theoretically, a primary clarifier operated at a constant flow should have less effluent variability than one experiencing diurnal flow fluctuations.

The DFS final clarifier during Phase II was operated at an SOR of 31.9 $m^3/day/m^2$ (785 gpd/ft^2) at the average flow and 64.0 $m^3/day/m^2$ (1,570 gpd/ft^2) at the peak flow. DFS final effluent averaged 22 mg/l TSS, 19 mg/l $TBOD_5$, and 77 mg/l TCOD. Final effluent quality from the CFS was less averaging 30 mg/l TSS, 24 mg/l $TBOD_5$, and 89 mg/l TCOD.

Both total system and secondary system removal efficiencies averaged 3-4 percent higher for the DFS during this phase of the study, even though the constant flow activated sludge system was operated at an F/M of 0.39 $kgBOD_5/day/kgMLVSS$ as compared to 0.51 for the diurnal flow activated sludge system. Soluble organic removals were equivalent in the two systems; therefore, the difference in overall secondary system performance in this phase can be attributed to less efficient solids capture in the CFS final clarifier.

Figures 13 and 14 show the daily variations in final effluent TSS and $TBOD_5$, respectively, for the constant and diurnal flow systems. These figures along with the average data for this phase from Table 2 support the observation that the DFS produced a slightly better effluent than the CFS. Based on Phase I and Phase II results, it appears that equalization of flows without dampening of pollutant loads does not offer any potential for improved average treatment performance at P/A diurnal variations of 2.0/1 or less.

PHASE III PEAK TO AVERAGE DIURNAL RATIO AT 2.5/1

Phase III of this study investigated imposing a 2.5/1 peak to average (P/A) diurnal flow variation to the DFS with the same 75.7 l/min. (20 gpm) constant flow as used in Phases I and II to the CFS. The diurnal flow pattern for this phase is shown in Figure 15.

Table 3 summarizes the averages of the parameters measured during the 7 wks. of Phase III. The source of raw wastewater was the same as that for Phase II. During this period, the raw wastewater averaged 167 mg/l TSS, 137 mg/l $TBOD_5$, and 255 mg/l TCOD. Daily variations of TSS and $TBOD_5$ are shown in Figures 16 and 17, respectively. Fluctuation in waste strengths were not as large as in Phase II.

With a P/A flow variation of 2.5/1, the DFS primary clarifiers operated at an SOR of 48.9 $m^3/day/m^2$ (1,200 gpd/ft^2) at the average flow of 75.7 l/min. (20 gpm) and 122.2 $m^3/day/m^2$ (3000 gpd/ft^2) at the peak flow of 189.3 l/min. (50 gpm). The diurnal flow primaries produced an average effluent quality of 117 mg/l TSS, 95 mg/l $TBOD_5$, and 220 mg/l TCOD. Primary effluent from the constant flow primary averaged 121 mg/l TSS, 86 mg/l $TBOD_5$, and 195 mg/l TCOD.

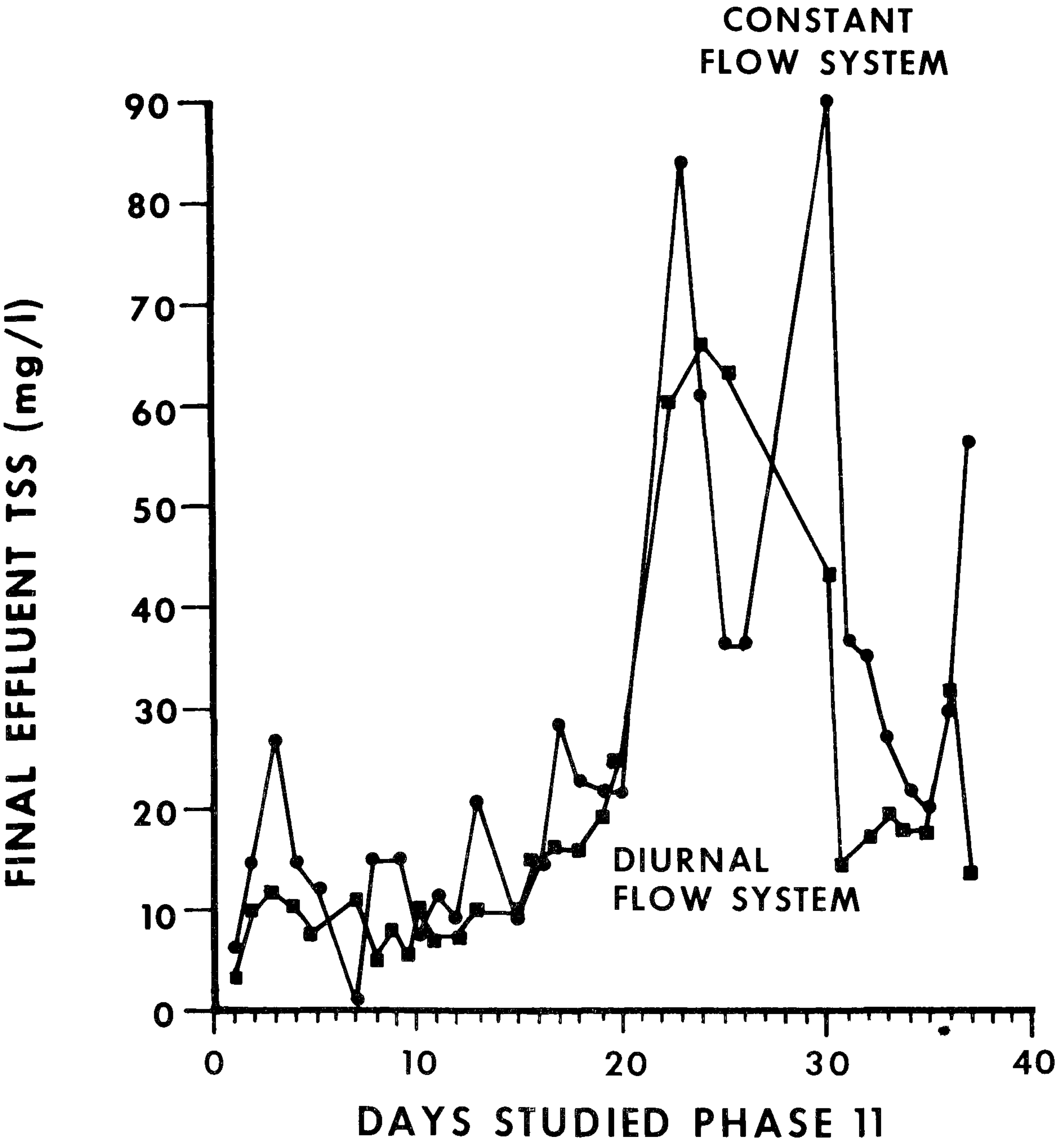

Figure 13. Daily variations of constant flow system and diurnal flow system final effluent TSS for Phase II;peak to average diurnal ratio at 2.0/1.

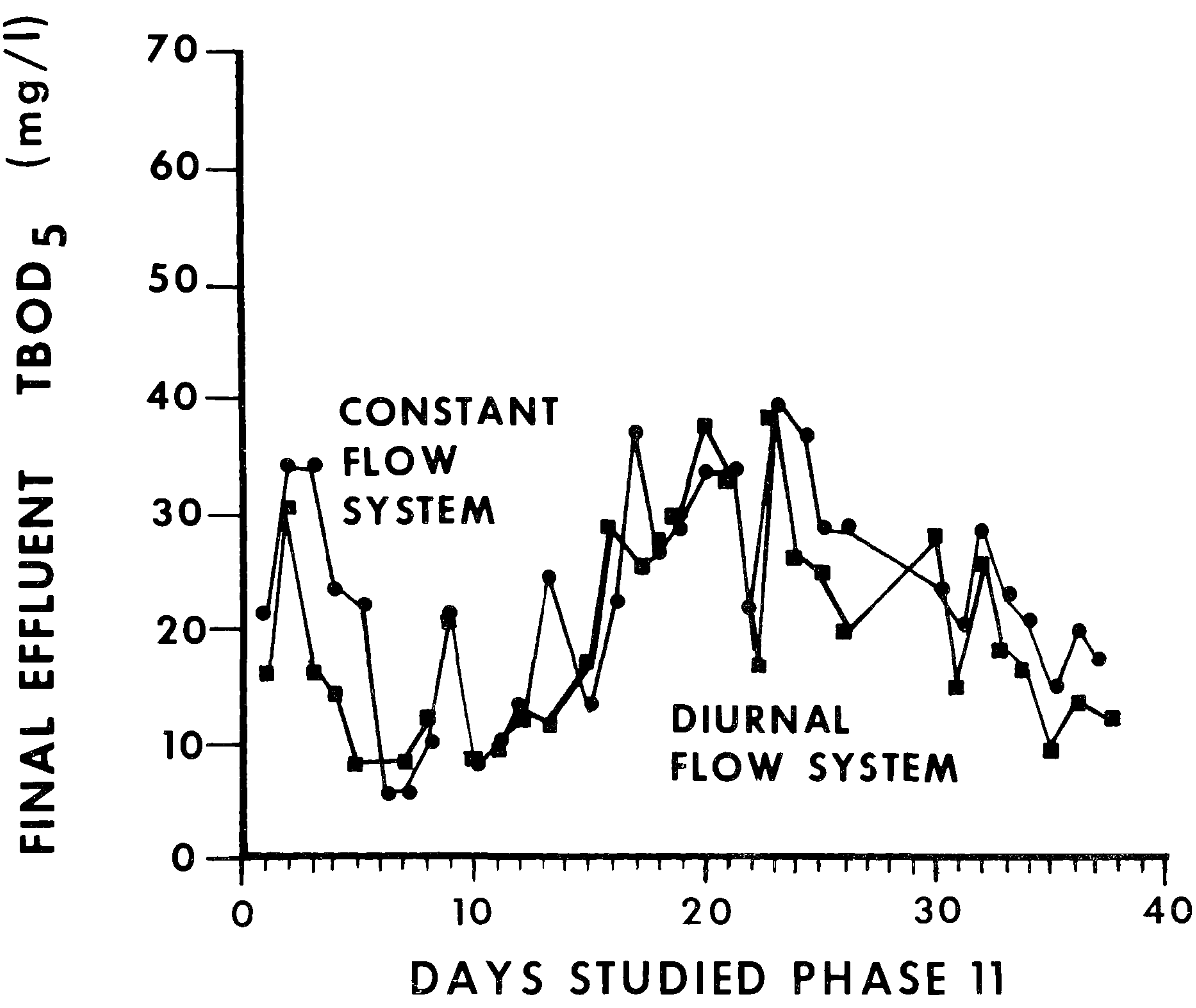

Figure 14. Daily variation of constant flow system and diurnal flow system final effluent $TBOD_5$ for Phase II;peak to average diurnal ratio at 2.0/1.

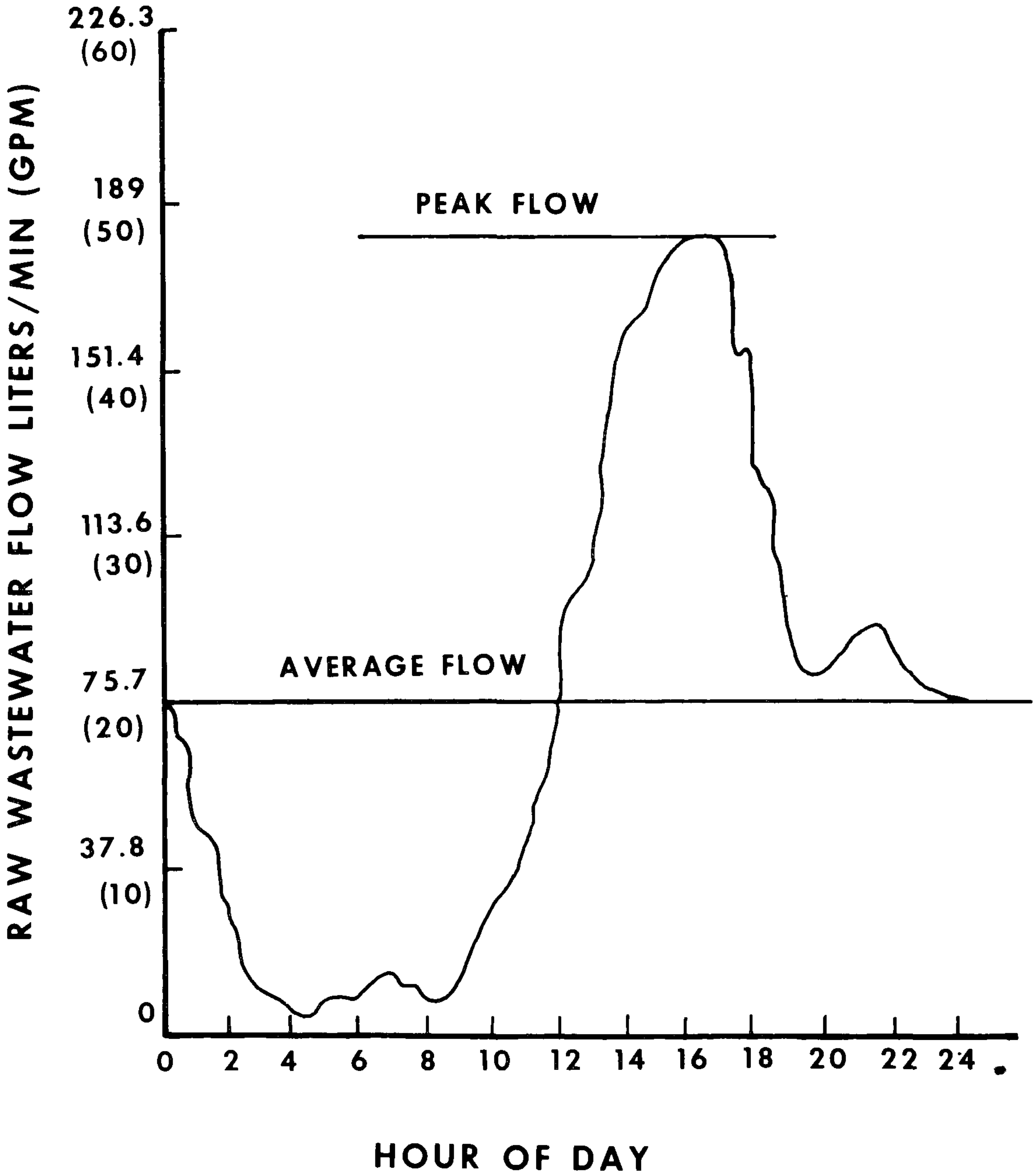

Figure 15. Diurnal flow pattern for Phase III; peak to average diurnal ratio at 2.5/1.

TABLE 3. AVERAGE PERFORMANCE VALUES FOR PHASE III: 2.5/1 PEAK-TO-AVERAGE FLOW (4-6-75 to 5-12-75)

	TOTAL COD (mg/l)	TOTAL COD REMOVED (%)	SOLUBLE COD (mg/l)	TOTAL BOD_5 (mg/l)	TOTAL BOD_5 REMOVED	SOLUBLE BOD_5 (mg/l)	SOLUBLE BOD_5 REMOVED (%)	TOTAL SUSPENDED SOLIDS (mg/l)	TOTAL SUSPENDED SOLIDS REMOVED	VOLATILE SUSPENDED SOLIDS (mg/l)	F/M $\frac{(k_g TBOD_5/day)}{(k_g\ MLVSS)}$
RAW WASTEWATER	255		94	137		40		167		114	
PRIMARY EFFLUENT DIURNAL SYSTEM	220	14+		95	31+			117	30+	76	
PRIMARY EFFLUENT CONSTANT SYSTEM	195	24+		86	37+			121	28+	81	
FINAL EFFLUENT DIURNAL SYSTEM	60	73* 76+	40	20	79* 85+	6	94^{o} 96^{Δ}	24	80* 86+	16	0.24
FINAL EFFLUENT CONSTANT SYSTEM	50	74* 80+	32	19	78* 86+	3	97^{o} 98^{Δ}	19	84* 87+	13	0.20

+ Based on raw wastewater

* Based on primary effluent

^{o} Based on $TBOD_5$ of primary effluent and $SBOD_5$ of final effluent

$^{\Delta}$ Based on $TBOD_5$ of raw wastewater and $SBOD_5$ of final effluent

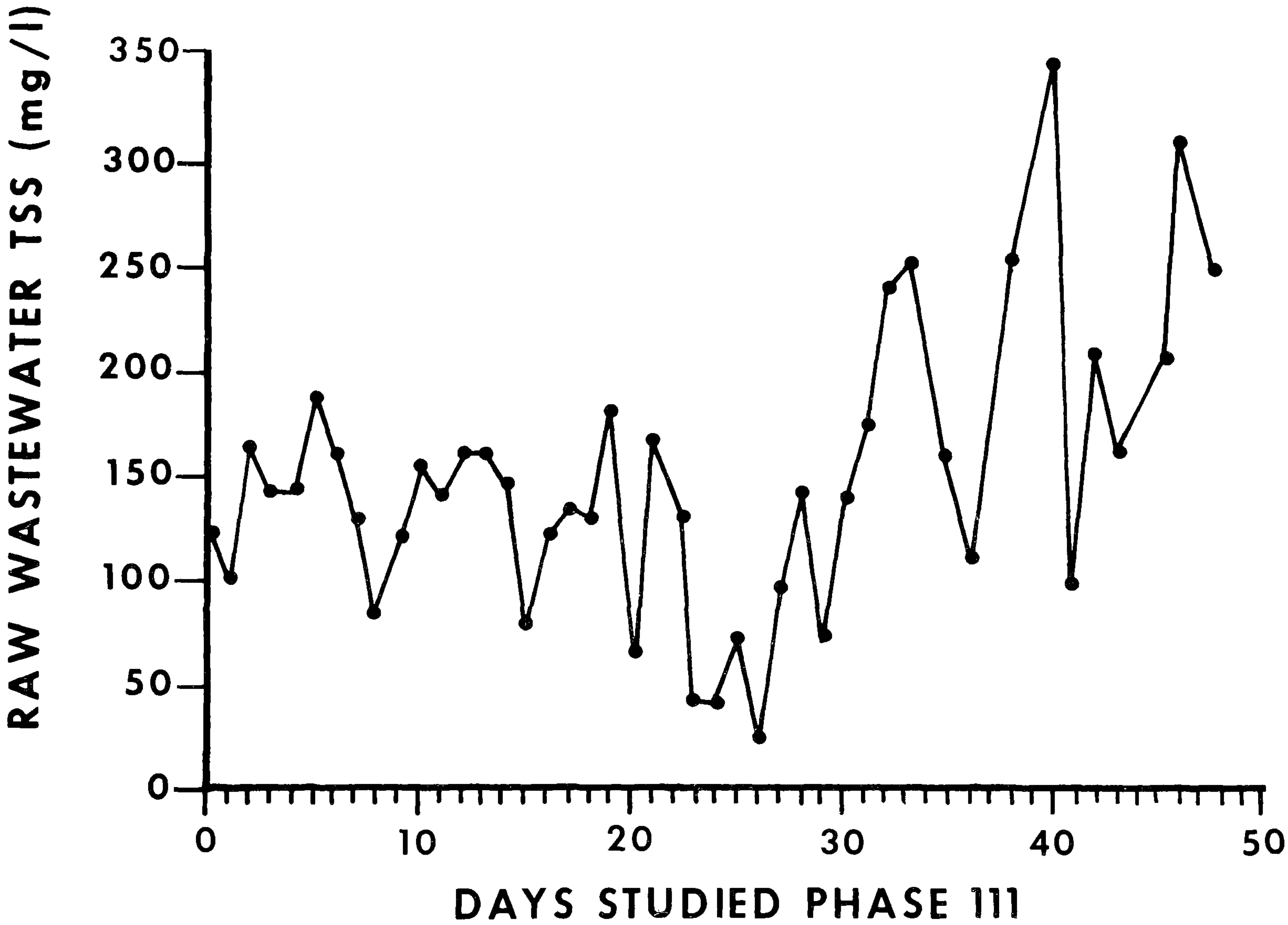

Figure 16. Daily variation of raw wastewater TSS for Phase III; peak to average diurnal ratio at 2.5/1.

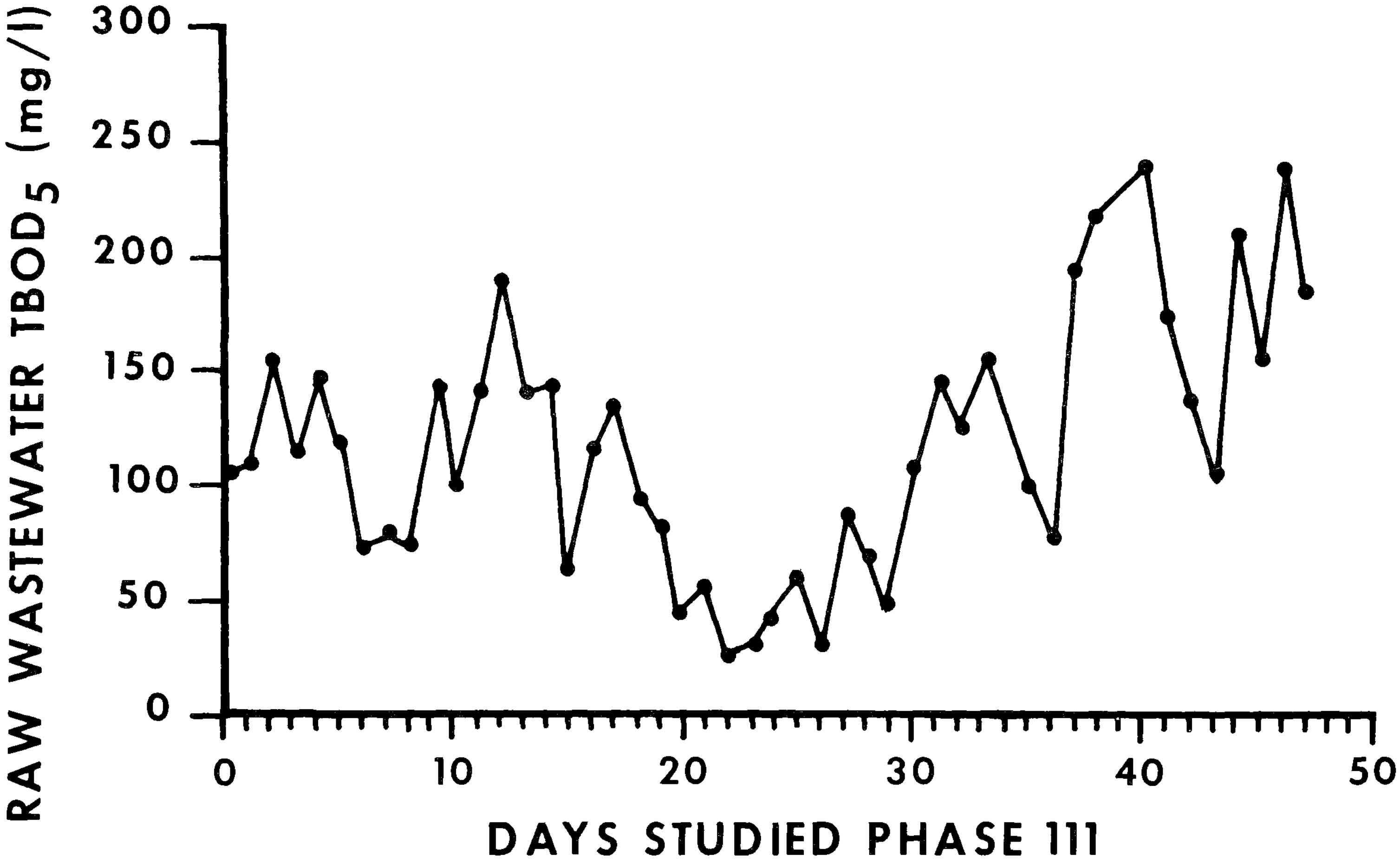

Figure 17. Daily variation of raw wastewater $TBOD_5$ for Phase III; peak to average diurnal ratio at 2.5/1.

Removals of TCOD and $TBOD_5$ averaged 10 and 6 percent higher, respectively, across the constant flow primary clarifier, representing a reversal in efficiency patterns observed in Phases I and II. The diurnal flow primary clarifier removed on the average 2 percent more TSS than the constant flow primary. Daily variations in primary effluent TSS levels, as shown in Figure 18, indicate some fluctuation between constant and diurnal primary clarifier performance but there was no significant trend.

During this phase the DFS final clarifiers were operated at an SOR of 31.9 $m^3/day/m^2$ (785 gpd/ft^2) at the average flow and 80.0 $m^3/day/m^2$ (1,963 gpd/ft^2) at the peak flow. On the average, the DFS final effluent showed a TSS of 24 mg/l, $TBOD_5$ of 20 mg/l, and TCOD of 60 mg/l. Final effluent average values from the CFS were 19 mg/l TSS, 19 mg/l BOD_5, and 50 mg/l TCOD. Both secondary systems removed essentially the same percentage of TCOD and $TBOD_5$. However, on a total system basis, TCOD removal was 4 percent higher for the CFS. Soluble BOD_5 and TSS removals were 3 and 4 percent higher respectively, for the CFS on a secondary system basis only and virtually equal on a total system basis. Figures 18 and 19 depict the daily variations in final effluent TSS and $TBOD_5$, respectively, for the two systems. Final effluent TSS exhibited greater variance at times from the diurnal flow clarifier, but no detectable trend was evident. No significant differences between the daily $TBOD_5$ levels of the constant and diurnal flow final effluents were shown. The results from Phase III indicate that no discernible differences in performance trends between the two systems could be quantified at the 2.5/1 P/A diurnal cycle.

INTENSIVE 24 HR SAMPLING STUDIES

During one 24 hr. period of each phase of this study, an intensive sampling schedule was initiated. Grab samples from the raw wastewater, primary effluent, and secondary effluent were collected every 2 hrs. from both the DFS and CFS. From these grab samples, incremental total mass loadings were calculated for the 2 hr. period that the grab sample represented. Cumulative mass loadings were then calculated by summation of the 2 hr. incremental mass loadings. The cumulative mass plots show the progression of the influent and effluent system loadings and represent the total mass loading for the system at any time during the 24 hr. period.

The purpose of flow equalization is to provide treatment plant process units with a relatively constant flow and mass loading. Flow equalization is accomplished through use of a basin with sufficient volume to store raw wastewater flows in excess of the constant flow supplied to the treatment plant. This storage volume also allows the diurnally fluctuating wastewater concentrations to be combined such that a relatively constant concentration can be supplied to the treatment plant. Therefore, if true flow equalization was provided to the CFS, incremental mass loadings would be essentially equal and the cumulative mass loading would be essentially a straight line with a constant slope. The DFS would have diurnally fluctuating incremental mass loadings which could affect the shape of the cumulative mass loading plots. Since both systems were operated so as to process the same total volume of wastewater per day, the cumulative mass

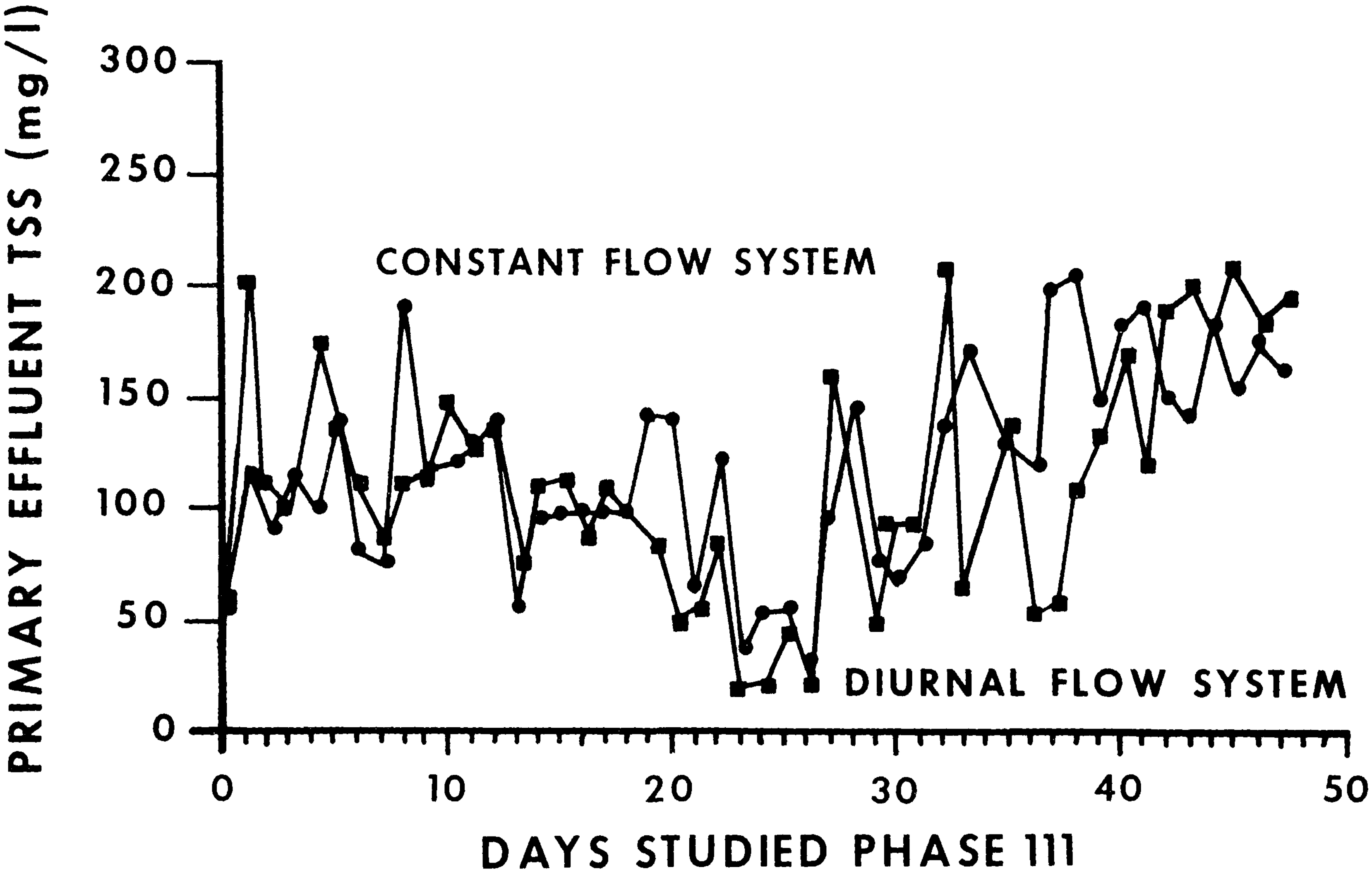

Figure 18. Daily variation of constant flow system and diurnal flow system primary effluent TSS for Phase III;peak to average diurnal ratio at 2.0/1.

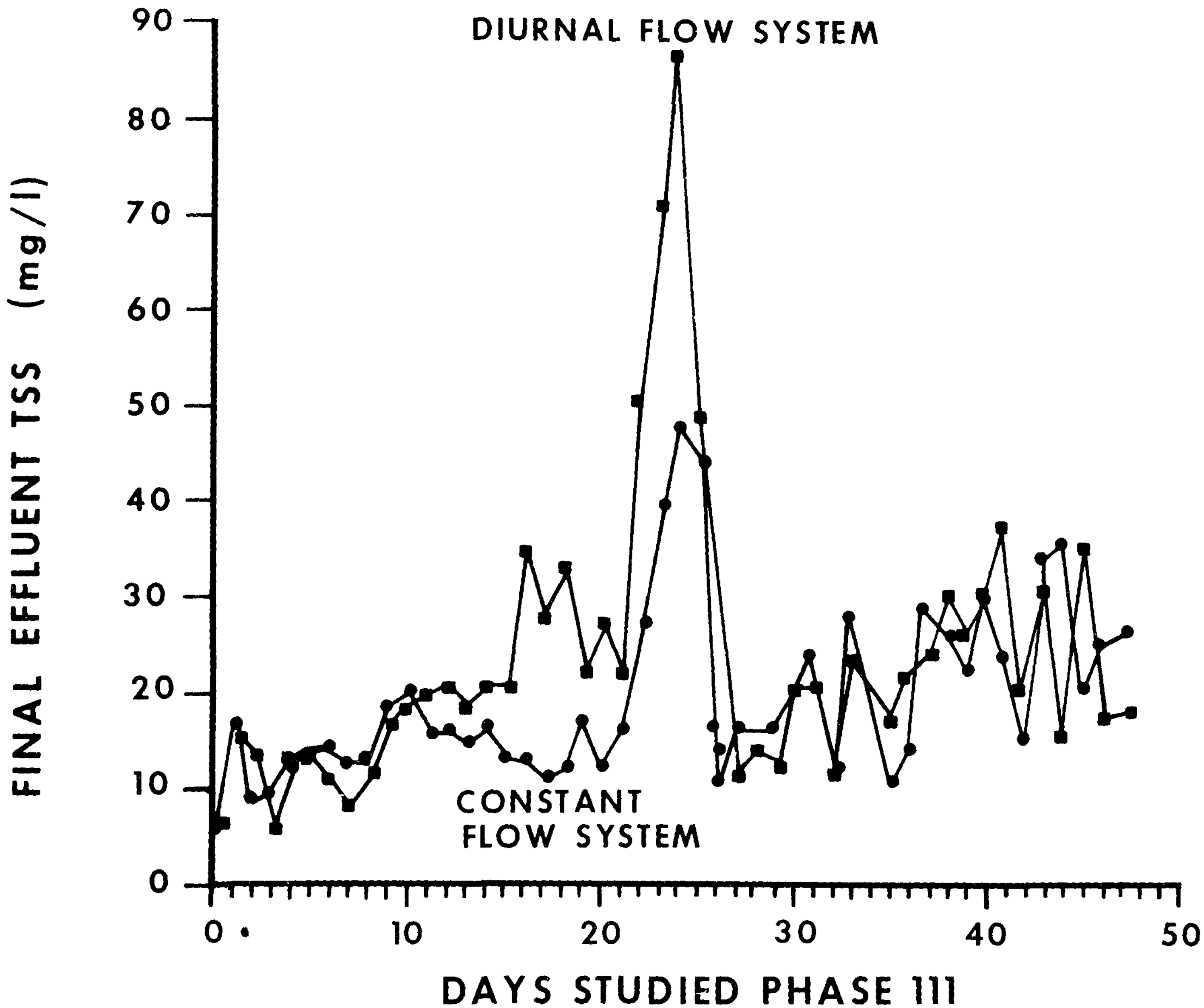

Figure 19. Daily variation of constant flow system and diurnal flow system final effluent system TSS for Phase III;peak to average diurnal ratio at 2.5/1.

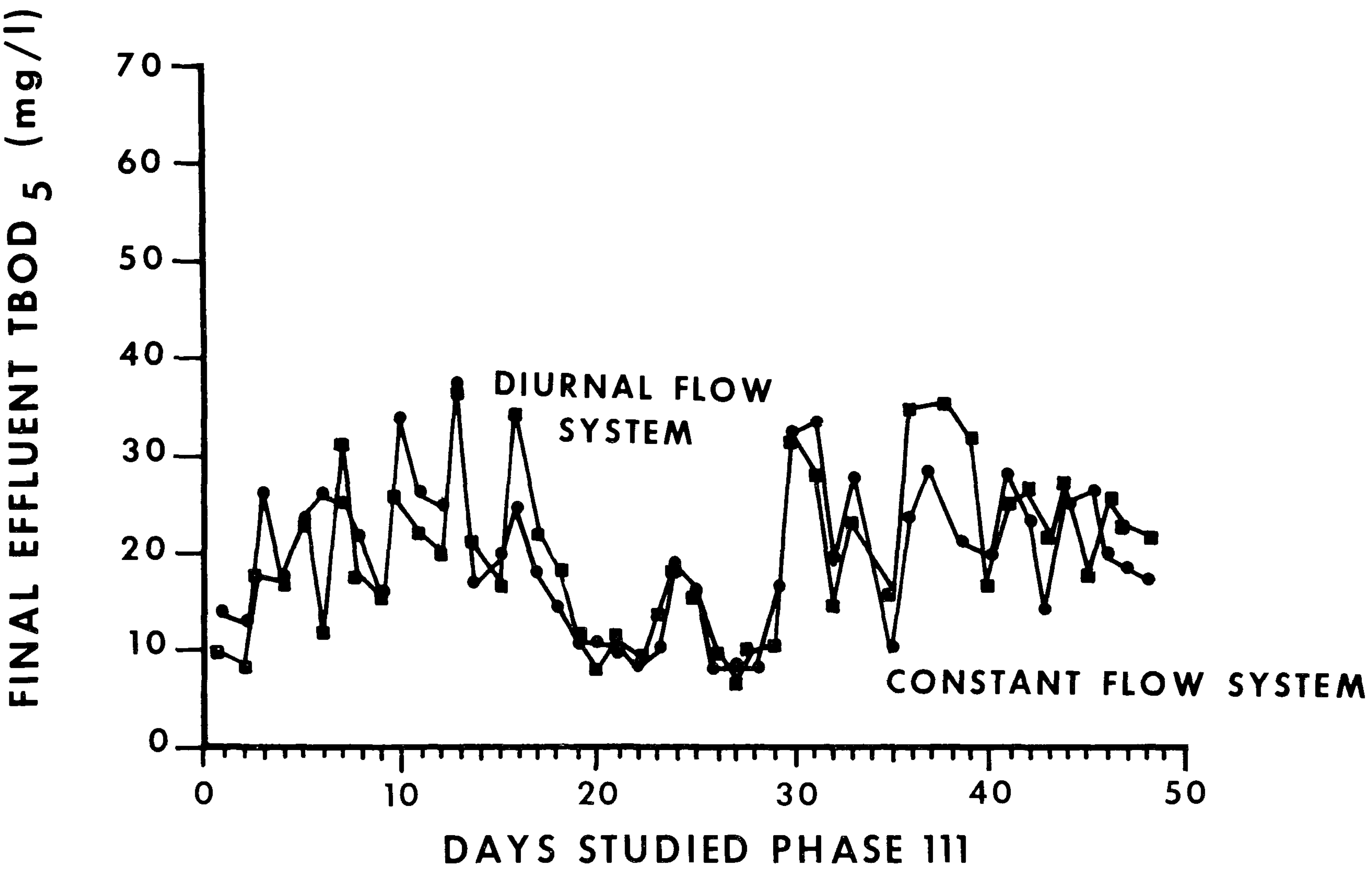

Figure 20. Daily variation of constant flow system final effluent $TBOD_5$ for Phase III; peak to average diurnal ratio at 2.5/1.

loadings for the raw wastewater at the end of the 24 hr. cycle, theoretically, should be the same for both the DFS and CFS.

The CFS did not completely simulate flow equalization since raw wastewater storage was not provided. Therefore, the CFS received a constant flow of a diurnally fluctuating raw wastewater. This could result in the CFS receiving a higher or lower total mass loading over a 24 hr. period than the DFS. For instance, if high wastewater concentrations occurred during periods of low flow in the diurnal cycle, the incremental mass loading for the CFS would be substantially higher than that for the DFS, thus possibly showing the cumulative mass loading at the end of the 24 hr. cycle to be higher than that for the DFS. Since both systems may have received different total waste loads over the 24 hr. intensive sampling period, process unit effluent quality may have been affected.

Phase I - Peak-to-Average Diurnal Ratio at 1.5/1

Figures 21 and 22 show the raw wastewater concentrations, incremental mass loadings and cumulative mass loadings for TCOD and TSS, respectively, calculated for the intensive 24 hr. sampling study performed during Phase I of this study. The effect of the imposed diurnal flow pattern is shown on the incremental and cumulative mass loading plots for the CFS and DFS. At a 1.5/1 P/A diurnal cycle, TCOD incremental and cumulative mass loadings were essentially the same. However, the DFS received a 25 percent less TSS total mass loading over the 24 hr. cycle.

Primary effluent concentrations, incremental and cumulative mass loadings are shown in Figure 23 and 24 for TCOD and TSS, respectively. The diurnal primary effluent TCOD concentrations were consistently, though only slightly below those of the constant flow primary. No consistent trend was observed for TSS. Cumulative TCOD mass loading for the CFS and DFS primaries showed both systems producing essentially the same effluent total mass over the 24 hr. period. The DFS primary effluent cumulative mass loading for TSS was approximately 25 percent less than the CFS. The difference appears to correspond with the difference in influent TSS loadings to the CFS and DFS primaries. Incremental mass TCOD and TSS loadings for the DFS primaries show only small diurnal fluctuation over that observed with the CFS. The slope of the cumulative mass loading plots substantiates this result since both plots had essentially the same slope. This indicates that the imposed diurnal flow at the 1.5 P/A ratio did not substantially affect primary effluent mass loading rates over the 24 hr. period studied.

Figures 25 and 26 show the final effluent TCOD and TSS concentrations, incremental mass loadings, and cumulative mass loadings, respectively, for the 24 hr. period sampled during Phase I of this study. There were no significant trends between the CFS and DFS secondary effluent TCOD and TSS concentrations. The incremental mass loadings for final effluent TCOD did show a significant increase over the six hours of peak diurnal flow. Over the entire 24 hr. sampling period, the incremental mass loadings for final effluent TSS were essentially the same. The cumulative mass loadings for the DFS final effluent TCOD were slightly higher than those observed from

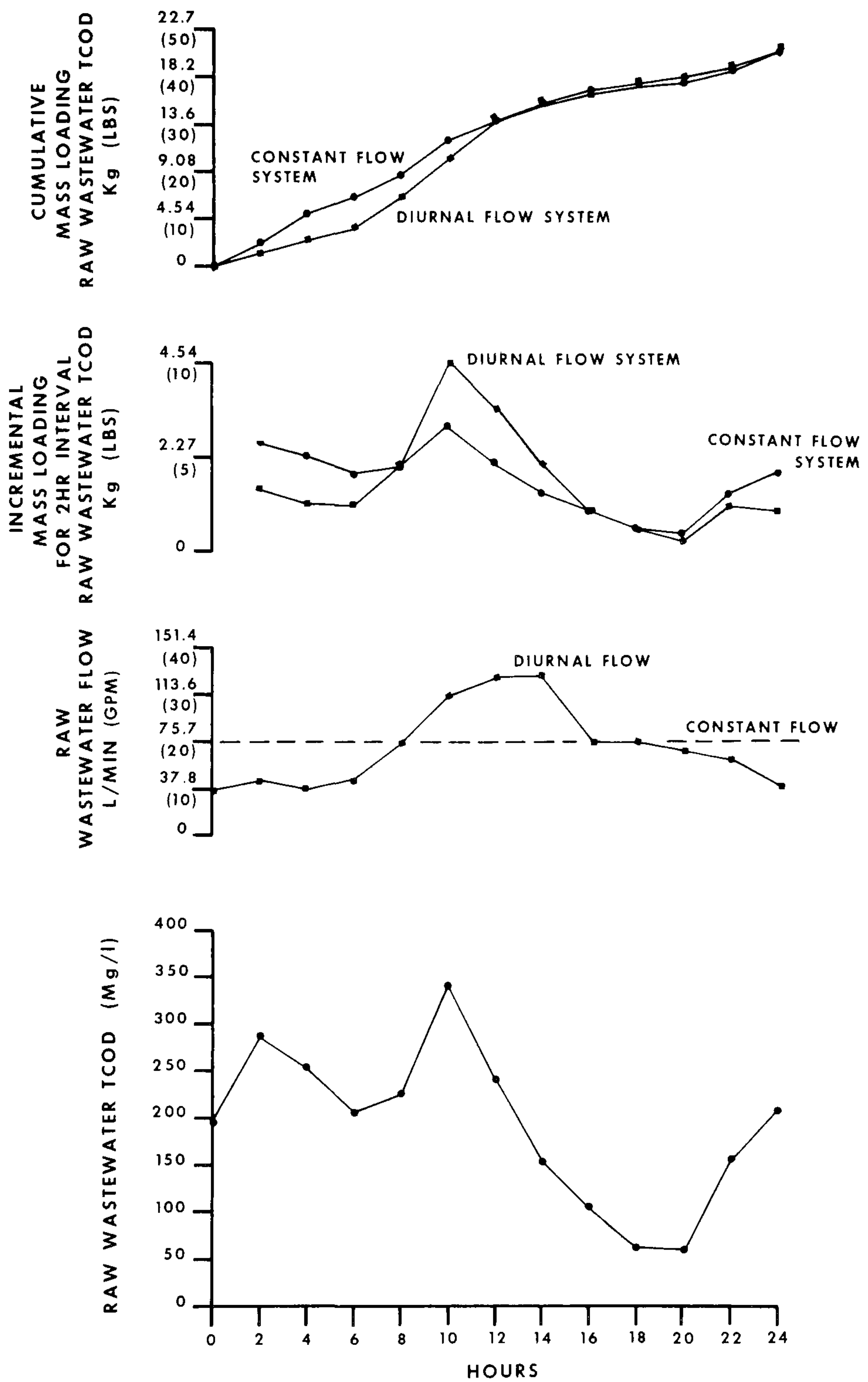

Figure 21. Results of intensive 24 hr. sampling study for Phase I; raw wastewater TCOD.

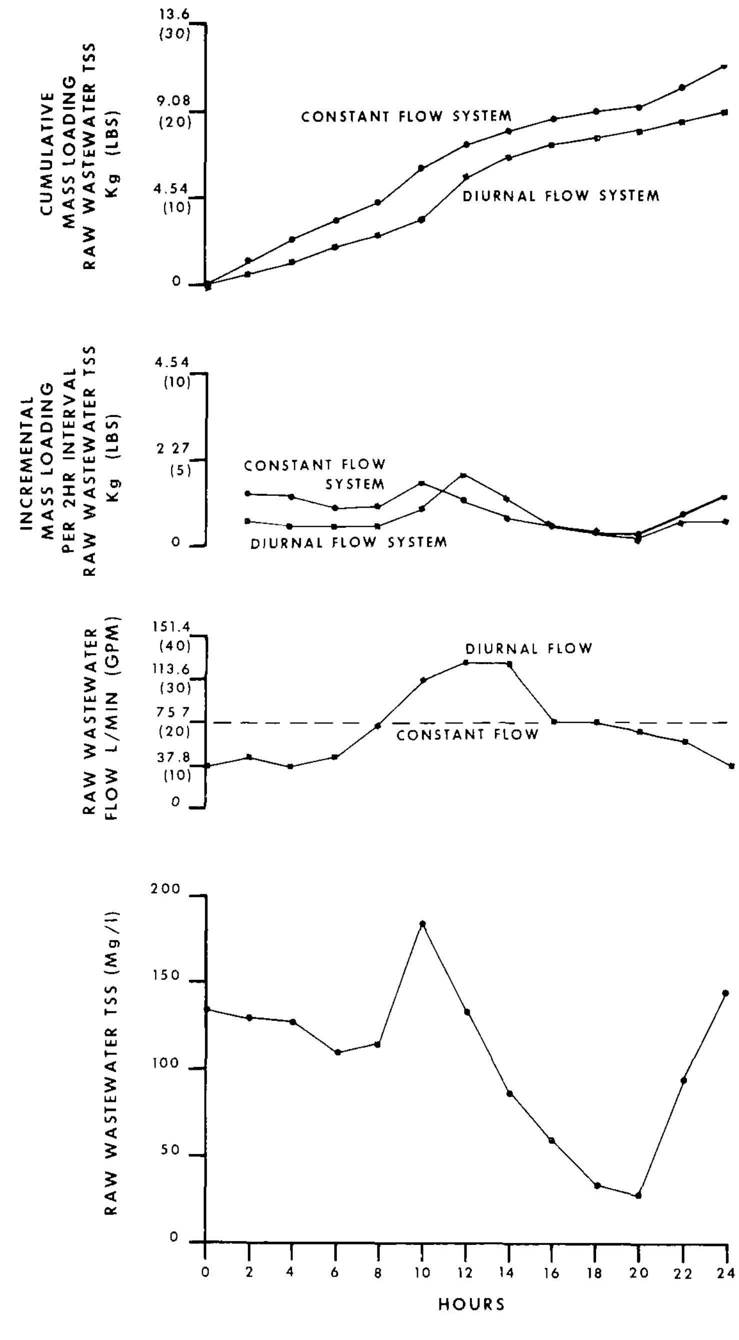

Figure 22. Results of intensive 24 hr. sampling study for Phase I; raw wastewater TSS.

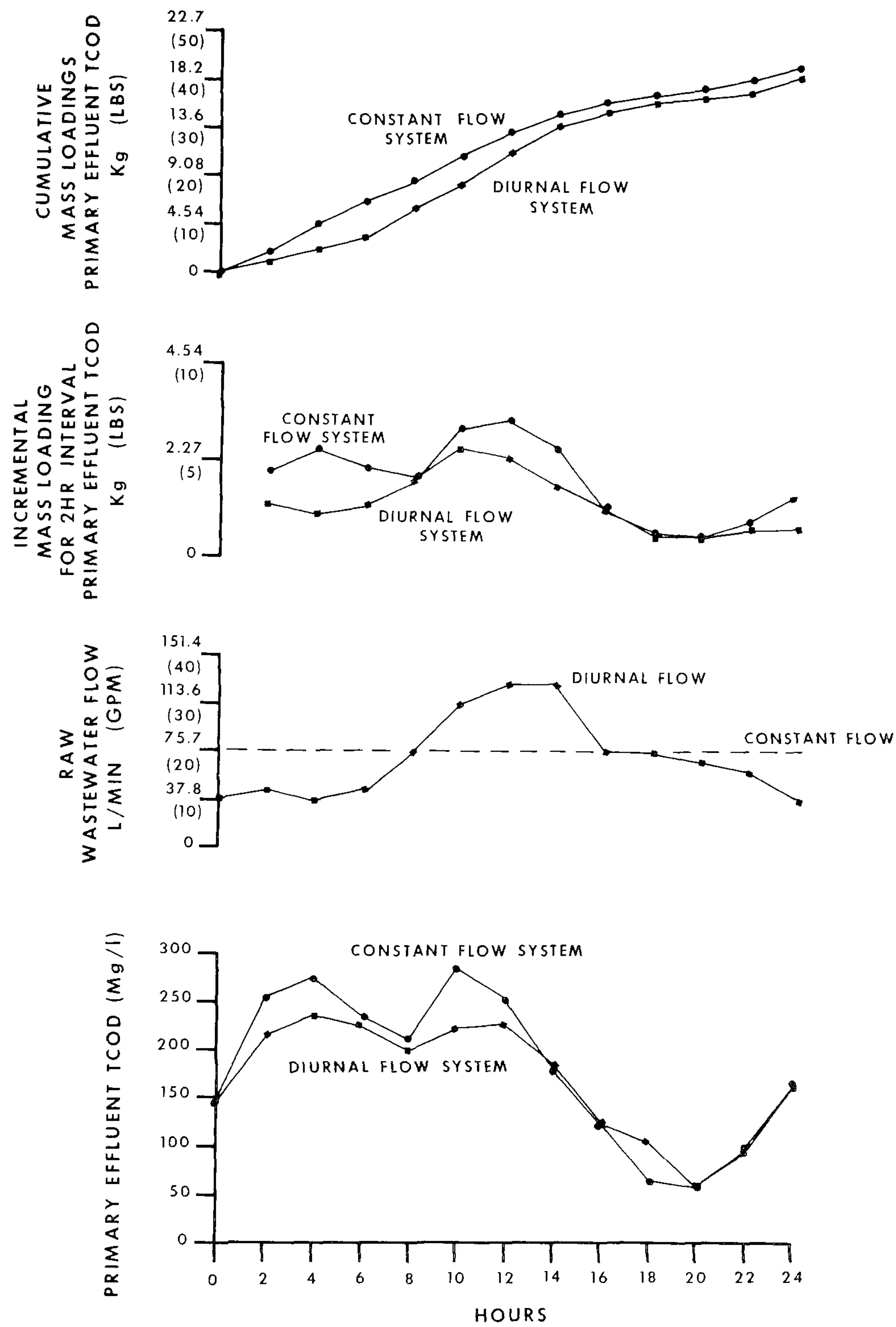

Figure 23. Results of intensive 24 hr. sampling study for Phase I; primary effluent TCOD.

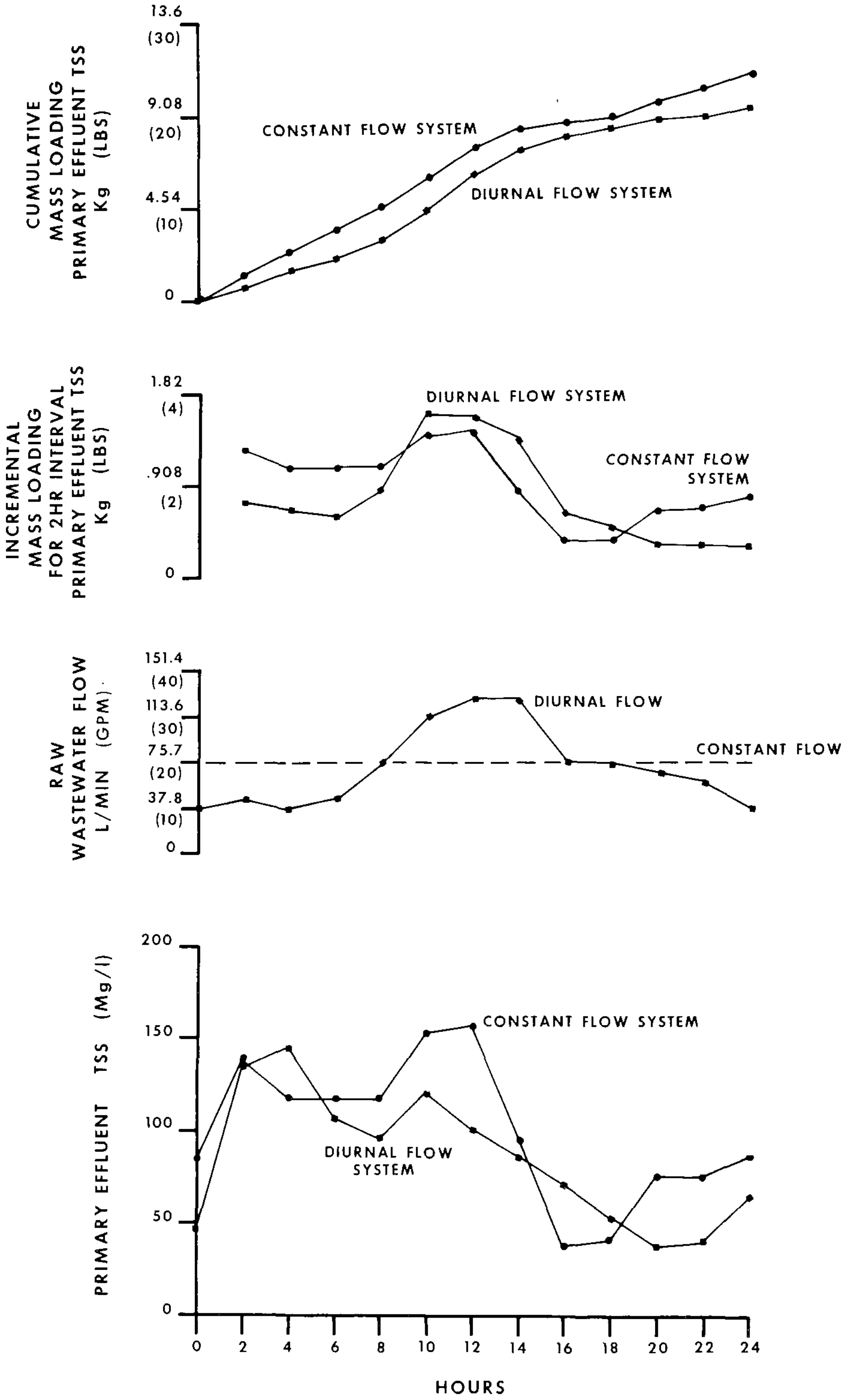

Figure 24. Results of intensive 24 hr. sampling study for Phase I; primary effluent TSS.

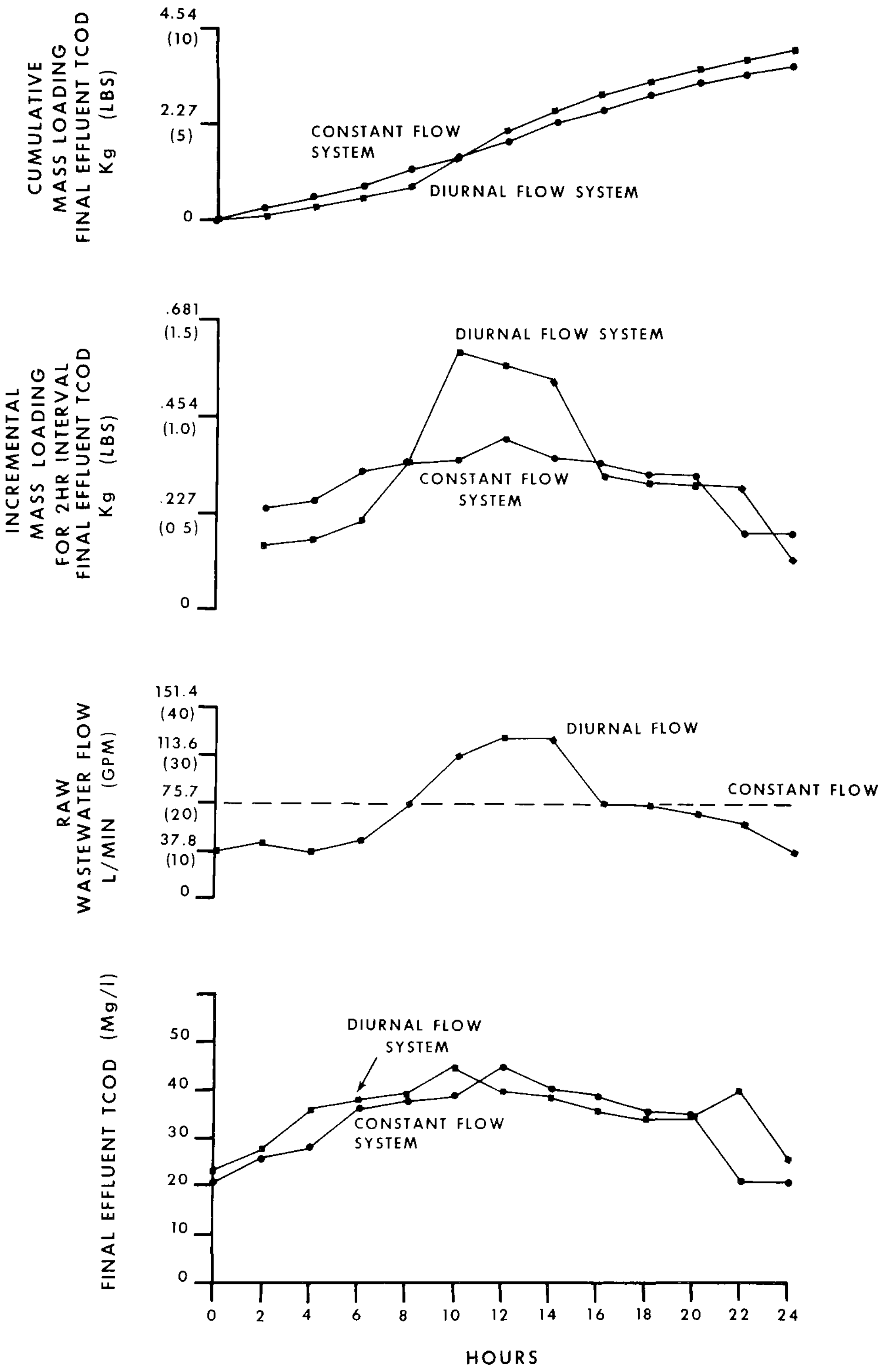

Figure 25. Results of intensive 24 hr. sampling study for Phase I; final effluent TCOD.

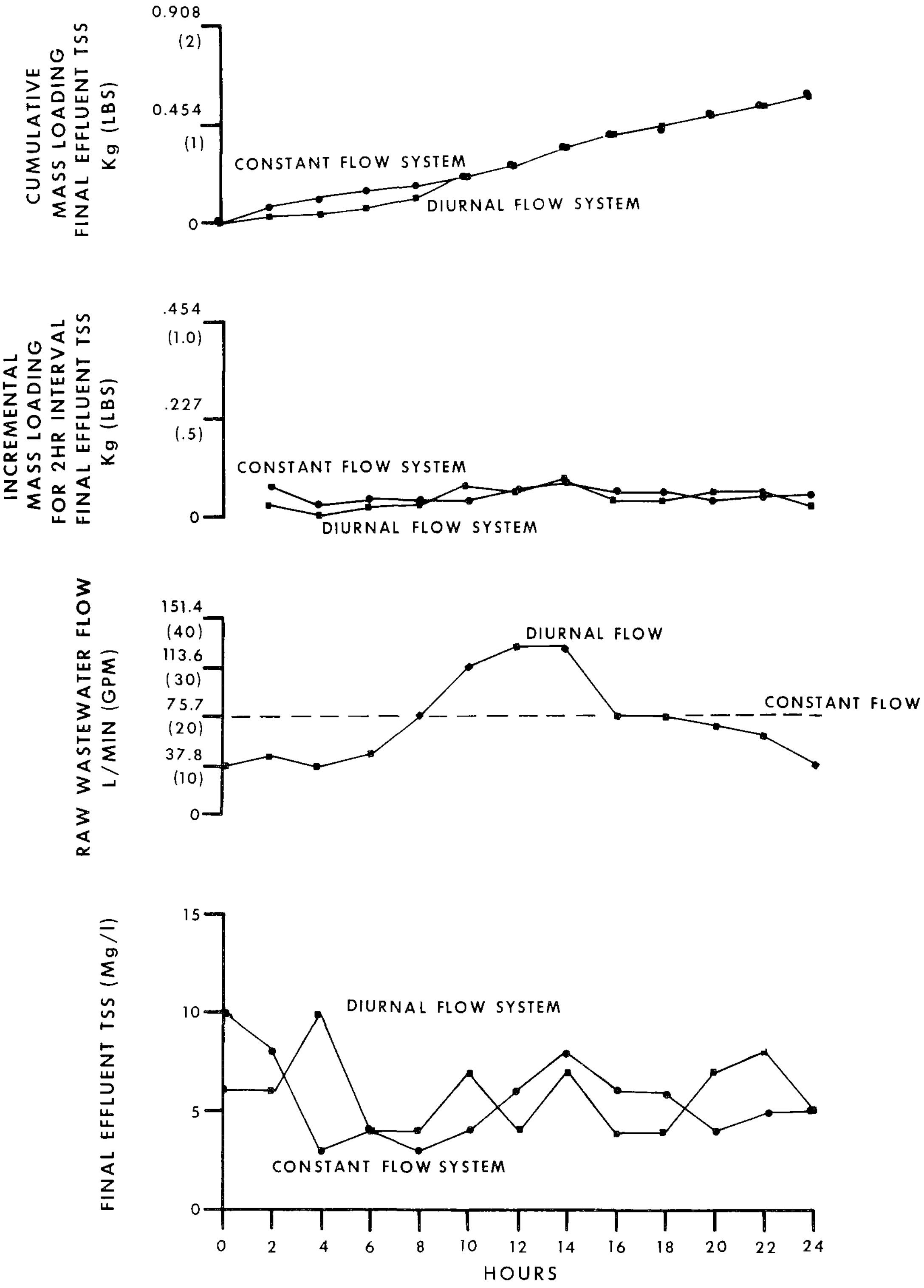

Figure 26. Results of intensive 24 hr. sampling study for Phase I; final effluent TSS.

the CFS. Final effluent TSS cumulative mass loadings were essentially the same for both systems and the 24 hr. sampling period.

The results from the Phase I intensive 24 hr. sampling study indicate that the DFS primary clarifier and activated sludge secondary treatment performance were essentially unaffected by the 1.5/1 P/A diurnal flow ratio, as compared to the CFS operated at a constant flow.

Phase II - Peak-to-Average Diurnal Ratio at 2.0/1

Figures 27 and 28 show the raw wastewater concentrations, incremental mass loadings, and cumulative mass loadings for TCOD and TSS, respectively, calculated for the intensive 24 hr. sampling study performed during Phase II of this study. The incremental mass loadings plots for both TCOD and TSS show that the DFS was receiving mass loadings that had a substantial diurnal fluctuation. Mass loadings to the CFS were essentially constant. The cumulative mass loading plots for both TCOD and TSS also showed the diurnally fluctuating mass loadings to the DFS. However, for both TCOD and TSS the DFS received a total mass loading 12 percent less than the CFS, over the 24 hr. period.

CFS and DFS primary effluent concentrations, incremental mass loadings, and cumulative mass loadings for TCOD and TSS are shown in Figures 29 and 30, respectively. There were no significant trends in primary effluent TCOD or TSS observed between the CFS and DFS. The incremental mass loading plots showed that the DFS primary effluent mass loadings for TCOD had a significant diurnal fluctuation corresponding to peak diurnal flows. However, the diurnal flow primary had only small fluctuations in effluent TSS mass loadings during the peak diurnal flows. The constant flow primary had relatively constant effluent mass loading for both TCOD and TSS over the 24 hr. period sampled. Cumulative mass loading plots for TCOD showed both the CFS and DFS primary effluent TCOD mass loadings to be equivalent over the 24 hr. period. The TSS cumulative mass loading for the DFS primary effluent was 18 percent less than the CFS over the 24 hr. sampling period.

Figures 31 and 32 show the final effluent TCOD and TSS concentrations, incremental mass loadings, and cumulative mass loadings, respectively, for the 24 hr. period sampled. There were no significant trends between the CFS and DFS secondary effluent TCOD and TSS concentrations. The incremental mass loadings for DFS final effluent TCOD and TSS did show significant fluctuations corresponding to the diurnal flow pattern. Final effluent incremental mass loadings for the CFS were essentially constant over the 24 hr. sampling period. The final effluent cumulative mass loadings for the DFS were 10 percent and 5 percent for TCOD and TSS, respectively, less than those for the CFS.

The results from the Phase II intensive 24 hr. sampling study indicate that both the primary clarifier and activated sludge secondary treatment performance were essentially unaffected by the 2.0/1 P/A diurnal flow imposed on the DFS as compared to the CFS operated at a constant flow. Lack of equalization of the raw wastewater TCOD and TSS concentrations to the CFS

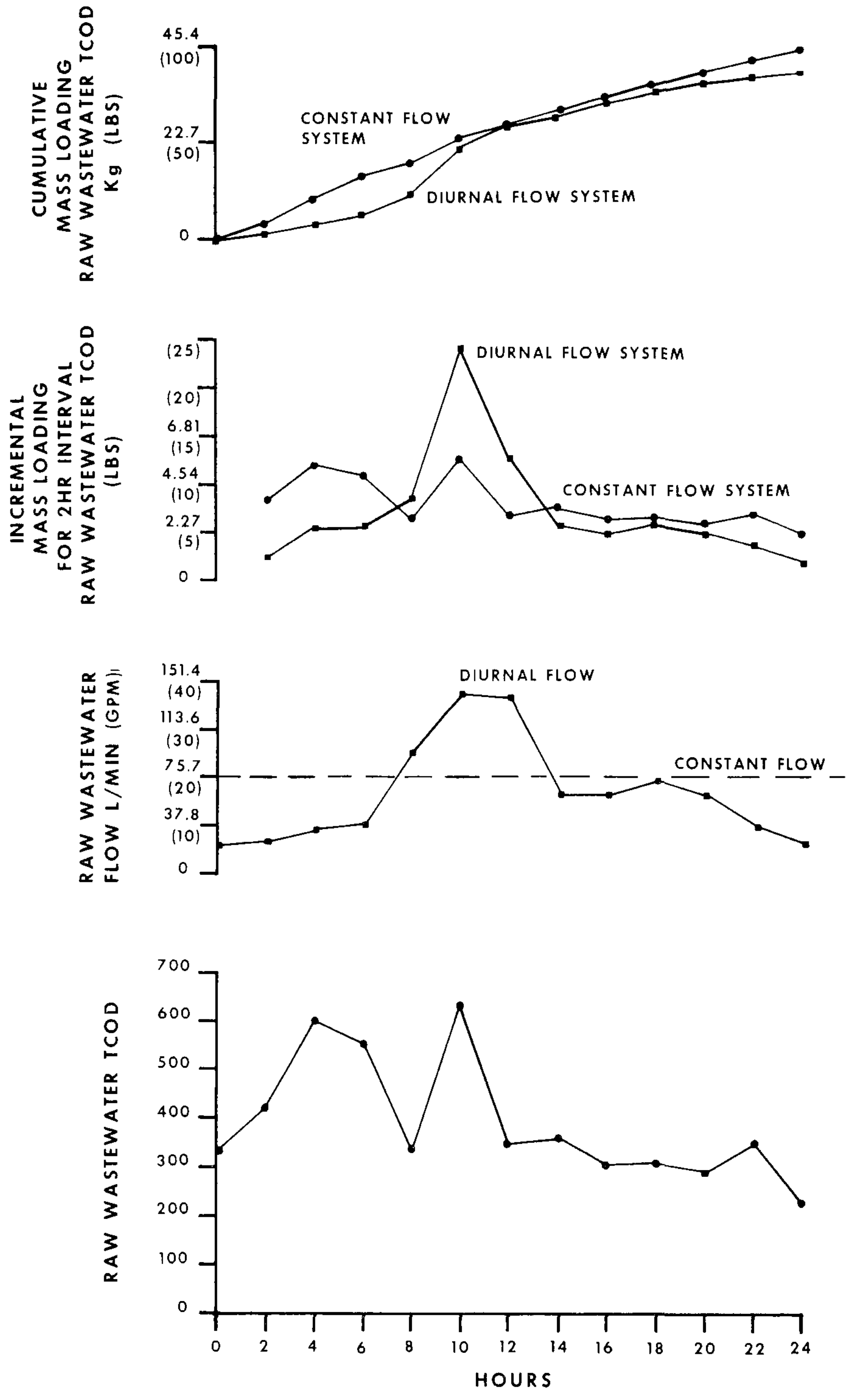

Figure 27. Results of intensive 24 hr. sampling study for Phase II; raw wastewater TCOD.

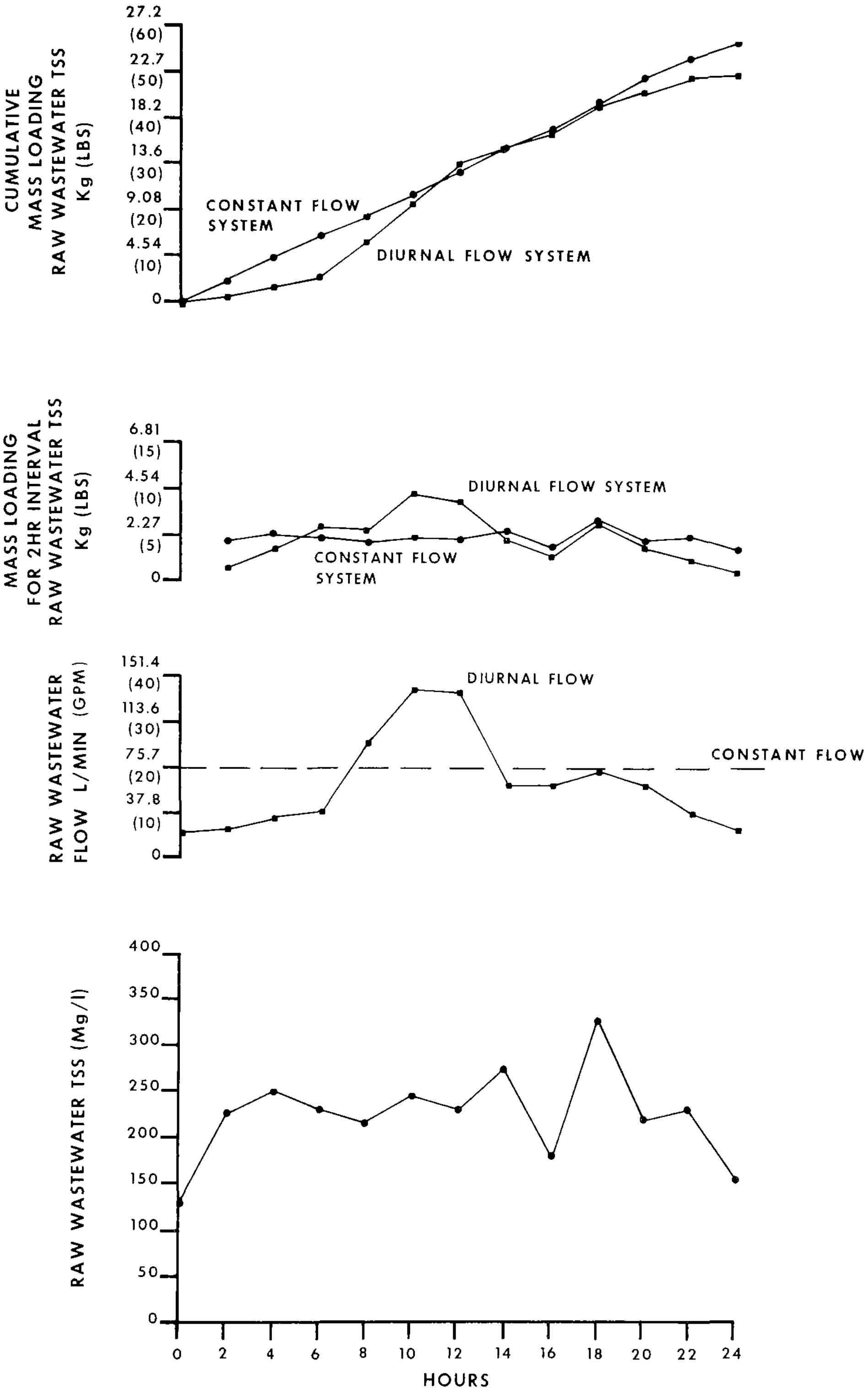

Figure 28. Results of intensive 24 hr. sampling study for Phase II; raw wastewater TSS.

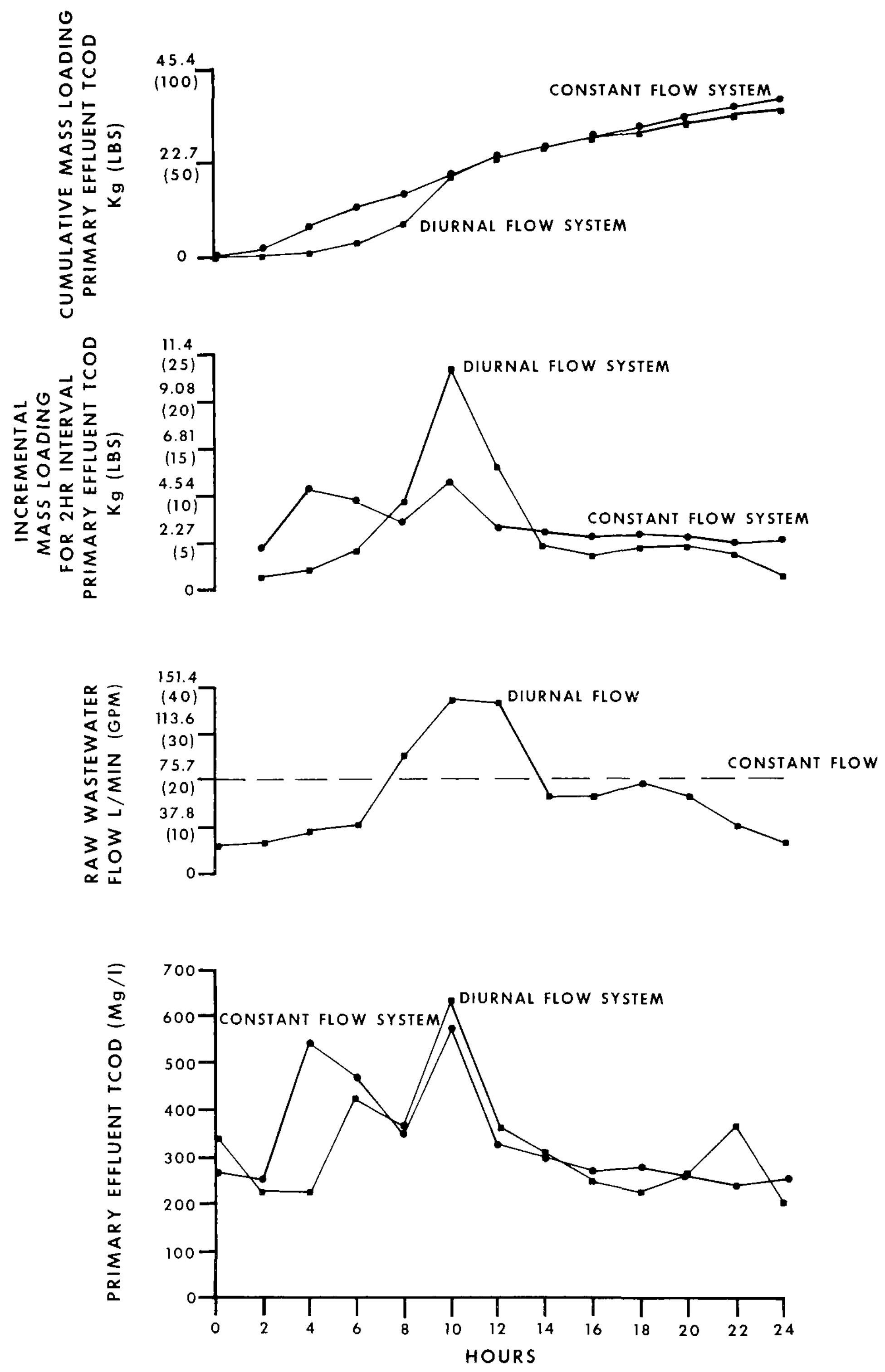

Figure 29. Results of intensive 24 hr. sampling study for Phase II; primary effluent TCOD.

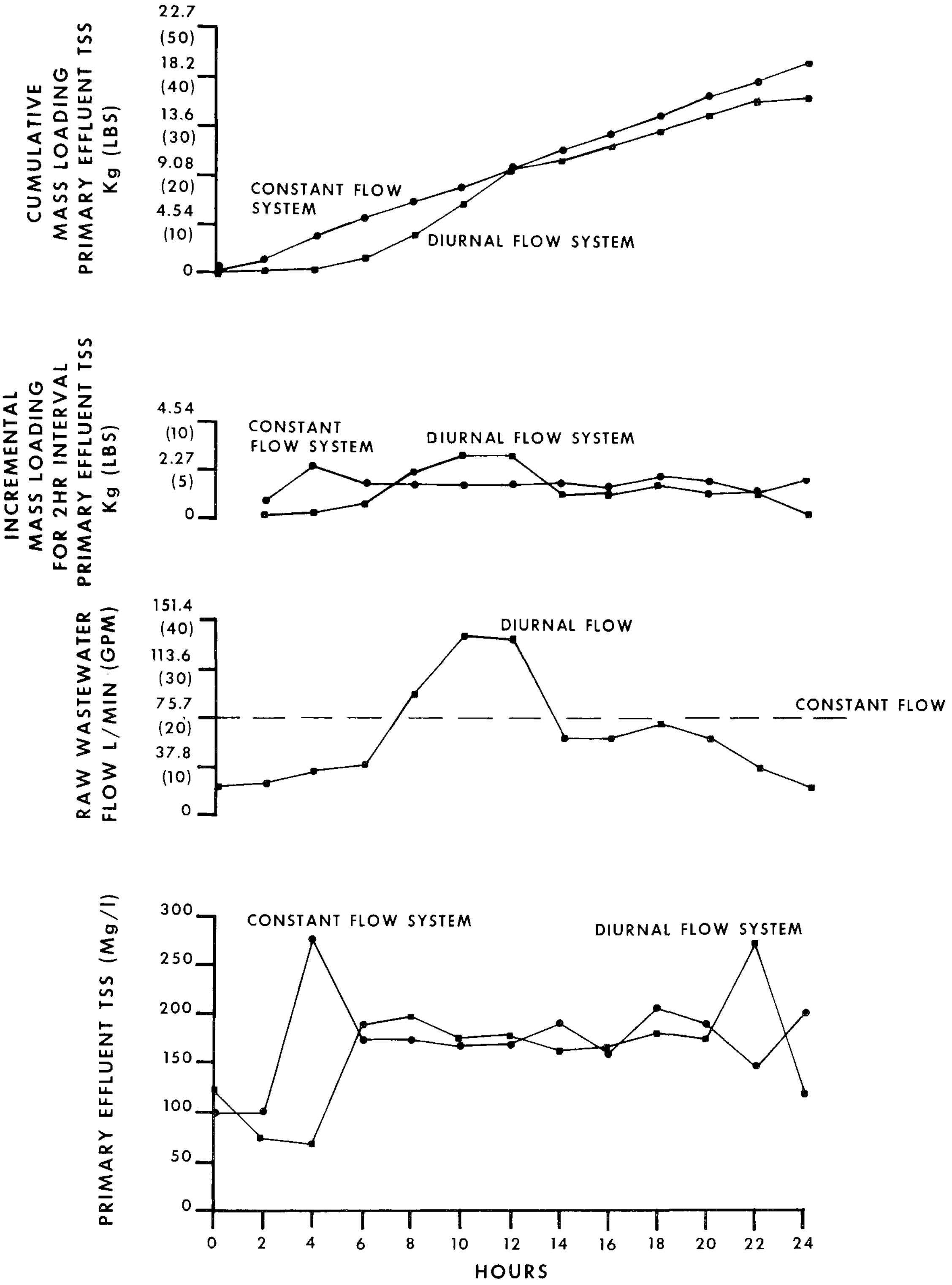

Figure 30. Results of intensive 24 hr. sampling study for Phase II; primary effluent TSS.

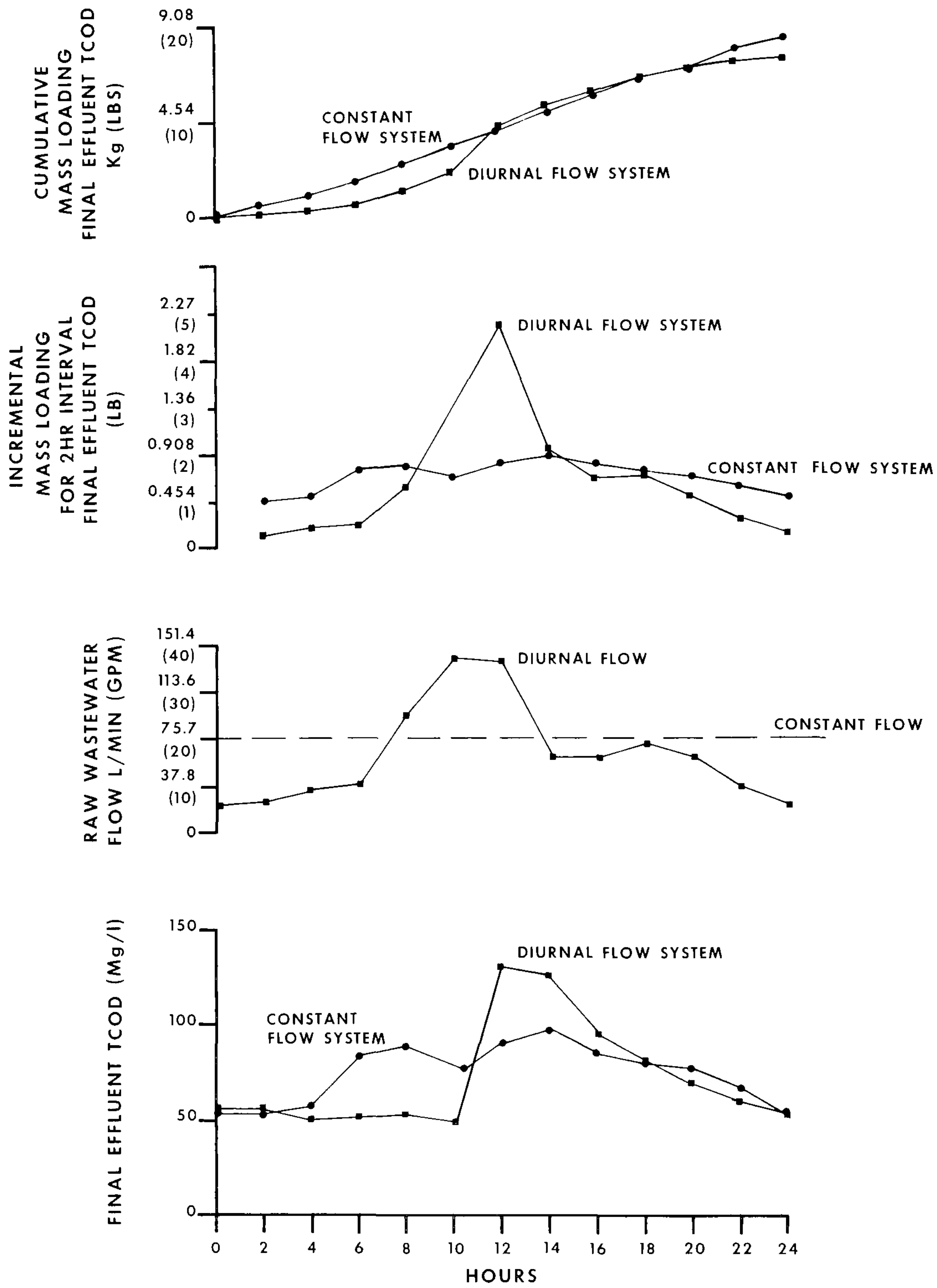

Figure 31. Results of intensive 24 hr. sampling study for Phase II; final effluent TCOD.

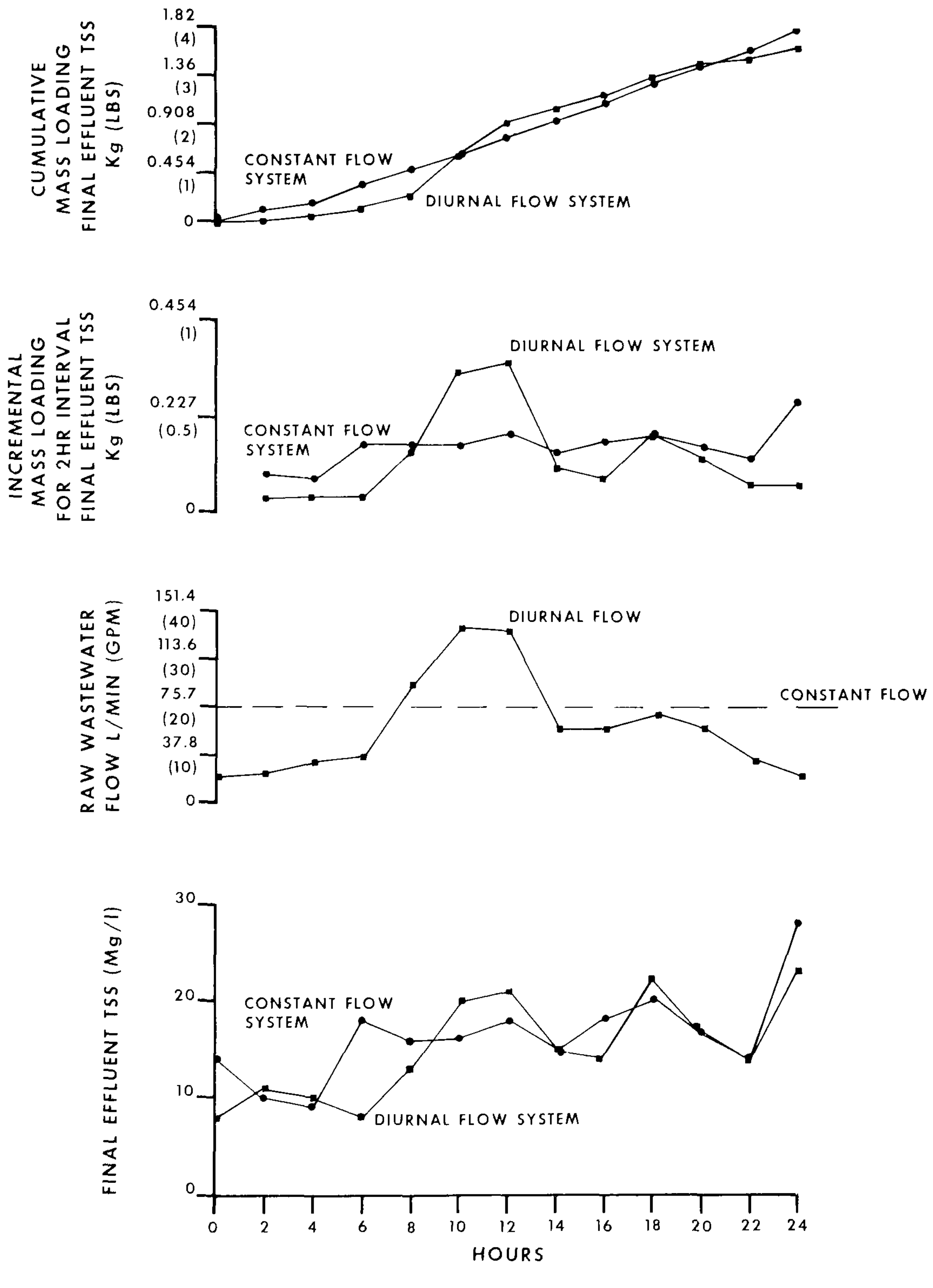

Figure 32. Results of intensive 24 hr. sampling study for Phase II; final effluent TSS.

may have caused primary and final effluent total mass loadings for this system to be slightly higher than the DFS.

Phase III - Peak-to-Average Diurnal Ratio at 2.5/1

Figures 33 and 34 show the raw wastewater concentrations, incremental mass loadings, and cumulative mass loadings for TCOD and TSS, respectively, calculated for the intensive 24 hr. sampling study performed during Phase III of this study. The incremental mass loading plots for both TCOD and TSS show that the DFS was receiving mass loadings that fluctuated significantly over the diurnal cycle. Mass loadings to the CFS were essentially constant except during large fluctuations in raw wastewater concentrations. Cumulative mass loading plots for both TCOD and TSS showed that both systems were receiving essentially the same total mass over the 24 hr. sampling period.

CFS and DFS primary effluent concentrations, incremental mass loadings, and cumulative mass loadings for TCOD and TSS are shown in Figures 35 and 36, respectively. The DFS primary effluent quality for both TCOD and TSS was consistently less than the CFS, except for effluent TCOD during the last six hours of the intensive sampling study. No explanation for this difference in primary effluent quality is apparent. DFS primary effluent incremental mass loading plots for both TCOD and TSS show large diurnal fluctuations while the CFS primary effluent had a relatively constant mass loading. The primary effluent TCOD cumulative mass loading plots showed no siginficant difference between the two systems. However, the TSS total mass loading over the 24 hr. sampling period was 15 percent less for the DFS primary than the CFS primary. This is related to the better performance of the DFS primary clarifier during this 24 hr. study.

Figures 37 and 38 show the final effluent TCOD and TSS concentrations, incremental mass loadings, and cumulative mass loadings, respectively, for the 24 hr. period sampled. The CFS TCOD final effluent quality was better than that of the DFS for most of the 24 hr. period. The DFS final effluent TSS concentrations were more variable than the CFS and followed the diurnal flow pattern as would be expected at this 2.5/1 P/A diurnal ratio. The incremental mass loadings for the DFS final effluent TCOD and TSS showed large fluctuations corresponding to the diurnal flow pattern. Final effluent incremental mass loadings for the CFS were essentially constant over the 24 hr. sampling period. The final effluent cumulative mass loadings for TCOD and TSS were 25 percent and 21 percent higher, respectively, for the DFS than for the CFS.

The results from the Phase III intensive 24 hr. sampling study indicate the 2.5/1 P/A imposed diurnal flow variation significantly affected the DFS activated sludge secondary clarifier performance when compared to the similar CFS operated at a constant flow. However, since this represents only one day of intensive sampling, it is difficult to make any definite conclusions regarding the effects of the 2.5/1 P/A imposed diurnal flow ratio on the treatment system over extended periods of time.

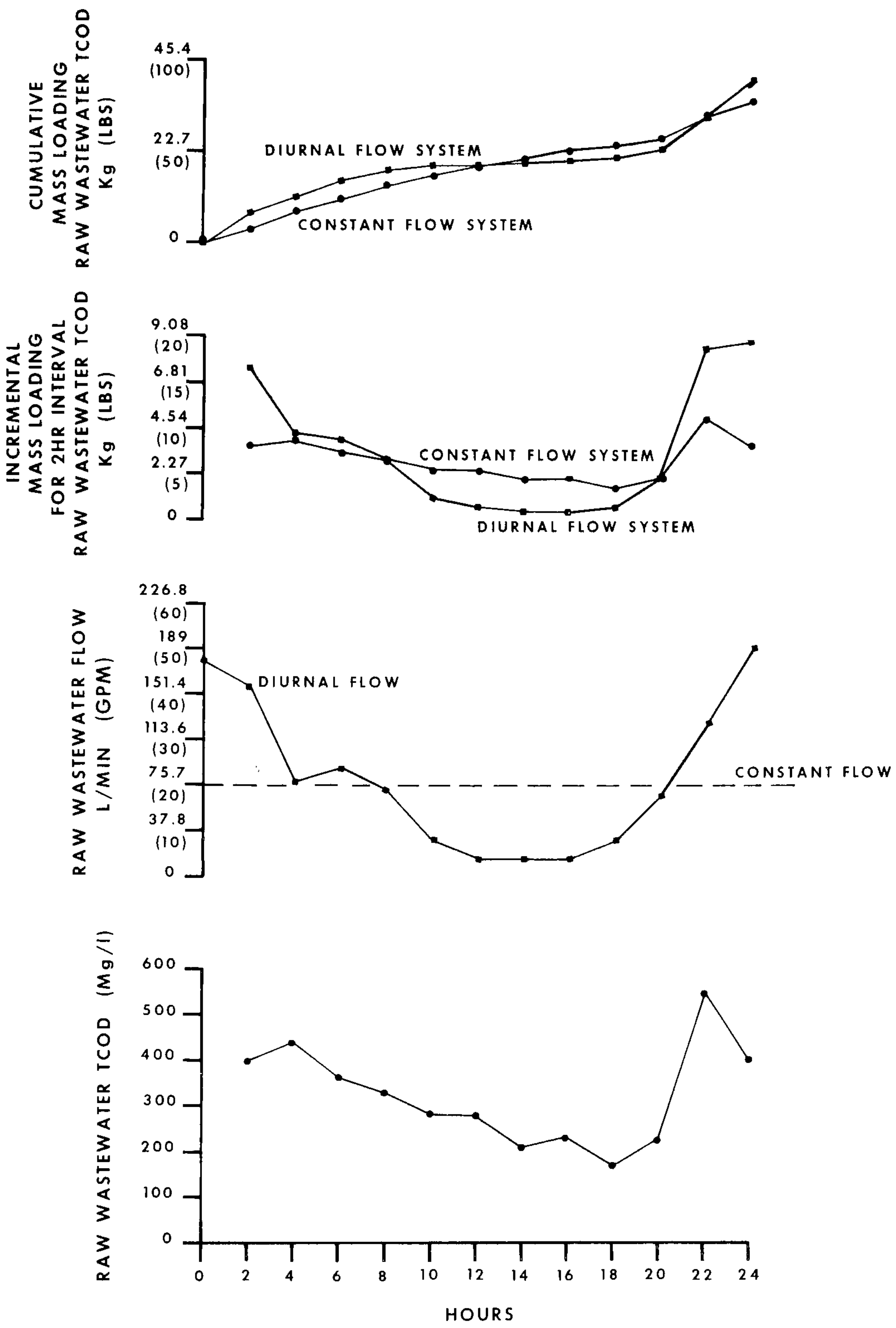

Figure 33. Results of intensive 24 hr. sampling study for Phase III; raw wastewater TCOD.

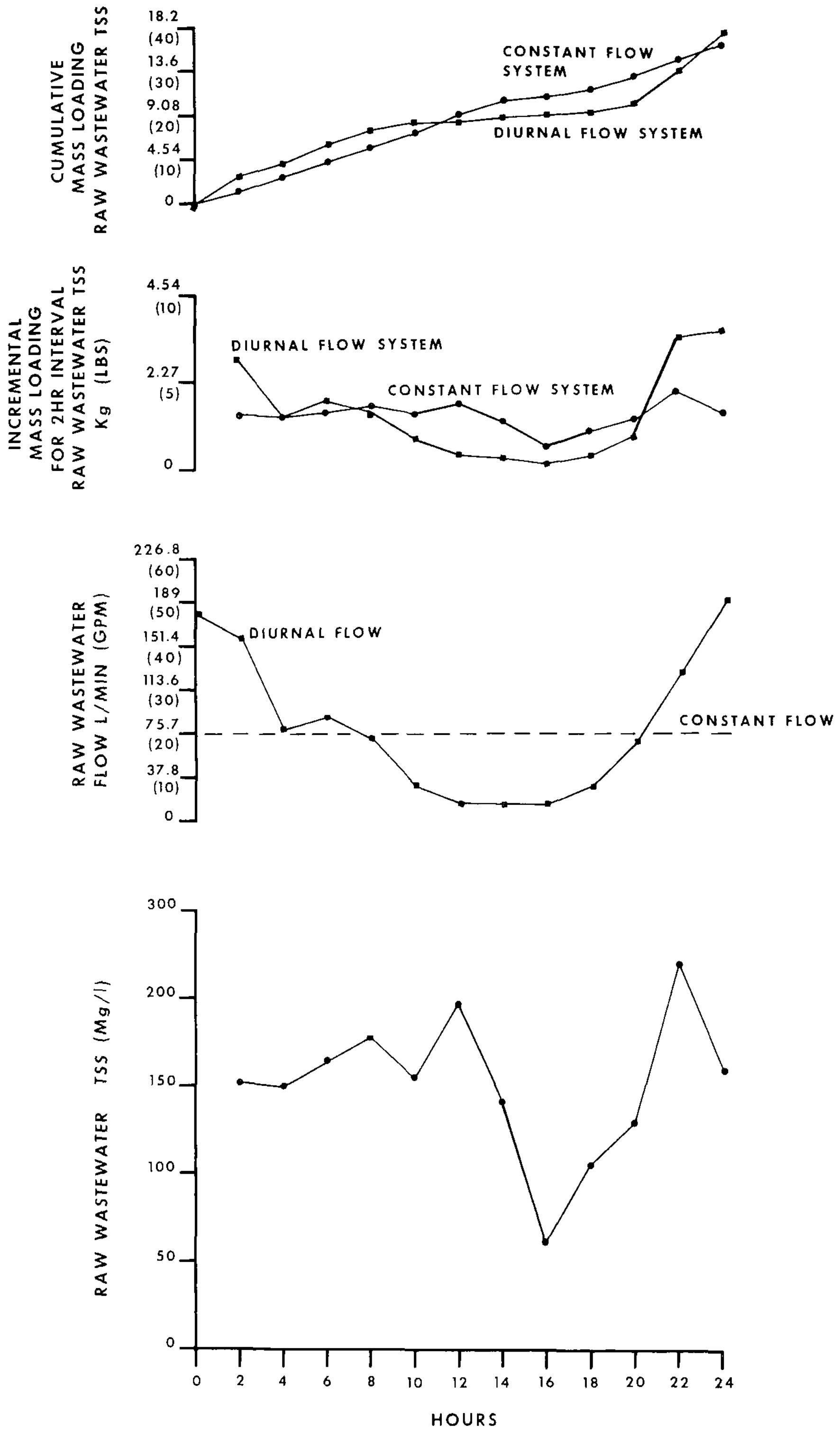

Figure 34. Results of intensive 24 hr. sampling study for Phase III; raw wastewater TSS.

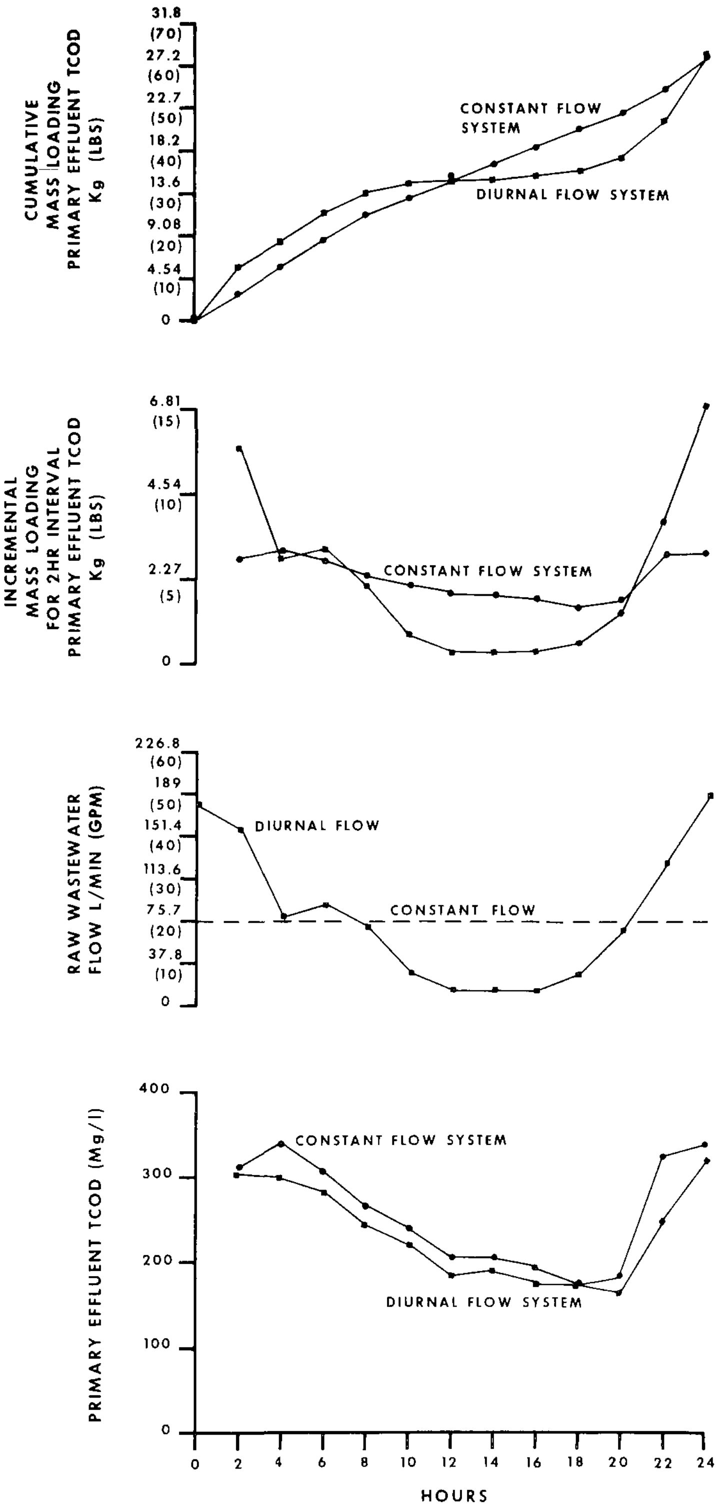

Figure 35. Results of intensive 24 hr. sampling study for Phase III; primary effluent TCOD.

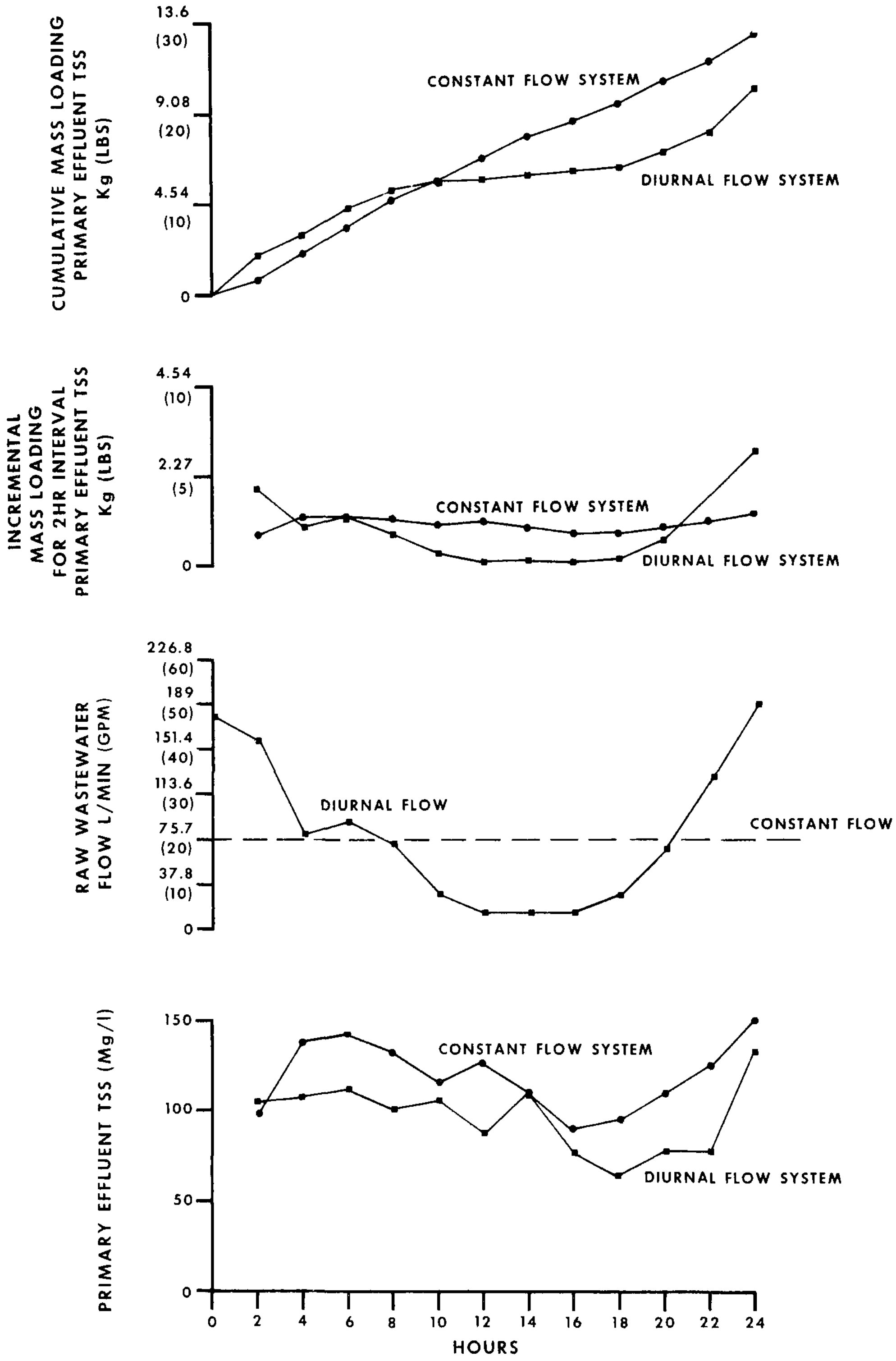

Figure 36. Results of intensive 24 hr. sampling study for Phase III; primary effluent TSS.

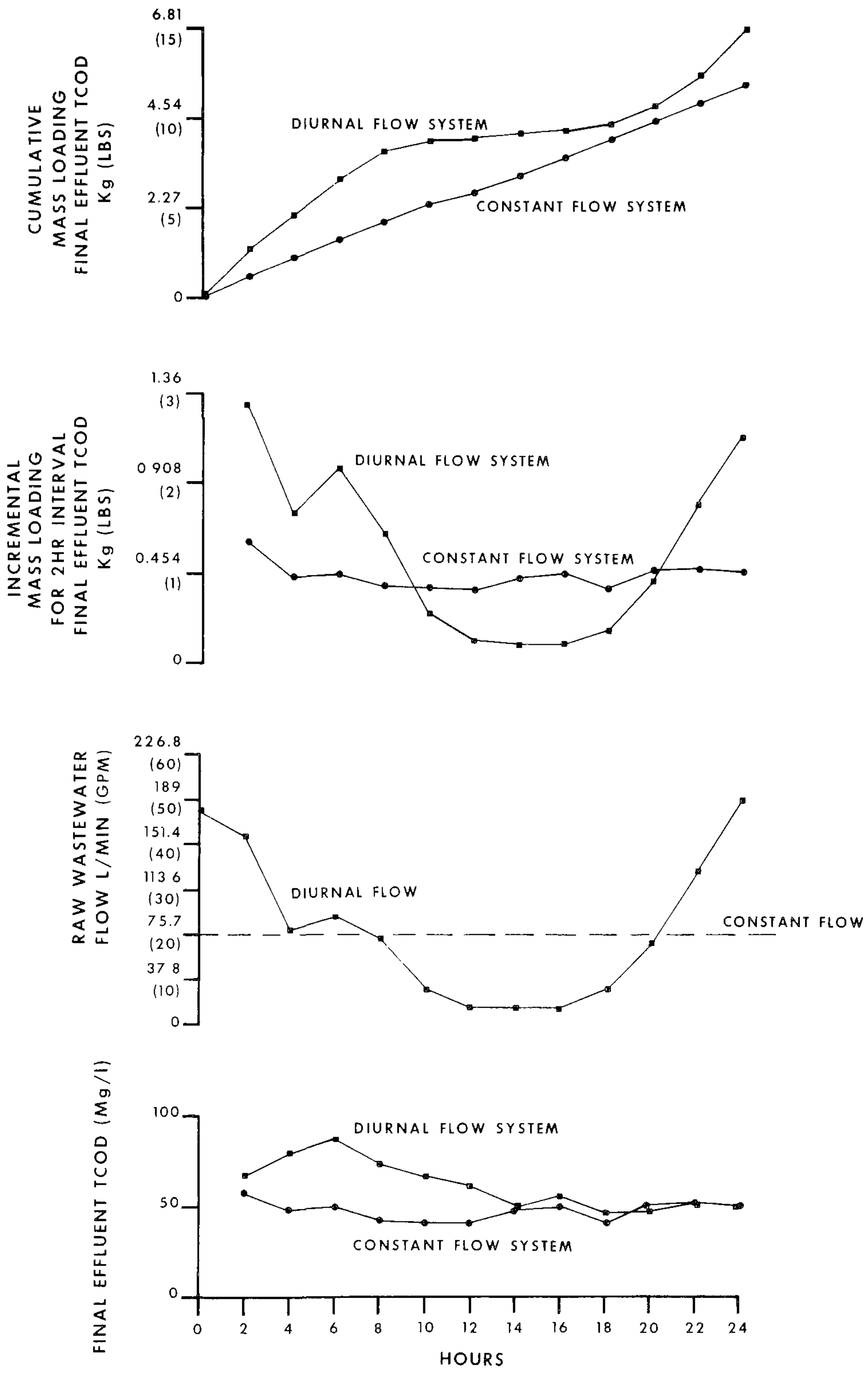

Figure 37. Results of intensive 24 hr. sampling study for Phase III; final effluent TCOD.

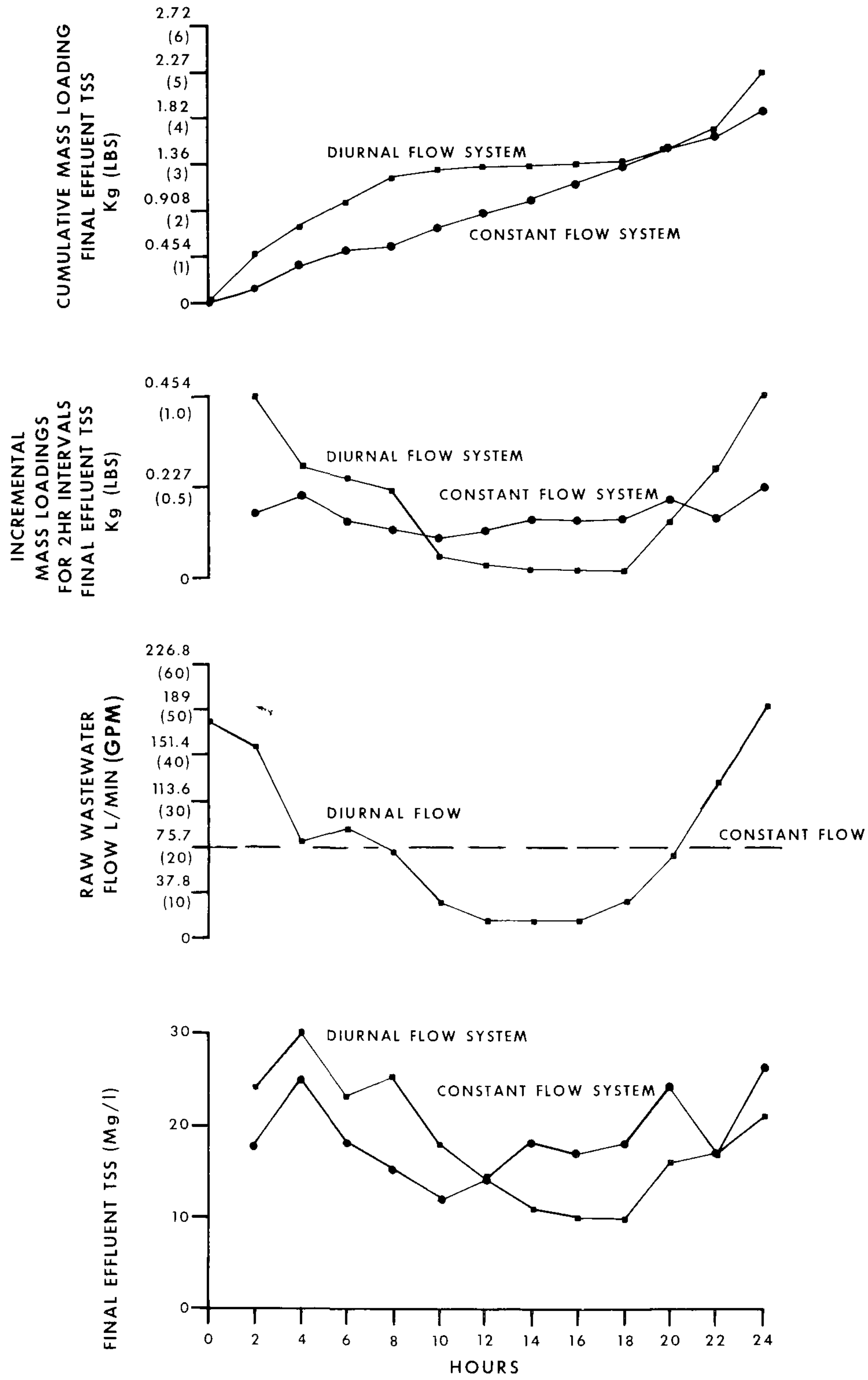

Figure 38. Results of intensive 24 hr. sampling study for Phase III; final effluent TSS.

EFFECTS ON PLANT STABILITY

Diurnal flow variations could also have some impact on other areas of plant stability. These would be generally related to variations in aeration basin dissolved oxygen (DO) concentrations and final clarifier sludge blanket levels during periods of peak flows.

The lack of continuous on-line DO measurement made quantifying diurnal DO levels in the aeration basins difficult. During this study, DO levels were measured 6 times daily. However, data relating DO levels to the imposed diurnal flow pattern were not collected. Generally, the operations staff did not observe any regular fluctuation of DO levels during the peak flows of the diurnal cycle.

Sludge blanket levels would theoretically vary during the diurnal flow cycle. These variations would be caused by fluctuating upflow velocities in the diurnal flow final clarifier. Data on sludge blanket levels was collected. However, these data could not be related to the diurnal flow pattern and are not included in this report. The operations staff noted consistently high sludge blanket levels in the DFS clarifier only during the 2.5/1 P/A phase of the study. The DFS effluent solids levels were not adversely affected by the high blanket seen except when the blanket would come over the weirs. The frequency levels of high effluent solids due to high sludge blanket was not recorded.

$FeCl_3$ ADDITION RESULTS

Earlier investigations (3,4) into flow equalization concluded the mixed liquor settleability was a more important factor in final clarifier performance than diurnal peak flows. During Phases II and III of the study, 10 mg/l of $FeCl_3$ was added periodically to the mixed liquor just before entering the final clarifiers to stabilize sludge settleability. Though these $FeCl_3$ additions were performed only for 2 to 3 week intervals, they provide insight into final clarifier performance under conditions of very stable sludge settleability.

Table 4 shows the averages of data collected over a 4 week period during Phase II of this study. Primary effluent data are similar to that previously reported at the 2.0/1 P/A diurnal ratio. CFS activated sludge performance, however, improved considerably in contrast to the DFS with mineral addition. $TBOD_5$ and TSS levels were 50 percent higher in the DFS final effluents than in CFS final effluent. However, final effluent soluble BOD_5 levels were the same for both systems.

Similar data with $FeCl_3$ addition was collected during 2 weeks of the Phase III 2.5/1 P/A diurnal flow study. As shown in Table 5, final effluent TCOD and $TBOD_5$ levels were 3 times greater for the DFS as compared to the CFS. Final effluent TSS values were 4 times greater for the DFS, and final effluent soluble BOD_5 was 3 times greater.

TABLE 4. RESULTS OF $FeCl_3$ ADDITION STUDY DURING PHASE II: 2.0/1 PEAK-TO-AVERAGE FLOW (6-30-74 to 7-23-74)

	TOTAL COD (mg/l)	TOTAL COD REMOVED	SOLUBLE COD (mg/l)	TOTAL BOD_5 (mg/l)	TOTAL BOD_5 REMOVED (%)	SOLUBLE BOD_5 (mg/l)	SOLUBLE BOD_5 REMOVED (%)	TOTAL SUSPENDED SOLIDS (mg/l)	TOTAL SUSPENDED SOLIDS REMOVED (%)	VOLATILE SUSPENDED SOLIDS (mg/l)	F/M $\frac{(k_g TBOD_5/day)}{(k_g MLVSS)}$
RAW WASTEWATER	483		123	225		51		288		238	
PRIMARY EFFLUENT DIURNAL SYSTEM	290	40+		123	45+			168	42+	133	
PRIMARY EFFLUENT CONSTANT SYSTEM	315	35+		140	38+			159	45+	114	
FINAL EFFLUENT DIURNAL SYSTEM	64	78* 87+	48	21	83* 91+	3	97^{o} 99^{Δ}	19	89* 93+	13	0.31
FINAL EFFLUENT CONSTANT SYSTEM	40	87* 92+	35	11	92* 95+	2.5	98^{o} 99^{Δ}	9	94* 97+	6	0.33

\+ Based on raw wastewater

* Based on primary effluent

^{o} Based on primary effluent $TBOD_5$ and final effluent $SBOD_5$

$^{\Delta}$ Based on raw wastewater $TBOD_5$ and final effluent $SBOD_5$

TABLE 5. RESULTS OF $FeCl_3$ ADDITION STUDY DURING PHASE III: 2.5/1 PEAK-TO-AVERAGE FLOW (2-16-75 to 3-1-75)

	TOTAL COD (mg/l)	TOTAL COD REMOVED (mg/l)	SOLUBLE COD (mg/l)	TOTAL BOD_5 (mg/l)	TOTAL BOD_5 REMOVED (%)	SOLUBLE BOD_5 (mg/l)	SOLUBLE BOD_5 REMOVED (%)	TOTAL SUSPENDED SOLIDS (mg/l)	TOTAL SUSPENDED SOLIDS REMOVED (%)	VOLATILE SUSPENDED SOLIDS (mg/l)	F/M $\frac{(k_g TBOD_5/day)}{(k_g MLVSS}$
RAW WASTEWATER	233		96	122		54		128		92	
PRIMARY EFFLUENT DIURNAL SYSTEM	233	0+		117	4+			95	26	68	
PRIMARY EFFLUENT CONSTANT SYSTEM	189	19+		101	17+			90	30	66	
FINAL EFFLUENT DIURNAL SYSTEM	95	59* 59+	38	27	77* 78+	10	92^o 92^Δ	44	54* 66+	29	0.41
FINAL EFFLUENT CONSTANT SYSTEM	36	83* 83+	27	10	90* 92+	3.5	97^o 97^Δ	10	89* 92+	7.5	0.27

\+ Based on raw wastewater

* Based on primary effluent

^{o} Based on primary effluent $TBOD_5$ and final effluent $SBOD_5$

$^\Delta$ Based on raw wastewater $TBOD_5$ and final effluent $SBOD_5$

These results indicate that $FeCl_3$ addition had significantly better stabilizing effect on the CFS than the DFS during periods of biological upset. Broad generalization cannot be made from these limited results, however mixed liquor settleability does appear to have a greater influence on final clarifier performance than the range of diurnal flow patterns imposed for this study.

Summary

The treatment plant average performances are summarized in Table 6 for all phases of this study. Data collected during the 3 long term phases of this project indicated that the DFS overall and individual treatment unit performance was unaffected up to and including a 2.5/1 P/A diurnal flow variation when compared to the CFS performance. Results from the intensive 24 hr. sampling studies essentially substantiated these results. The 2.5/1 P/A intensive study did show the CFS final effluent cumulative mass loadings for both TCOD and TSS to be significantly lower than the DFS over the 24 hr. period studied. These results could indicate a possibility that at a P/A diurnal ratio above 2.5/1 significant differences between the CFS and DFS would be observed. However, the extrapolation of long term treatment plant performance data from one day of data is very difficult.

Several factors affected the data and the conclusions that can be made from this report. The major factor was the lack of true flow equalization for the CFS and the resultant diurnally fluctuating organic and solids loadings to the CFS which may have altered the performance of the two systems in favor of the DFS. The biological stability could have also altered the results related to secondary clarifier performance. The settling properties of the activated sludge could have varied between the various phases and even between the CFS and DFS. These variations in sludge settleability would directly impact the maximum diurnal variation that the plant could receive. Adknowledging the impact of sludge settleability, the maximum diurnal flow variation that the treatment plant can receive would be related to the peak overflow rate imposed on the final clarifiers and its duration.

TABLE 6. SUMMARY OF AVERAGE PERFORMANCE VALUES FOR PHASES I, II, AND III

	PHASE	TOTAL COD (mg/l)	TOTAL COD REMOVED (%)	SOLUBLE COD (mg/l)	TOTAL BOD_5 (mg/l)	TOTAL BOD_5 REMOVED	SOLUBLE BOD_5 (mg/l)	SOLUBLE BOD_5 REMOVED	TOTAL SUSPENDED SOLIDS (mg/l)	TOTAL SUSPENDED SOLIDS RE-MOVED (%)	VOLATILE SUSPENDED SOLIDS (mg/l)	F/M $\frac{(k_g TBOD_5/day)}{(k_g\ MLVSS)}$
RAW WASTEWATER	1.5/1	156		55	106		26		98		77	
	2.0/1	354		131	170		67		244		191	
	2.5/1	255		94	137		40		167		114	
	2.0/1 ($FeCl_3$)	403		123	225		51		288		238	
	2.5/1 ($FeCl_3$)	233		96	122		54		128		92	
PRIMARY EFFLUENT DIURNAL SYSTEM	1.5/1	116	26+		84	20+			67	32+	50	
	2.0/1	330	7+		148	13+			200	18+	142	
	2.5/1	220	14+		95	31+			117	30+	76	
	2.0/1 ($FeCl_3$)	290	40+		123	45+			168	42+	133	
	2.5/1 ($FeCl_3$)	233	0+		117	4+			95	26+	68	
PRIMARY EFFLUENT CONSTANT SYSTEM	1.5/1	134	14+		93	12+			84	14+	64	
	2.0/1	342	5+		151	11+			203	21+	152	
	2.5/1	195	24+		86	37+			121	28+	81	
	2.0/1 ($FeCl_3$)	315	35+		140	38+			159	45+	114	
	2.5/1 ($FeCl_3$)	189	19+		101	17+			90	30+	66	
FINAL EFFLUENT DIURNAL SYSTEM	1.5/1	34	71• 78+	23	16	81• 85+	5	94° 95Δ	10	85• 90+	8	0.26
	2.0/1	77	77• 78+	55	19	87• 89+	10	93° 94Δ	22	89• 91+	16	0.51
	2.5/1	60	73• 76+	40	20	79• 85+	6	94° 96Δ	24	80• 86+	16	0.24
	2.0/1 ($FeCl_3$)	64	78• 87+	48	21	83• 91+	3	97° 99Δ	19	89• 93+	13	0.31
	2.5/1 ($FeCl_3$)	95	59• 59•	38	27	77• 78•	10	92° 92Δ	44	54• 66+	29	0.41
FINAL EFFLUENT CONSTANT SYSTEM	1.5/1	31	77• 80+	24	16	83• 85+	5	95° 95Δ	9	89• 91+	7	0.27
	2.0/1	89	74+ 74•	56	24	84• 86+	11	93° 94Δ	30	85• 88+	21	0.39
	2.5/1	50	74• 76+	40	20	78• 86+	3	97° 98Δ	19	84• 87+	13	0.2
	2.0/1 ($FeCl_3$)	40	87• 92+	35	11	92• 95+	2.5	98° 99Δ	9	94• 97+	6	0.33
	2.5/1 ($FeCl_3$)	36	83• 83•	27	10	90• 92+	3.5	97° 97Δ	10	89• 92+	7.5	0.27

+ Based on raw wastewater

• Based on primary effluent

° Based on primary effluent $TBOD_5$ and final effluent $SBOD_5$

Δ Based on raw wastewater $TBOD_5$ and final effluent $SBOD_5$

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-78-034	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Parallel Evaluation of Constant and Diurnal Flow Treatment Systems		5. REPORT DATE March 1978 (Issuing Date) 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Jon H. Bender		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Municipal Environmental Research Laboratory - Cinti., OH. Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		10. PROGRAM ELEMENT NO. 1BC611 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Same as Above		13. TYPE OF REPORT AND PERIOD COVERED In-house 14. SPONSORING AGENCY CODE EPA-600/14

15. SUPPLEMENTARY NOTES
Project Officer: Richard C. Brenner 513/684-7721
EPA-MERL-WRD Cincinnati, Ohio 45268

16. ABSTRACT

Pilot plant studies were performed to evaluate the effects of an imposed diurnal flow pattern on a conventional activated sludge treatment plant. These results were compared against data generated on a similar system treating a constant flow. Effects on primary clarifier and final clarifier performance as well as soluble or organic removals were evaluated. Other effects on general plant stability were noted.

There were essentially no differences between the diurnal and constant flow systems at the 1.5/1, 2.0/1, and 2.5/1 peak-to-average diurnal flows imposed. Intensive sampling over a 24 hour diurnal flow cycle did not alter this basic conclusion. General plant stability was not affected except for some sludge blanket level problems at the 2.5/1 peak-to-average flow phase.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Performance	Primary Clarifier Secondary Clarifier Activated Sludge Treatment Diurnal Flow Variations	13B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 71
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1978-757-140/6809 Region No. 5-11