NATIONAL FIELD INVESTIGATIONS CENTER
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PLANT PERFORMANCE

AT

WILLIAMSBURG WASTE TREATMENT PLANT

HAMPTON ROADS SANITATION DISTRICT

WILLIAMSBURG, VIRGINIA

FEBRUARY 1973

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF ENFORCEMENT AND GENERAL COUNSEL

REPORT

ON

OPERATIONAL CONTROL AND PLANT PERFORMANCE

OF THE

HAMPTON ROADS SANITATION DISTRICT'S

WILLIAMSBURG WASTE TREATMENT PLANT

AT

WILLIAMSBURG, VIRGINIA

JANUARY 1972 - JUNE 1972

by

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WASTE TREATMENT BRANCH

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NATIONAL FIELD INVESTIGATIONS CENTER - CINCINNATI

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ABSTRACT

A technical assistance project was conducted at the Williamsburg Waste Treatment Plant to demonstrate plant start-up and operational control procedures. The project was directed by personnel of the Waste Treatment Branch, National Field Investigations Center - Cincinnati with the support of Hampton Roads Sanitation District personnel.

The Williamsburg Waste Treatment Plant is a complete-mix activated sludge plant equipped with surface-mechanical aeration devices. It is designed to treat 9.6 mgd of combined brewery and domestic waste.

Only brewery waste was treated during the first three months of operation. Organic and hydraulic loads were low during these months since the incoming flow averaged only 2 mgd. Plant loadings reached normal levels in April with the addition of domestic waste from the City of Williamsburg. The incoming flow averaged approximately 5 mgd for the final three months of the project.

Despite many mechanical and operational problems associated with the start-up of the new plant, reductions in BOD_5 averaged 97 percent (529 to 15 mg/l) for the entire project while reductions in suspended solids averaged 92 percent (320 to 22 mg/l). Table 1 gives a summary of project average BOD values, TSS values, and reductions.

TABLE NO. 1

SUMMARY OF PROJECT
AVERAGE BOD & TSS VALUES & REDUCTIONS

HAMPTON ROADS SANITATION DISTRICT, WILLIAMSBURG - WTP

BOD_5

RAW BOD	529 mg/l
P.E. BOD	317 mg/l
F.E. BOD	14.5 mg/l
SECONDARY REDUCTION IN BOD	95.4 %
PLANT REDUCTION IN BOD	97.3 %

SUSPENDED SOLIDS

RAW SUSPENDED SOLIDS	320 mg/l
P.E. SUSPENDED SOLIDS	125 mg/l
F.E. SUSPENDED SOLIDS	22.2 mg/l
SECONDARY REDUCTION IN TSS	81.6 %
PLANT REDUCTION IN TSS	92.0 %

Some of the problems that caused the effluent quality to exceed desired limits at times were:

1. Acid wastes that entered the plant during the first month of operation.
2. Sludge bulking during April.
3. Unwarranted recycle of digested sludge from the sludge disposal system to the activated sludge process.

With the elimination of these and other problems, Hampton Roads Sanitation District personnel should be able to produce a consistently high quality final effluent at the Williamsburg Waste Treatment Plant.

INTRODUCTION

This report describes the results achieved during the federal technical assistance project conducted at the Williamsburg Waste Treatment Plant. Personnel of the Waste Treatment Branch, National Field Investigations Center - Cincinnati, assisted the Hampton Roads Sanitation District in the start-up and operation of their new Williamsburg, Virginia plant. The request for assistance originated with the Hampton Roads Sanitation District and the Virginia State Water Control Board and was approved by the Office of Enforcement and General Counsel, Environmental Protection Agency.

The cooperative support of the plant management and operating personnel of the Hampton Roads Sanitation District and the assistance provided by the State Water Control Board is gratefully acknowledged.

TREATMENT FACILITIES

The Williamsburg, Virginia, Waste Treatment Plant is a complete - mix activated sludge (CMAS) plant designed to treat combined brewery and domestic waste.

FLOW PATTERN

Brewery waste is pumped from the Anheuser-Busch plant to the new Williamsburg Waste Treatment Plant where it is combined with raw domestic waste pumped from the old Williamsburg Municipal Treatment Plant site. This combined plant influent then flows through a screening chamber and a grit removal structure. After metering through a Parshall flume, the flow is divided between two primary clarifiers. (See Figure 1 for plant layout.)

Effluent from the primary clarifiers flows by gravity to a splitter box where it is diverted to either one or two of the four existing aeration basins and mixed with return sludge. Although only two basins were used in the CMAS System, all four basins have fixed surface mechanical aerators.

The effluent from the aeration tanks flows by gravity to the two peripherally fed circular final clarifiers for solids separation. The clarifiers are equipped with combination suction-scraper type sludge removal devices.

The clarified effluent is chlorinated and discharged to the James River.

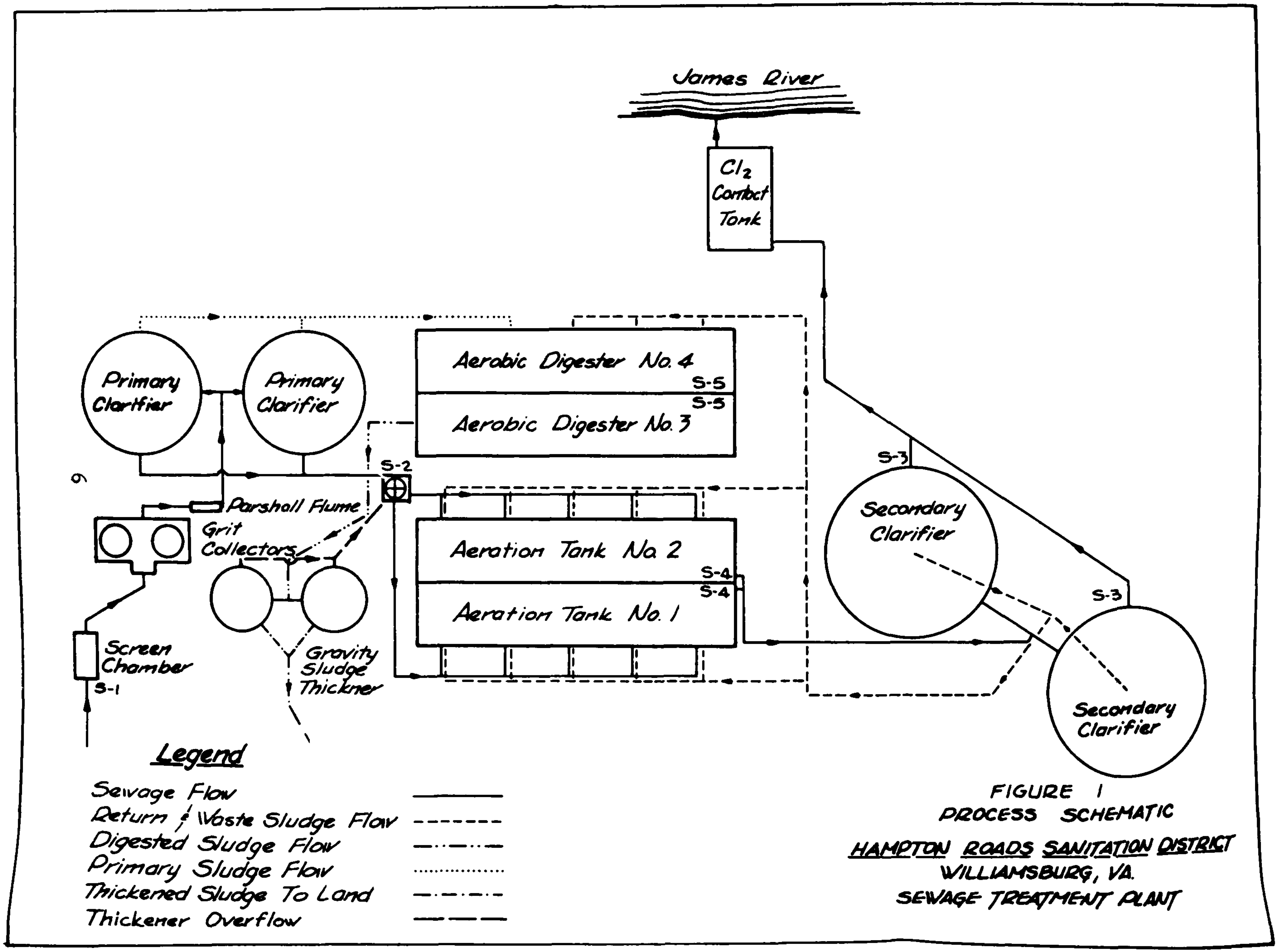


FIGURE 1
PROCESS SCHEMATIC
HAMPTON ROADS SANITATION DISTRICT
WILLIAMSBURG, VA.
SEWAGE TREATMENT PLANT

The settled mixed liquor which is removed from the secondary clarifiers is pumped to the active aeration tanks; excess sludge is wasted to the other two aeration tanks, No. 3 and No. 4, which are operated as aerobic sludge digesters.

The aerobically digested sludge is pumped to gravity thickeners where it is concentrated prior to disposal at a nearby spray irrigation site. Overflow from the thickener is returned to the splitter box ahead of the aeration tanks.

DESIGN CRITERIA

The consulting engineers' design figures (Table 2), state that the total plant capacity utilizing four aeration tanks in the CMAS System, is 9.6 mgd of combined brewery and domestic wastes at 667 mg/l or 53,376 pounds per day of 5-day BOD.

The sizes and capacities of the secondary treatment facilities are listed in Table 3. It should be noted that although four aeration tanks are listed, areas and volumes are the totals for only the two tanks providing mixed liquor aeration since the other two tanks were used as aerobic digestion basins for the duration of the project.

TABLE NO. 2

CONSULTING ENGINEERS' DESIGN CRITERIA

AVERAGE DAILY FLOW		
Domestic Wastewater	4.6	
Brewery Wastewater	5.0	
TOTAL ------	9.6	mgd
BOD LOAD (mg/l)		
Domestic	200	mg/l
Brewery	1000	mg/l
Combined	667	mg/l
BOD LOAD (#/day)		
Domestic	6672	
Brewery	46704	
TOTAL -----	53376	#/day
SUSPENDED SOLIDS LOAD (mg/l)		
Domestic	240	mg/l
Brewery	450	mg/l
Combined	362	mg/l
SUSPENDED SOLIDS LOAD (#/day)		
Domestic	8006	
Brewery	21017	
TOTAL -----	29023	lbs./day

TABLE NO. 3

TREATMENT FACILITIES

HAMPTON ROADS SANITATION DISTRICT, WILLIAMSBURG - STP

SCREEN CHAMBER

Type........................ Manually and Mechanically Cleaned

Number of Screen Channels................................. 2

Number of Bypass Channels................................. 1

Bar Rack - Bar Spacing.................................... 3 in.

Mechanically Cleaned Bar Screen - Bar Spacing............. 1

GRIT COLLECTOR

Number of Units... 2

Type...detritor

Diameter.. 28 ft.

PRIMARY CLARIFIERS

Number.. 2

Type................................Circular, peripheral feed

Dimensions(each)........................ 95' dia. x 10' s.w.d.

CSA - Total Clarifier Surface Area - Sq. Ft. 14,176

CVF - Total Clarifier Volume - Cu. Ft.............. 141,764

CVG - Total Clarifier Volume - Gal. 1,060,397

Mechanism Type...................................... Scraper

TABLE NO. 3
(contd)
TREATMENT FACILITIES

HAMPTON ROADS SANITATION DISTRICT, WILLIAMSBURG - STP

PRIMARY SLUDGE PUMPS

Number	2
Type	Centrifugal
Capacity (ea.)	100 GPM
Total Head	19.5 ft.
Drive	3 H.P. Constant Speed

PLANT DRAIN PUMPS

Number	1	1
Type	Centrifugal	Centrifugal
Capacity	1,200 GPM	200 GPM
Total Head	35 ft.	29 ft.
Drive	Constant Speed	Constant Speed

AERATION TANKS (for CMAS)

Number	2
Type	Concrete
Dimensions (each)	250' L x 50' W x 14' Deep
ASA - Total Aeration Tank Surface Area - Sq. Ft.	25,000
AVF - Total Aeration Tank Volume - Cu.Ft.	350,000
AVG - Total Aeration Tank Volume - Gal.	2,617,999

TABLE NO. 3
(contd)
TREATMENT FACILITIES

HAMPTON ROADS SANITATION DISTRICT, WILLIAMSBURG - STP

AERATION EQUIPMENT

Number of Aerators per Tank....................	5
Type...........................	2-speed Surface-Mechanical
Horsepower.................	High - 50 H.P., Low - 12.5 H.P.

SECONDARY CLARIFIERS

Number..	2
Type...........................	Circular, peripheral feed
Dimensions(each)...............	130' dia. x 10' s.w.d.
CSA - Total Clarifier Surface Area - Sq. Ft.	26,546
CVF - Total Clarifier Volume - Cu.Ft.	265,464
CVG - Total Clarifier Volume - Gal.	1,985,673
Mechanism Type.........................	Suction-Scraper

SLUDGE RECIRCULATION PUMPS

Number..................	2
Type................................	Vertical-Centrifugal
Capacity (ea.)........................	7,000 GPM
Total Head...........................	10.5 ft.
ive...............................	50 H.P. Variable Speed

TABLE NO. 3
(contd)
TREATMENT FACILITIES

HAMPTON ROADS SANITATION DISTRICT, WILLIAMSBURG - STP

CHLORINE CONTACT TANK

Number..	1
Number of Passes..............................	4
Detention Time @ 9.6 mgd.........................	45 min.

AEROBIC DIGESTER TRANSFER PUMP - No. 3 TANK TO THICKENERS

Number..	2
Type.............................	Self-priming Centrifugal
Capacity (ea.)....................	700 GPM
Total Head.......................	29 ft.
Drive............................	10 H.P. - Constant Speed

TABLE NO. 3
(contd)
TREATMENT FACILITIES

HAMPTON ROADS SANITATION DISTRICT, WILLIAMSBURG - STP

GRAVITY SLUDGE THICKENERS

Number..	2
Diameter......................................	50 ft.
Side Water Depth..............................	10 ft.
Total Thickener Tank Surface Area - Sq. Ft.	3,927
Total Thickener Tank Volume - Cu.Ft.............	39,270
Total Thickener Tank Volume - Gals..............	293,740

THICKENED SLUDGE PUMP (pumps thickened sludge to irrigation site)

Number..	1
Type..	Reciprocating
Capacity......................................	200 GPM
Total Head....................................	78 ft.
Drive.............................	10 H.P. Constant Speed

SAMPLE COLLECTION AND ANALYSIS

SAMPLE COLLECTION

PLANT INFLUENT - The plant influent samples were collected every two hours at the screening chamber and composited into a 24-hour sample for analysis. The sample point is shown as S-1 on Figure 1.

The sample was not an accurate representation of the incoming waste, however, since the plant recycle line discharged in the vicinity of the sampling point.

AERATOR INFLUENT - The sample was collected every four hours at the splitter box located ahead of the aeration basins. The sample point is shown as S-2 on Figure 1.

Although this sample is not representative of the primary effluent since it frequently contained overflow from the gravity thickeners, it is a true representation of the waste load to the activated sludge system.

MIXED LIQUOR - Mixed liquor samples were collected every four hours from each aeration tank for the settleometer and centrifuge test (See Operational Control Methods Section) and determination of mixed liquor solids (only run on noon sample). The samples were collected from the discharge box at the end of the aeration tank, shown as S-4 on Figure 1.

FINAL EFFLUENT - The unchlorinated final effluent sample was gathered every four hours at the manhole adjacent to the final clarifiers. This sample was composited into a 24-hour sample for effluent quality analysis. The sample point is shown as S-3 on Figure 1. Another final effluent sample, this one chlorinated for discharge to the James River, was collected hourly and checked for chlorine residual.

AEROBIC DIGESTER MIXED LIQUOR - At noon each day, samples were gathered from the discharge box of the aerobic digesters for total and volatile suspended solids analysis. The sample point is shown as S-5 on Figure 1.

ANALYSIS

Analysis of all the above samples was done by HRSD personnel in the Williamsburg WTP laboratory in accordance with procedures detailed in Standard Methods for the Examination of Water and Wastewater, Thirteenth Edition.

All reported plant performance data, with the exception of those analyses listed below, are based on the data supplied to NFIC-C personnel by the HRSD personnel. All reported BOD values are based on a 5-day incubation period at 20° C.

An aliquot of the composite samples (plant influent, aerator influent, and final effluent) was filtered through 0.45 μ membrane filters daily (by NFIC-C personnel) and shipped along with unfiltered aliquot of the composite samples to the NFIC-C laboratory for Nitrogen, Phosphorus and TOC analysis. Both the filtrate and the unfiltered composite sample were preserved for shipment with 1 ml/liter of H_2SO_4.

WASTE CHARACTERISTICS

Significant characteristics of the plant influent and aeration tank influent waste streams are described below. A complete tabulation of monthly average BOD, suspended solids, and flow values are shown in Table No. 4. Probability plots of BOD_5 and suspended solids concentrations are located in Appendix A.

FLOW

Flow during the start-up month of January varied from 0.9 mgd to 2.5 mgd and averaged 1.74 mgd. Increased flow from the brewery and the addition of the City of Williamsburg waste in early April boosted the raw flow average to approximately 5.5 mgd for the last two months of the project.

pH

The 24-hour composite raw pH values ranged from 3.0 to 11.4, during the entire project, and averaged 6.3. The composite pH values for the aeration tank influent varied from 3.1 to 9.6 and averaged 6.2 for the project. At times very low pH (1.5 to 2.5) waste streams entered the plant but most were of short

TABLE NO. 4

SUMMARY OF GENERAL OPERATING CHARACTERISTICS

	JAN	FEB	MAR	APR	MAY	JUNE
RAW BOD 5 (MG/L)	512.00	590.00	547.00	556.00	471.00	514.00
PRIMARY EFFLUENT BOD 5 (MG/L)	258.00	296.00	346.00	330.00	329.00	342.00
FINAL EFFLUENT BOD 5 (MG/L)	12.00	10.00	12.00	24.00	17.00	11.00
RAW SUSPENDED SOLIDS (MG/L)	566.00	369.00	276.00	259.00	199.00	276.00
PRIMARY EFFLUENT SUSPENDED SOLIDS	117.00	142.00	100.00	119.00	153.00	114.00
FINAL EFFLUENT SUSPENDED SOLIDS	15.00	17.00	17.00	58.00	14.00	10.00
SUSP. SOLIDS DISCHARGED (LBS/DAY)	228.93	320.42	267.96	2147.71	704.06	430.34
SECONDARY S. S. REMOVAL PERCENT	87.18	88.03	83.00	51.26	90.85	91.23
PLANT S. S. REMOVAL PERCENT	97.35	95.39	93.84	77.61	92.96	96.38
BOD 5 DISCHARGED (LBS/DAY)	183.15	188.48	189.15	888.71	854.93	473.38
SECONDARY BOD 5 REMOVAL PERCENT	95.35	96.62	96.53	92.73	94.83	96.78
PLANT BOD 5 REMOVAL PERCENT	97.66	98.31	97.81	95.68	96.39	97.86
INFLUENT FLOW (MGD)	1.83	2.26	1.89	4.44	6.03	5.16
INFLUENT BOD 5 LOAD (MG/L)	512.00	590.00	547.00	556.00	471.00	514.00
INFLUENT BOD 5 LOAD (LBS/DAY)	7814.24	11120.55	8622.14	20588.45	23686.68	22119.68
TFL TOTAL FLOW THRU AER TANKS (MGD)	4.21	4.62	4.41	9.69	13.71	13.53
AER TANK BOD 5 LOAD (LBS/DAY)	3937.65	5579.12	5453.86	12219.76	16545.47	14717.76
MLTSS (MG/L)	1800.00	2311.00	2221.00	1316.00	2289.00	2051.00
MLVSS (MG/L)	1578.00	2207.00	2088.00	1231.00	2127.00	1918.00
MLVSS (LBS. IN AERATION TANKS)	17227.10	24093.93	22794.80	26877.78	46441.14	41877.79
BOD LDNG (LBS/1000 CUFT AER VOL)	22.50	31.88	31.16	34.91	47.27	42.05
F / M (LBS BOD/LBS MLVSS)	0.229	0.232	0.239	0.455	0.356	0.351
RETURN SLUDGE FLOW (MGD)	2.380	2.360	2.520	5.250	7.680	8.370
RETURN SLUDGE FLOW PERCENT	130.05	104.42	133.33	118.24	127.36	162.21
AER TK DET TIME AT FLOW	17.17	13.90	16.62	14.15	10.42	12.18
AER TK DET TIME AT FLOW PLUS RTRN	7.46	6.80	7.12	6.48	4.58	4.64
FINAL CLAR. DET. TIME	5.66	5.16	5.40	4.92	3.48	3.52
OVERFLOW RATE (GAL/SQFT/DAY)	137.87	170.27	142.39	167.25	227.15	194.38
ADT X MLVSS	27089.82	30679.23	34707.17	17420.30	22163.12	23354.98
ADT X MLVSS / MG/L BOD IN	105.00	103.65	100.31	52.79	67.37	68.29
HP/1000 SQFT ASA	18.80	12.48	13.04	12.96	20.00	20.00
HP HR/MGD	3081.97	1656.64	2069.84	1751.36	1990.04	2325.58
HP HR/LB BOD 5	1.43	0.67	0.72	0.64	0.72	0.82
HP HR/LB MLVSS	0.33	0.16	0.17	0.28	0.26	0.28

enough duration that they were buffered during treatment. One, however, towards the end of January 1972 lasted for several hours and destroyed the activated sludge biota necessitating reseeding the aeration tanks.

BOD

During January, both the brewery and the plant were in start-up mode, therefore, the average plant influent BOD of 512 mg/l for this period does not necessarily represent full scale brewery operation. The average BOD of the aerator influent for the same period was 258 mg/l. The average plant influent BOD for the first three months of operation, when only brewery waste was treated, was 550 mg/l. The aerator influent BOD for the same period was 302 mg/l.

The City of Williamsburg force main was completed in late March and the plant started treating a combined brewery and domestic waste on April 5, 1972. For the final three months of the project (April, May, and June) when the combined brewery and domestic waste was treated, the average raw BOD_5 was 514 mg/l while the aeration basin influent for the same period averaged 334 mg/l.

COD

A complete analysis of the waste characteristics cannot be made because COD's were not run consistently after February 23 and not at all after April 8, 1972. Available data indicates, however, average plant influent COD concentrations during the period when only the brewery was tributary of 1,575 mg/l in the plant influent and 1,120 mg/l in the aeration basin influent.

SUSPENDED SOLIDS

Total suspended solids for the month of January averaged 566 mg/l. Aeration basin influent TSS for the same period averaged 117 mg/l. Towards the end of the assistance project, when a combined domestic and brewery waste was treated, TSS averaged 250 mg/l in the raw influent and 130 mg/l in the aeration basin influent.

NUTRIENTS

The BOD:Nitrogen:Phosphorus ratio of the aeration basin influent averaged 100:10.2:1.8 for the project. Nitrogen and Phosphorus were added to the screen chamber to provide nutrients based on the recommendations of the consulting engineers.

OPERATIONAL CONTROL METHODS

The operational control procedures described below were demonstrated to HRSD Williamsburg personnel during the NFIC-C technical assistance project.

The series of operational control tests initiated at the Williamsburg plant by NFIC-C personnel enabled plant personnel to determine sludge quality, process status, and effluent quality during each 24-hour cycle. The results of these tests were then used to calculate process demands and operational control requirements and tó dictate operational control adjustments. The tests that were used for control are as follows:

1. <u>Settleometer</u>

   A settling test in which the mixed liquor sludge interface level (settled sludge volume - SSV) was recorded (in cc/l.) at 5-minute intervals for the first 30 minutes and 10-minute intervals for the next 30 minutes. This test indicated sludge settling in the final clarifiers.

2. <u>Centrifuge Test</u>

   A 15-minute centrifuge spin of the aeration tank mixed liquor and return sludge samples permitted a quick determination of the suspended solids concentrations. Centrifuge test results were also used to ds distribution ratios, check flow measurements, and other process relationships.

3. Depth of Blanket

Depth of clarifier sludge blanket interface below the surface of the final clarifier was used in determinating the amount of solids in the final clarifier, solids balance, and wasting requirements.

4. D.O. Test

The dissolved oxygen concentration of the mixed liquor was measured to determine that aeration requirements were met.

5. Turbidity Test

Turbidity of the final effluent, determined by the use of a standard photoelectric type turbidimeter, was used to rapidly determine the effect of process changes on effluent quality without waiting for the results of conventional monitoring-type tests.

6. Physical Observations of Plant Conditions

As samples for testing were collected, physical observations of process features such as, sludge color, amount of foam on the aeration tank surface, presence of "klumping" or straggler floc in the final clarifier, etc. were noted by the operators.

7. Flow Meter Readings

Flow meter readings were also recorded as part of the testing procedure for use in calculating process demands.

The above full series of tests were run three times per day; at 4:00 AM, 12:00 Noon, and 8:00 PM. In addition, partial tests in which the depth of blanket, centrifuge test results, and the first 20 minutes of the settleometer test were recorded, were run at midnight, 8:00 AM, 4:00 PM.

The results of the settleometer and centrifuge tests were used to determine settled sludge concentration (SSC). The SSC curve, which defines sludge quality, is calculated from the settled sludge volume (SSV) and the concentration (in percent) of the mixed liquor leaving the aeration tank (ATC). This is expressed as:

$$SSC = \frac{1000\ ATC}{SSV}$$

Illustrative settling curves (SSV) and concentration curves (SSC) are shown in Appendix "C-7". The curve labeled "Fast" illustrates a sludge characterized by rapid settling and compaction, the curve labeled "Normal" illustrates a normal settling and compacting sludge, while the curve labeled "Slow" represents a slowly settling sludge with almost no compaction.

Trend Chart Plots of the process parameters (SSC, SSV, effluent turbidity) were plotted on two-cycle, semi-log paper at the conclusion of each full test series described above. An illustration of the SSV, SSC and effluent turbidity trend charts for the period from January 24, 1972 to February 21, 1972 appears in Appendix "C-1,2&3". By referring to these charts the operator could see the relative response of the process factors to the three main control adjustments, i.e., return sludge flow, waste sludge flow, and aeration intensity.

At the end of each day the individual test data were averaged for the day and the parameters listed in Table 5 were determined. Three of the parameters, XSU, SDT and BLT were also plotted on semi-logarithmic paper for use as trend charts to determine excess sludge wasting policy. A summary of the monthly averages of such parameters may be found in Table 5 and a list of the symbols used in this table may be found in Appendix B.

Return sludge flows were determined on the basis of process demands, i.e., after each full test series the operator would insert the current value of the ATC, RSC, SSC_t and CSF into the clarifier sludge flow demand formula -

$$CSD = CSF \times \frac{RSC - ATC}{SSC_t - ATC}$$

where SSC_t = Settled Sludge Concentration at some sludge settling time (SST) to calculate new clarifier sludge demand (CSD). It should be noted that when the excess waste sludge flow (XSF) was zero, or XSF was minimal compared to the return sludge flow (RSF), RSC and RSD would be substituted for CSF and CSD to yield:

$$RSD = RSF \times \frac{RSC - ATC}{SSC_t - ATC}$$

For the most part, excess sludge wasting rates were adjusted to maintain an approximate sludge age of 5 days. At times, however,

TABLE NO. 5

SUMMARY OF PROCESS PARAMETERS

DATE TIME	JAN 1972 AVG	FEB 1972 AVG	MAR 1972 AVG	APR 1972 AVG	MAY 1972 AVG	JUNE 1972 AVG
ATC	5.75	8.31	6.98	3.05	7.08	5.81
RSC	10.02	15.93	11.93	5.51	12.45	9.26
SLR	1.743	1.917	1.709	1.807	1.758	1.594
RSP	1.347	1.091	1.410	1.240	1.318	1.684
METERED AFI	1.760	2.220	1.800	4.180	6.090	5.140
RSF	2.380	2.360	2.520	5.250	7.680	8.370
RFP	1.352	1.063	1.400	1.256	1.261	1.628
RFP/RSP	1.004	0.975	0.993	1.013	0.956	0.967
XSF	0.090	0.100	0.146	0.249	0.275	0.315
CSF	2.470	2.460	2.666	5.499	7.955	8.685
CALC. AFI	1.834	2.256	1.891	4.435	6.034	5.157
TFL	4.214	4.616	4.411	9.685	13.714	13.527
ADT(AFI)	17.13	13.93	16.62	14.17	10.41	12.18
ADT(TFL)	7.45	6.81	7.12	6.49	4.58	4.64
CDT(TFL)	5.65	5.16	5.40	4.92	3.48	3.52
OFR(AFI)	138.19	169.95	142.44	167.08	227.29	194.27
SLU/DAY/CSA	18.26	28.90	23.19	11.13	36.57	29.61
ATC*ADT	42.86	56.56	49.72	19.79	32.44	26.99
DOB	9.46	9.41	8.96	4.77	8.92	8.69
BLT	0.0540	0.0590	0.1040	0.5230	0.1080	0.1310
ASU	0.0753	0.1088	0.0914	0.0798	0.1854	0.1521
CSU	0.0042	0.0071	0.0098	0.0444	0.0209	0.0196
TSU	0.0795	0.1159	0.1011	0.1243	0.2063	0.1717
ASU/CSU	17.8046	15.3217	9.3588	1.7965	8.8511	7.7604
RSU/DAY	0.2385	0.3759	0.3006	0.2893	0.9562	0.7751
RSU/GAL(AFI)	0.1300	0.1667	0.1590	0.0652	0.1585	0.1503
RSU/GAL*ADT(TFL)	0.9692	1.1344	1.1326	0.4231	0.7261	0.6981
SDT	0.4099	0.4348	0.7367	3.5207	0.5075	0.5849
ADT/SDT	18.1849	15.6537	9.6686	1.8426	9.0286	7.9411
SAH	22.749	22.559	21.750	15.557	21.607	21.316
SAP	0.948	0.940	0.906	0.648	0.900	0.888
XSU/DAY	0.0090	0.0159	0.0174	0.0137	0.0342	0.0292
AGE	8.82	7.27	5.81	9.06	6.03	5.89
AAG	8.36	6.84	5.26	5.87	5.42	5.23
SCR	1.751	1.086	0.826	0.966	1.003	0.855
LT & FC	1 - 1	1 - 1	1 - 1	2 - 2	2 - 2	2 - 2

it was necessary to adjust wasting to develop a different quality sludge; thus in April, sludge wasting was reduced in an attempt to develop an older, higher density, better settling sludge.

PLANT PERFORMANCE

Monthly average overall BOD reductions exceeded 95% throughout the entire project despite numerous mechanical and operational problems. Complete performance data for the period from January 4, 1972 to June 25, 1972 have been plotted on arithmetic probability paper on a month-by-month basis and can be found on Figures A-1 and A-2 in Appendix A.

For purposes of discussion, however, the project data can be broken up into four logical segments which corresponded closely to the individual months. The four segments of the project and the associated months are as follows:

1. Start-up and acid waste problems----- January (only brewery waste - no domestic sewage)
2. Brewery waste alone--------- February & March
3. Combined brewery and domestic wastes--- April
4. Stable Operation Period----------- May & June

START-UP AND ACID WASTE PROBLEMS

Since construction of the domestic sewage force main had not been completed, only brewery wastes (from the recently completed 2-million barrel per year Anheuser-Busch Inc. Plant) entered the treatment plant during start-up (January 1972), and for two months thereafter. Only one of the two aeration tanks and one of the two final clarifiers were used to treat the relatively low volume of incoming waste.

Immediately prior to start-up, 65,000 gallons of seed sludge from the HRSD James River Waste Treatment Plant were added to Aeration Tank No. 1 that had previously been filled with city water. Only three of the five mechanical surface aerators, set at low speed, were operated, and the return sludge pumps were set to discharge about 50% of the incoming waste flow.

On Day 1 (Tuesday, January 4, 1972) of NFIC-C assistance, mixed liquor total suspended solids (MLTSS) concentrations were in the 500 to 600 mg/l range and the settleometer test revealed a rapid settling sludge (SSV_5 = 100, SSV_{60}= 70). The Return Sludge Flow (RSF) was immediately increased to more than 100% of the incoming flow. On Day 2, the two idle aerators were turned on, with all five units remaining on the low speed setting. On Day 3, all five aerators were switched to the high setting, thereby increasing the oxygen transfer capacity approximately fourfold. Sludge settling characteristics and final effluent turbidity responded favorably to these operational changes as evidenced by the first week reduction in final effluent turbidity from 16 to 6 JTU.

Effluent quality did not improve during the first few days of the second week. In fact, the turbidity increased slightly from 6 to 8 JTU. To build up the low mixed solids concentration, primary sludge was being pumped to the aeration tanks. This practice most probably impeded further improvement, especially when the volume of sludge ncreased with the increase in incoming flow. On Thursday this practice was discontinued and all primary sludge was sent to the aerobic digesters. Final effluent quality then improved dramatically and the turbidity was reduced to 2.2 JTU by the end of the week.

During the third week a plant upset occurred when the return sludge pumps and the final clarifier mechanism failed. The aerators were also inadvertently switched from high to low, and control became difficult due to the erratic operation of the plant flow meters.

On Saturday of the third week, the pH of the incoming waste suddenly dropped to 1.6 as a result of a slug of acid waste accidentally released from the brewery during a weekend shutdown for maintenance and cleaning. This destroyed all biological life in the secondary system and caused the final effluent turbidity to jump from 4 to 60 JTU.

At the start of the fourth week (Monday, January 24th) the idle Aeration Tank No. 2 was seeded with sludge from the No. 4 Aerobic Digester and placed in service. No. 1 Aeration Tank containing the acid mixed liquor was taken out of service. All primary effluent and return sludge was then rerouted to this aeration tank. Process characteristics started to improve immediately thereafter, and by Saturday the final effluent turbidity had been reduced from 60 to 3.5 JTU. On Saturday the process was again upset by another slug of acid waste. Fortunately this acid slug was less destructive than the previous and it was not necessary to reseed and switch aeration tanks again. Effluent quality was, however, degraded almost as much as during the first slug, and by Sunday the final effluent turbidity again increased to 60 JTU.

Even with these start-up problems in January, final effluent BOD ranged from 1.0 to 54 mg/l averaging 12 mg/l for the month with an overall plant reduction of 97.7%.* Suspended solids in the final effluent ranged from 1.0 to 52 mg/l averaging 15 mg/l, for a plant reduction of 97.4%. A summary of plant performance figures may be found in Table 3 (Page 9).

As shown by the following, the average plant loading was considerably below the theoretical treatment capability during start-up:

lbs. BOD_5/1,000 cu. ft. Aeration Tank Volume....	22.5	
lbs. BOD_5/lbs. MLVSS	0.23	
Aeration Tank Detention Time @ Flow alone.......	17.2	hrs.
Aeration Tank Detention Time @ Flow & Return....	7.5	hrs.
Final Clarifier Detention Time..................	5.7	hrs.
Final Clarifier Surface Overflow Rate...........	138	gals./d/sq.ft.

Despite plant upsets during this month, the average mixed liquor sludge settling and concentration characteristics were excellent and the sludge blanket remained deep down in the final clarifier.

A complete listing of general operating characteristics on a month-by-month basis is shown in Table 4 (Page 17), and a summary of plant loadings and process responses for the four major project segments is shown in Table 6.

$$\text{* Overall plant reduction} = \frac{\text{Raw Concentration - F.E. Concentration}}{\text{Raw Concentration}}$$

TABLE NO. 6

SUMMARY OF PLANT LOADINGS AND PROCESS RESPONSES

HAMPTON ROADS SANITATION DISTRICT - WILLIAMSBURG STP

Line No.		Jan. Start-up	Feb. & Mar. Brewery Waste	April Bulking	May & June Stable Operation	Last Week of Project 6/19 to 6/25	Project Average
	Column Number	1	2	3	4	5	6
	UNITS IN SERVICE						
1	No. of Aeration Tanks	1	1	2	2	2	2
2	No. of Final Clarifiers	1	1	2	2	2	2
	AERATION INTENSITY						
3	Average H.P.	235	160	162	500	500	282
4	H.P./1000 sq. ft. ASA	18.80	12.77	12.96	20.0	20.0	16.10
5	H.P. Hrs./MGD AFI	3082	1870	1751	2139	2139	2131
6	H.P. Hrs./lb. Influent BOD	1.43	0.70	0.64	0.76	0.76	0.83
7	H.P. Hrs./ASU	0.075	0.038	0.097	0.141	0.199	0.084
8	H.P. Hrs./lb. MLVSS	0.33	0.17	0.29	0.27	0.27	0.25
9	Resultant Aeration Tank D.O. mg/l	7.3	5.8	3.2	4.1	4.2	5.1
	PLANT LOADINGS (to Act. Sl. System)						
	Metered Flows in MGD						
10	AFI - Aeration Tank Influent Flow	1.83	2.07	4.44	5.64	4.84	3.59
11	RSF - Return Sludge Flow	2.38	2.44	5.25	7.99	8.47	4.70
12	TFL - Total Flow	4.21	4.51	9.69	13.63	13.31	8.29
13	XSF - Excess Sludge Flow to Waste	0.090	0.124	0.249	0.293	0.352	0.194
	Unit Flow Rates in Hrs.						
14	ADT - Aeration Detention Time at AFI	17.13	15.32	14.17	11.20	13.35	14.09
15	ADT - Aeration Detention Time at TFL	7.45	6.97	6.49	4.61	4.75	6.20
16	CDT - Clarifier Detention Time at TFL	5.65	5.28	4.92	3.50	3.61	4.71
17	OFR - Clarifier Overflow Rate at AFI	138	156	167	213	182	173
	BOD_5 - Aeration Basin Influent						
18	Concentration (mg/l)	258	322	330	329	361	317
19	Mass (lbs/day)	3938	5514	12220	15736	14863	9706
20	Aerator Loading (lbs. BOD/1000 cu. ft.)	22.5	31.5	34.9	45.0	42.5	35.0
	PROCESS LOADINGS (As Functions of Operational Control)						
21	ATC X ADT/mg/l BOD	0.166	0.165	0.060	0.091	0.06	0.121
22	Lbs RSTSS/lb. BOD	15.12	14.80	7.84	14.95	13.66	13.65
23	Organic Loading F/M (lbs. BOD_5/ lb. MLVSS)	0.23	0.24	0.46	0.35	0.37	0.31
24	RSP - Return Sludge Percentage (% of AFI)	130	118	118	142	175	131
25	SCR - Sludge Concentration Ratio	1.75	0.95	0.97	0.94	0.83	1.08
26	AGE - Sludge Age (days)	8.82	6.52	9.06	5.97	6.32	7.15
27	AAG - Aerator Age (days)	8.36	6.02	5.87	5.34	5.23	6.15

TABLE NO. 6
(contd)

SUMMARY OF PLANT LOADINGS AND PROCESS RESPONSES

HAMPTON ROADS SANITATION DISTRICT - WILLIAMSBURG STP

Line No.		Jan. Start-up	Feb. & Mar. Brewery Waste	April Bulking	May & June Stable Operation	Last Week of Project 6/19 to 6/25	Project Average
	Column Number	1	2	3	4	5	6
	PROCESS RESPONSES						
	Sludge Settling						
28	SSV_5 (cc/l)	760	938	957	941	974	914
29	SSV_{30} (cc/l)	420	746	794	778	872	712
30	SSV_{60} (cc/l)	363	615	650	660	774	595
31	DOB (ft.)	9.46	9.18	4.77	8.80	7.87	8.35
32	BLT (% of CWD)	0.054	0.082	0.523	0.118	0.213	0.165
	Sludge Solids (In Terms of Sludge Units)						
33	ATC - Aeration Tank Conc. (%)	5.75	7.62	3.05	6.51	4.60	6.18
34	WCR - Weight to Centrifuge Ratio (MLTSS/ATC)	313	297	431	335	441	323
35	RSC - Return Sludge Conc. (%)	10.02	13.86	5.51	11.03	7.12	10.89
36	SSC_{60} - Settled Sludge Conc. at t = 60 min. (%)	18.37	13.43	5.32	10.45	5.86	11.87
37	SCR - Sludge Conc. Ratio (SSC_{60}/RSC)	1.75	0.95	0.97	0.94	0.83	1.08
38	SLR - Sludge Ratio (RSC/ATC)	1.74	1.81	1.81	1.68	1.55	1.76
39	SDR - Sludge Distribution Ratio (ASU/CSU)	17.80	12.24	1.80	8.36	7.12	10.09
40	SDT - Sludge Detention Time (hrs.)	0.41	0.59	3.52	0.54	0.95	1.05
41	STR - Sludge Detention Time Ratio (ADT/SDT)	18.18	12.56	1.84	8.54	7.31	10.33
42	SCY - Sludge Cycles (No. per Day)	3.05	3.17	2.40	4.66	4.21	3.31
43	SAH - Sludge Aeration Hours (Hrs./day)	22.75	22.14	15.56	21.48	20.09	20.89
44	ASU to Final Clarifier (Million SLU/day)	0.105	0.158	0.135	0.367	0.223	0.222
45	Clar. Floor Loading (SLU/day/sq. ft.)	7.91	11.90	5.09	13.82	8.40	8.36
	Sludge Solids (In Terms of Weight)						
46	MLTSS (mg/l)	1800	2265	1316	2183	2030	2000
47	MLVSS (mg/l)	1578	2146	1231	2034	1908	1861
48	% Volatile	87.7	94.7	93.5	93.2	94.0	93.1
49	RSTSS (mg/l)	3000	4011	2187	3531	2874	3379
50	RSVSS (mg/l)	2740	3724	2108	3246	2643	3133
51	% Vol.	91.3	92.8	96.4	91.9	92.0	92.8
52	SVI	233	329	603	356	430	356
53	SDI	0.43	0.30	0.17	0.28	0.23	0.28
54	ML Solids to Final Clarifiers (lbs/day)	27472	39103	48731	102683	81942	59881
55	Clar. Floor Loading (lbs/D/sq.ft.)	2.07	2.95	1.84	3.87	3.09	2.26

TABLE NO. 6
(contd)

SUMMARY OF PLANT LOADINGS AND PROCESS RESPONSES

HAMPTON ROADS SANITATION DISTRICT - WILLIAMSBURG STP

Line No.	Column Number	Jan. Start-up	Feb. & Mar. Brewery Waste	April Bulking	May & June Stable Oper.	Last Week of Project 6/19 to 6/25	Project Average
	PROCESS RESPONSES						
	Effluent Quality						
56	F. E. Turbidity (JTU)	9.79	6.76	21.9	5.01	2.47	9.29
57	F. E. BOD_5 (mg/l)	12.0	11.0	24.0	14.3	8.3	14.5
58	F. E. BOD_5 (lbs. discharged)	183	189	889	685	347	468
59	F. E. TSS (mg/l)	15.0	17.0	58.0	12.2	8.4	22.2
60	F. E. TSS (lbs. discharged)	229	293	2148	574	339	696
	Reductions by Act. Sl. Process						
61	BOD_5 (%)	95.4	96.6	92.7	95.7	97.7	95.4
62	TSS (%)	87.2	85.4	51.3	91.0	90.8	81.6
	Overall Plant Reduction						
63	BOD_5 (%)	97.7	98.1	95.7	97.0	98.1	97.3
64	TSS (%)	97.4	94.6	77.6	94.4	96.2	92.0

BREWERY WASTE ALONE

During the months of February and March, when only brewery wastes were treated, effluent turbidities fluctuated widely in a 2 to 20 JTC range. One rise in turbidity, just after the start of recovery from the second acid spill, was caused by an open valve on the No. 4 Aerobic Digester effluent line which permitted digested sludge to flow into the final clarifier, and thence to the aeration basin as return activated sludge. This resulted in a mixed liquor with a dark gray color. Other fluctuations during this period were related to an overflow of digested sludge from the thickener to the aeration tank and numerous mechanical and electrical difficulties.

Final effluent BOD ranged from 5 to 26 mg/l averaging 11 mg/l during these two months for an overall plant reduction of 98.0%. Final effluent suspended solids concentrations ranged from 5 to 38 mg/l averaging 17.0 mg/l for an overall plant reduction of 94.6%.

Though the February-March two-month average incoming flow increased 15% and the BOD_5 increased 40% over January, the plant loadings were:

lbs. BOD_5/1,000 cu. ft. Aeration Tank Volume....	31.5	
lbs. BOD_5/lbs. MLVSS..........................	0.24	
Aeration Tank Detention Time @ Flow alone.......	15.3	hrs.
Aeration Tank Detention Time @ Flow plus Return.	7.0	hrs.
Final Clarifier Detention Time..................	5.3	hrs.
Final Clarifier Surface Overflow Rate..	156	gals./d/sq.ft.

COMBINED BREWERY AND DOMESTIC WASTES

During the last week of March, sludge settling became progressively worse and the sludge blanket in the final clarifier began to rise. Since the additional load of domestic sewage was anticipated from the City of Williamsburg, a second aeration basin was placed in operation to use sludge dilution as a method to increase sludge settling. This interim method worked for about a week until the system became so glutted with sludge that bulking became inevitable. Even the addition of the second clarifier at this time did little to improve the situation. Sludge was being lost over the final clarifier weirs intermittently during this period.

A sludge loss occurred even on days when the sludge blanket was two to three feet below the final clarifier water surface because of the excessive velocity currents in the vicinity of the weirs and around the submerged effluent pipe. Proper leveling of the final clarifier weirs should eliminate this part of the problem by providing uniform overflow velocities.

When waste activated and primary sludge were handled as described on Page 5 of this report, problems were encountered. For instance, when high sludge wasting rates were employed, the aerobic digestion tanks frequently filled faster than the thickened sludge could be transferred to the irrigation site. This would cause liquid levels to rise in the tanks to the point where the aerator blades would become submerged, overdraw amperage, and shut off. Furthermore, sludge detention times in these tanks were minimal, at best, and during periods of high wasting were insufficient for sludge stabilization.

A more conventional and perhaps better method of waste sludge handling would have been to waste sludge directly to the gravity thickeners and thence to the aerobic digesters. This mode of operation would allow the sludge to be concentrated before digestion resulting in a lesser volume of sludge to be aerobically digested. Longer detention times would then be possible and volatile solids reduction would probably be enhanced.

The quantity of sludge wasted cannot be accurately documented because the meter used to measure waste sludge was inaccurate at low flow rates. During April, however, a general effort was made to increase sludge age by decreasing the volume of sludge wasted. The return sludge flow was gradually increased from 3.5 mgd to 6.8 mgd. These high return sludge flows (about 200% of the incoming flow) were instrumental in increasing the sludge concentration ratio (SCR)* from 0.8 to about 1.6. By the 25th of April settling was greatly improved, no sludge was lost over the weirs, and the daily average turbidity was again reduced to below 10 JTU.

During this period D.O. levels were maintained from about 1.5 mg/l D.O. to 5 mg/l D.O. Experience gained while operating other plants since the Williamsburg project showed, however, that proper

* Sludge Concentration Ratio(SCR)$=\frac{\text{60 min. Settled Sludge Concentration}(SSC_{60})}{\text{Return Sludge Concentration}(RSC)}$

dosages of ferric chloride and/or polymers can improve the settling characteristics of bulking sludges. It is, therefore, desirable that facilities (feeders, meters, controllers and piping) be available at the Williamsburg plant for the emergency addition of these chemicals when bulking occurs.

Final effluent BOD ranged from 10 to 33 mg/l averaging 24 mg/l during April for an overall plant reduction of 95.7%. Suspended solids removal in April was poor, however, with final effluent concentrations ranging from 3 to 300 mg/l averaging 58 mg/l for an overall plant reduction of 77.6%.

Plant loadings and detention times for April reflect the effect of the reduced mixed liquor concentrations and the increased flow from the City of Williamsburg as shown below:

lbs. BOD_5/1,000 cu. ft. Aeration Tank Volume......	34.9
lbs. BOD_5/lbs. MLVSS............................	0.46
Aeration Tank Detention Time @ Flow alone.........	14.17 hrs.
Aeration Tank Detention Time @ Flow plus Return...	6.49 hrs.
Final Clarifier Detention Time....................	4.92 hrs.
Final Clarifier Surface Overflow Rate.............	167 gals./d/sq.ft.

STABLE OPERATION PERIOD

The final two months of the technical assistance project (from May 1, to June 25, 1972) were characterized by relatively stable plant operation. Effluent turbidities were generally below 6 JTU and higher turbidities, when they occurred, were almost always due to an overflow of digested sludge from the thickener to the aeration basins.

During the first two weeks of May, sludge overflowed the thickener weirs almost daily causing an increase in turbidities and a general degradation of sludge settling characteristics. In order to minimize this problem it was recommended that thickener sludge blanket levels be recorded hourly and that sludge pumping to the thickeners be regulated closely when there was danger of the sludge overflowing the weirs.

When the above practice was adhered to, and process demands followed rigorously, turbidities below 4 JTU were not uncommon. Final effluent turbidities for the final week of Federal assistance (June 19 - June 25, 1972) averaged about 2.5 JTU. BOD_5 and suspended solids averaged less than 9 mg/l during the same period.

Final effluent BOD_5 ranged from 4 to 32 mg/l averaging 14 mg/l during the last two months for an overall plant reduction of 97.0%. Suspended solids concentrations ranged from 3 to 37 mg/l averaging 12 mg/l for an overall plant reduction of 94.5%.

The higher influent flows in May and June coupled with the increased return sludge flow percentages required to meet process demands increased aerator loadings and lowered detention times as shown below:

lbs. BOD_5/1,000 cu. ft. Aeration Tank Volume...	45.0	
lbs. BOD_5/lbs. MLVSS........................	0.35	
Aeration Tank Detention Time @ Flow alone	11.2	hrs.
Aeration Tank Detention Time @ Flow plus Return	4.6	hrs.
Final Clarifier Detention Time.................	3.5	hrs.
Final Clarifier Surface Overflow Rate..........	213	gals./d/sq.ft.

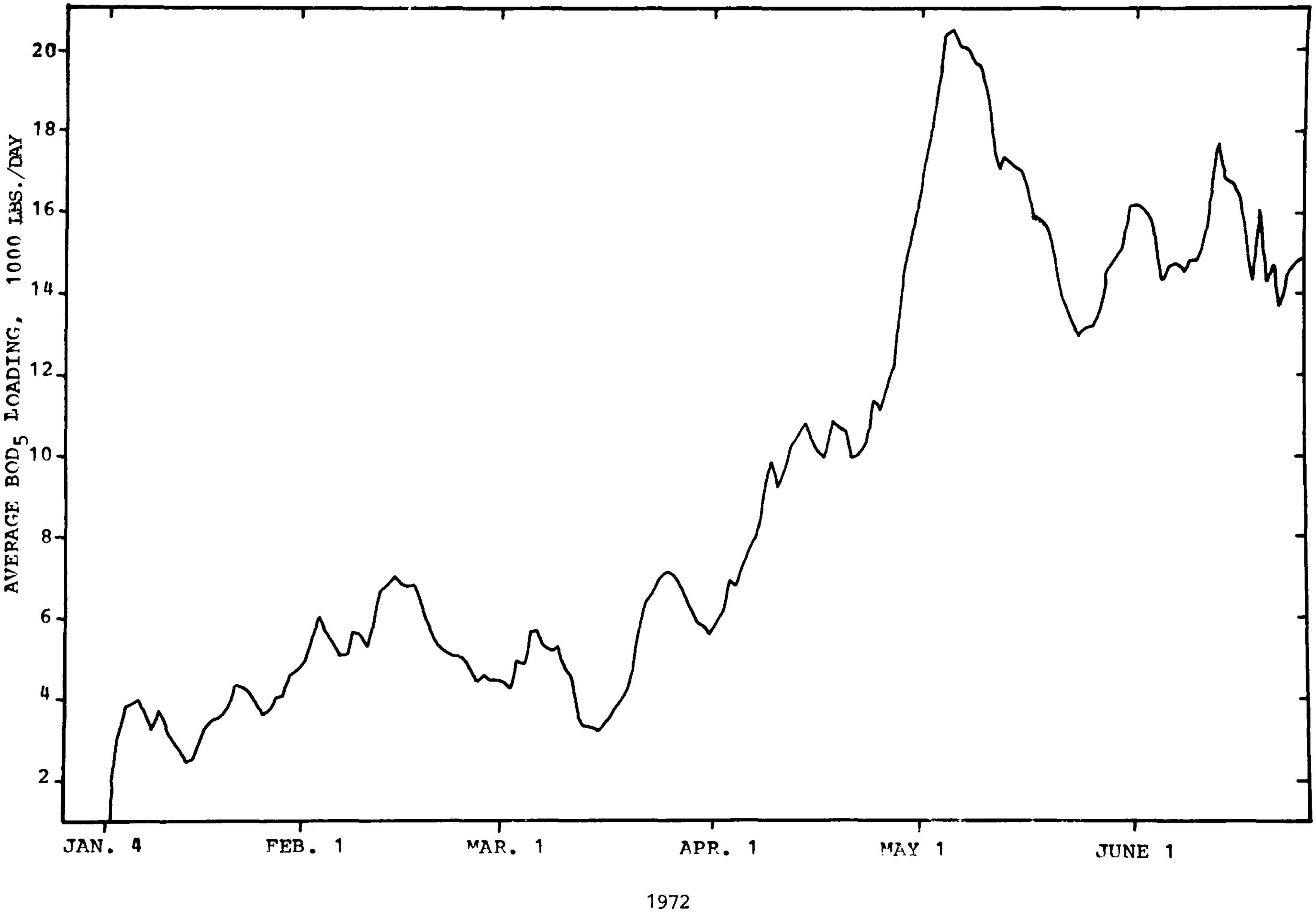
PLANT LOADING

According to the engineers' design figures the total BOD_5 loading to the secondary aeration tanks (4 tanks) was to be 40,000 lbs. of BOD_5 per day; i.e., 10,000 lbs. of BOD_5 per day per tank. For the first three months of operation the BOD_5 loading to the one tank in service averaged less than 6,000 lbs./day or about 60% of the design load. With the addition of the City of Williamsburg load in April the BOD_5 load to two tanks increased to 15,000 lbs./day or about 75% of the design load for two tanks. Figure 2 is a 7-day moving average plot of BOD_5 load to the aeration tanks in lbs./day.

The aerator load (lbs. BOD_5/1,000 cu. ft. of aeration tank capacity) was well within the capabilities of a complete-mix activated sludge plant throughout the duration of the project. In fact, during the first four months of the project the average aerator load (30.1 lbs. BOD/1,000 cu. ft.) was below the somewhat conservative

FIGURE 2

7-DAY MOVING AVERAGE OF BOD_5 LOADING



10-State Standard* value of 40 lbs. BOD_5/1,000 cubic feet. The increased load after the City of Williamsburg came on line caused this value to be exceeded 73% of the time during May and June for a mean of 47.4 lbs. BOD_5/1,000 cu. ft. Figure 3 is a 7-day moving average plot of aerator load.

The organic loadings experienced at Williamsburg were also well within the plant's treatment capabilities. The project average was 0.31 lb. BOD_5/lb. MLVSS with January having the lowest average F/M ratio of 0.23 and April the highest at 0.46. April's average was relatively high because of the decrease in mixed liquor solids during the bulking phase.

Hydraulic loadings in the plant were light throughout the project. This is particularly evident in the clarifier surface overflow rate which averaged only 173 gal./d/sq.ft. for the project. Figure 4 is a 7-day moving average plot of clarifier surface overflow rates.

SUMMARY OF PLANT PERFORMANCE

The Virginia State Water Control Board has set final effluent discharge standards of 35 mg/l BOD and 20 mg/l suspended solids (monthly average values) for the Williamsburg Sewage Treatment Plant. The monthly average final effluent BOD throughout the project was less than the State certification value and except for the month of April, when an average of 24 mg/l was recorded, the final effluent BOD was consistently below 17 mg/l. With the exception of April,

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* Recommended Standards for Sewage Works, 1971 edition.

FIGURE 3

7-DAY MOVING AVERAGE OF AERATOR BOD_5 LOADING

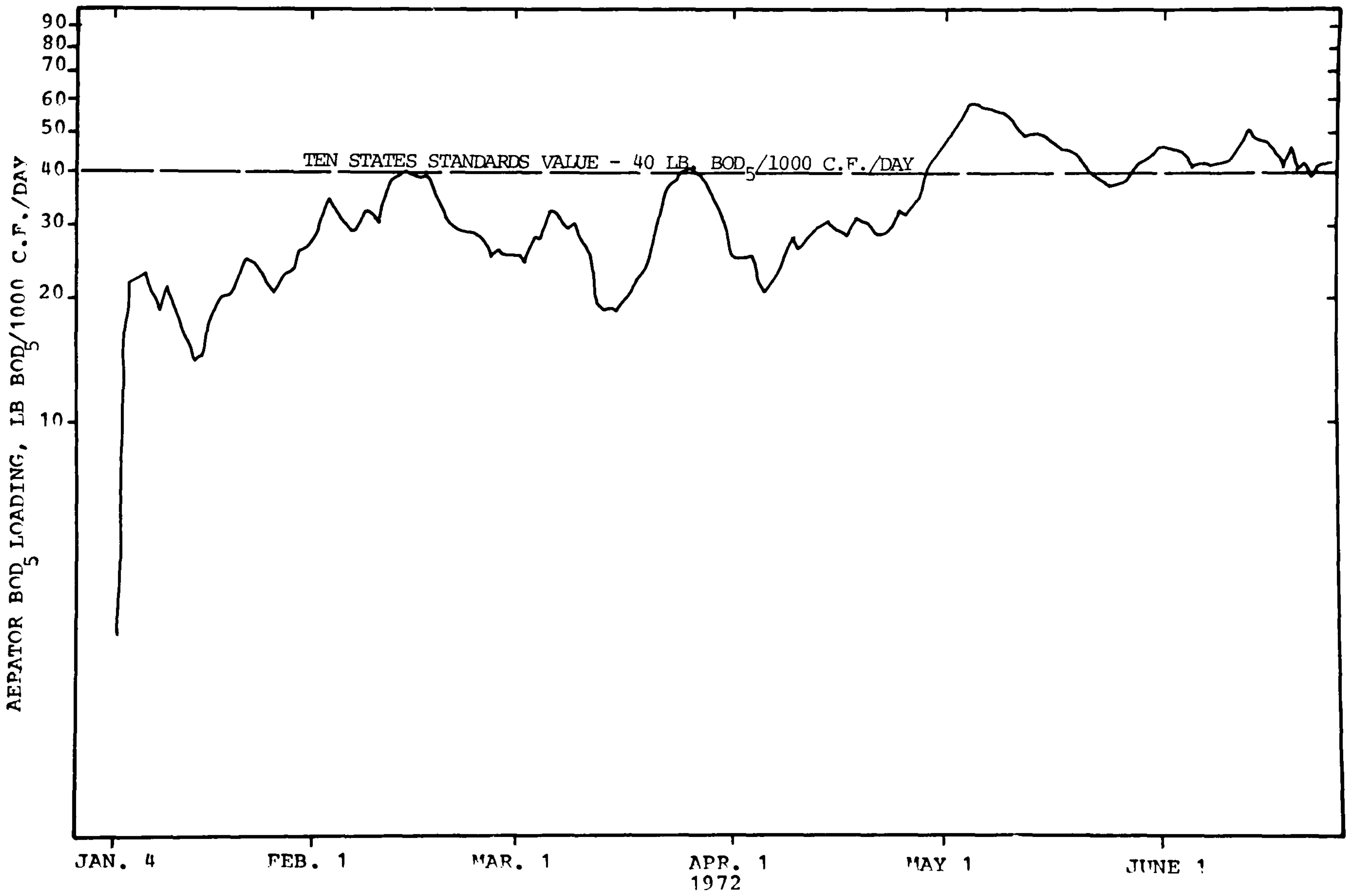
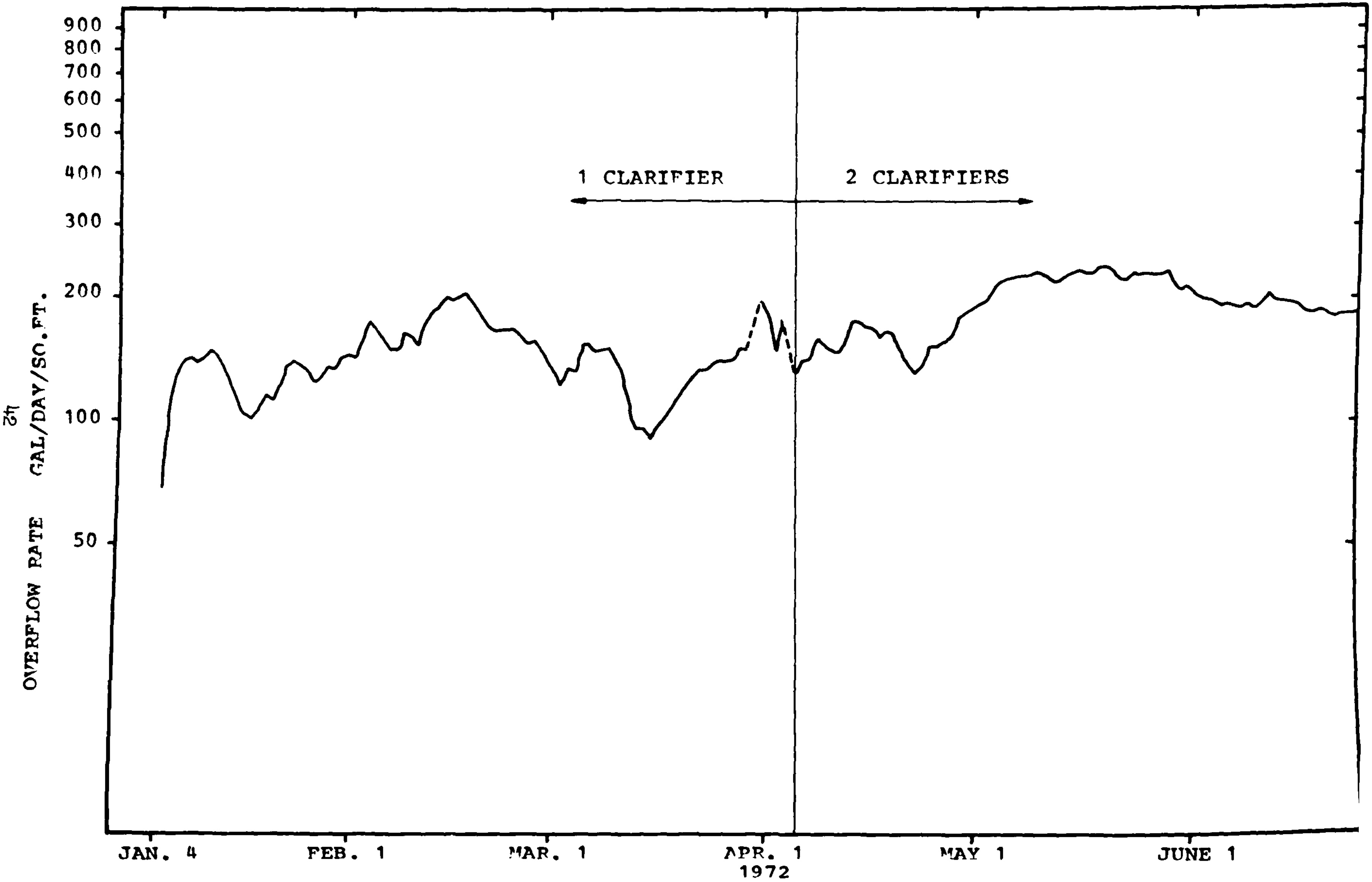


FIGURE 4

7-DAY MOVING AVERAGE OF CLARIFIER OVERFLOW RATE



when bulking caused the monthly average of suspended solids to reach 58 mg/l, the final effluent suspended solids were also consistently below 17 mg/l.

Figure 5 is a 7-day moving average plot showing the relationship of aerator influent BOD concentrations to that in the final effluent. Also shown on Figure 5 is the dashed line representing the State certification value of 35 mg/l BOD. The small hump in the final effluent BOD curve towards the end of January was due to the acid waste which hit the plant during start-up.

Figure 6 is a 7-day moving average plot of aerator influent suspended solids and final effluent suspended solids. The plot shows that the VSWCB certification limit of 20 mg/l suspended solids was exceeded only during the start-up month of January, for a short period during February (undetermined cause) and, of course, during April when bulking was experienced. Analysis of the BOD and suspended solids curves further indicates that final effluent quality was more a function of operational control procedures (aerobic digesters and sludge thickeners as well as the activated sludge system) than a response to variations in influent flow and BOD loadings. Seven-day moving averages were used in these plots since they tend to level out immediate fluctuations and smooth out a curve.

Probability plots of final effluent BOD_5, and suspended solids concentrations and percent reductions were also developed to permit

FIGURE 5

7-DAY MOVING AVERAGE OF AERATOR INFLUENT AND FINAL EFFLUENT BOD_5 CONCENTRATIONS

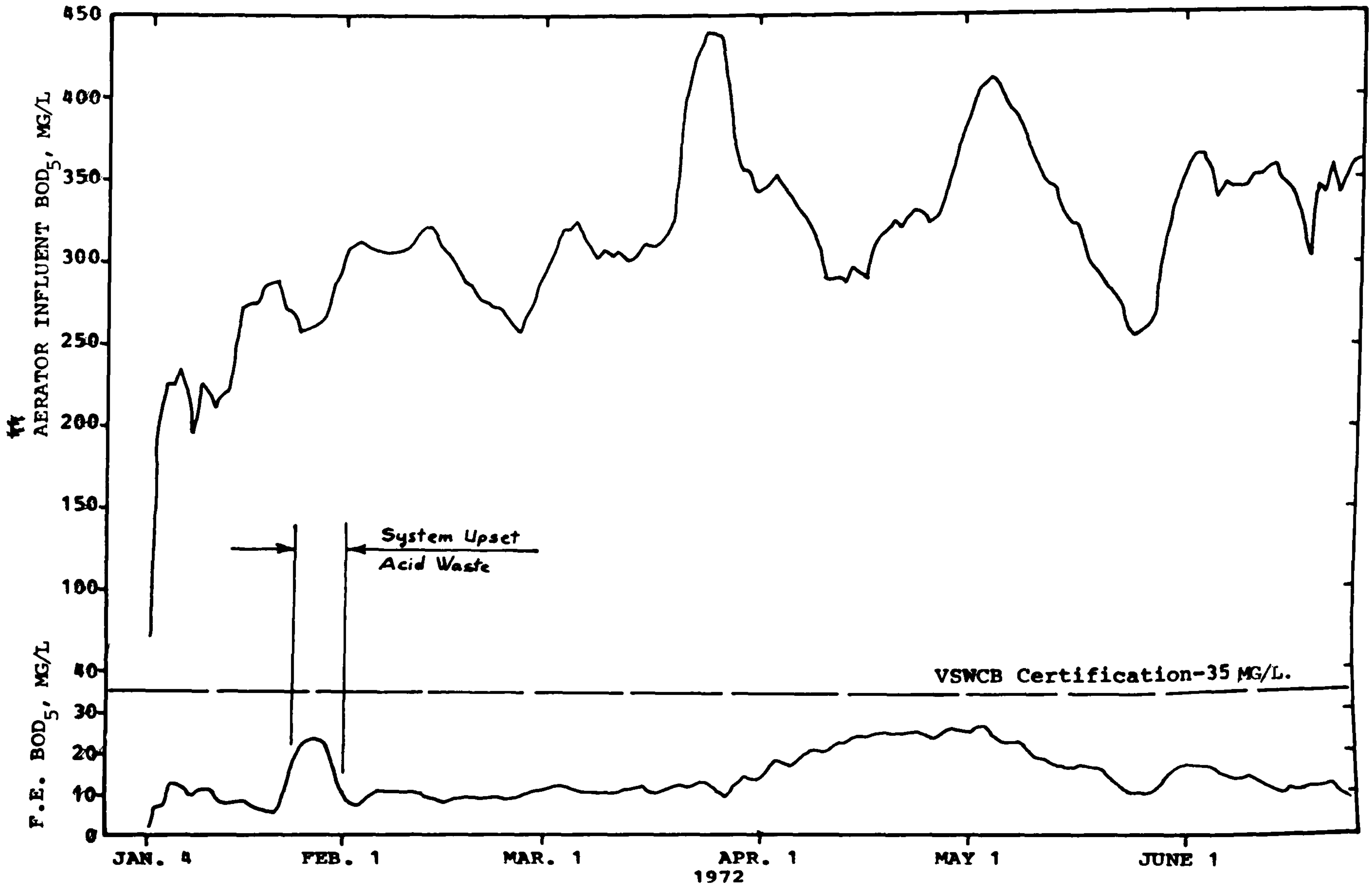
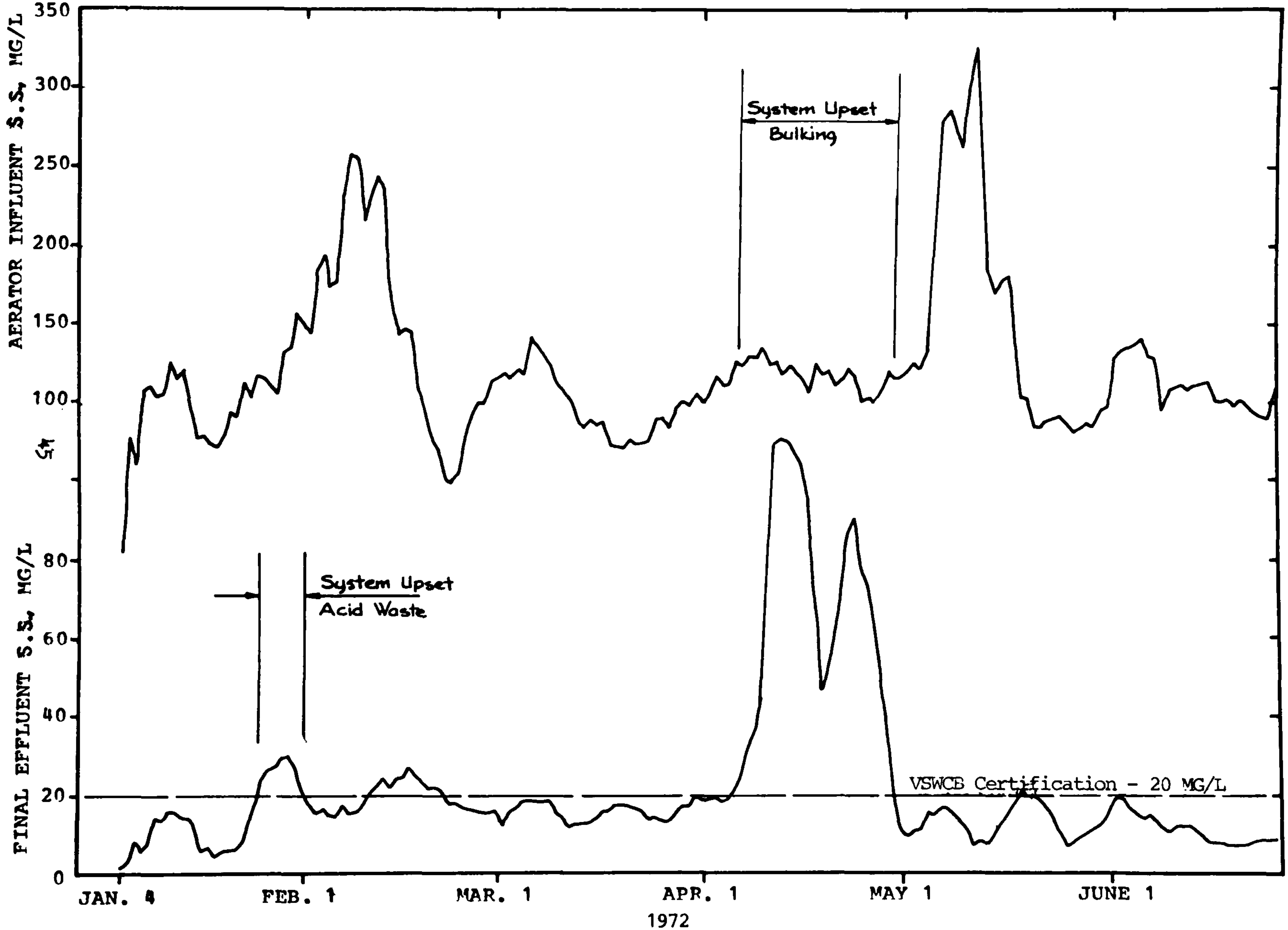


FIGURE 6

7-DAY MOVING AVERAGE OF AERATOR INFLUENT AND FINAL EFFLUENT SS CONCENTRATIONS



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more detailed evaluation of the effluent quality (See A-1 to A-31). A summary of this probability data is tabulated in Table 7 and 8.

Performance - Start-up vs Entire Project (Figures 7 and 8).

Figures 7 and 8 are of special interest since they show the relationship of final effluent BOD's and suspended solids during the start-up month of January to that of the entire project.

Entire Project Curves (January 4, 1972 - June 25, 1972)

The probability plots of all the final effluent BOD and Suspended Solids data from January 4, 1972 to June 25, 1972 are labeled "Entire Project" in Figures 7 and 8. They exhibit a wide variation in slope, which because of the somewhat uniform aeration tank influent BOD and Suspended Solids Concentrations (BOD range of 258 to 346 mg/l averaging 317 mg/l, TSS range of 100 to 153 mg/l averaging 125 mg/l), is indicative of changes in treatment performance.

Start-up Curves (January 1972)

The BOD and Suspended Solids curves for January 1972 (Figures 7 and 8) display the same wide variation in slope as the project curves. This variation is logical when one considers the problems that were associated with the Williamsburg start-up, for instance, the acid brewery waste which killed all the aeration tank biota. The steeply sloping portion of the January curves corresponds to this acid waste period.

TABLE NO. 7

SUMMARY OF BOD 5 PROBABILITY DATA

HAMPTON ROADS SANITATION DISTRICT - WILLIAMSBURG STP

Probability % Equal To Or Less Than	Jan. 72	Feb. 19	March 72	April 72	May 72	June 72
Raw BOD 5 (mg/l)						
50%	580	582	530	500	455	514
10%	244	460	280	290	280	324
90%	626	704	850	955	740	703
Aeration Tank Influent BOD 5 (mg/l)						
50%	286	297	334	333	332	340
10%	150	254	283	273	256	254
90%	317	340	433	393	410	400
Final Effluent BOD 5 (mg/l)						
50%	8.0	10.3	12.0	24.0	17.5	11.6
10%	2.6	7.2	6.4	18.3	9.0	6.3
90%	29.0	13.6	18.8	29.8	26.0	16.7
Secondary Reduction in BOD 5 %						
50%	96.8	96.6	95.9	92.4	95.1	96.9
10%	83.0	95.7	94.0	91.5	92.6	93.8
90%	98.8	97.5	98.2	94.8	96.6	98.2
Overall Plant Reduction in BOD 5 (%)						
50%	98.4	98.2	97.8	95.3	96.3	98.0
10%	91.3	97.6	95.6	91.5	92.7	95.3
90%	99.6	98.8	98.9	97.4	98.1	99.0

TABLE NO. 8

SUMMARY OF TOTAL SUSPENDED SOLIDS (TSS) PROBABILITY DATA

HAMPTON ROADS SANITATION DISTRICT - WILLIAMSBURG STP

Probability % Equal To Or Less Than	Jan. 72	Feb. 72	March 72	April 72	May 72	June 72
Raw Total Suspended Solids (mg/l)						
50%	335	336	270	255	186	278
10%	120	170	86	118	82	166
90%	1060	620	460	415	290	389
Aeration Tank Influent TSS (mg/l)						
50%	120	115	93	112	100	100
10%	41	44	62	80	52	74
90%	196	311	153	170	380	200
Final Effluent TSS (mg/l)						
50%	9	16	14	35	14	10
10%	2.4	9	10	10	5	4.3
90%	41	32.3	27.5	125	26	15.8
Secondary Reduction in TSS (%)						
50%	91.0	85.0	82.8	71.8	86.6	91.6
10%	56.4	60.3	74.7	43.6	71.1	83.6
90%	97.3	95.0	90.7	96.4	97.4	95.7
Overall Plant Reduction in TSS (%)						
50%	97.5	94.0	93.7	85.0	92.6	96.7
10%	88.5	90.0	89.5	58.0	82.6	92.9
90%	99.3	97.9	97.7	98.5	97.6	99.1

FIGURE 7

PROBABILITY OF FINAL EFFLUENT BOD_5

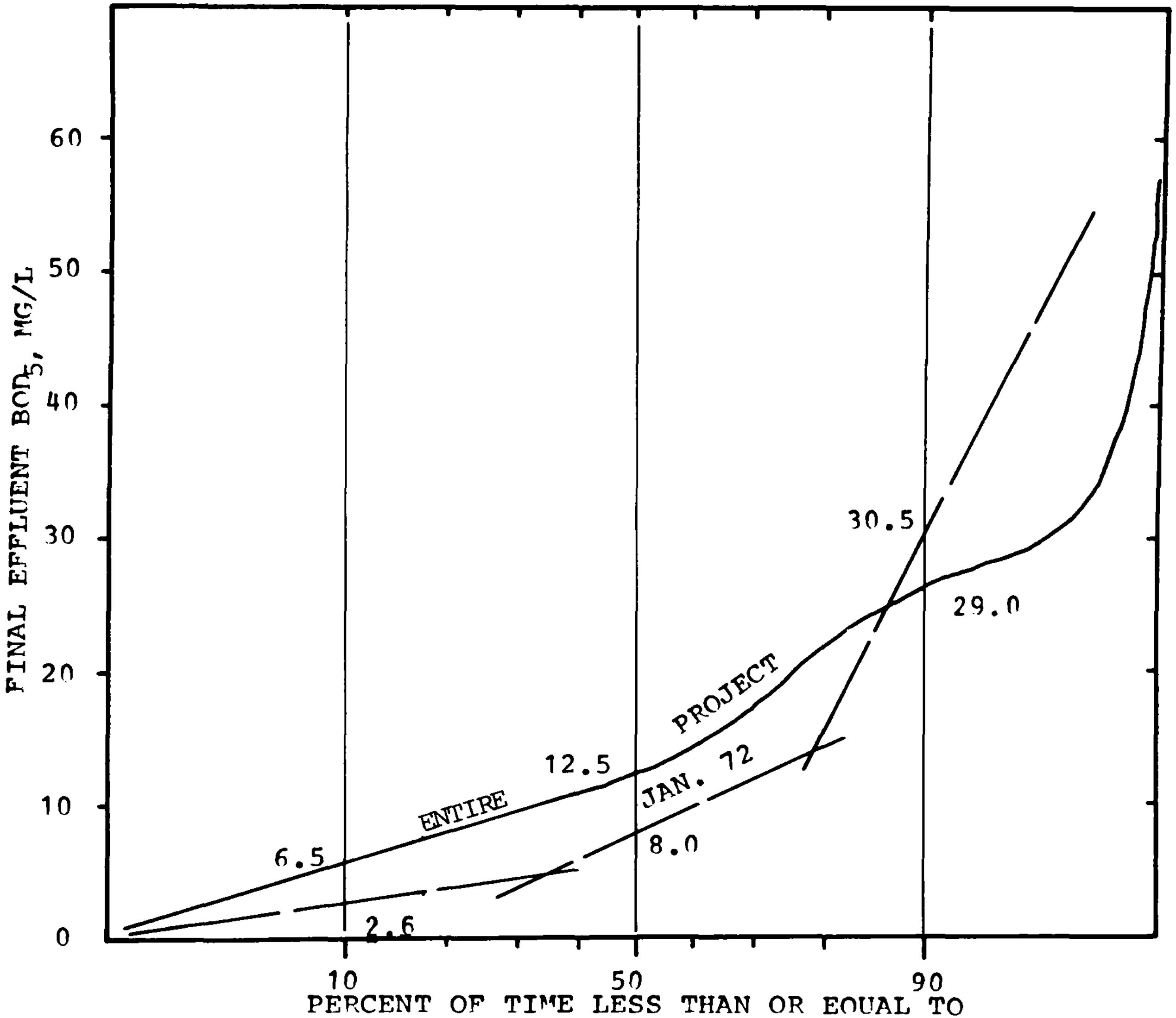


FIGURE 8

PROBABILITY OF FINAL EFFLUENT SUSPENDED SOLIDS

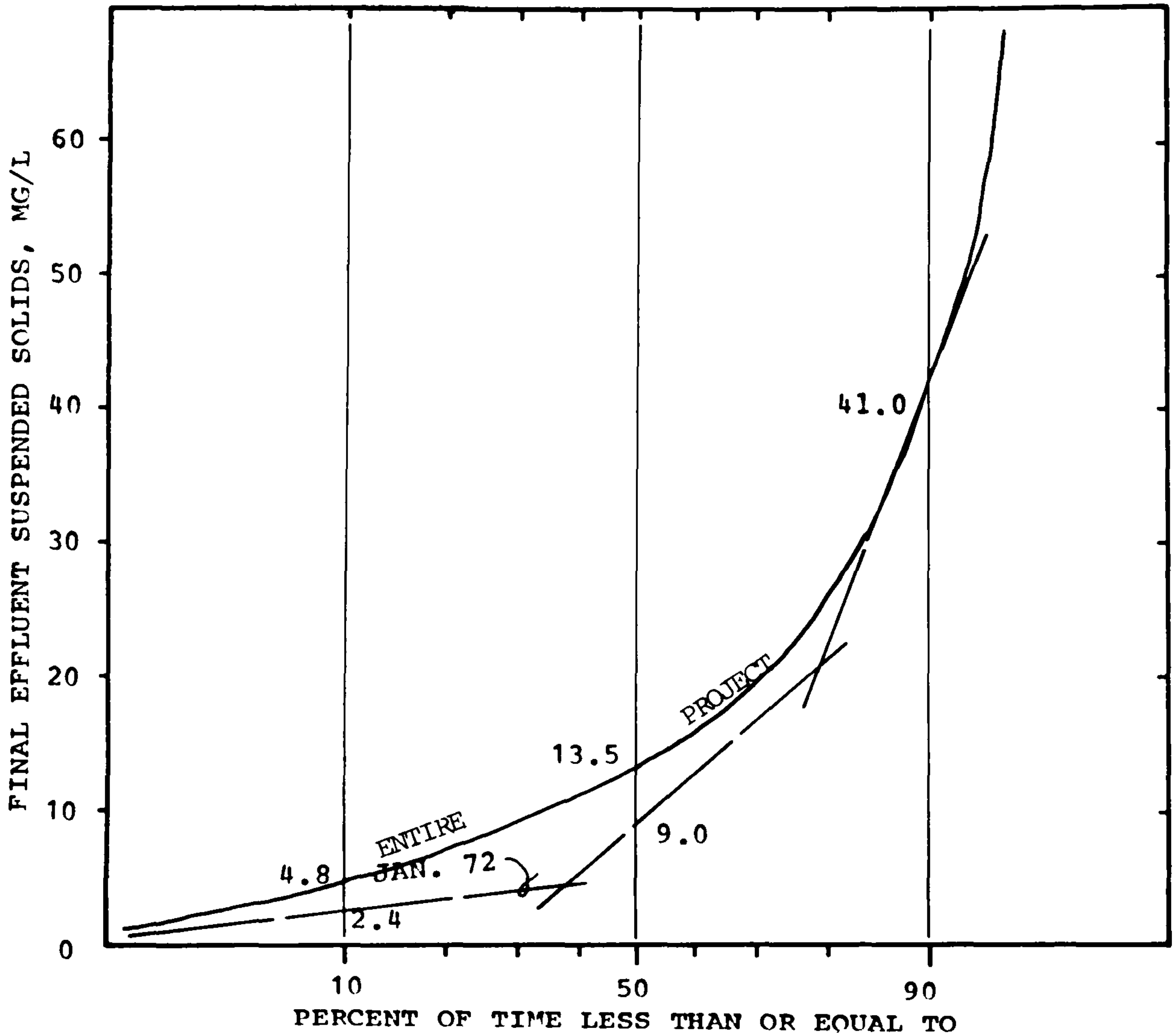


FIGURE 9

PROBABILITY OF FINAL EFFLUENT BOD

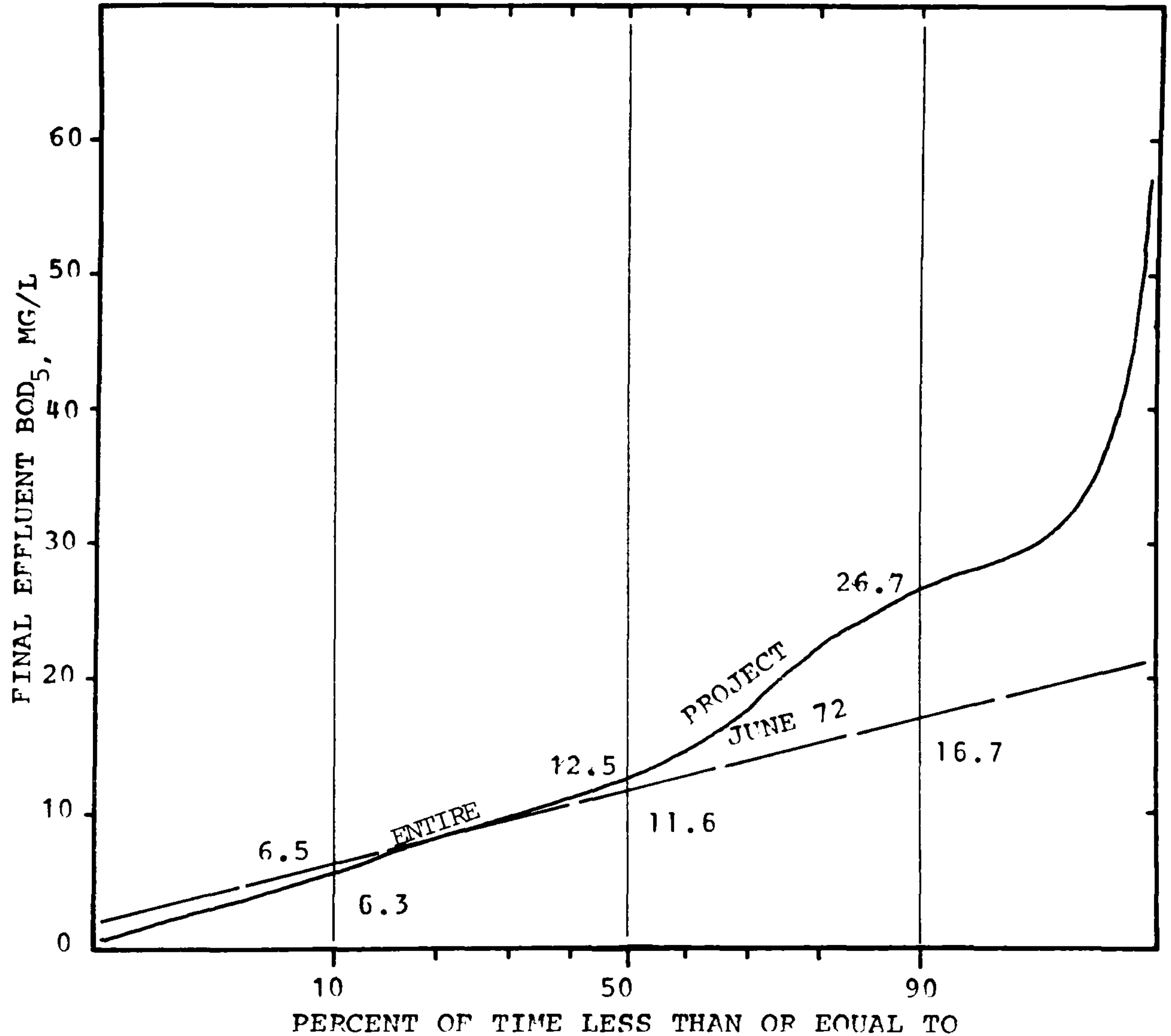
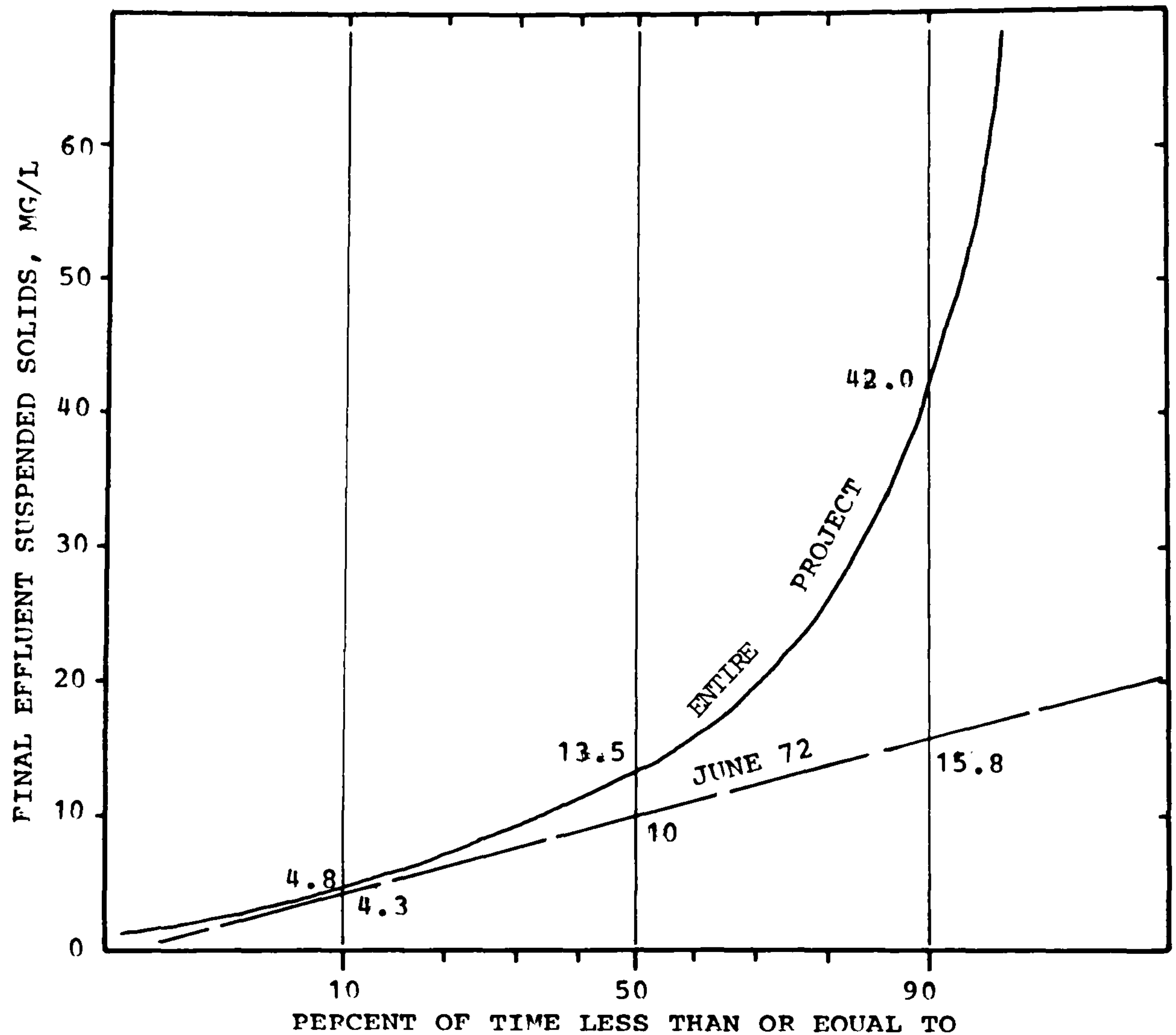


FIGURE 10

PROBABILITY OF FINAL EFFLUENT SUSPENDED SOLIDS



Performance - June 1972 vs Entire Project (Figures 9 and 10).

Figures 9 and 10 are similar to Figures 7 and 8 except that the June BOD and Suspended Solids curves are compared to the project curves.

Entire Project Curves (January 4, 1972 - June 25, 1972)

The "Entire Project Curves," described on Page 46, are also reproduced on the Figures 9 and 10 for comparison with the "Stable Operation Curves."

Stable Operation Curves (June 1972)

The curves representing June's data are straight and do not exhibit much slope which indicates a more stable plant operation. The reason for this improved performance in June was the absence of mechanical problems and the increase in operator familiarity with the plant and control techniques. It should be noted that the 50 percentile effluent BOD and Suspended Solids concentrations for June were well below the discharge limits set by the State of Virginia; even the 90-percentile values were below 17 mg/l for both BOD and Suspended Solids.

SUGGESTED PLANT MODIFICATIONS

The following are suggested improvements for the Williamsburg Waste Treatment Plant:

CONTROLS

It is necessary to adjust Return Sludge Flow (RSF) and Excess Waste Sludge Flow (XSF) to meet the process demands. The plant operators at Williamsburg were severely hampered in their control attempts since the appropriate meters could not be viewed by one man while the actuating valves were being turned. Therefore, two men were required to make the flow adjustments. The job was made doubly hard because the waste sludge and return sludge lines branched off a common header, and any adjustment of one flow would affect the other. The installation of remote manual controllers for RSF and XSF are, therefore, recommended to enable one operator to make the necessary adjustments while observing the appropriate meters at the control building meter panel.

SLUDGE HANDLING

Density sensors coupled to automatic control devices are recommended to regulate the pumping of primary sludge and thickener sludge. Minimum sludge volumes at maximum sludge density could be achieved by the addition of automatic controllers, thereby increasing the effective capacity of existing thickeners and aerobic digesters, and minimizing the deleterious recycle of septic sludge to the activated sludge system. While greatly reducing the number of man-hours needed for sludge control, such controllers should also induce improved performance of both the activated sludge process and the waste sludge disposal system.

Most important, however, is the need to accelerate the construction program for the sludge disposal facilities discussed in the Engineers' report. This sytem consists of centrifuging the thickened sludge followed by incineration.

In the future, when the Williamsburg WTP hydraulic load reaches or exceeds the true plant capacity, additional meters and control gates will be needed to insure accurate balancing of flows between multiple units. The recommended additional meters and valves include:

1. Control valves and meters on the mixed liquor inlet line to each final clarifier.
2. Control valves and meters on the sludge withdrawal line from each final clarifier.
3. Each of the valves noted above should be provided with remote manual controllers at the central meter-control panel.

Another automatic controller that should be considered for the Williamsburg plant when operating at design flows and loads is a one to proportion return sludge pumpage according to the varying incoming wastewater flow rates.

SUMMARY

The Hampton Roads Sanitation District and NFIC-C personnel demonstrated during the six-month technical assistance project at the Williamsburg WTP that this plant when properly operated will produce an excellent final effluent when treating brewery waste alone, or a combined brewery and domestic waste. It should be noted, however, that during the first three months of operation, when only brewery waste was treated, both organic and hydraulic loads were light. During the final three months of the project normal organic loadings were experienced but the clarifier surface overflow rate remained low. Throughout the project numerous mechanical and operational problems were encountered, but despite these problems reductions in BOD_5 averaged 97% (530 to 15 mg/l) while reductions in suspended solids averaged 92% (320 to 22 mg/l).

Three basic problems predominated causing intermittent high effluent BOD and suspended solids levels:

1. Acid spills entered the treatment plant during start-up. Closer cooperation between brewery and District personnel has prevented this problem from recurring.

2. Sludge bulking during April. This bulking sludge could probably have been controlled more effectively and rapidly by the application of coagulant aids.

3. Unwarranted recycle of septic sludge from the sludge disposal system to the activated sludge process. This problem should be eliminated by the addition of the proposed sludge handling facilities.

Elimination of these and other identified difficulties should enhance process control and further improve overall plant performance and final effluent quality.

A prime reason for the success of this project was that even though process imbalances did occur frequently, the demonstrated operational control tests that were used to monitor plant performance permitted such upsets to be quickly recognized and corrected.

RECOMMENDATIONS

The following recommendations are made in order that the Williamsburg Plant may consistently produce the high quality effluent of which it is capable:

1. The use of the full series of control tests demonstrated during the NFIC-C assistance project should be continued.
2. Return sludge flows and waste sludge flows should be determined by process demands.
3. An improved method of sludge disposal should be implemented as soon as possible to replace the temporary compromise waste sludge handling system.
4. As the incoming BOD_5 load increases, the two tanks now used as aerobic digesters should be put into service as additional aeration tanks. The first additional tank will be needed when the average load to the aeration tanks exceeds 20,000 lbs. BOD_5 per day.
5. Remote manual controllers should be installed to permit proper regulation of return sludge flow and waste sludge flow.

6. Installation of automatic density controllers should be considered to regulate the concentration and pumpage of primary sludge and thickener sludge for more efficient sludge disposal.

7. Additional control valves and meters should be considered to enable the balancing of flows between multiple units when the average hydraulic load approaches plant capacity.

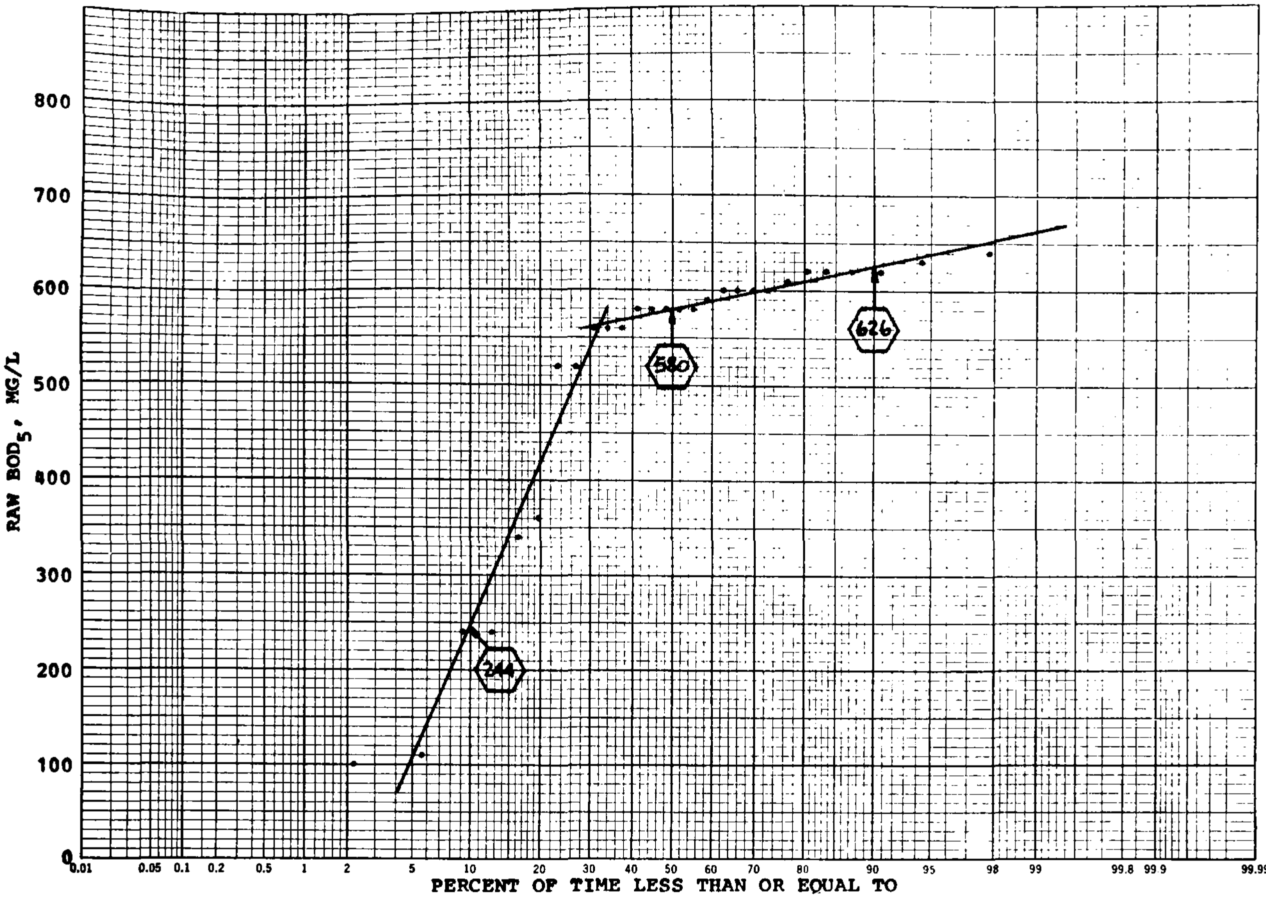
8. Chemical feed equipment and piping should be installed to permit emergency addition of metallic salts and/or polymers to the aeration tanks or final clarifiers to assure maintenance of satisfactory effluent quality in the event of bulking.

APPENDIX A

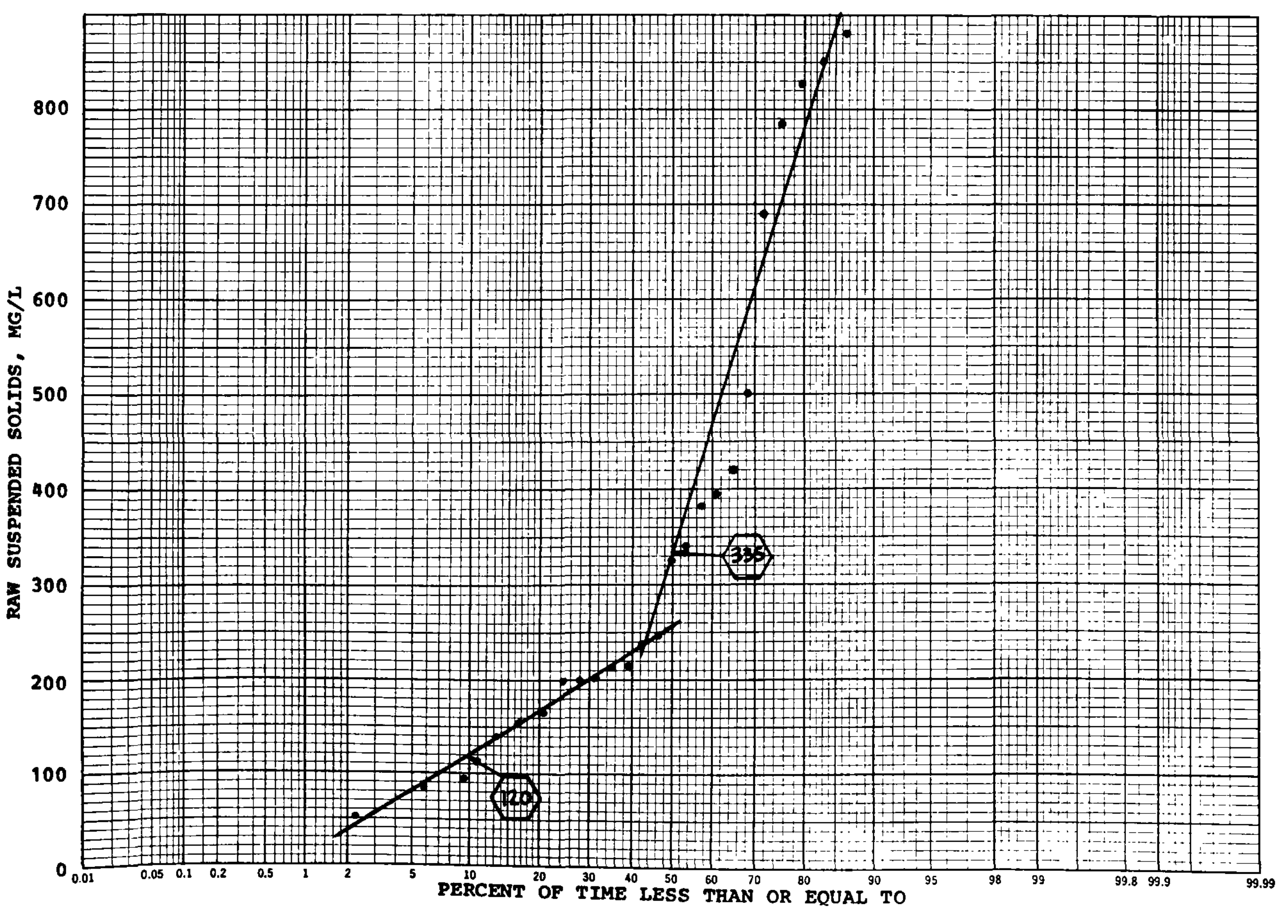
PROBABILITY PLOTS

JANUARY - JUNE 1972

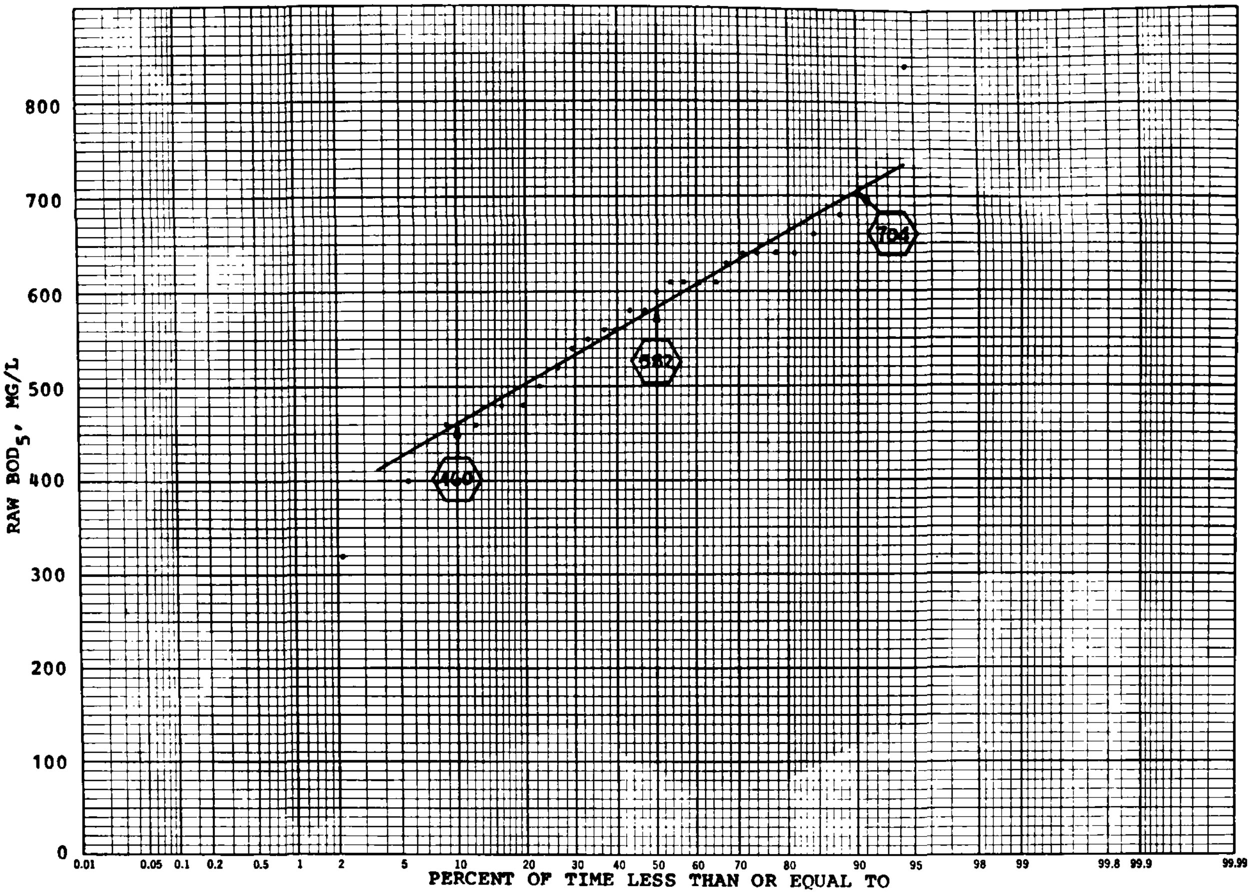
PROBABILITY OF RAW BOD-JAN.



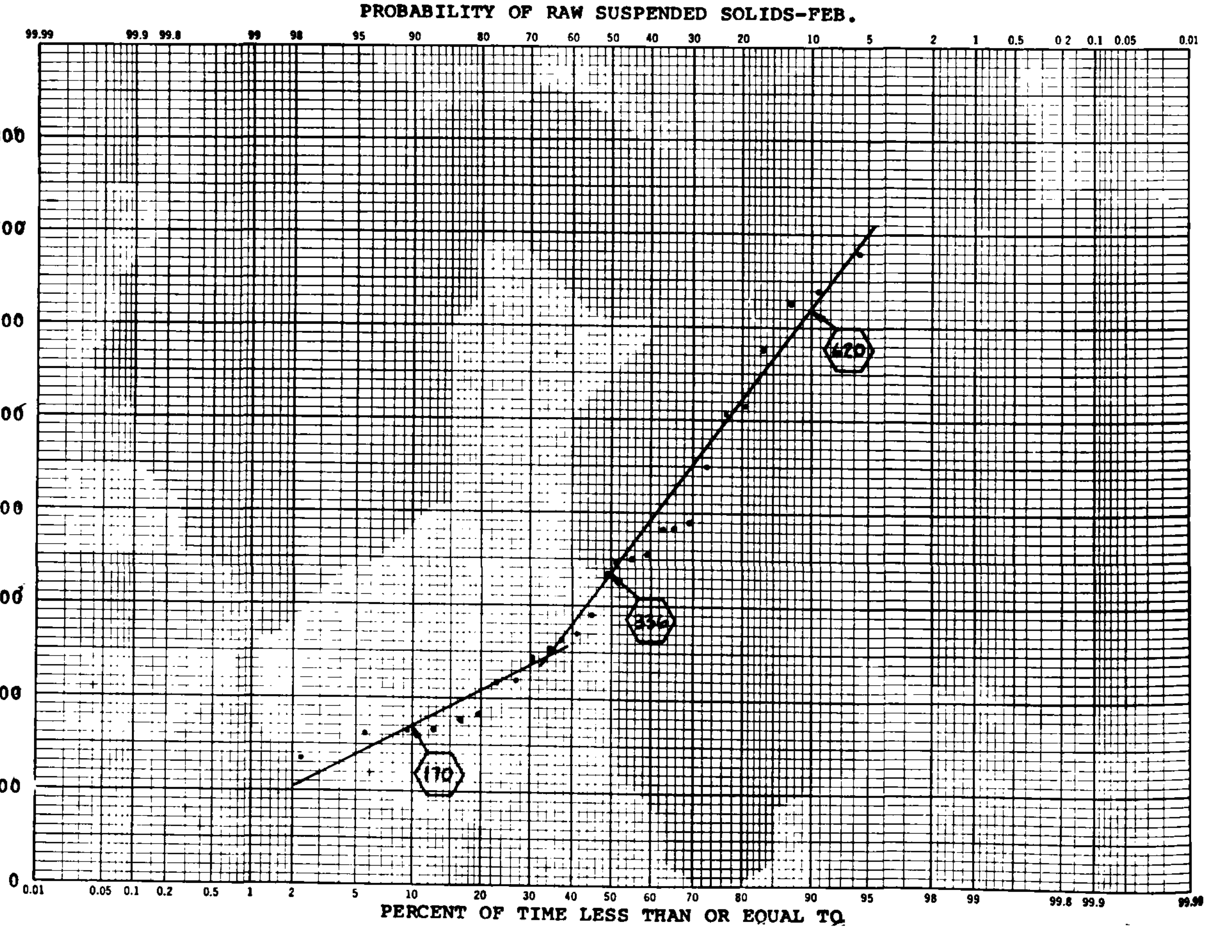
PROBABILITY OF RAW SUSPENDED SOLIDS-JAN.



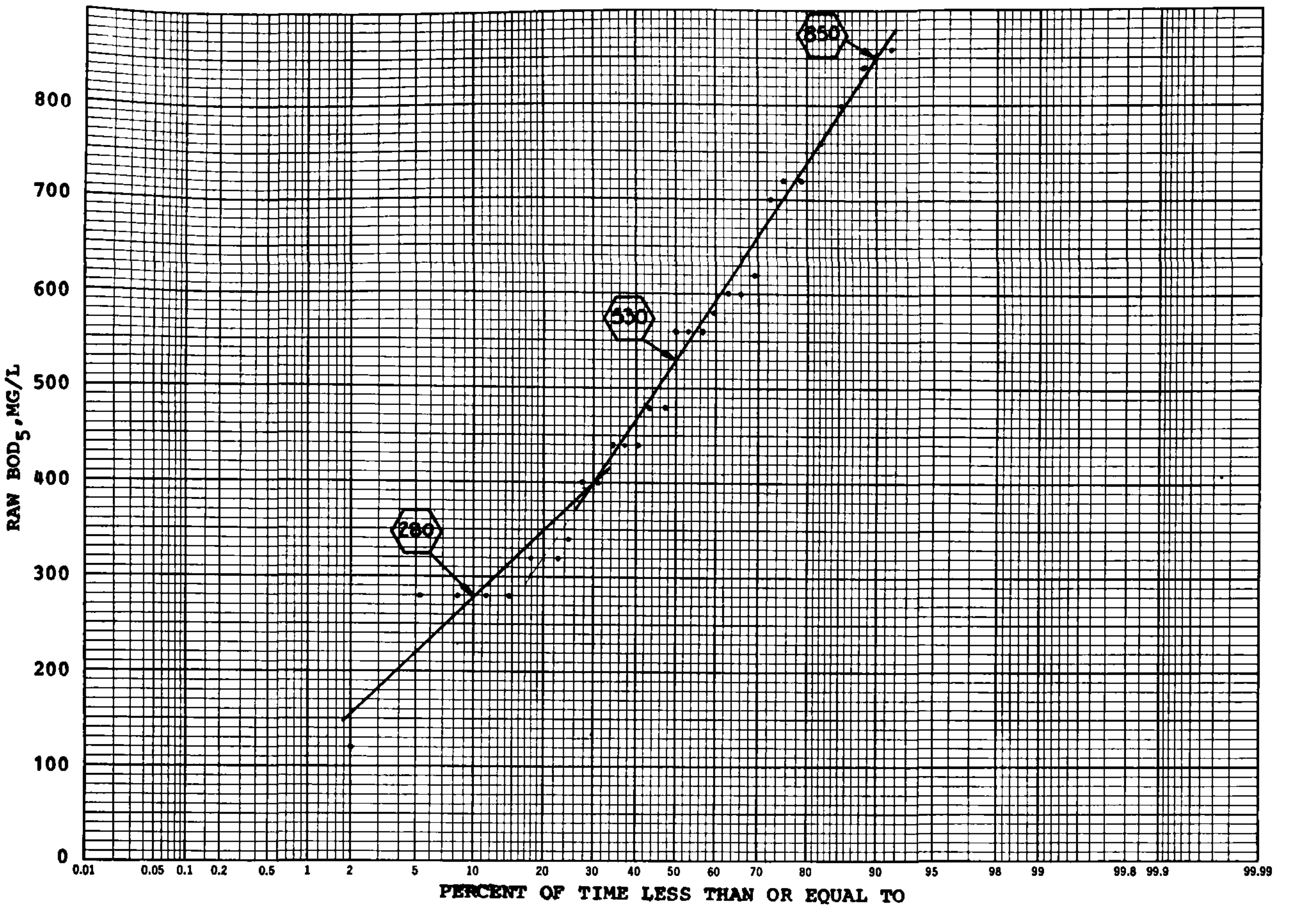
PROBABILITY OF RAW BOD-FEB.



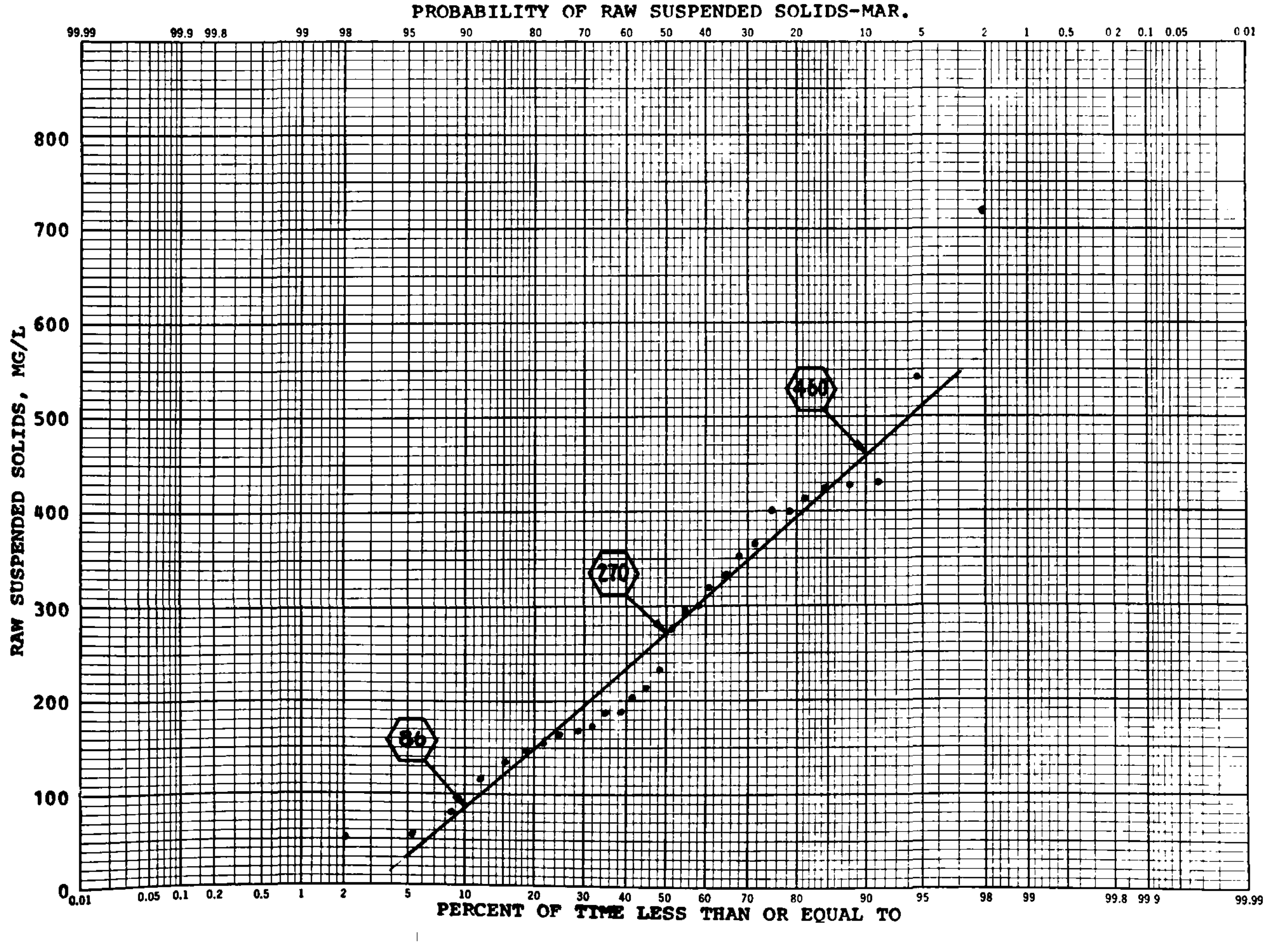
PROBABILITY OF RAW SUSPENDED SOLIDS-FEB.



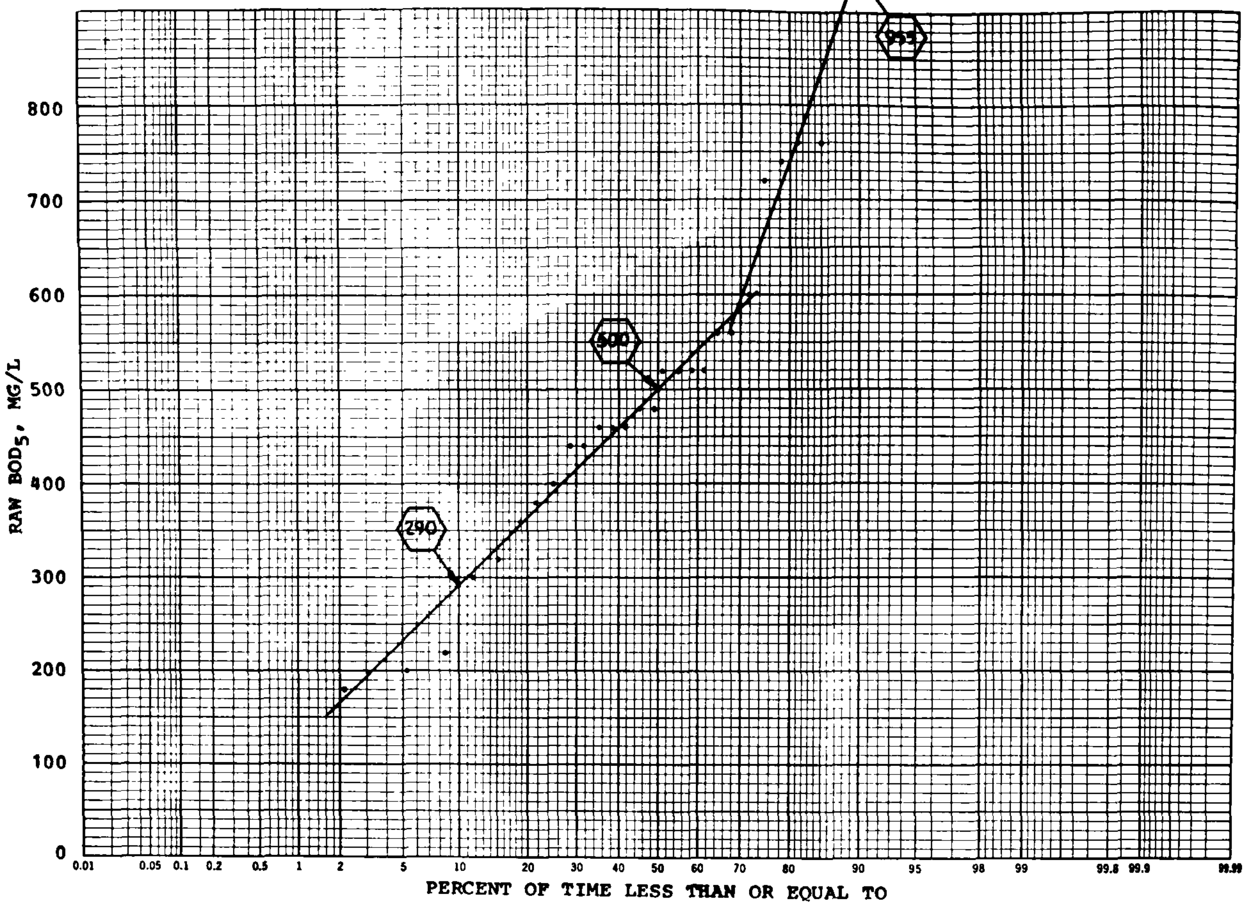
PROBABILITY OF RAW BOD-MAR.



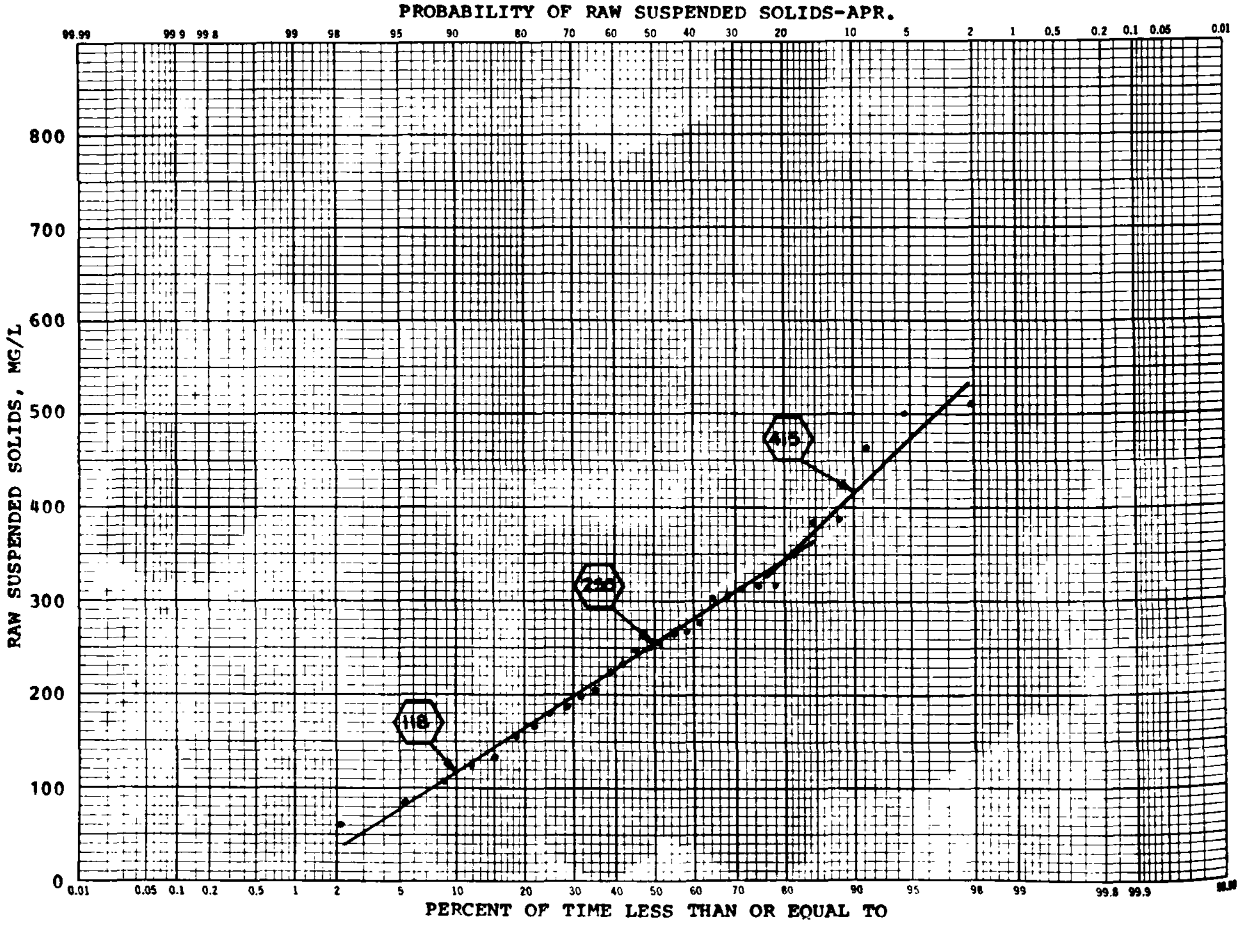
PROBABILITY OF RAW SUSPENDED SOLIDS-MAR.



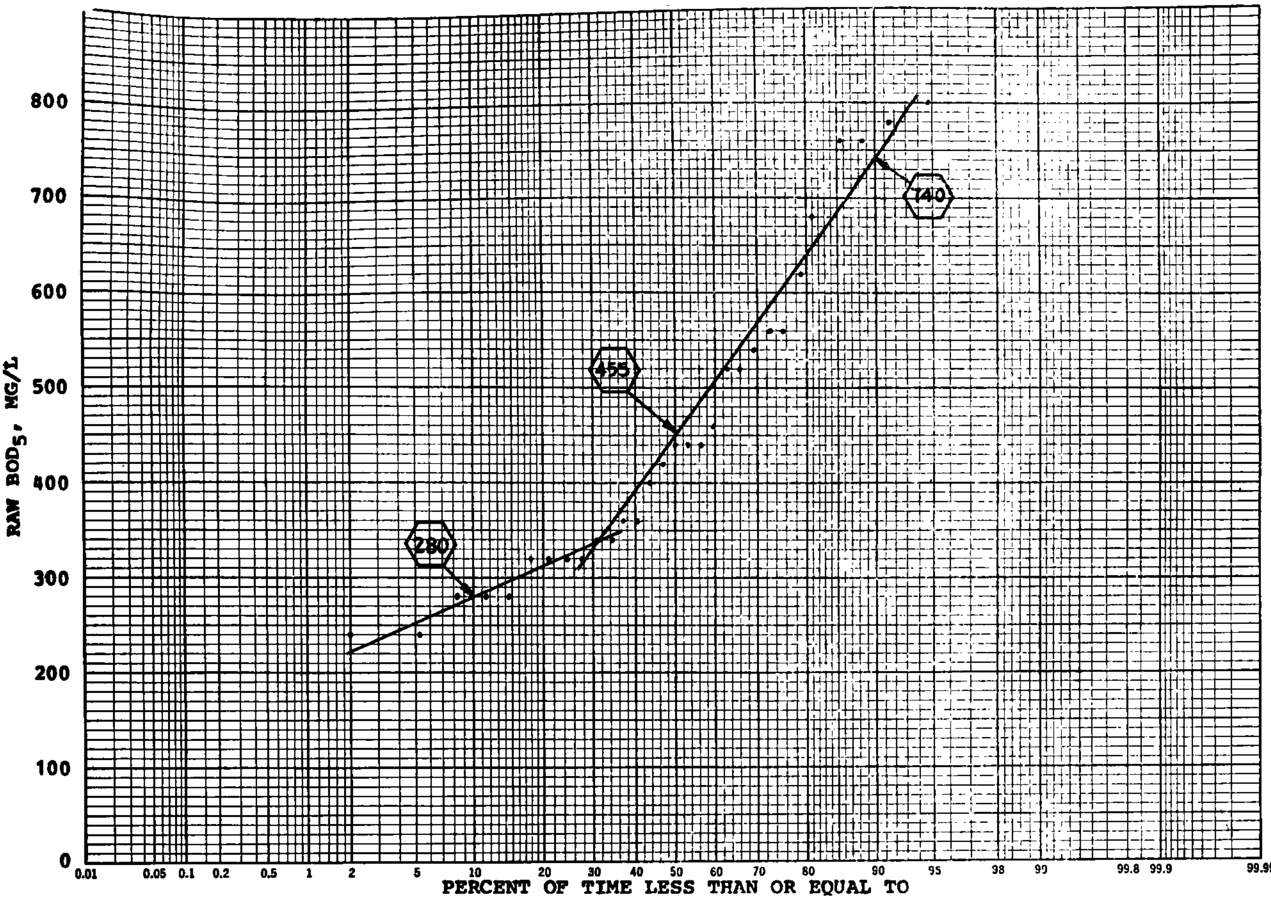
PROBABILITY OF RAW BOD-APR.



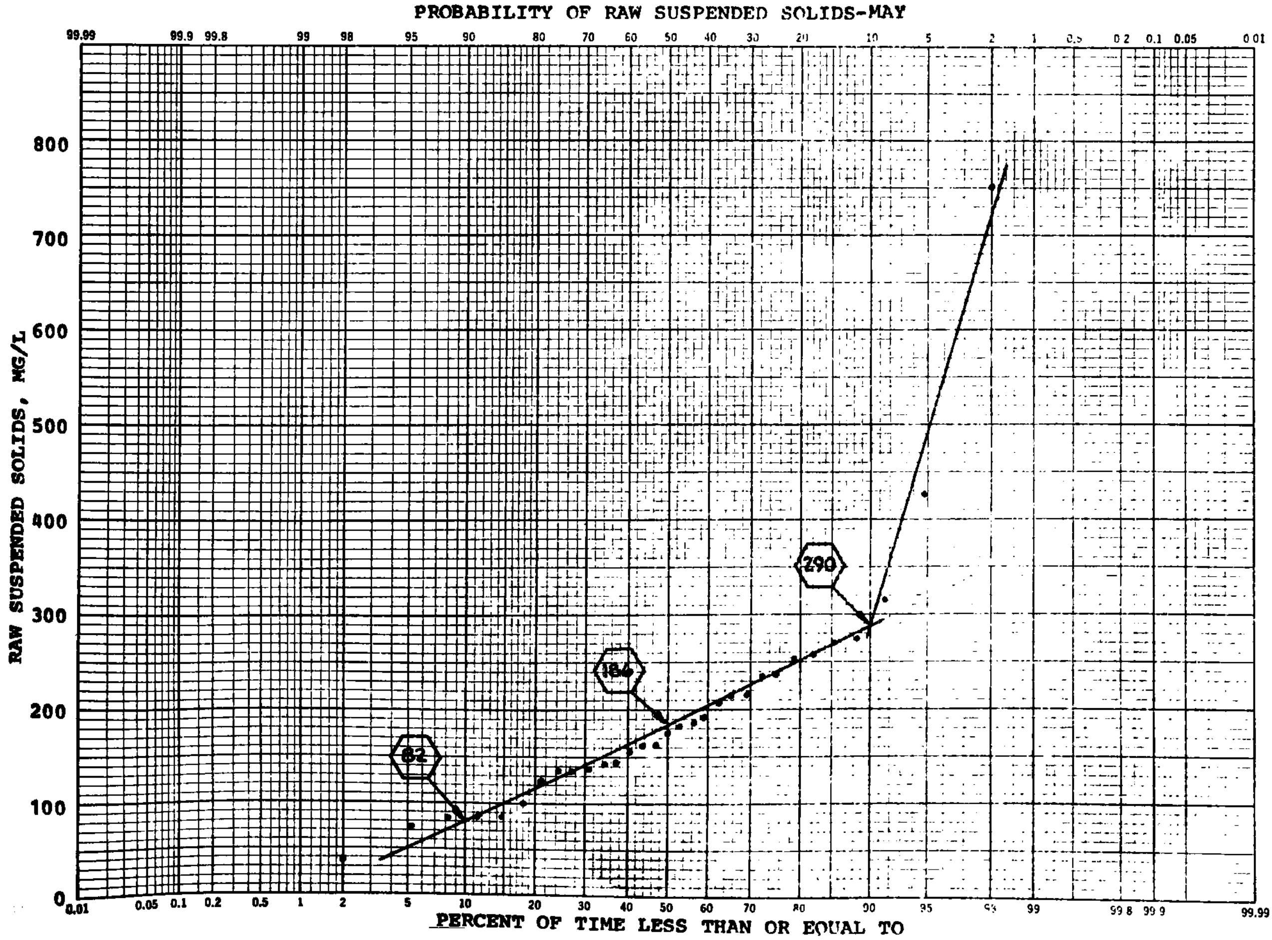
PROBABILITY OF RAW SUSPENDED SOLIDS-APR.



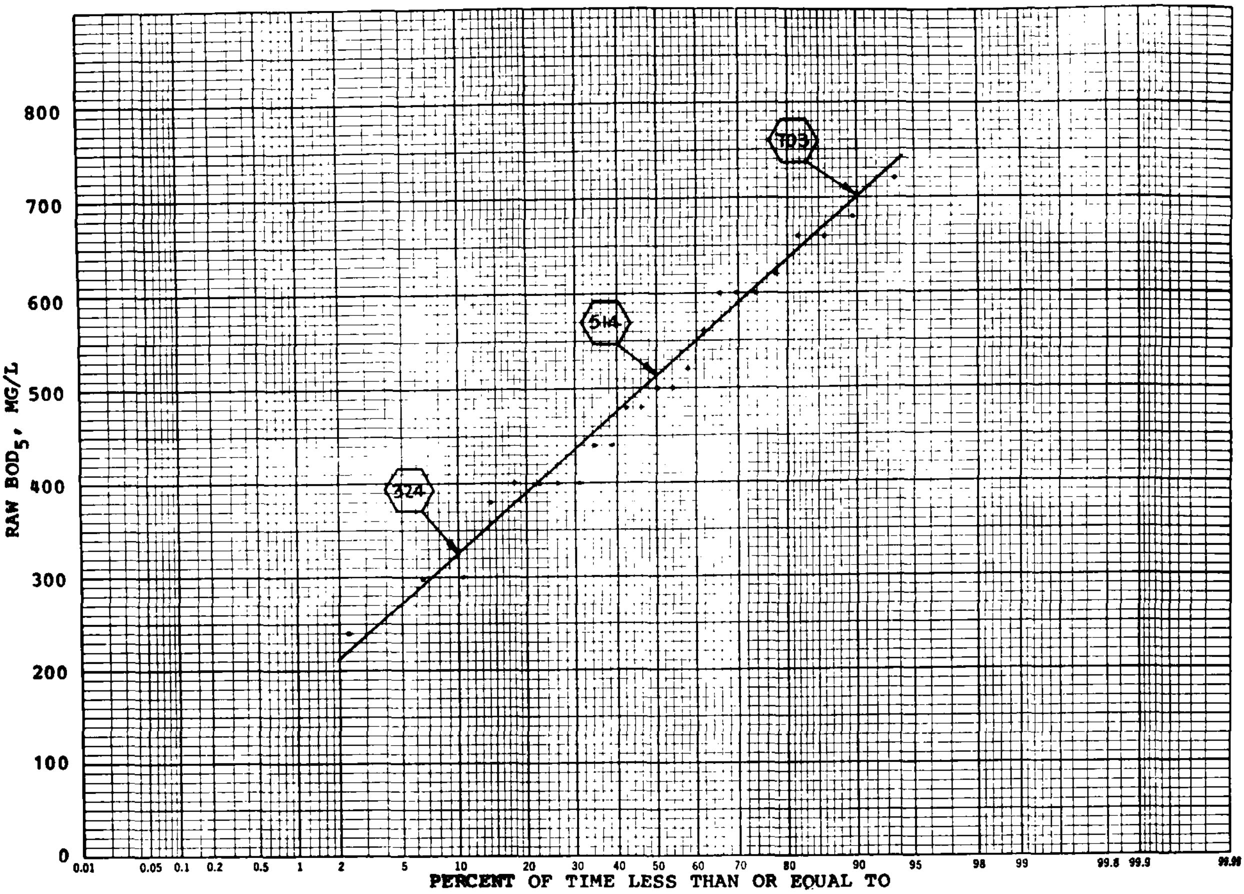
PROBABILITY OF RAW BOD-MAY



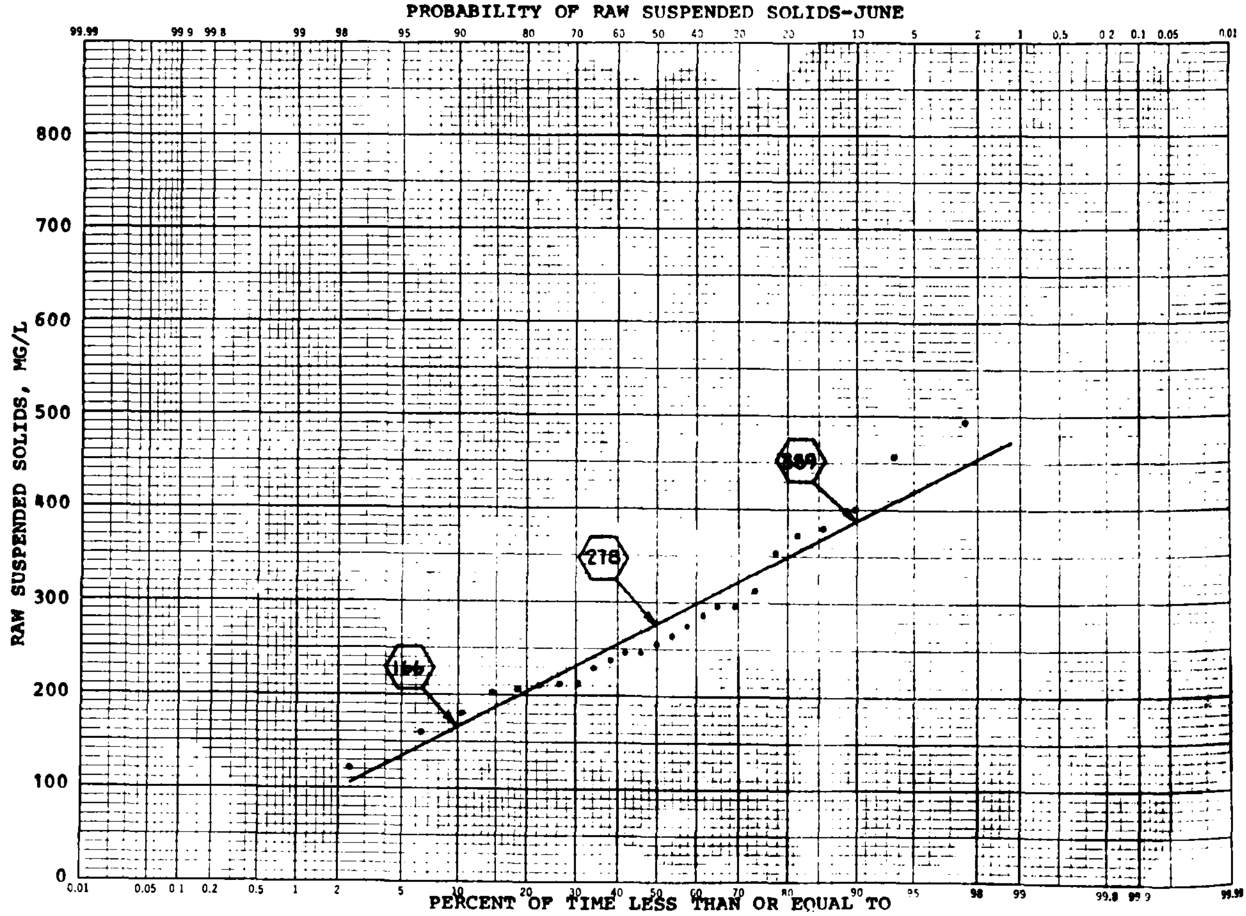
PROBABILITY OF RAW SUSPENDED SOLIDS-MAY



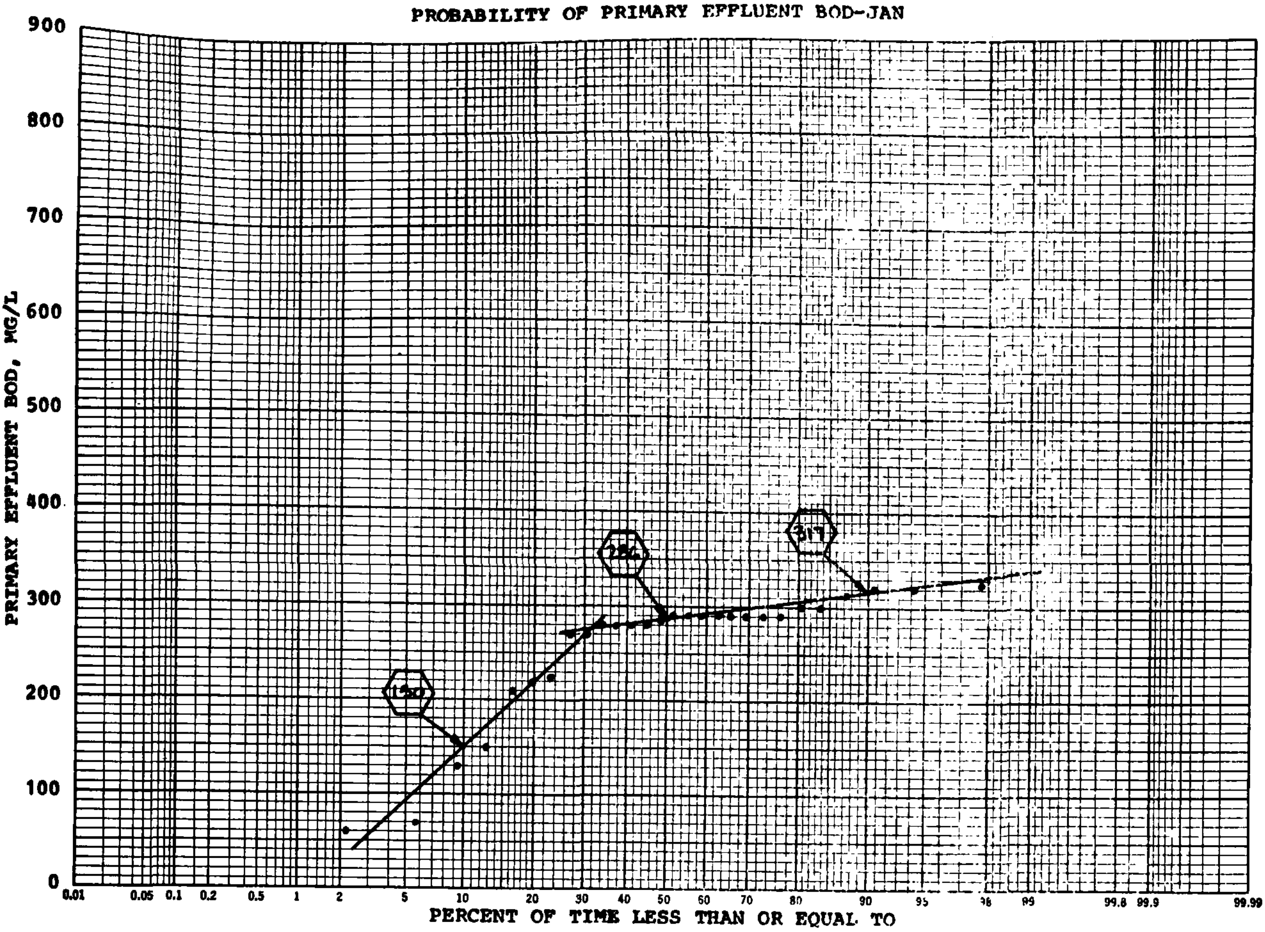
PROBABILITY OF RAW BOD-JUNE



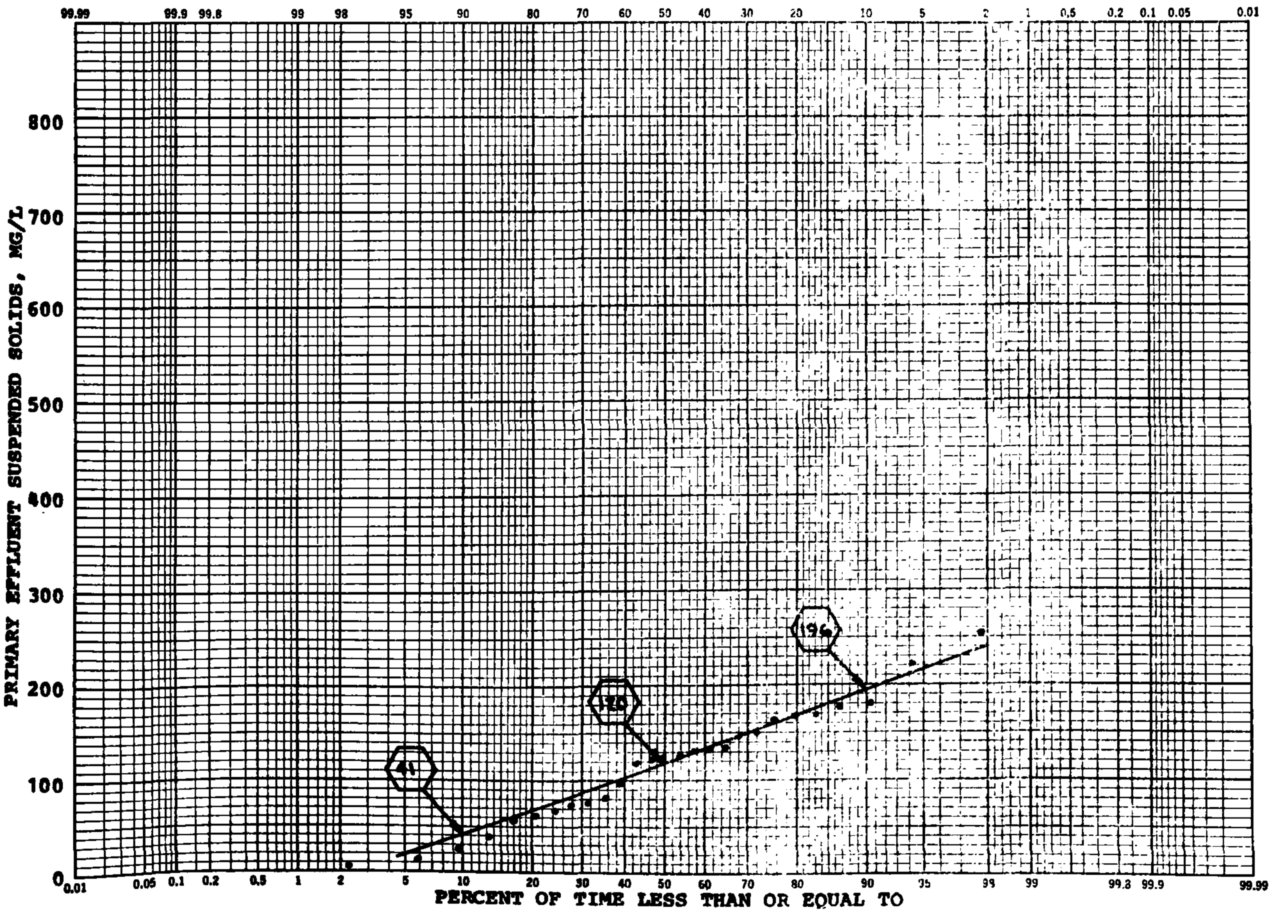
PROBABILITY OF RAW SUSPENDED SOLIDS-JUNE



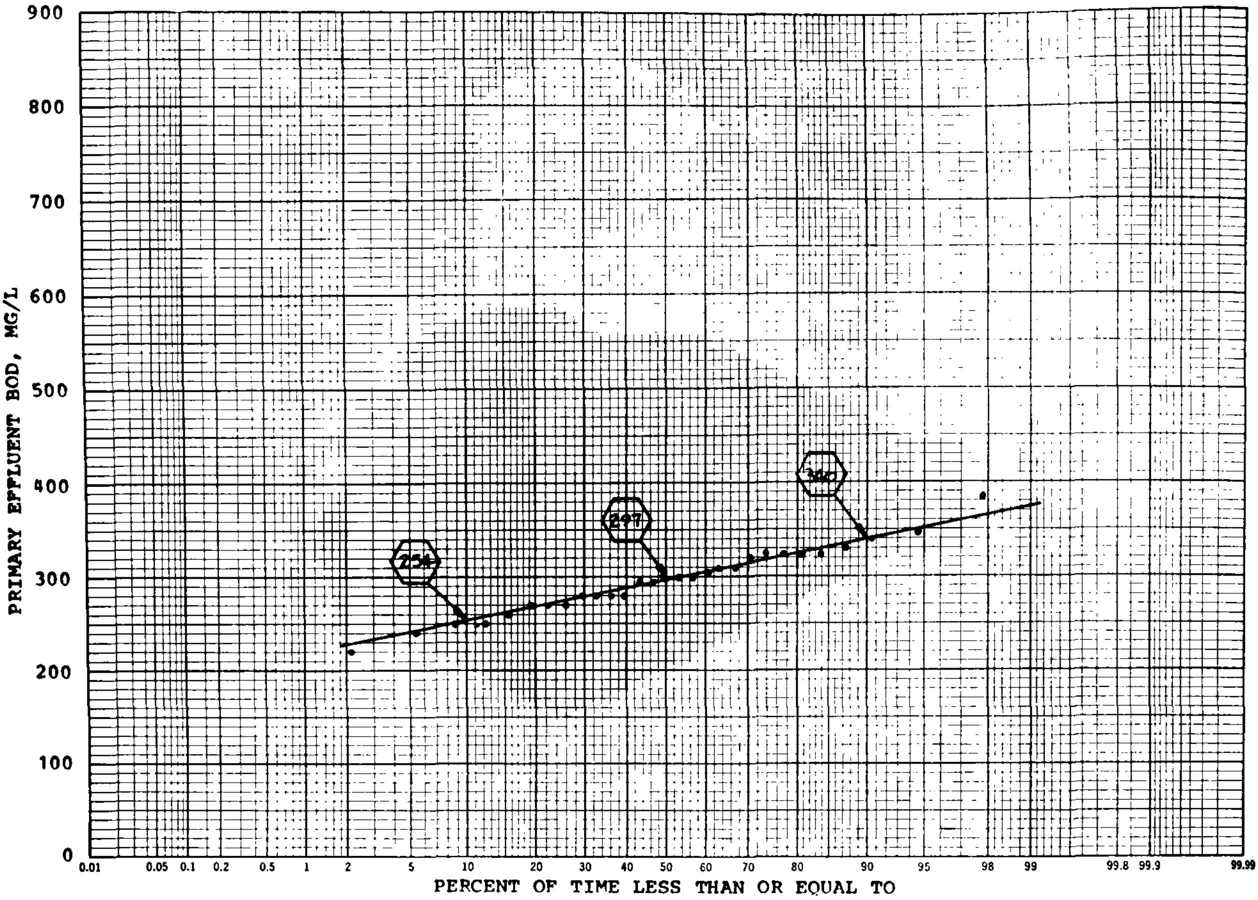
PROBABILITY OF PRIMARY EFFLUENT BOD-JAN



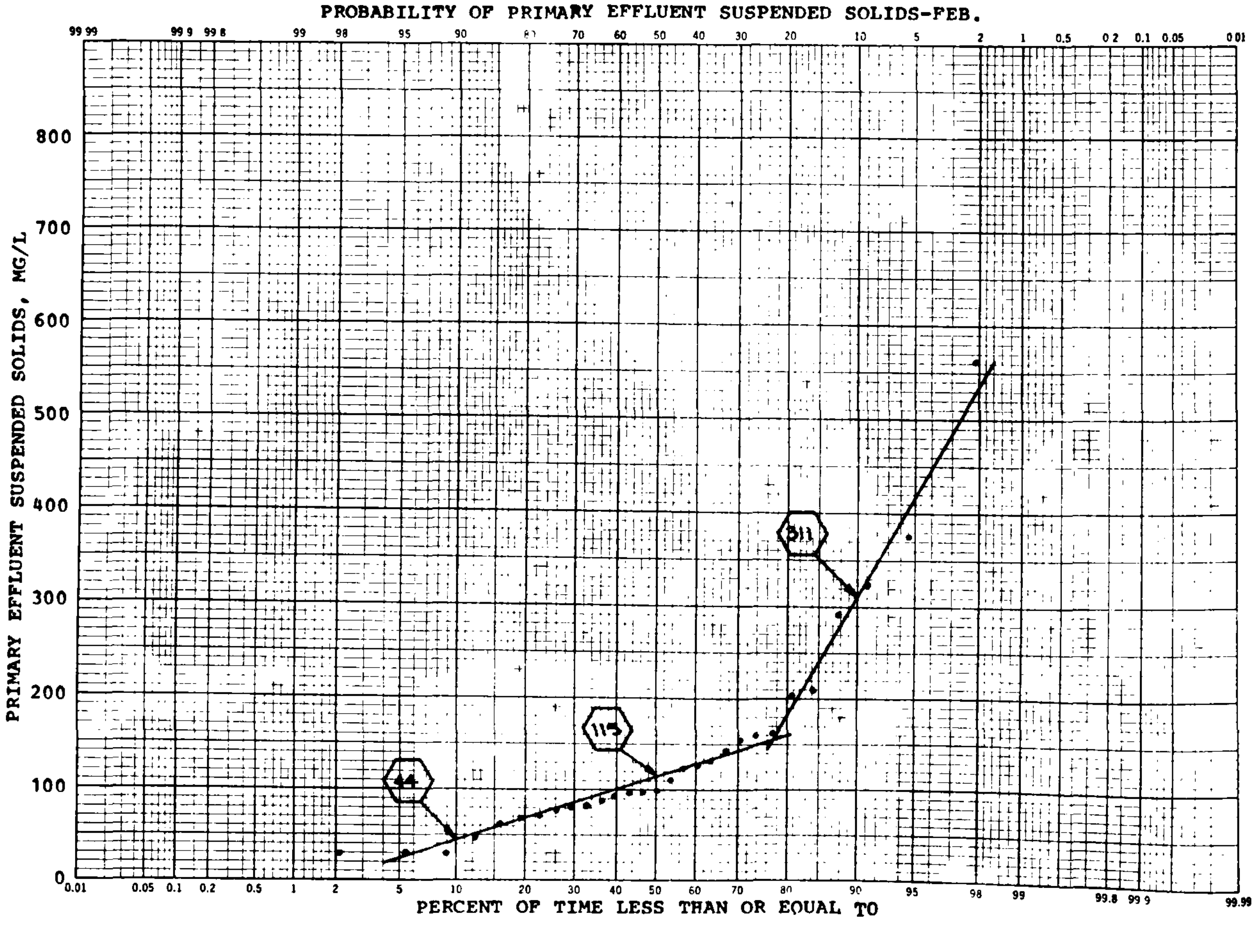
PROBABILITY OF PRIMARY EFFLUENT SUSPENDED SOLIDS-JAN.



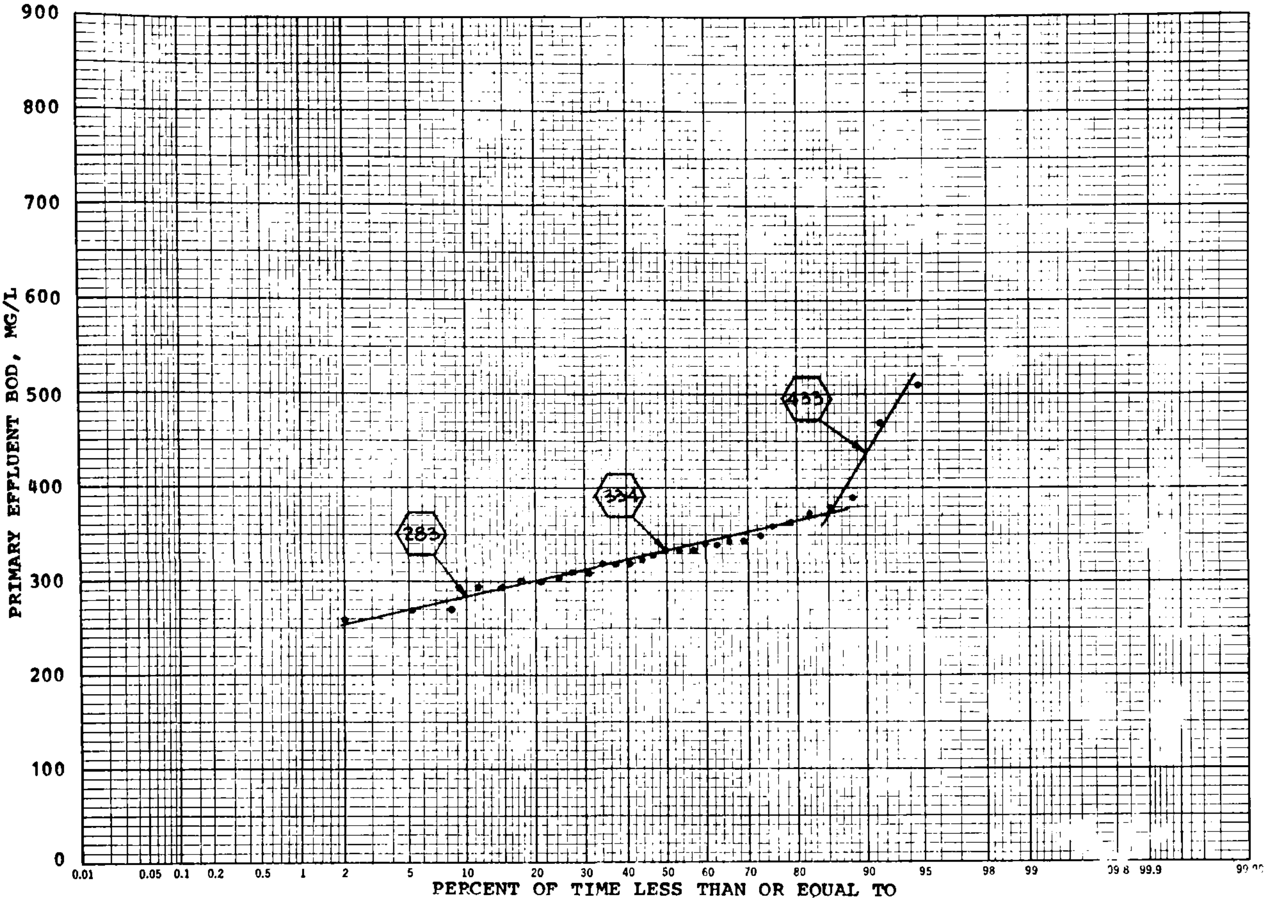
PROBABILITY OF PRIMARY EFFLUENT BOD-FEB.



PROBABILITY OF PRIMARY EFFLUENT SUSPENDED SOLIDS-FEB.



PROBABILITY OF PRIMARY EFFLUENT BOD-MAR.



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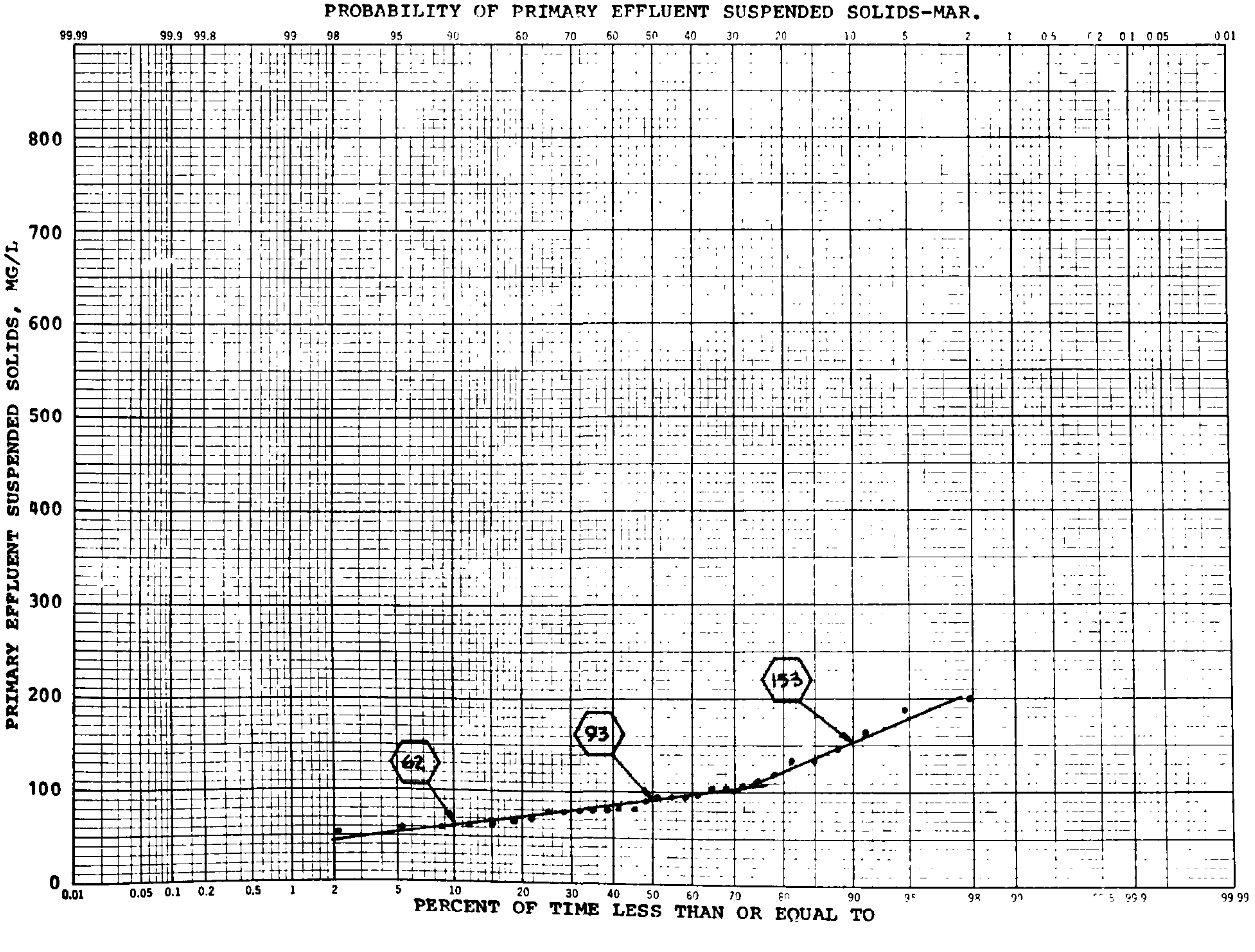
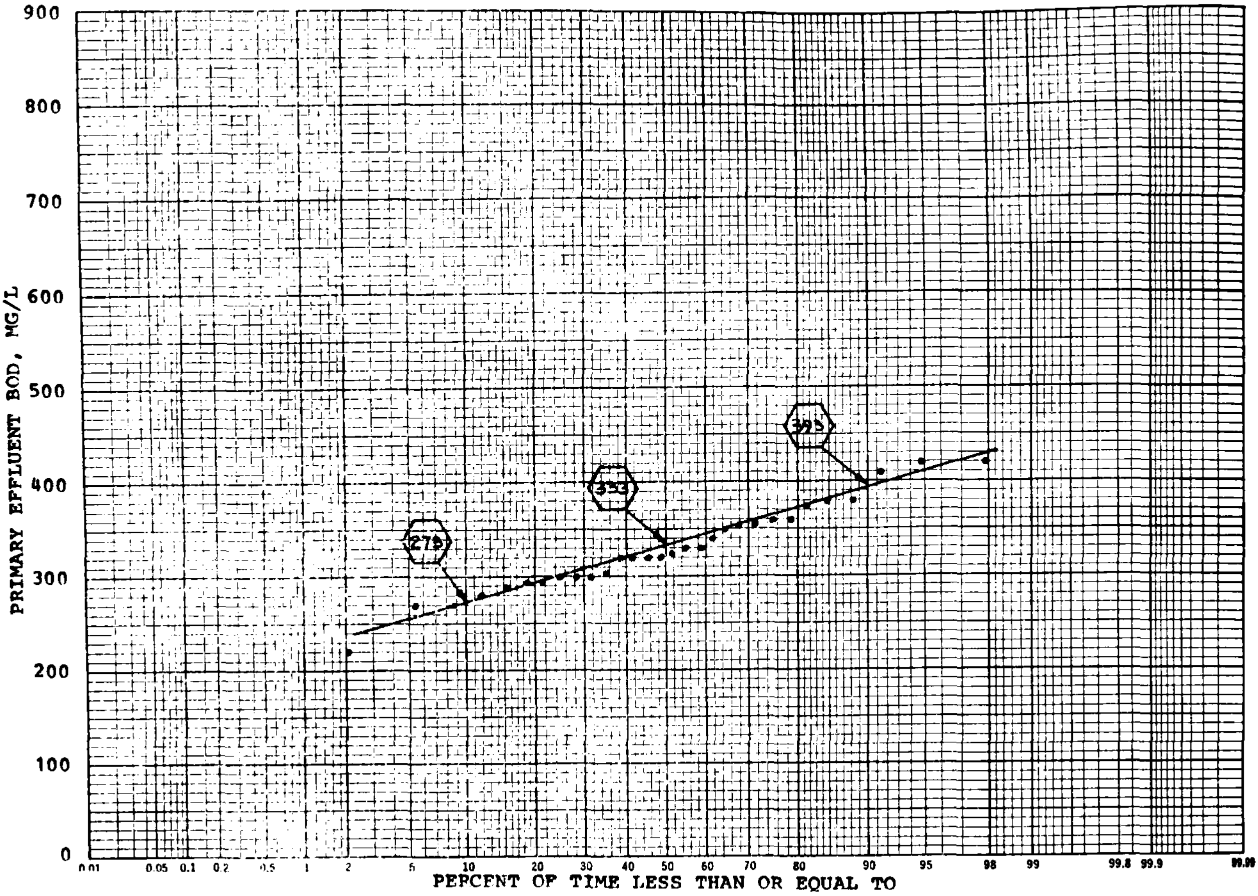
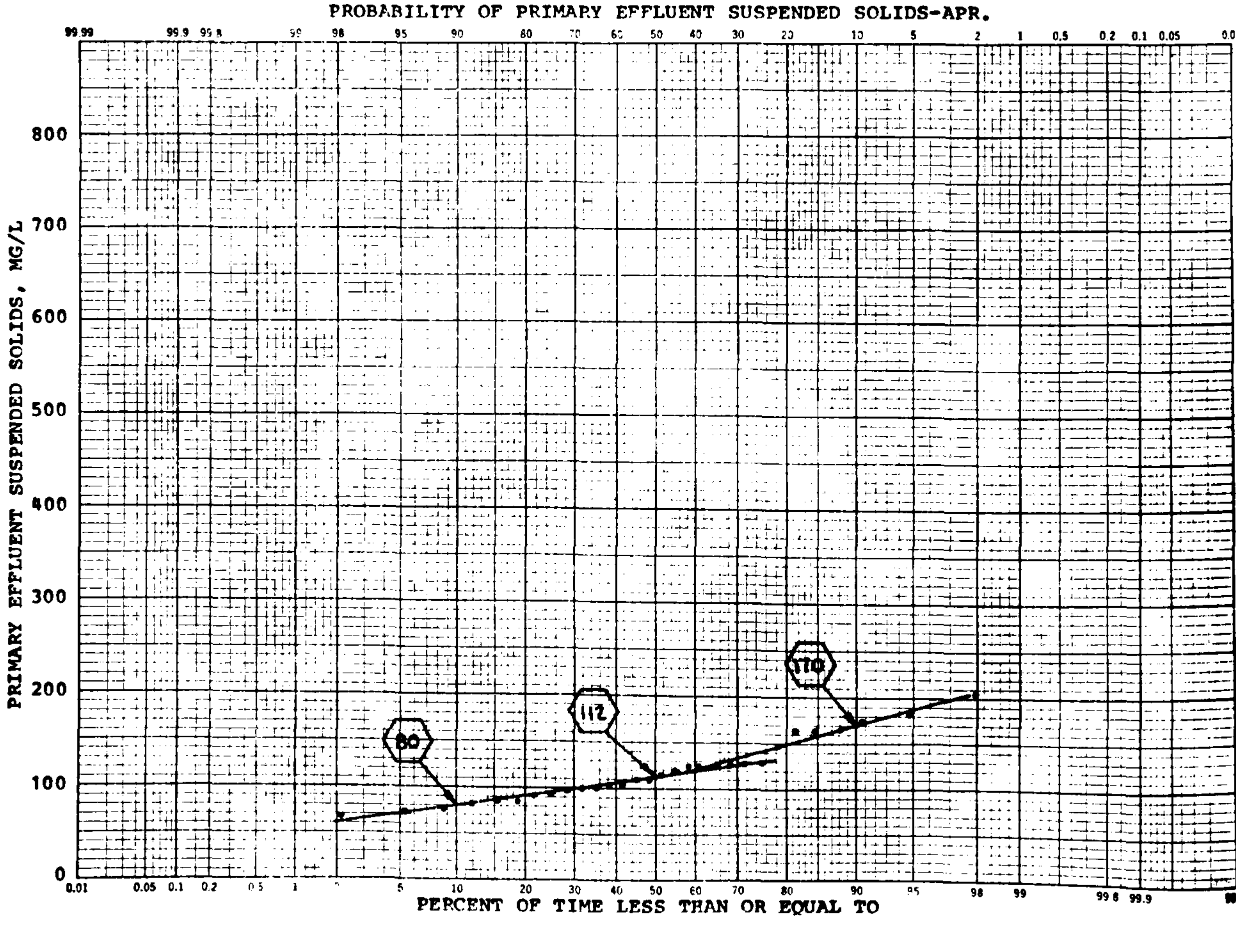


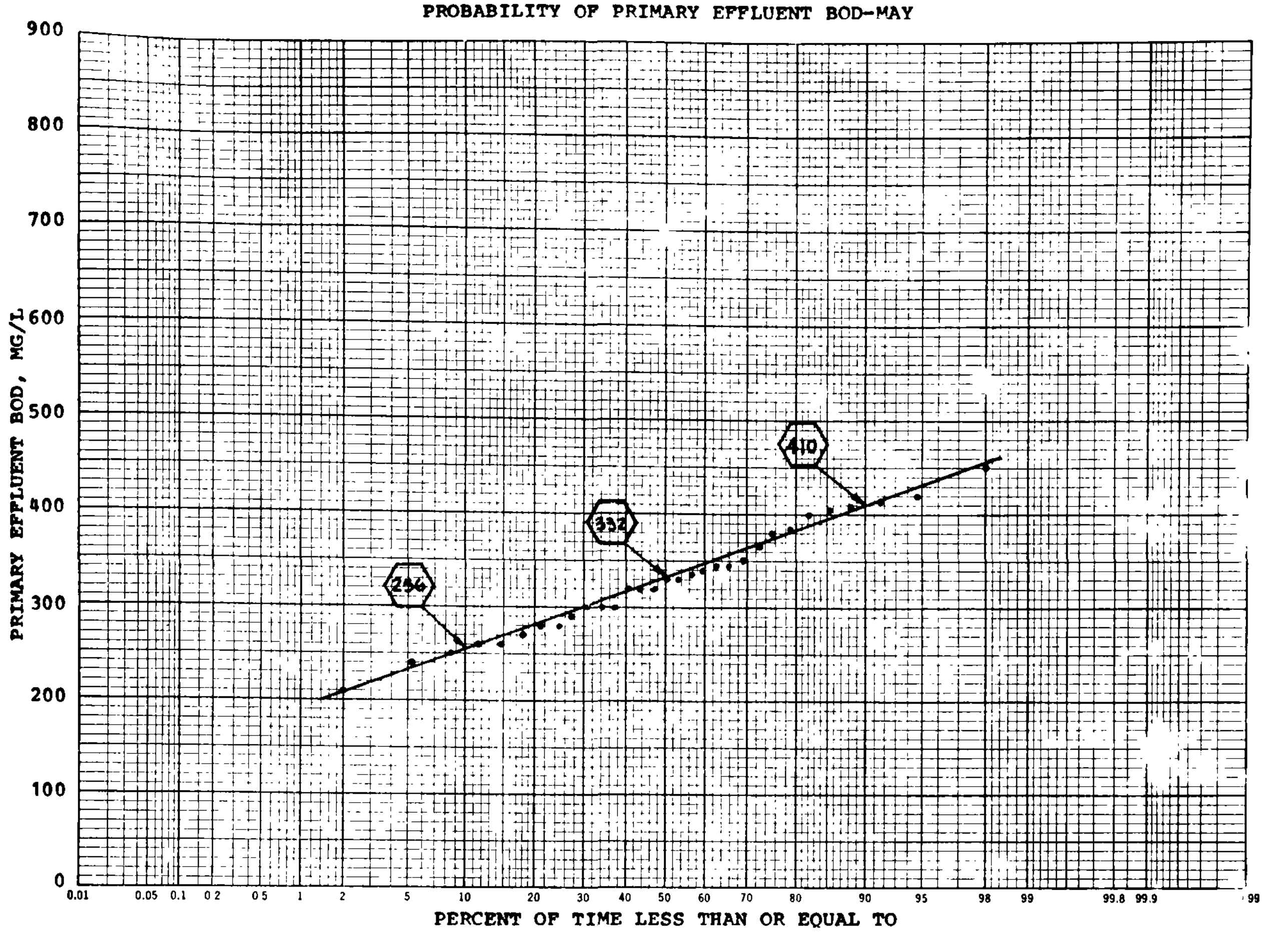
PROBABILITY OF PRIMARY EFFLUENT BOD-APR.



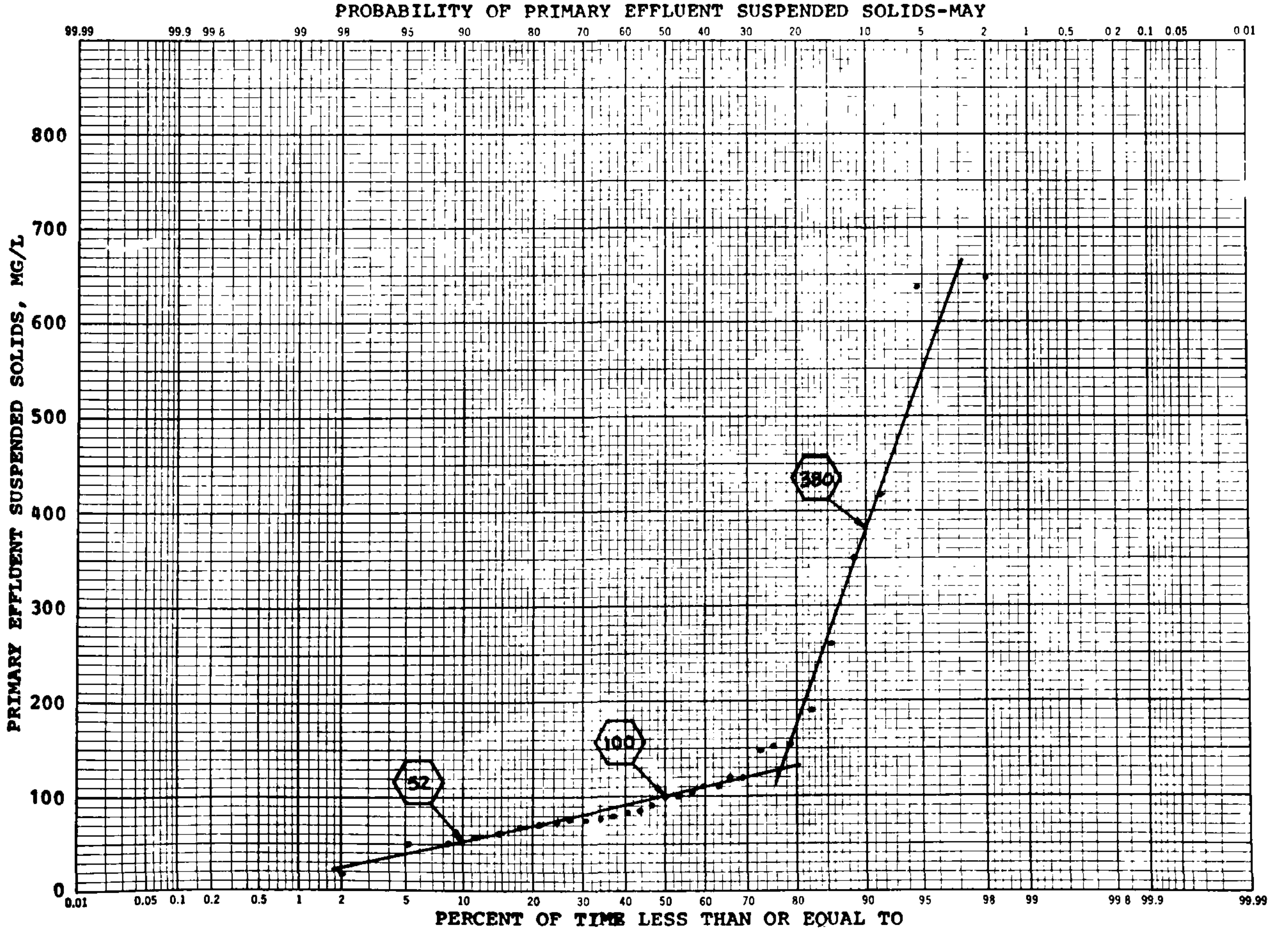
PROBABILITY OF PRIMARY EFFLUENT SUSPENDED SOLIDS-APR.



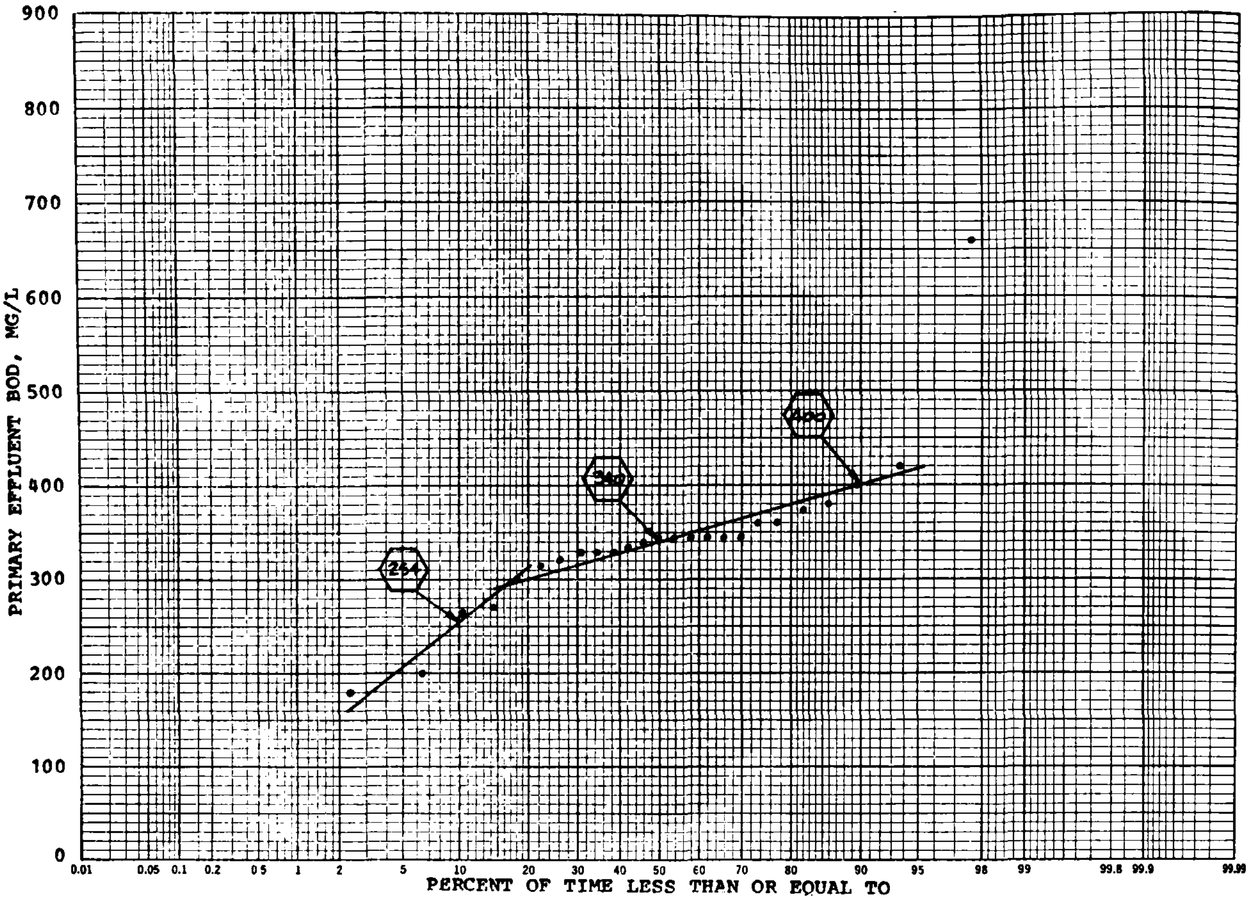
PROBABILITY OF PRIMARY EFFLUENT BOD-MAY



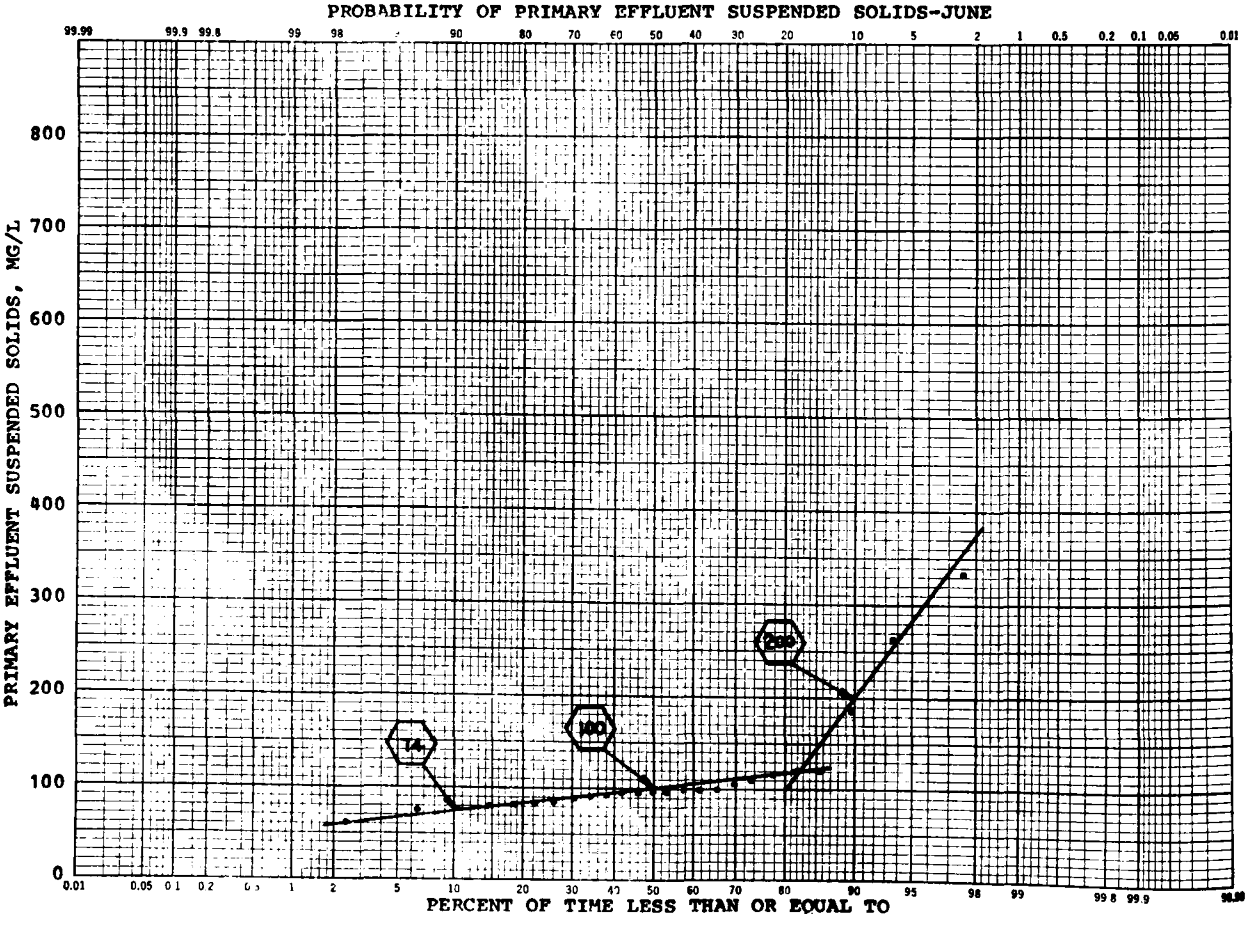
PROBABILITY OF PRIMARY EFFLUENT SUSPENDED SOLIDS-MAY



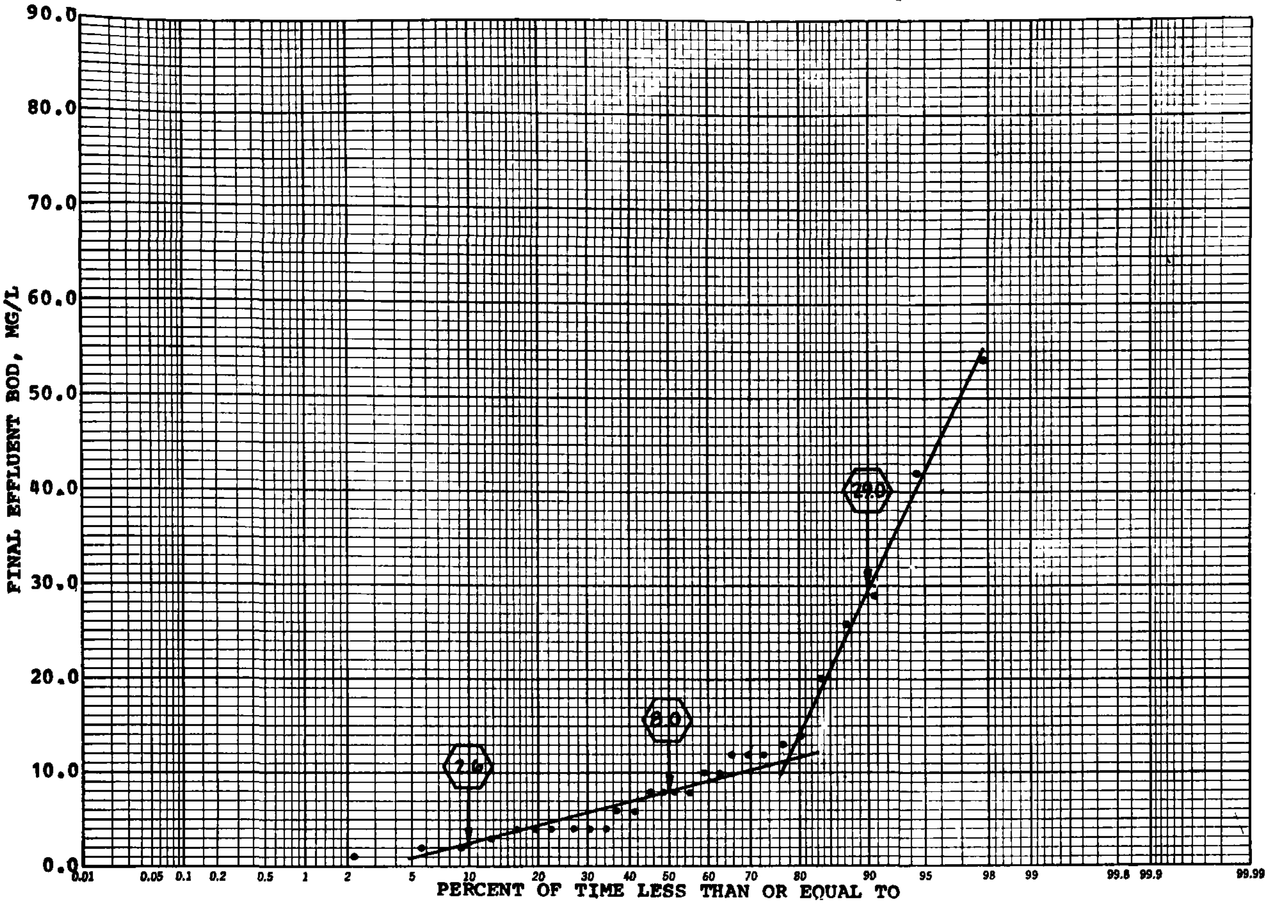
PROBABILITY OF PRIMARY EFFLUENT BOD-JUNE



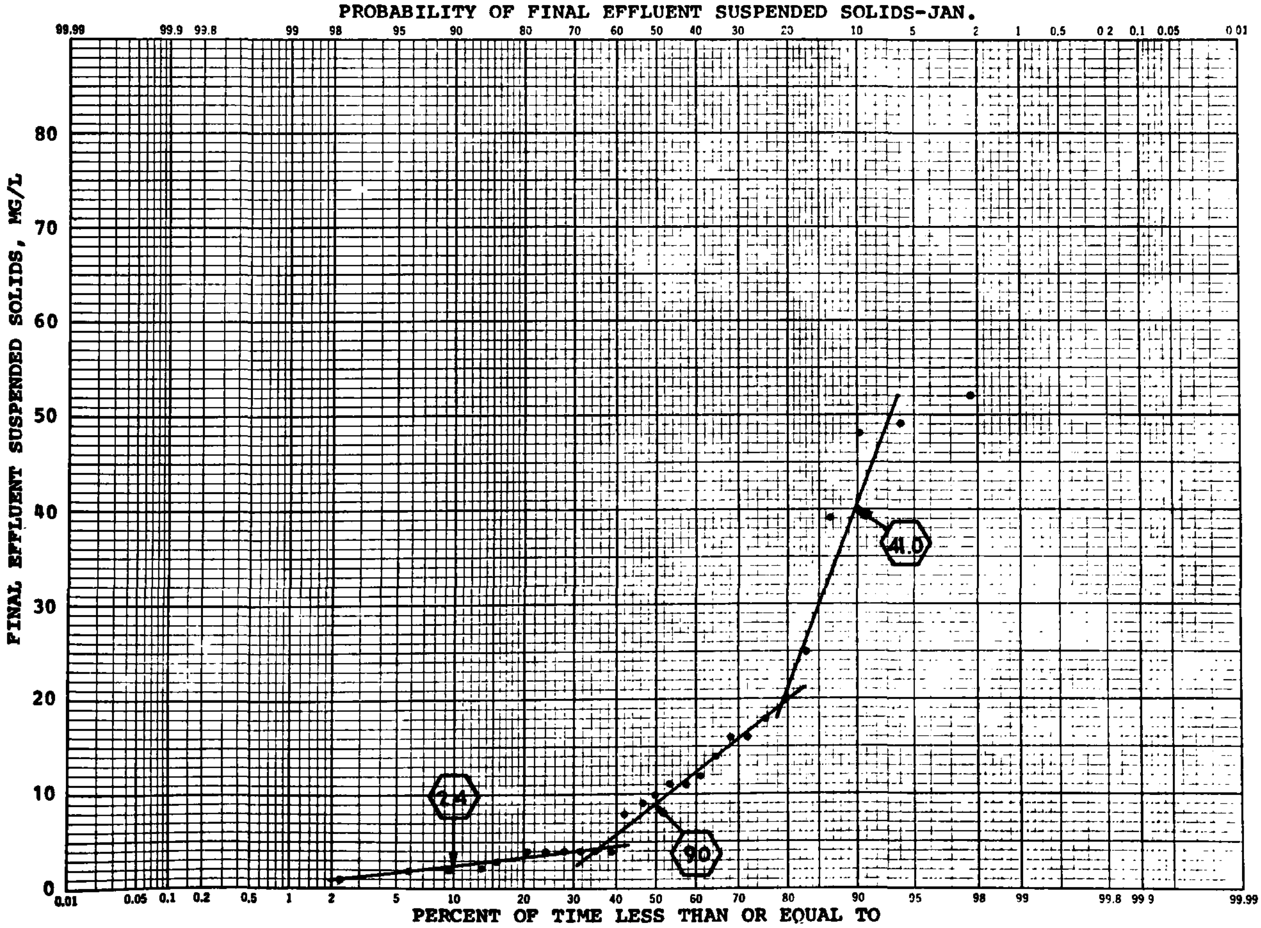
PROBABILITY OF PRIMARY EFFLUENT SUSPENDED SOLIDS-JUNE



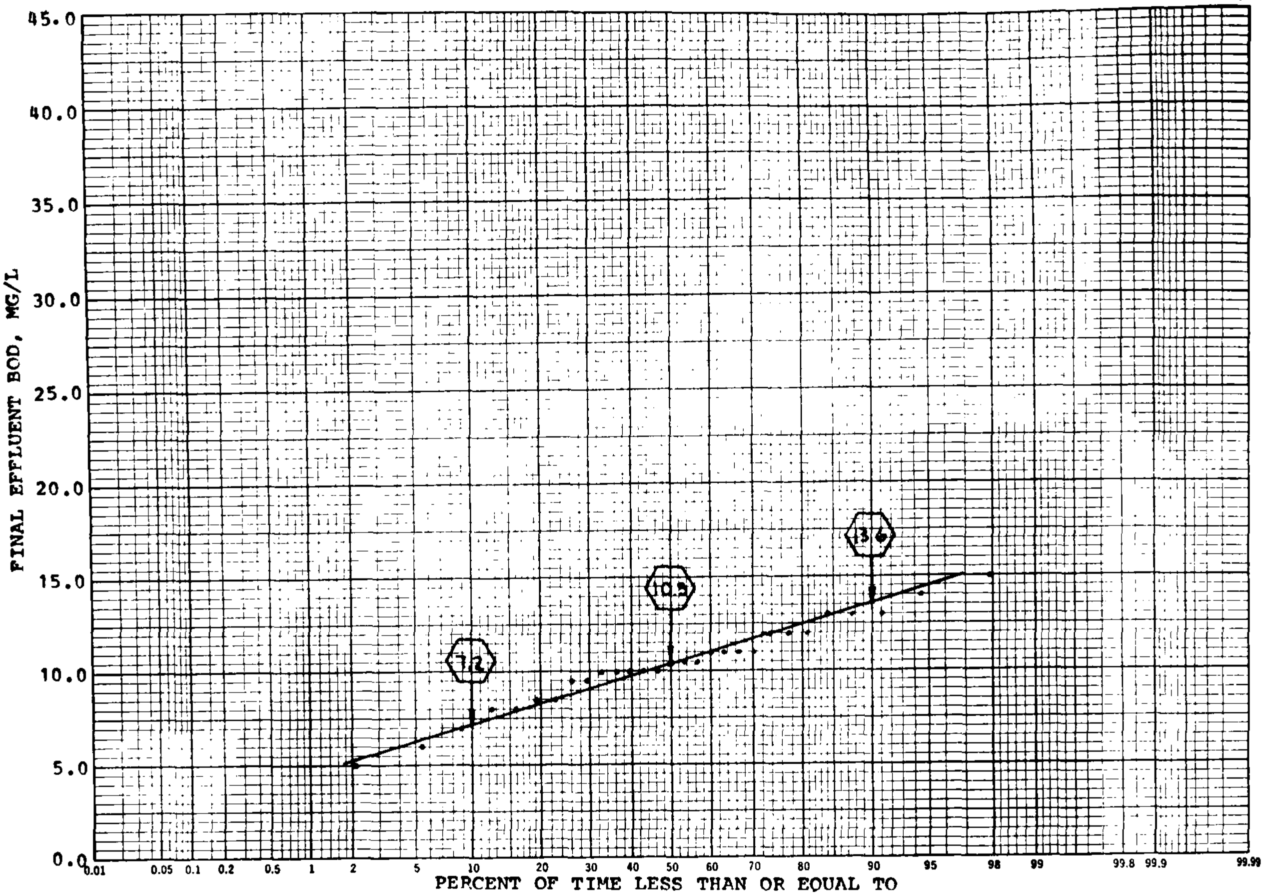
PROBABILITY OF FINAL EFFLUENT BOD-JAN.



PROBABILITY OF FINAL EFFLUENT SUSPENDED SOLIDS-JAN.



PROBABILITY OF FINAL EFFLUENT BOD-FEB.



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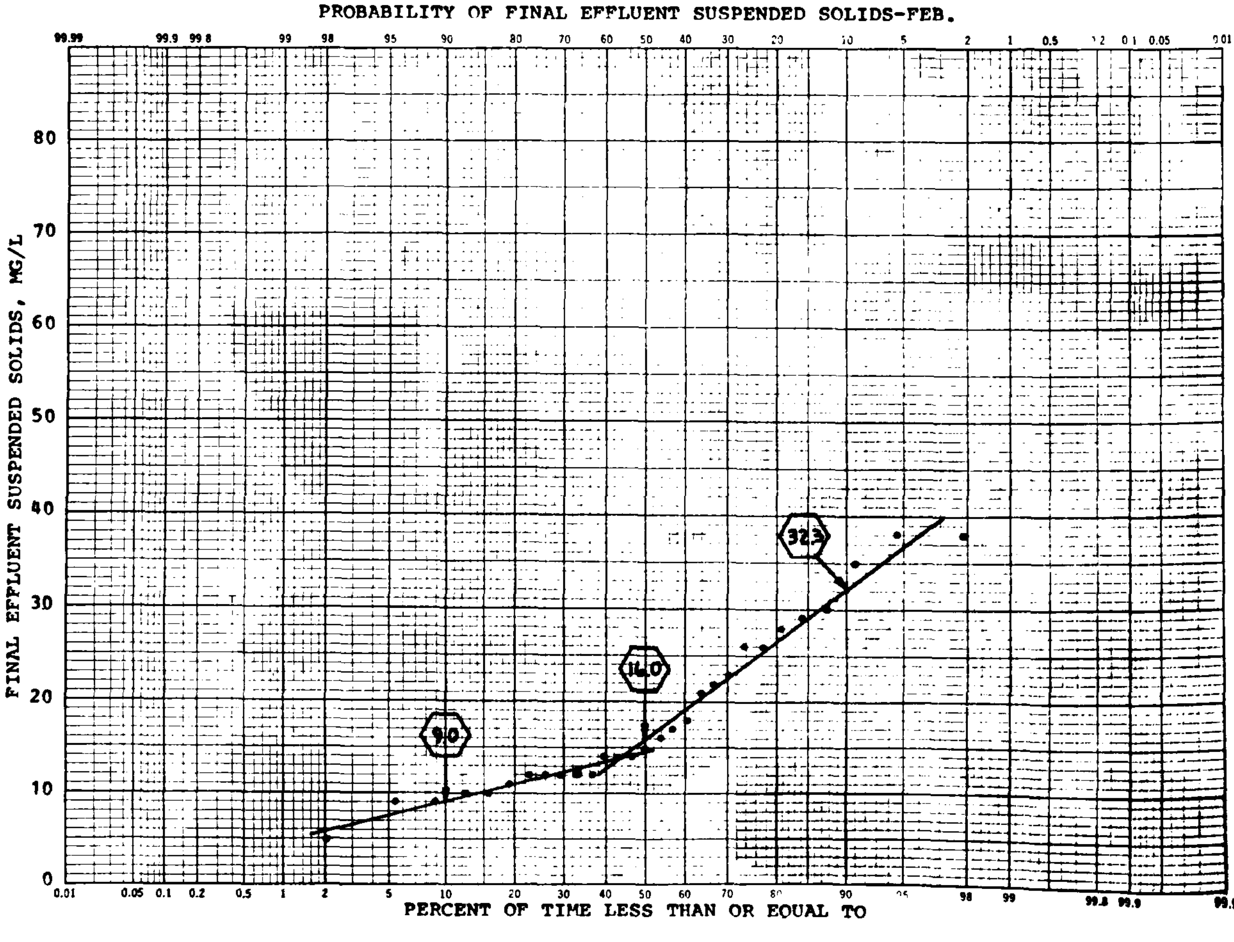

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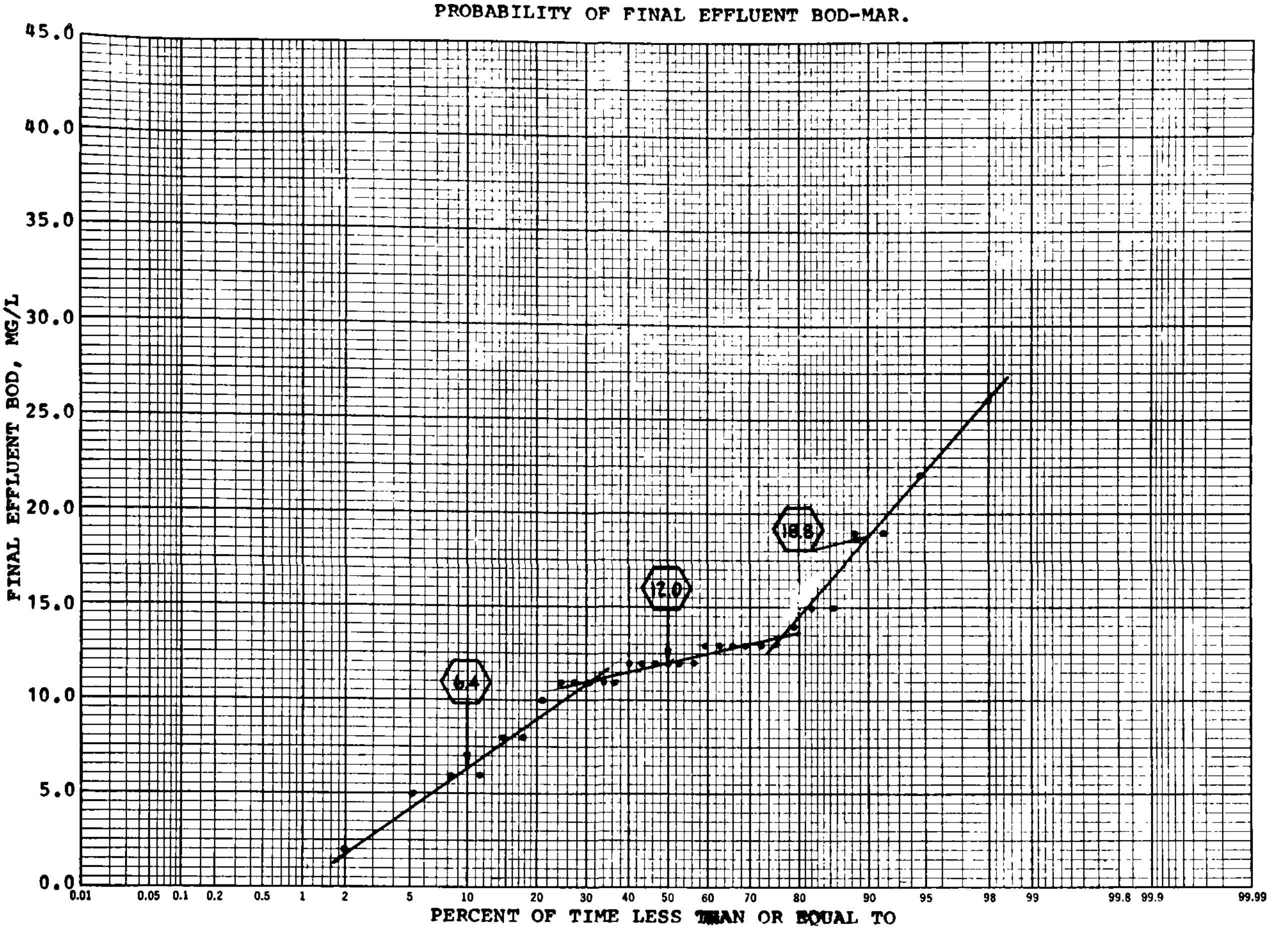

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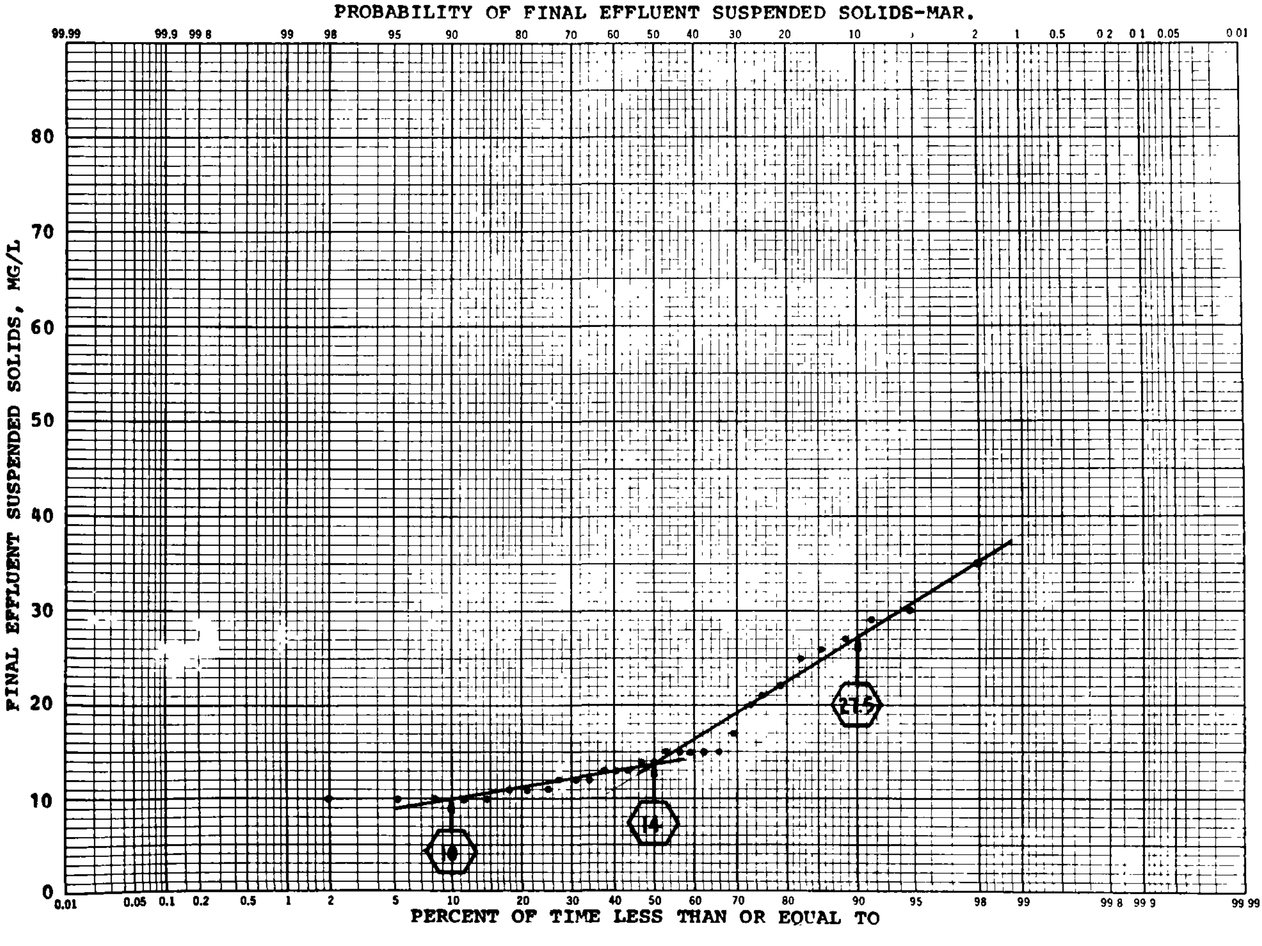
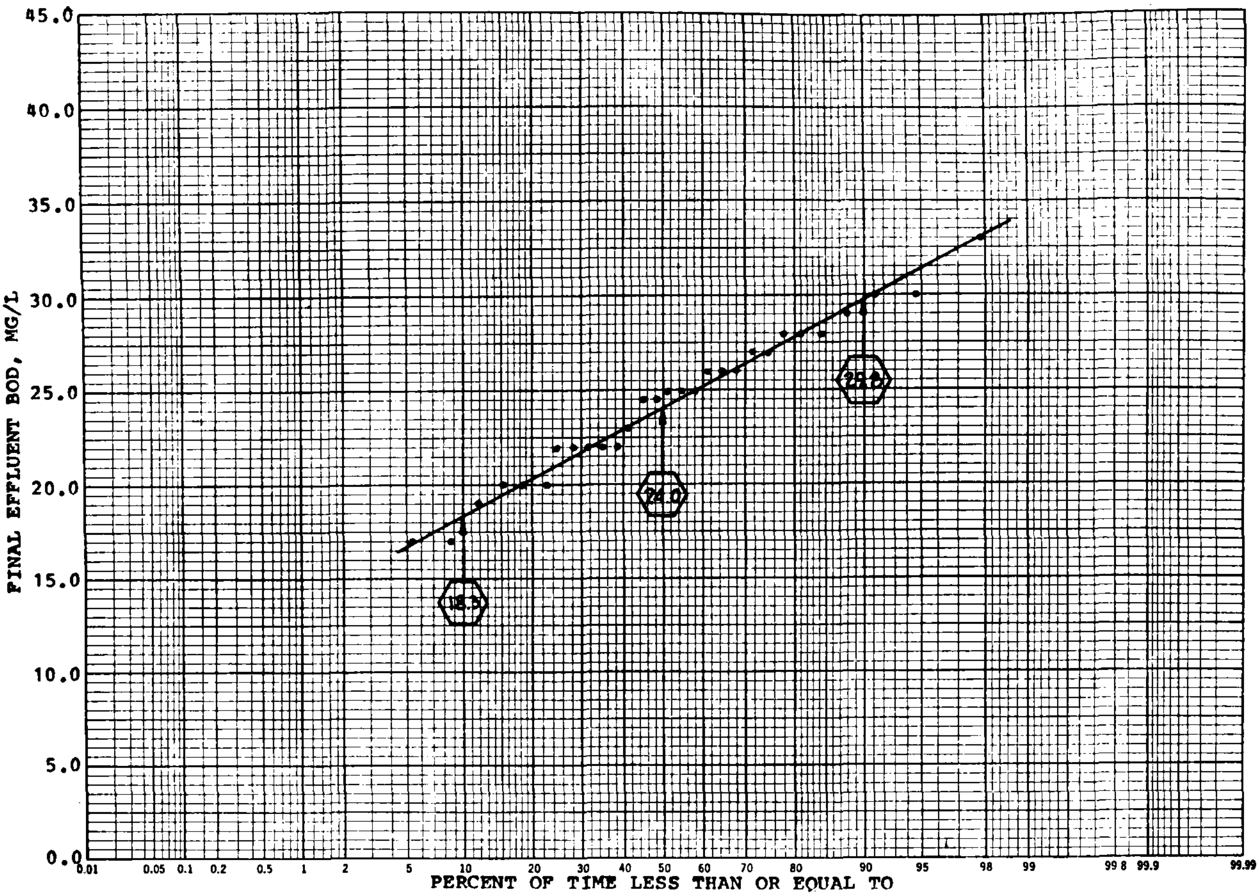


PROBABILITY OF FINAL EFFLUENT BOD-APRIL



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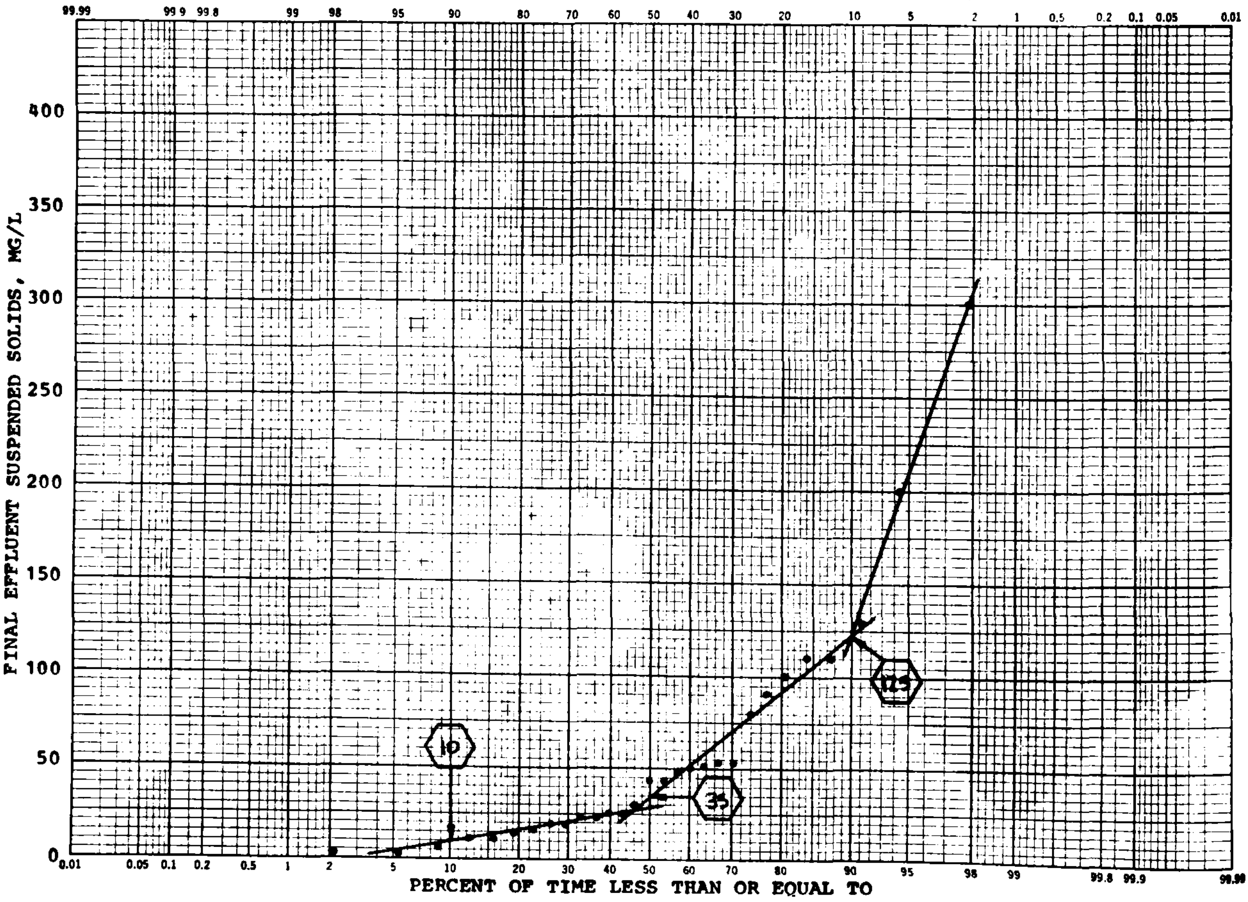
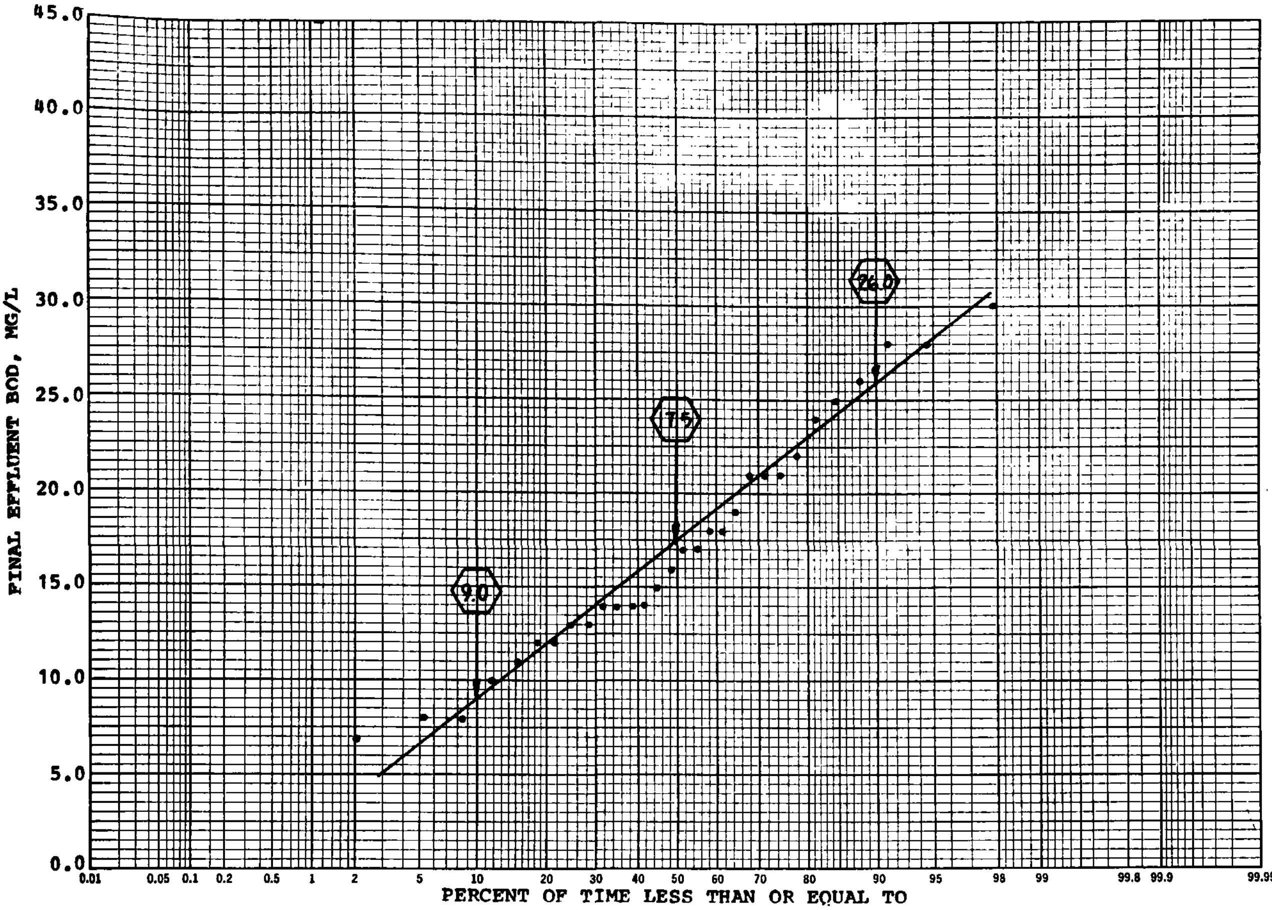
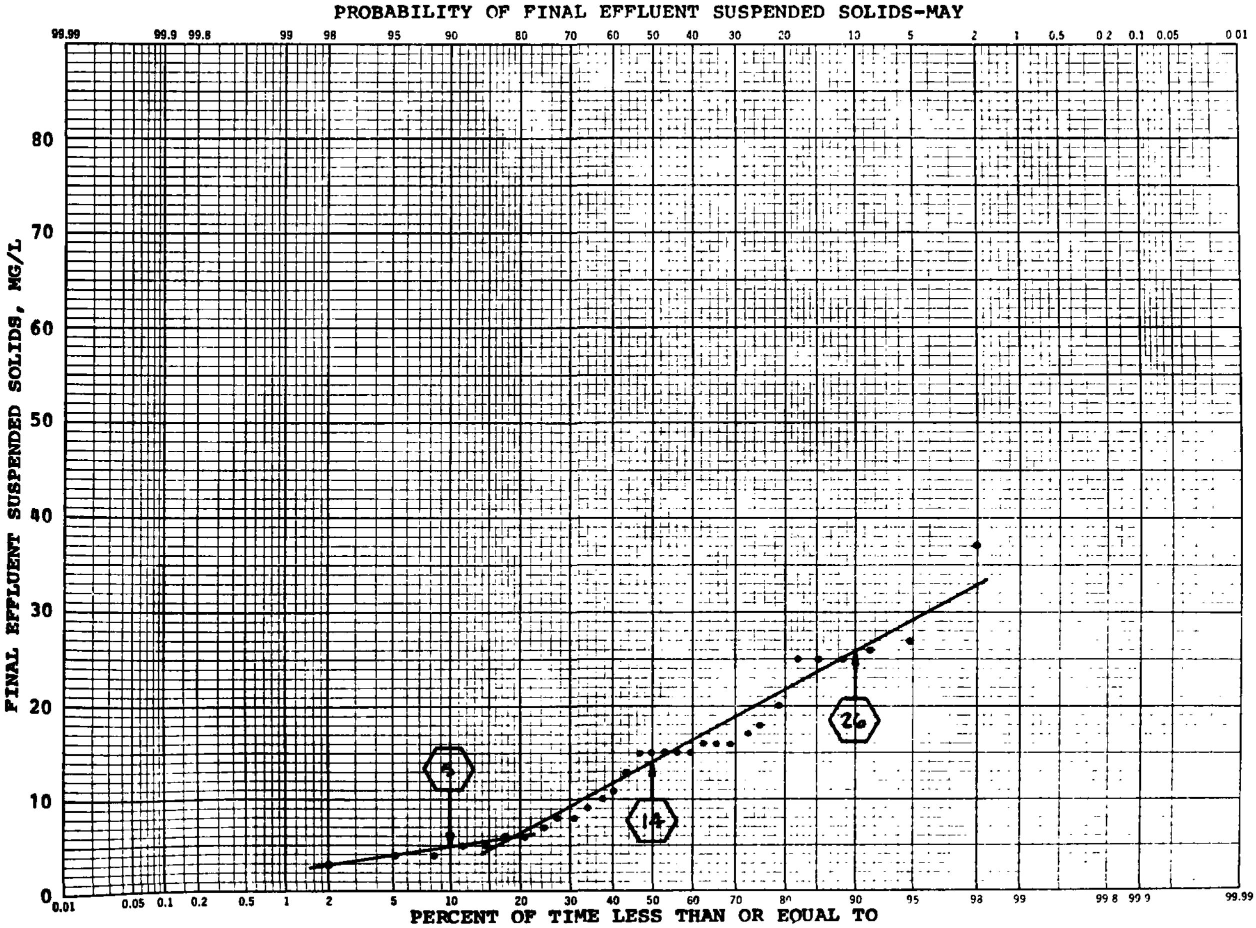


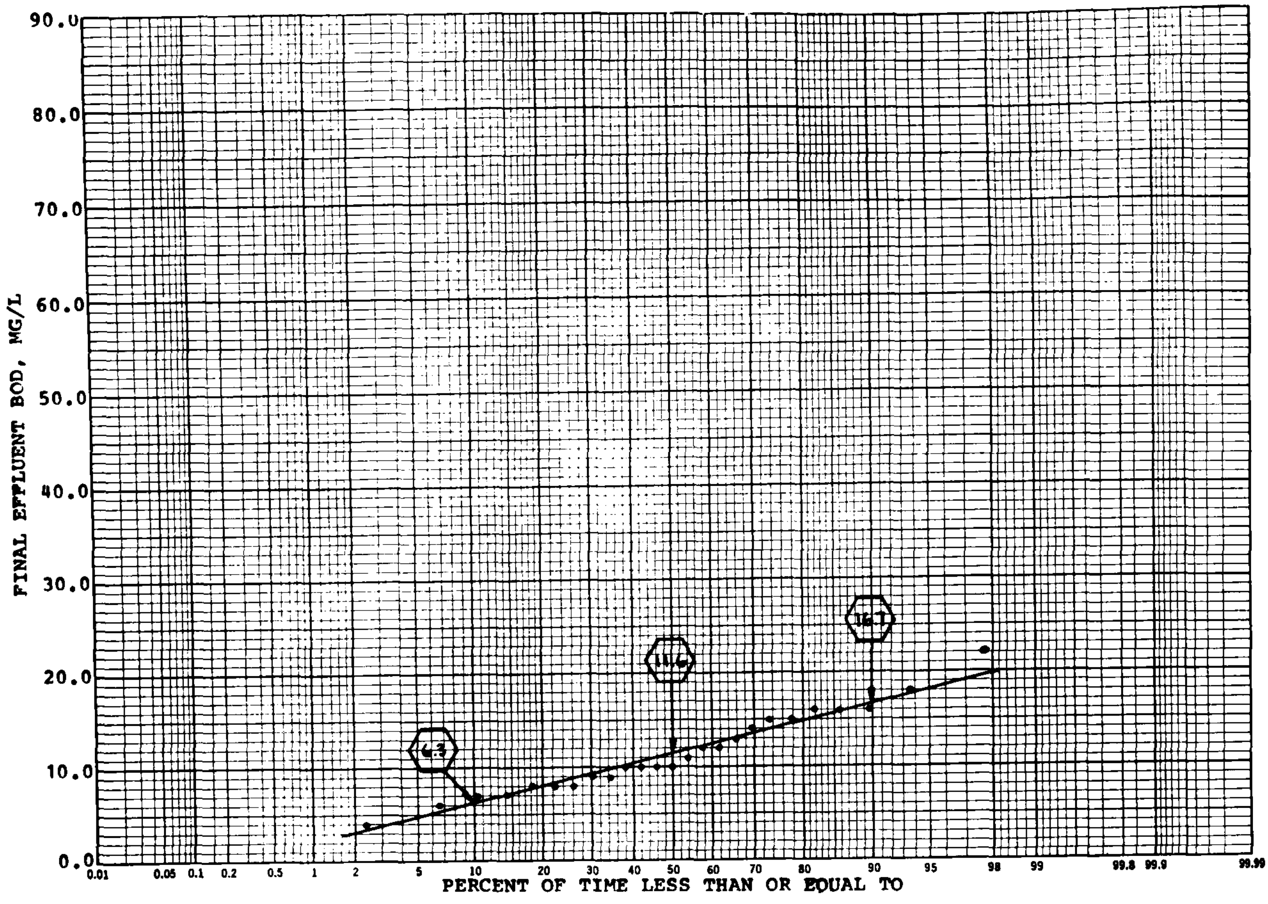
PROBABILITY OF FINAL EFFLUENT BOD-MAY



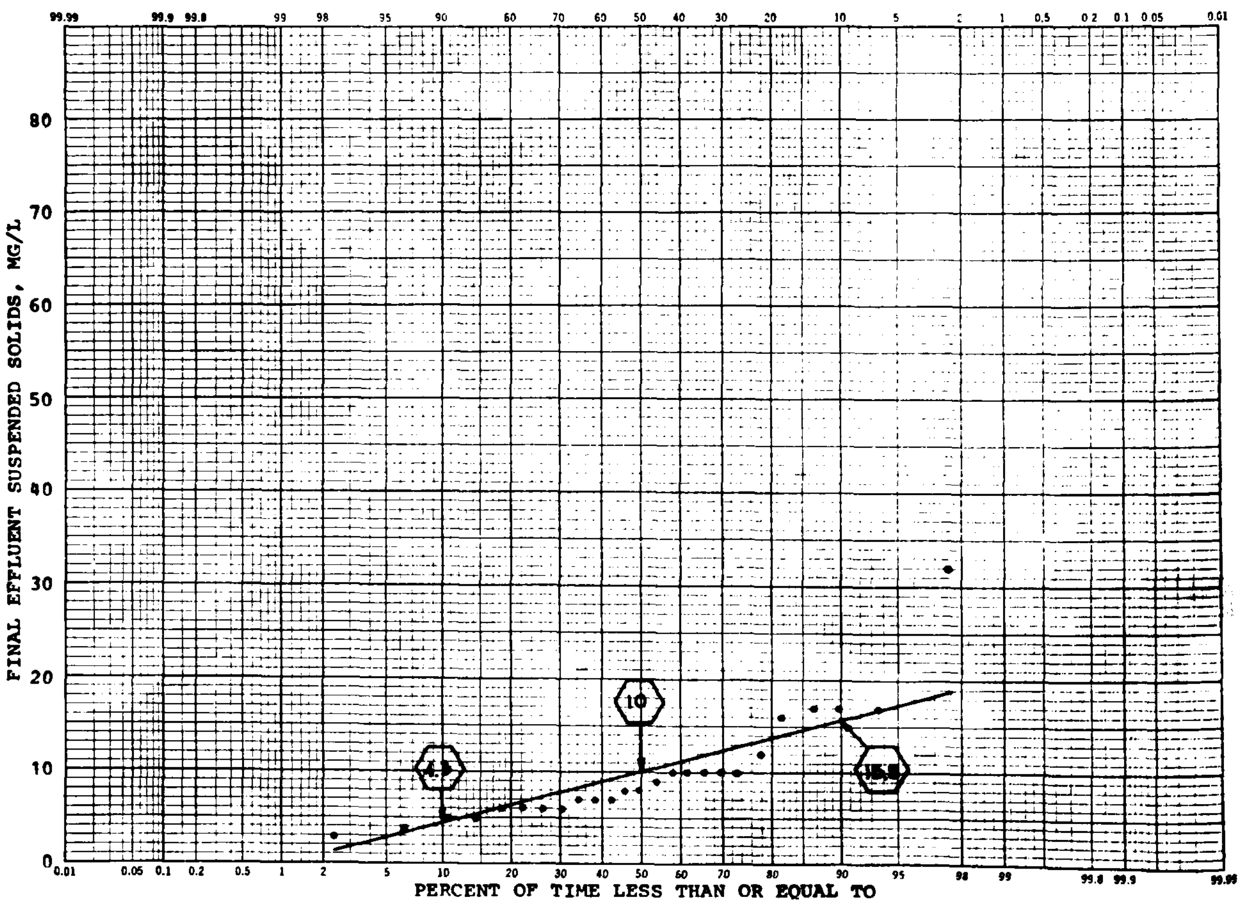
PROBABILITY OF FINAL EFFLUENT SUSPENDED SOLIDS-MAY



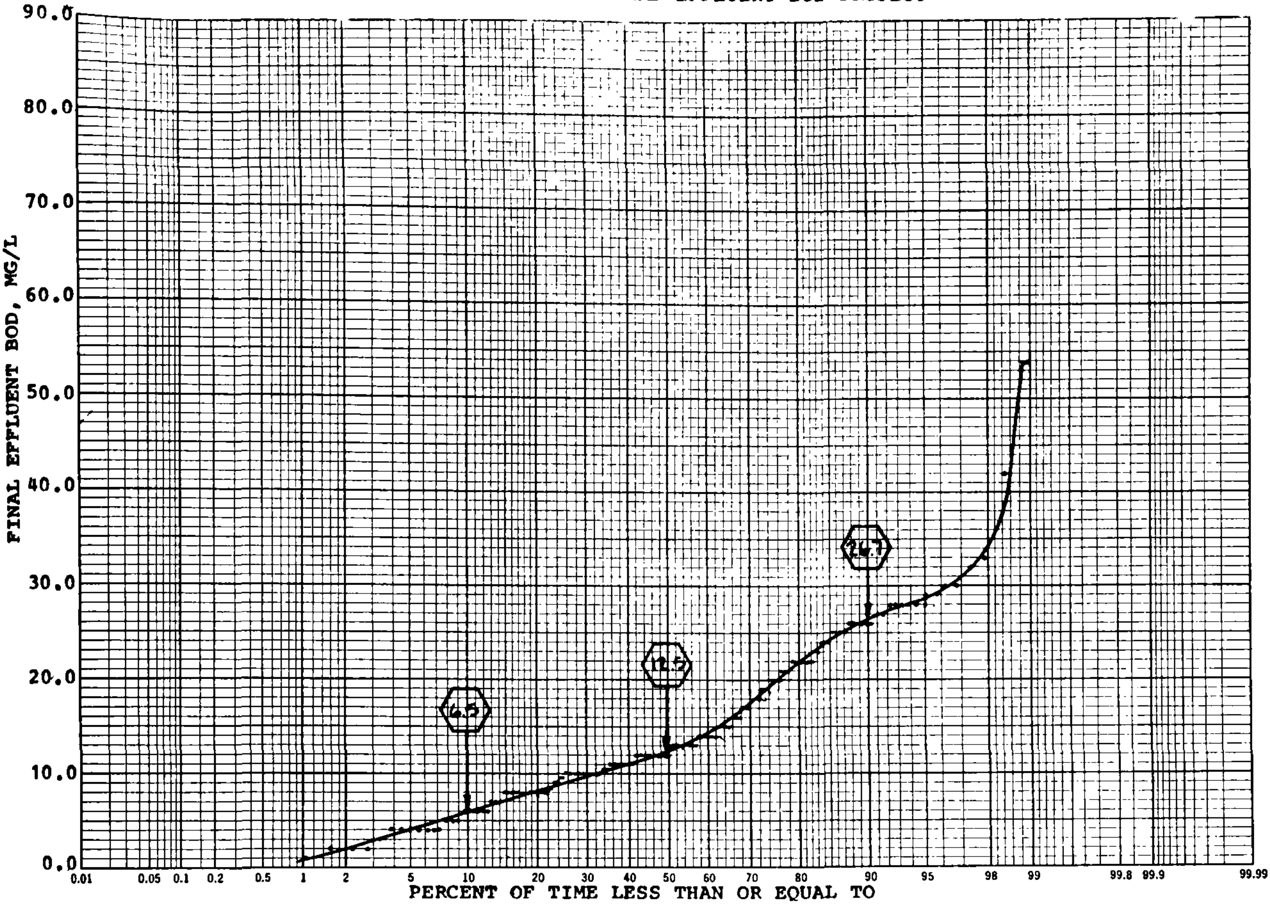
PROBABILITY OF FINAL EFFLUENT BOD-JUNE



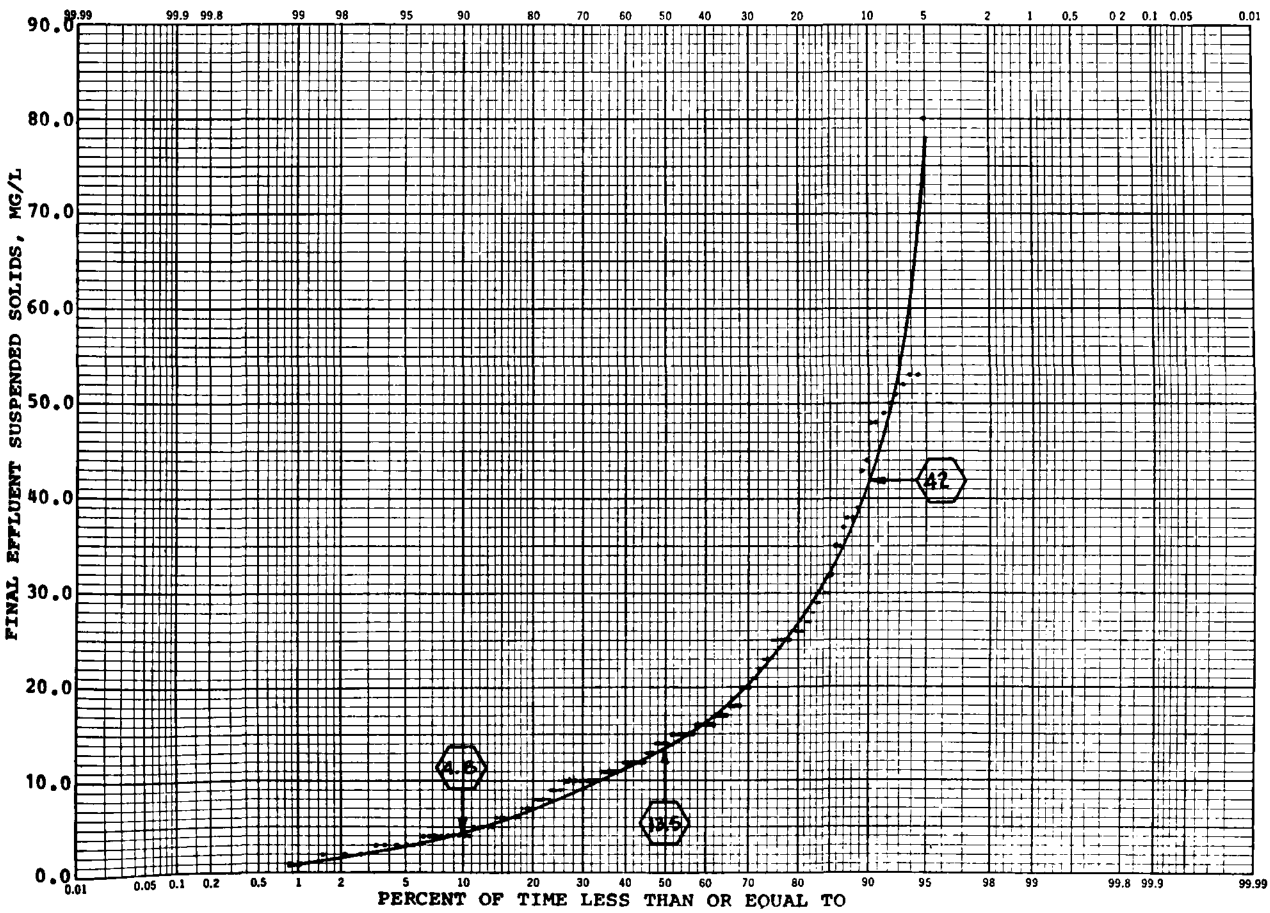
PROBABILITY OF FINAL EFFLUENT SUSPENDED SOLIDS-JUNE



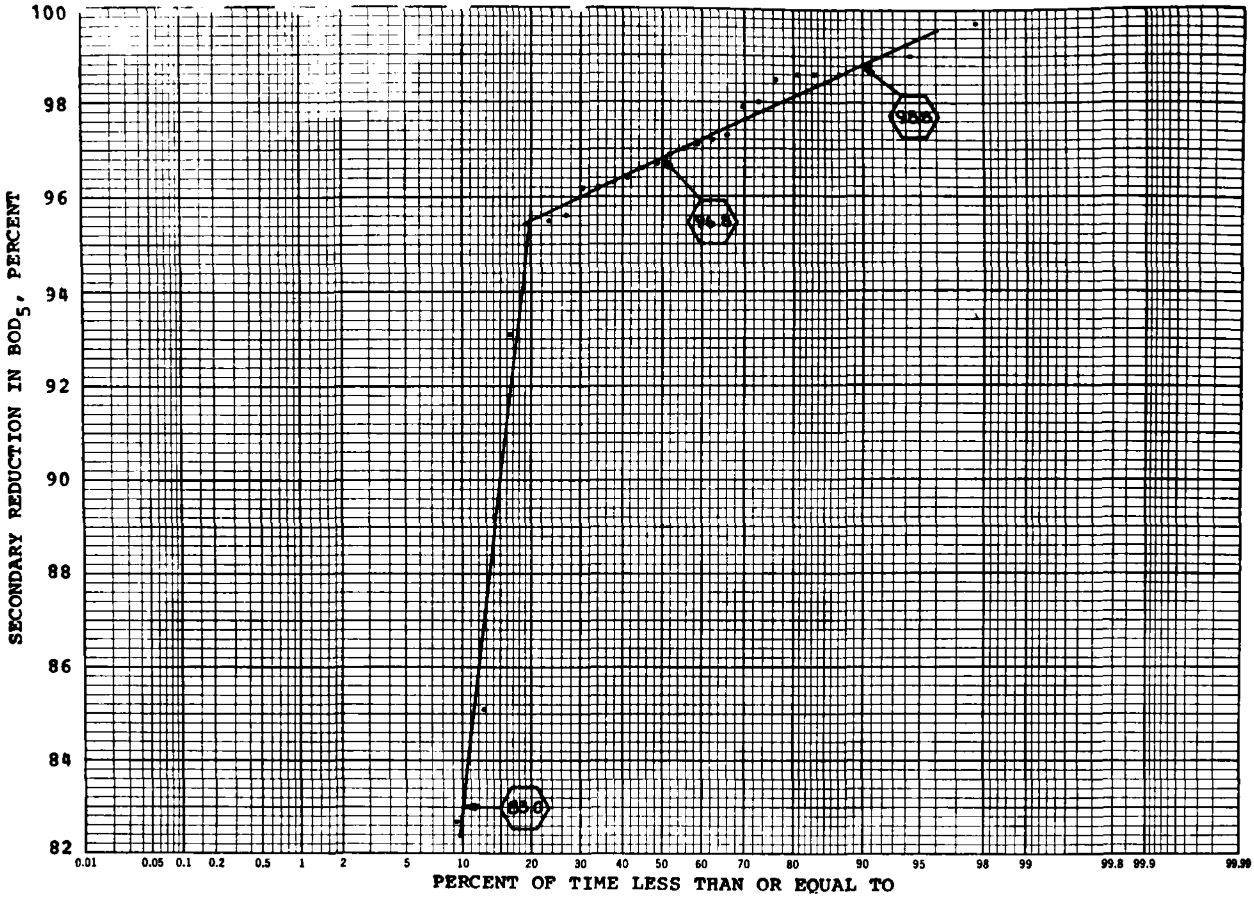
PROBABILITY OF FINAL EFFLUENT BOD-PROJECT



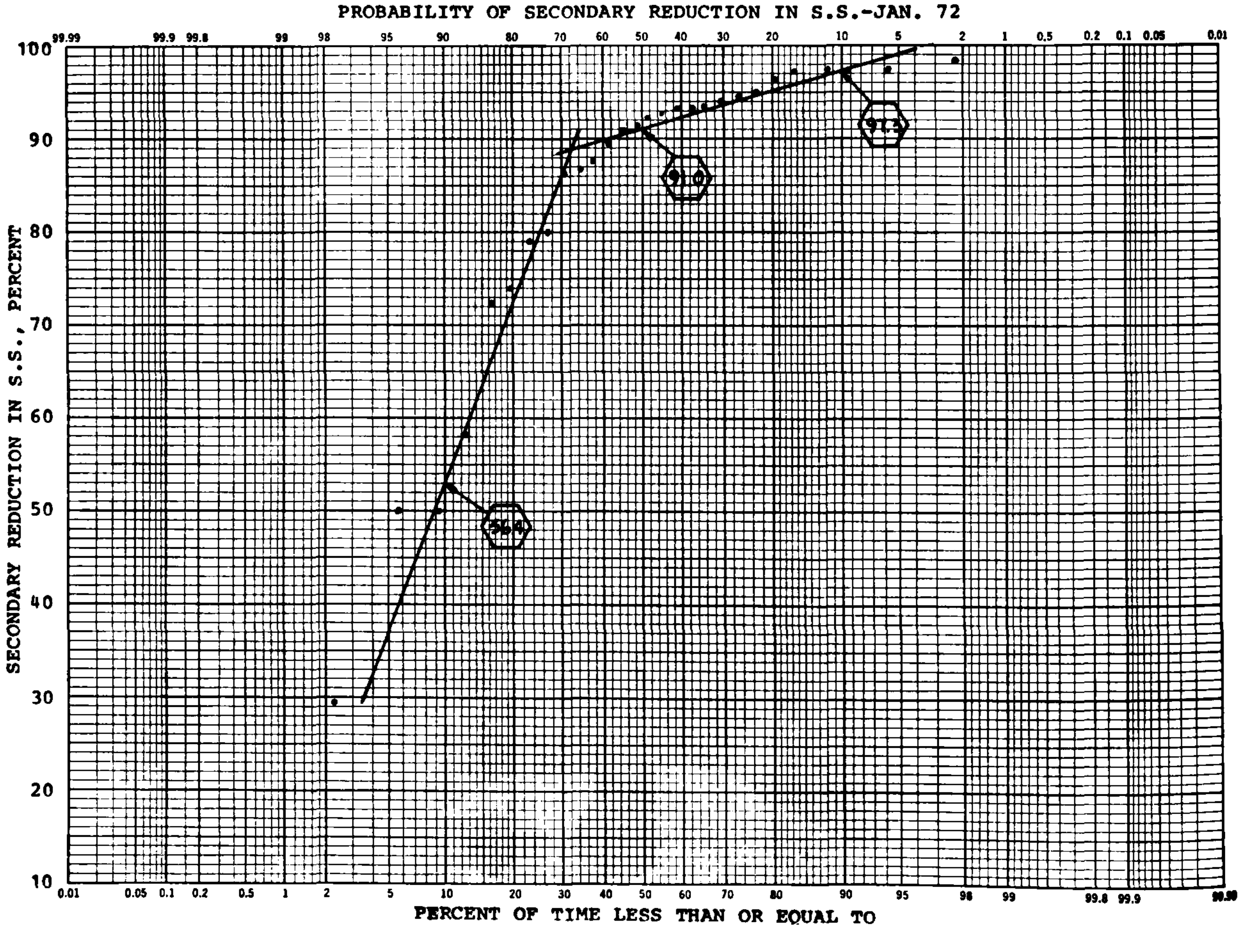
PROBABILITY OF FINAL EFFLUENT SUSPENDED SOLIDS-PROJECT



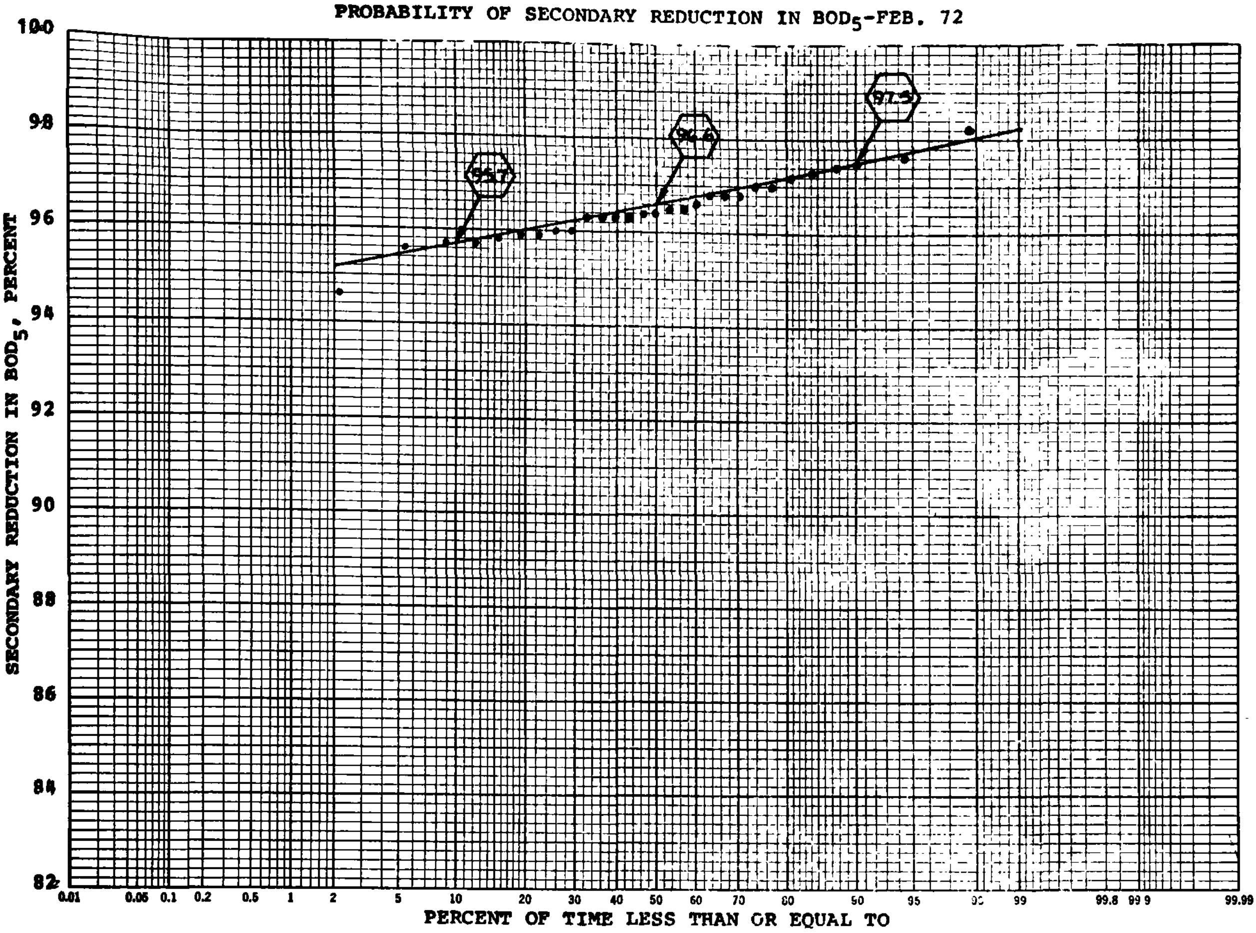
PROBABILITY OF SECONDARY REDUCTION IN BOD_5-JAN. 72



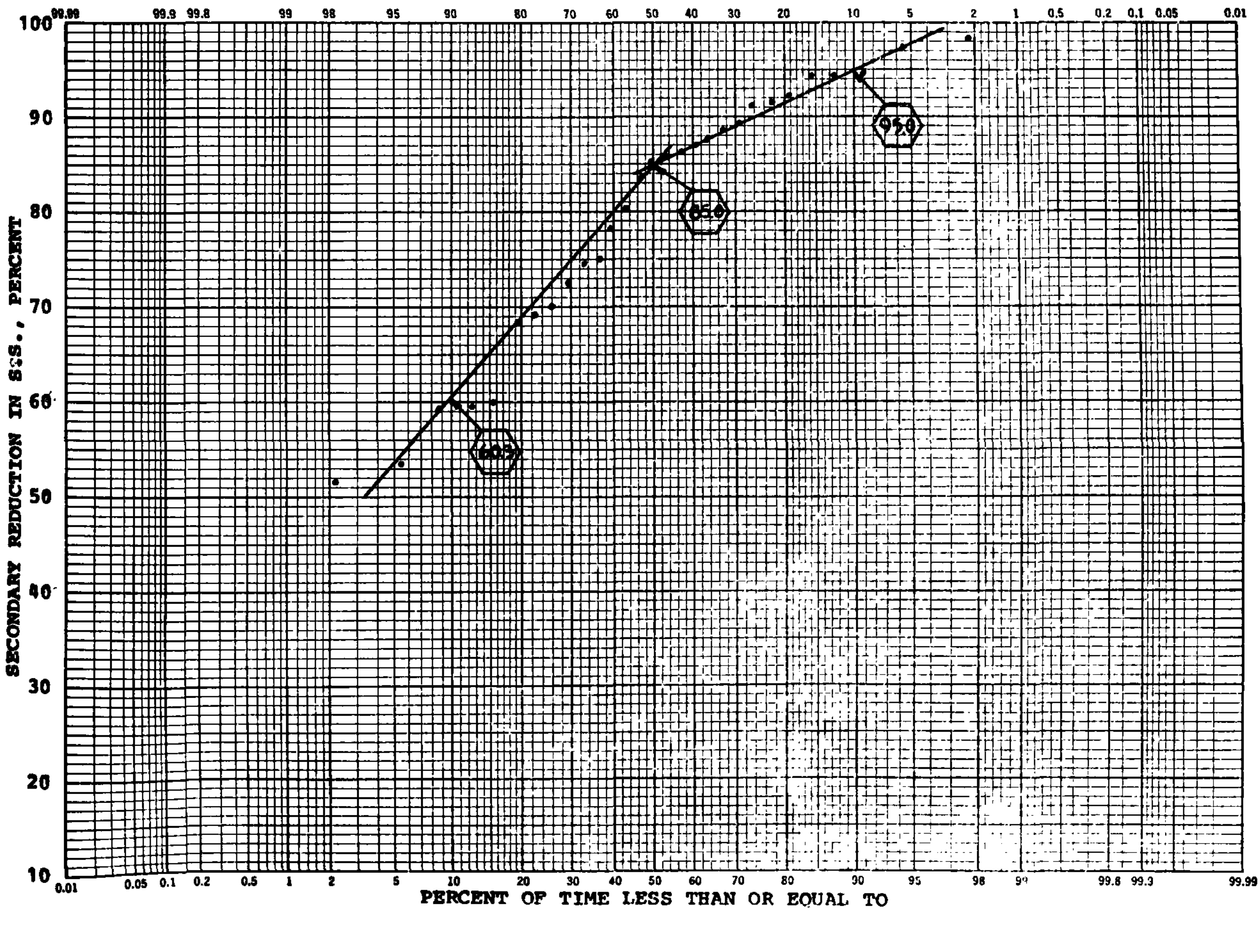
PROBABILITY OF SECONDARY REDUCTION IN S.S.-JAN. 72



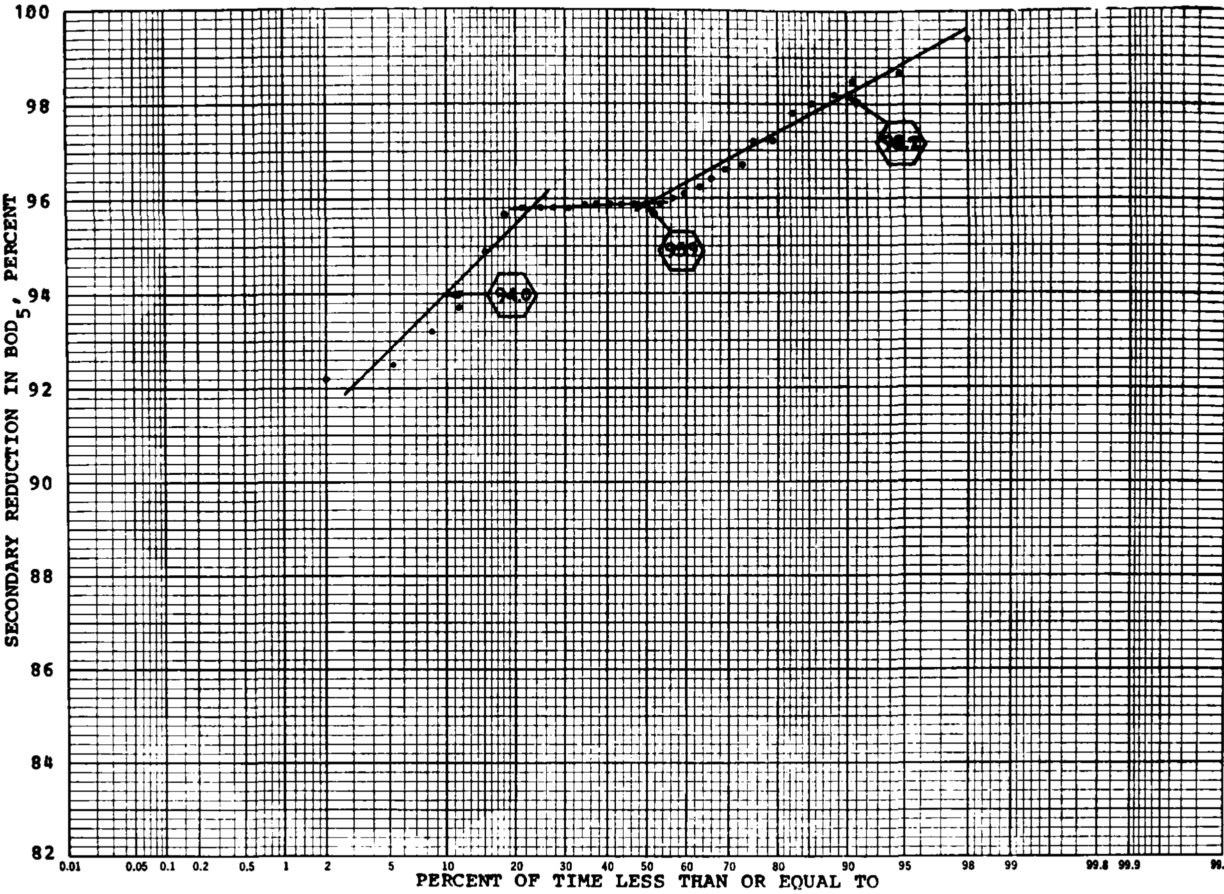
PROBABILITY OF SECONDARY REDUCTION IN BOD_5-FEB. 72



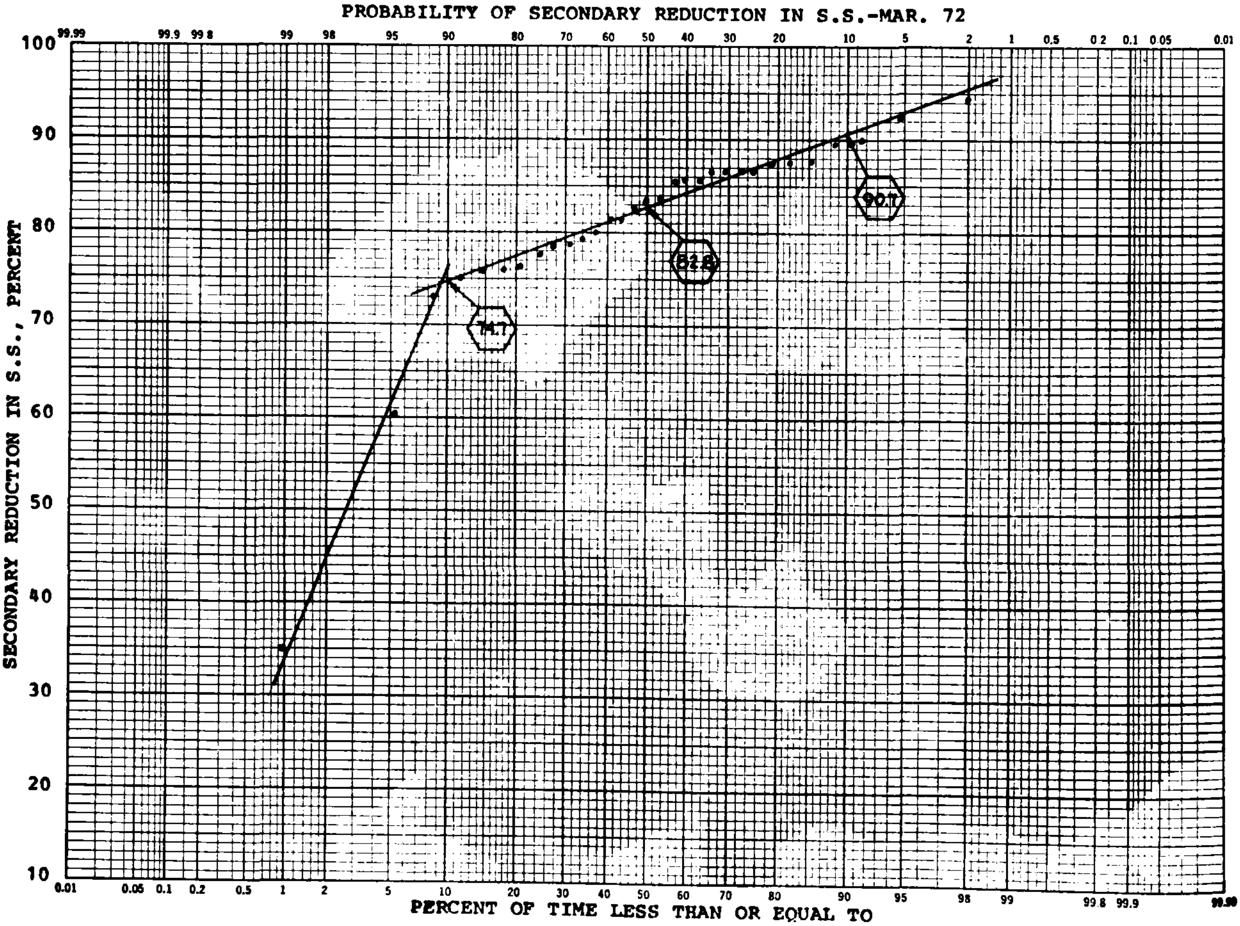
PROBABILITY OF SECONDARY REDUCTION IN S.S.-FEB. 72



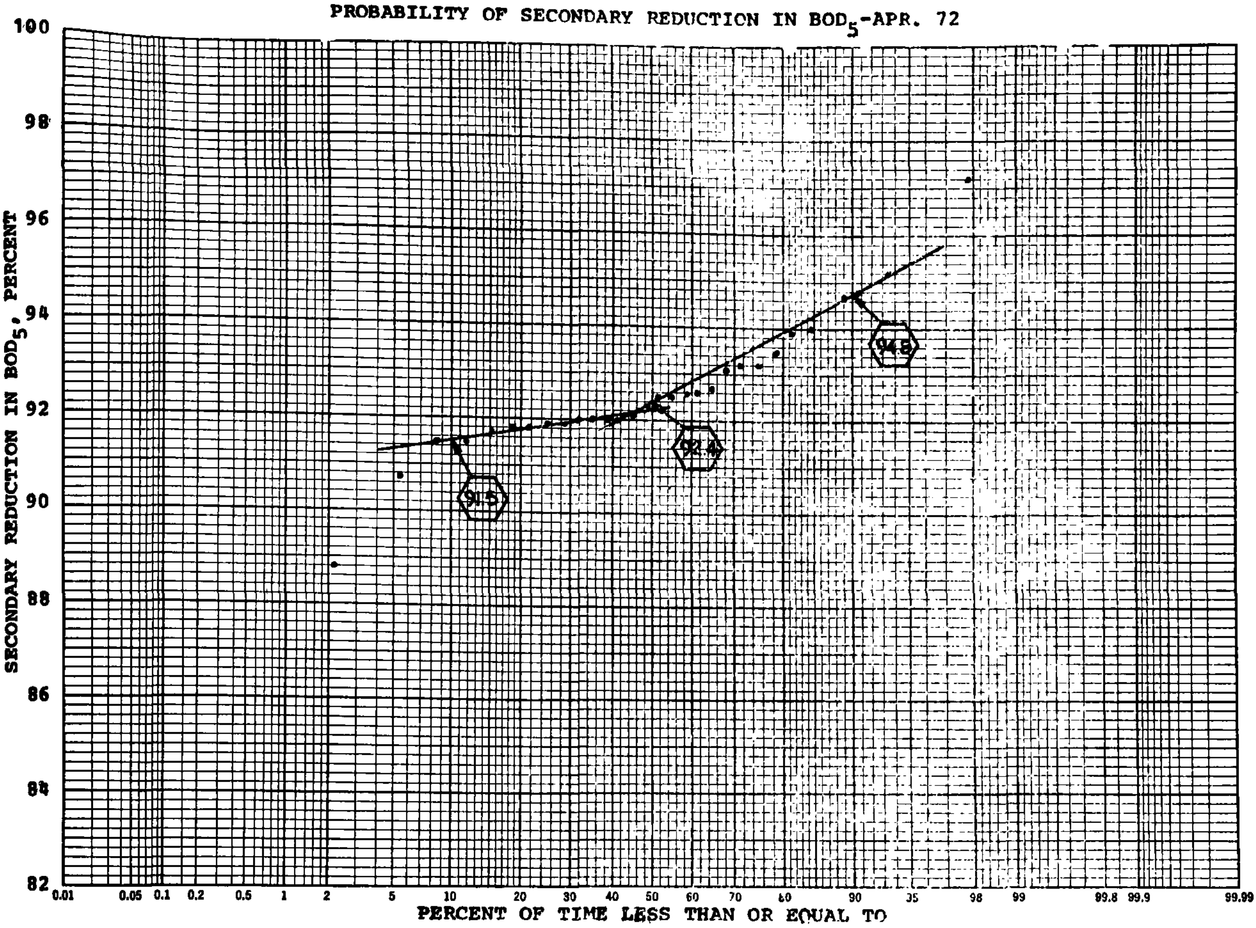
PROBABILITY OF SECONDARY REDUCTION IN BOD_5-MAR. 72



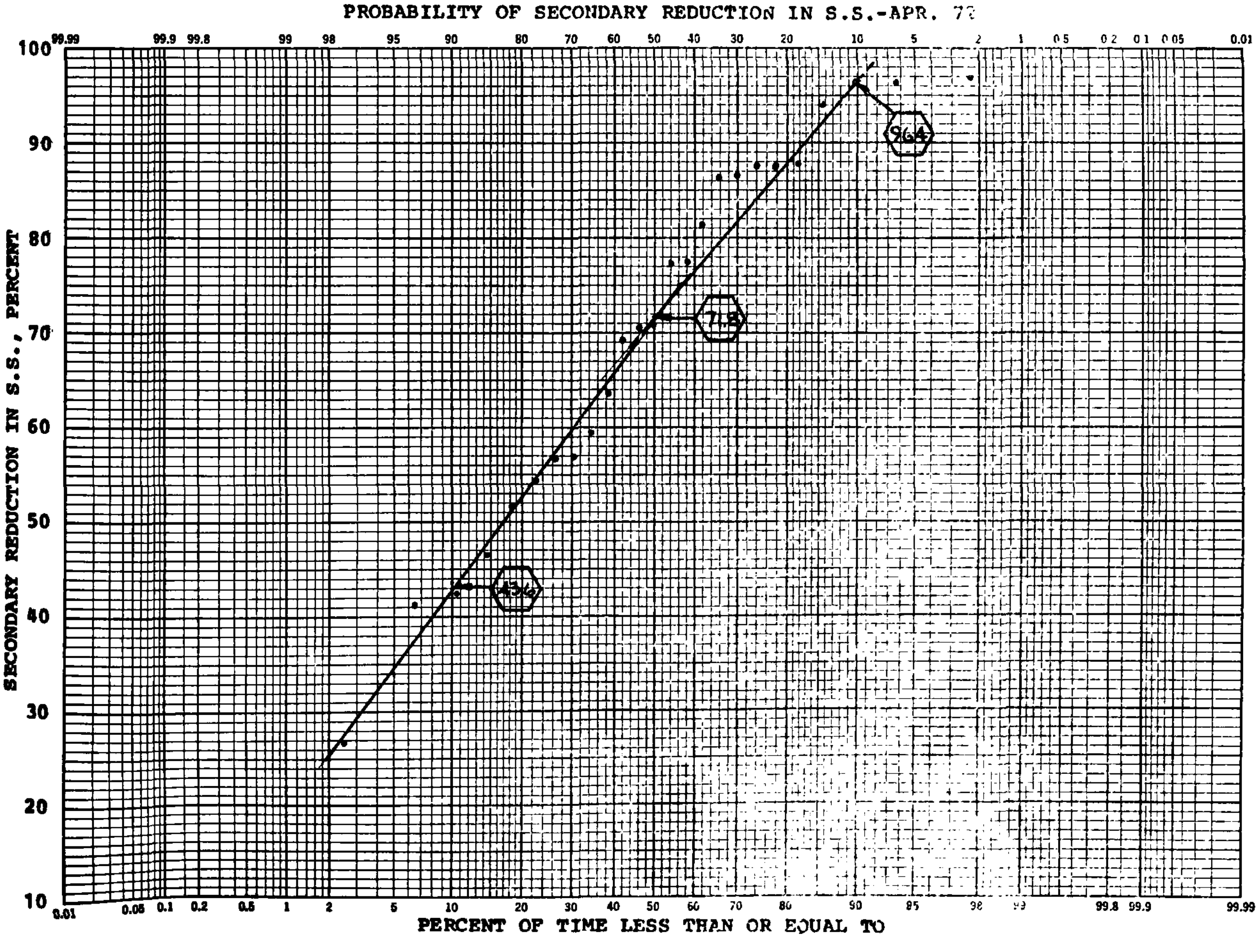
PROBABILITY OF SECONDARY REDUCTION IN S.S.-MAR. 72



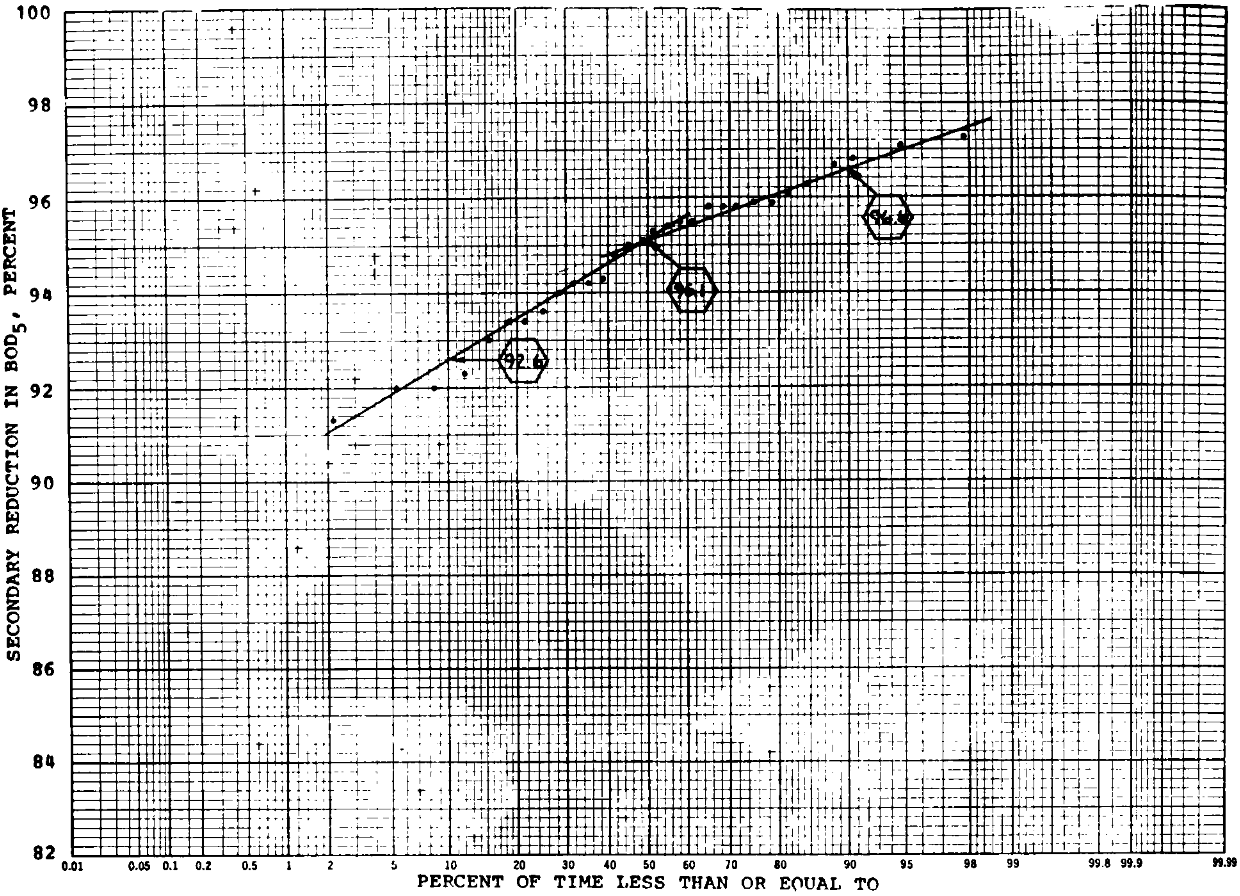
PROBABILITY OF SECONDARY REDUCTION IN BOD_5-APR. 72



PROBABILITY OF SECONDARY REDUCTION IN S.S.-APR. 72



PROBABILITY OF SECONDARY REDUCTION IN BOD_5



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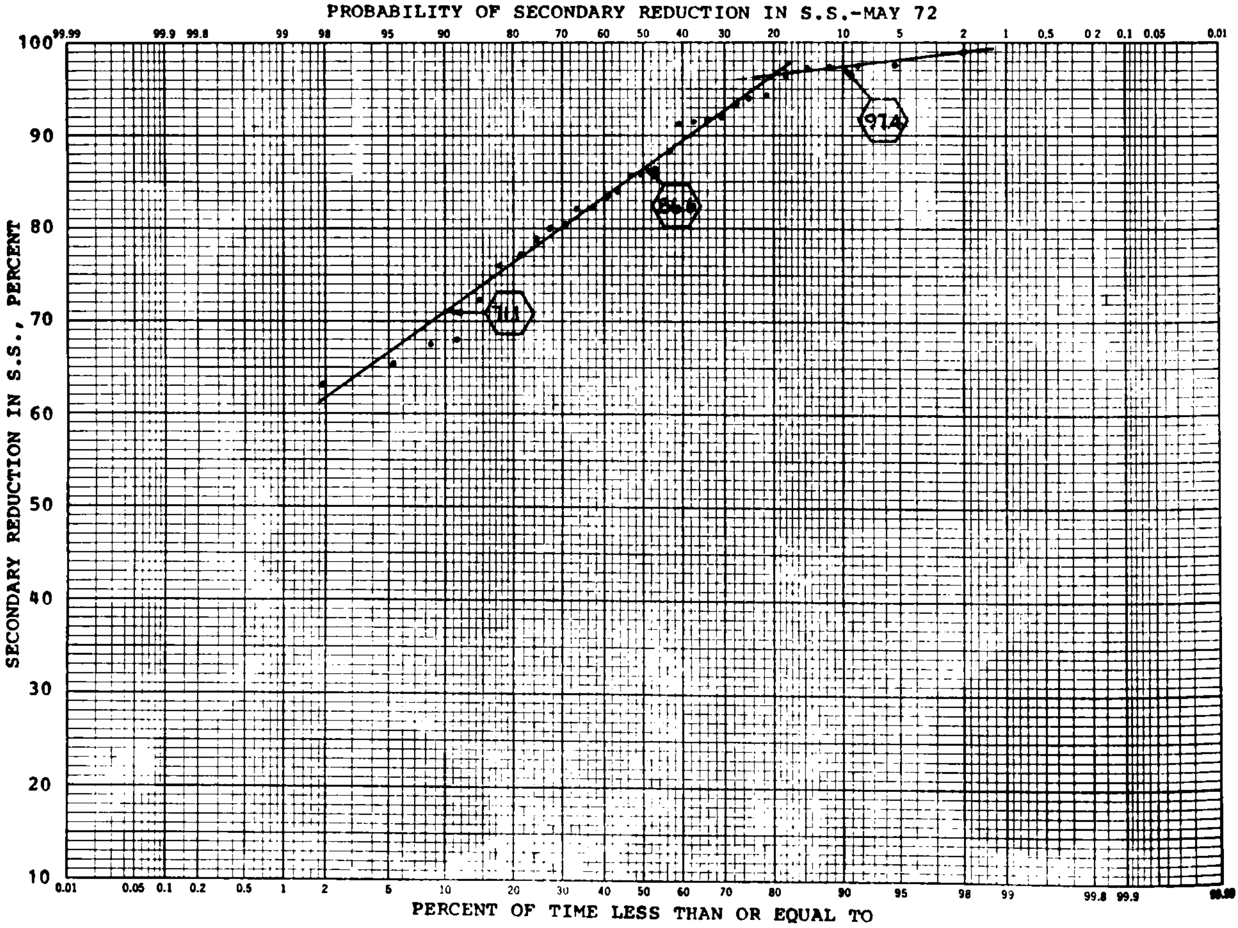

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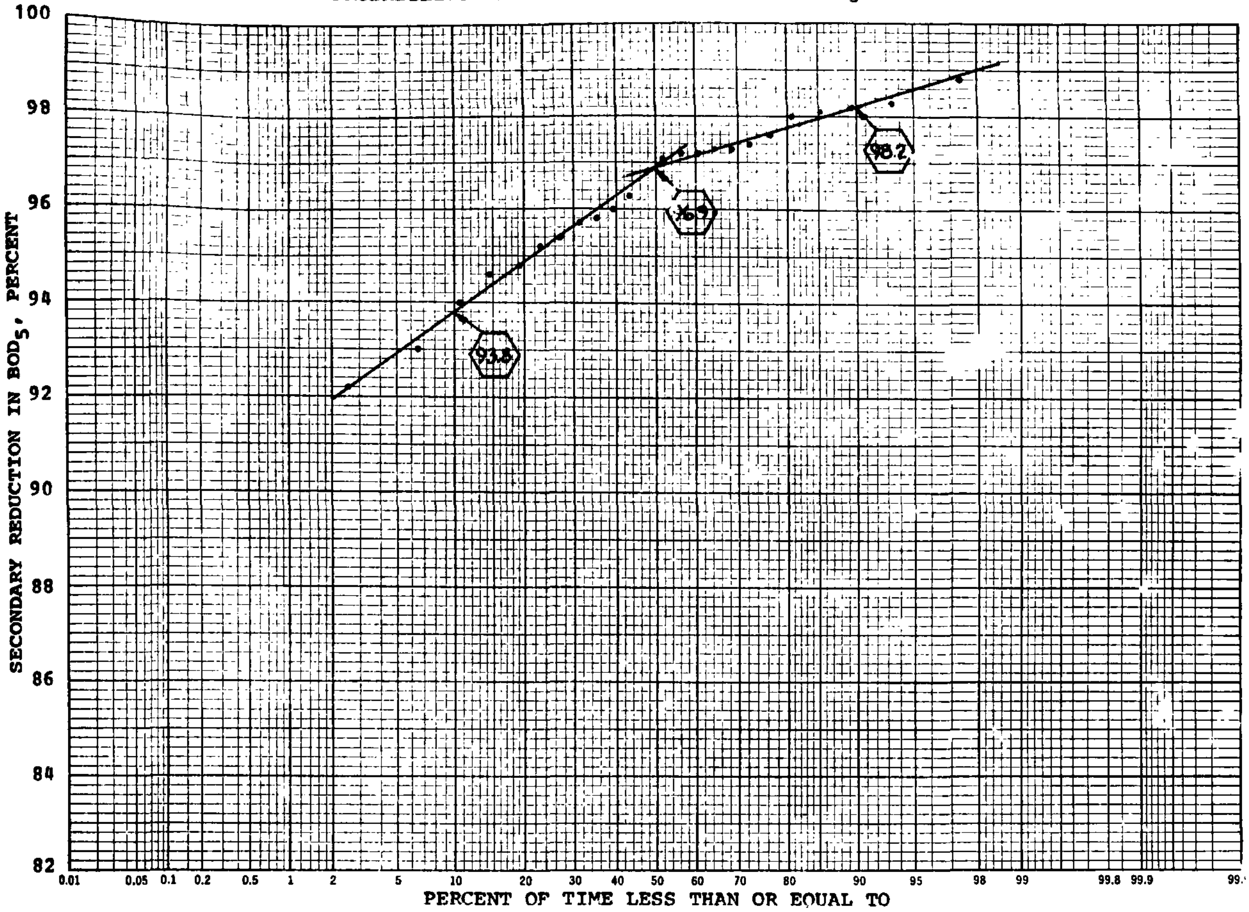

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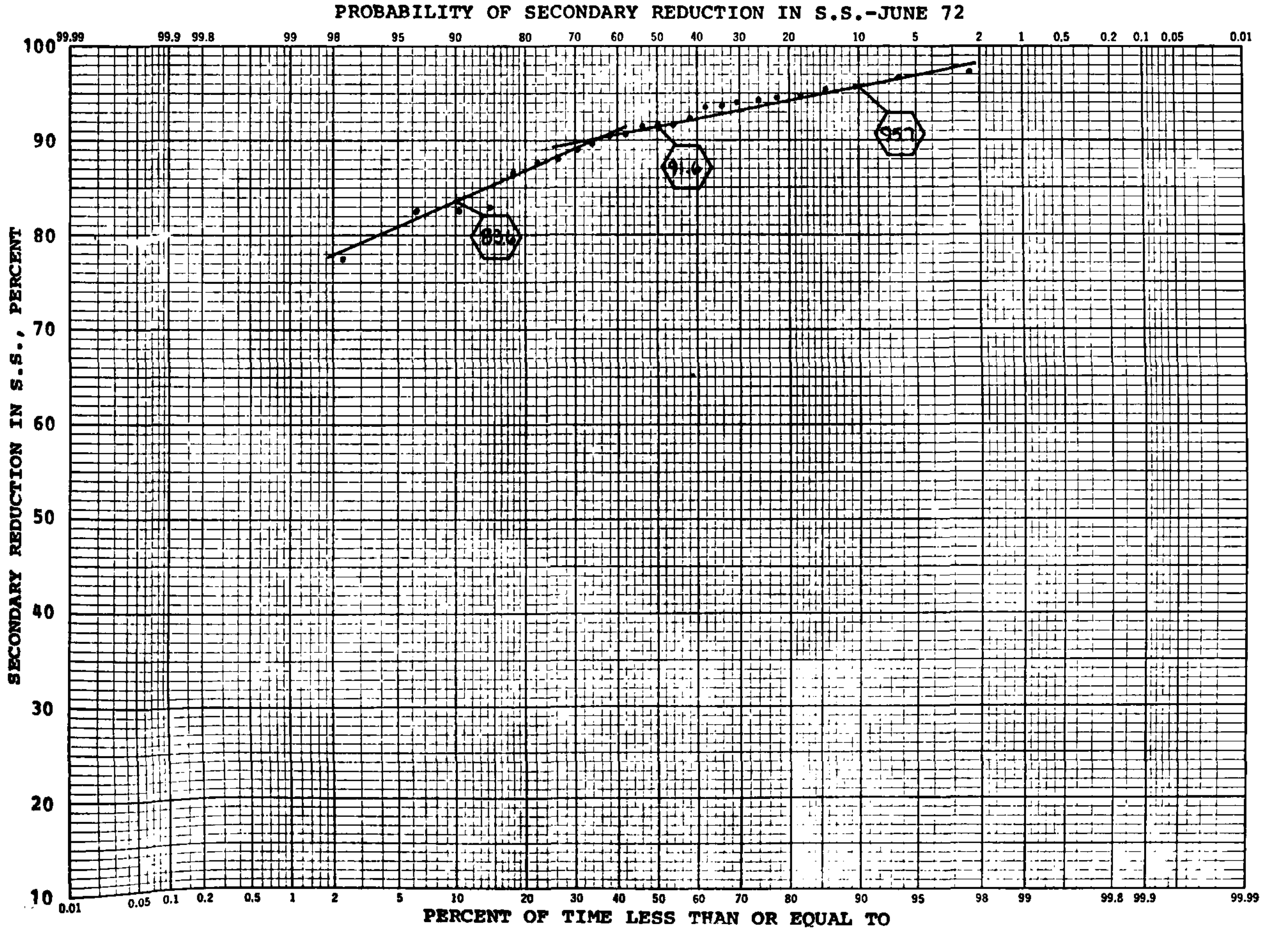

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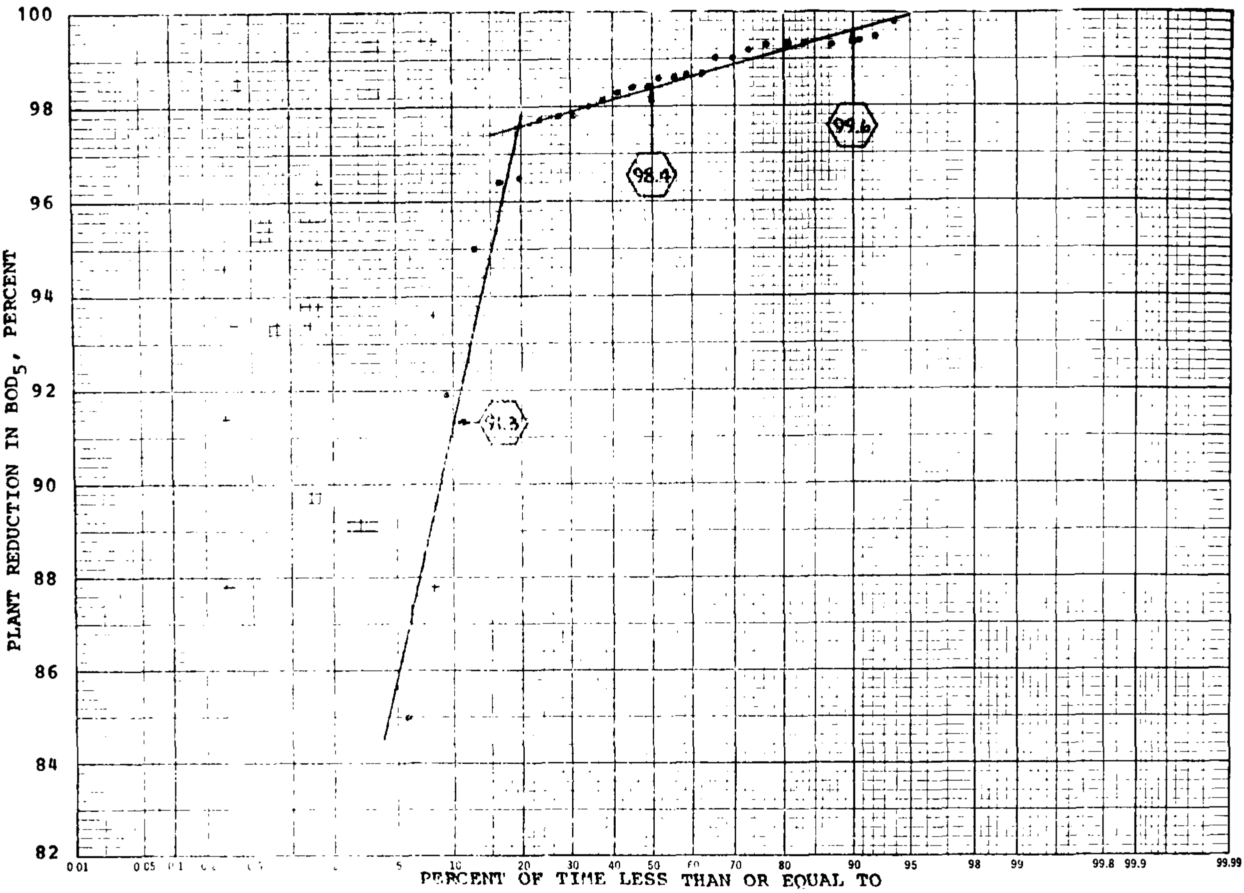

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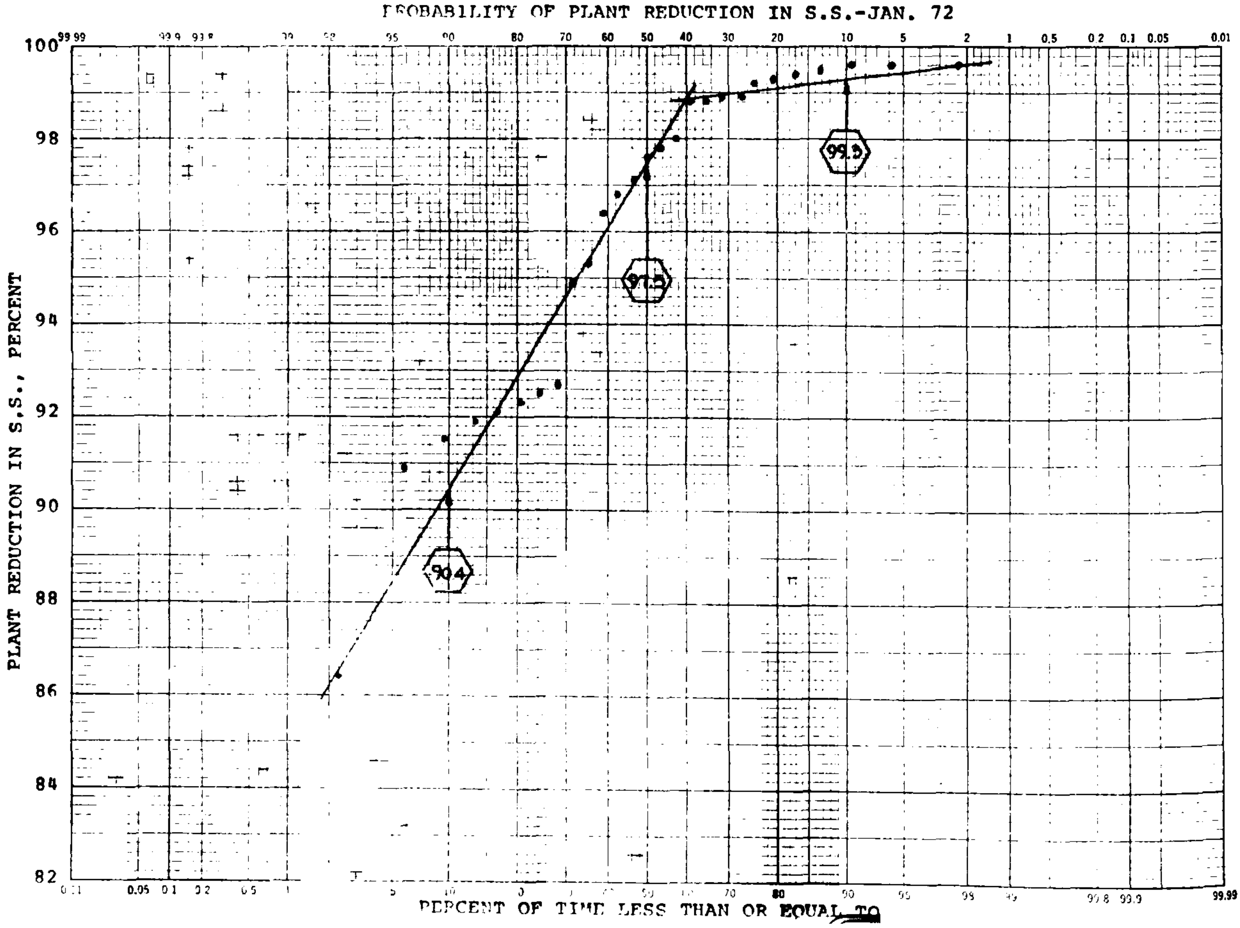

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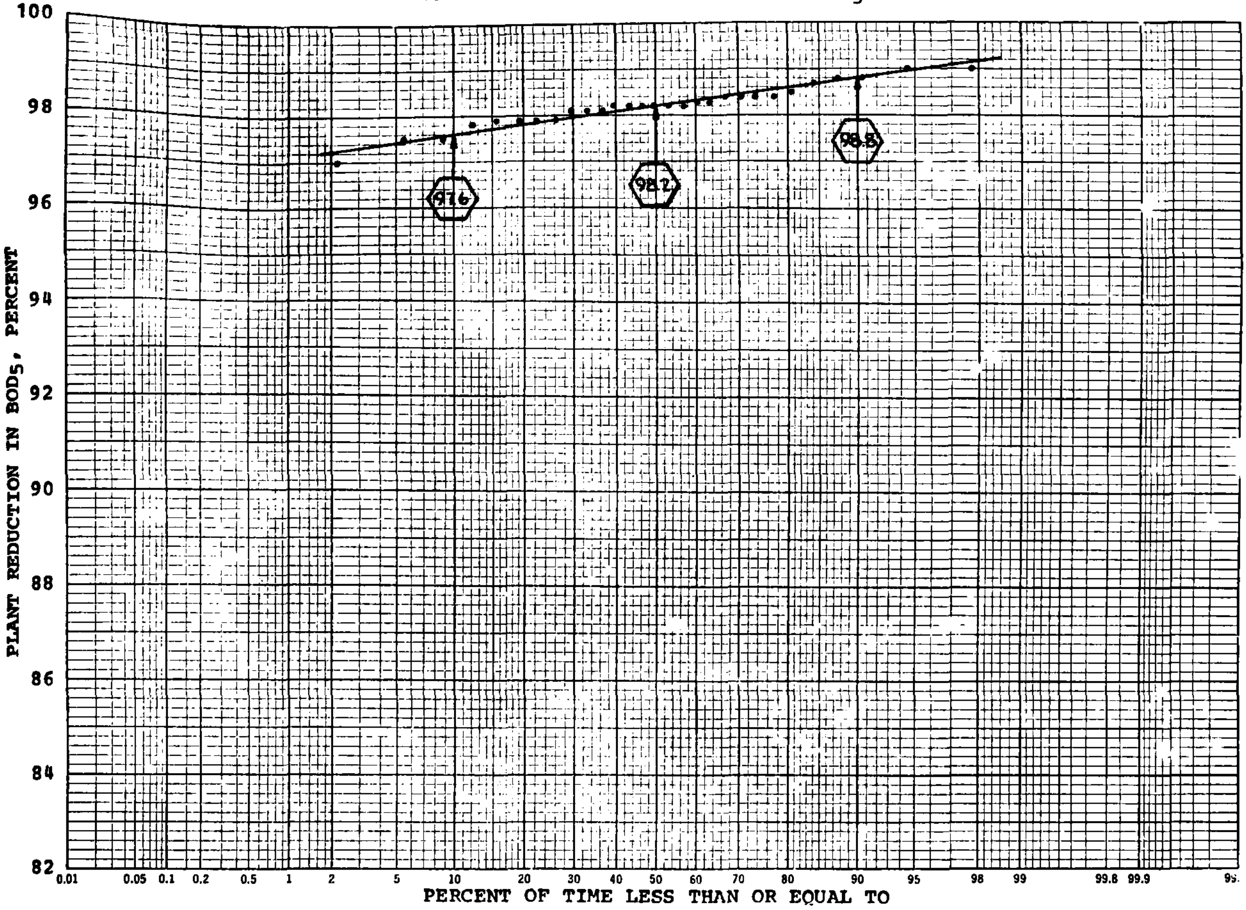

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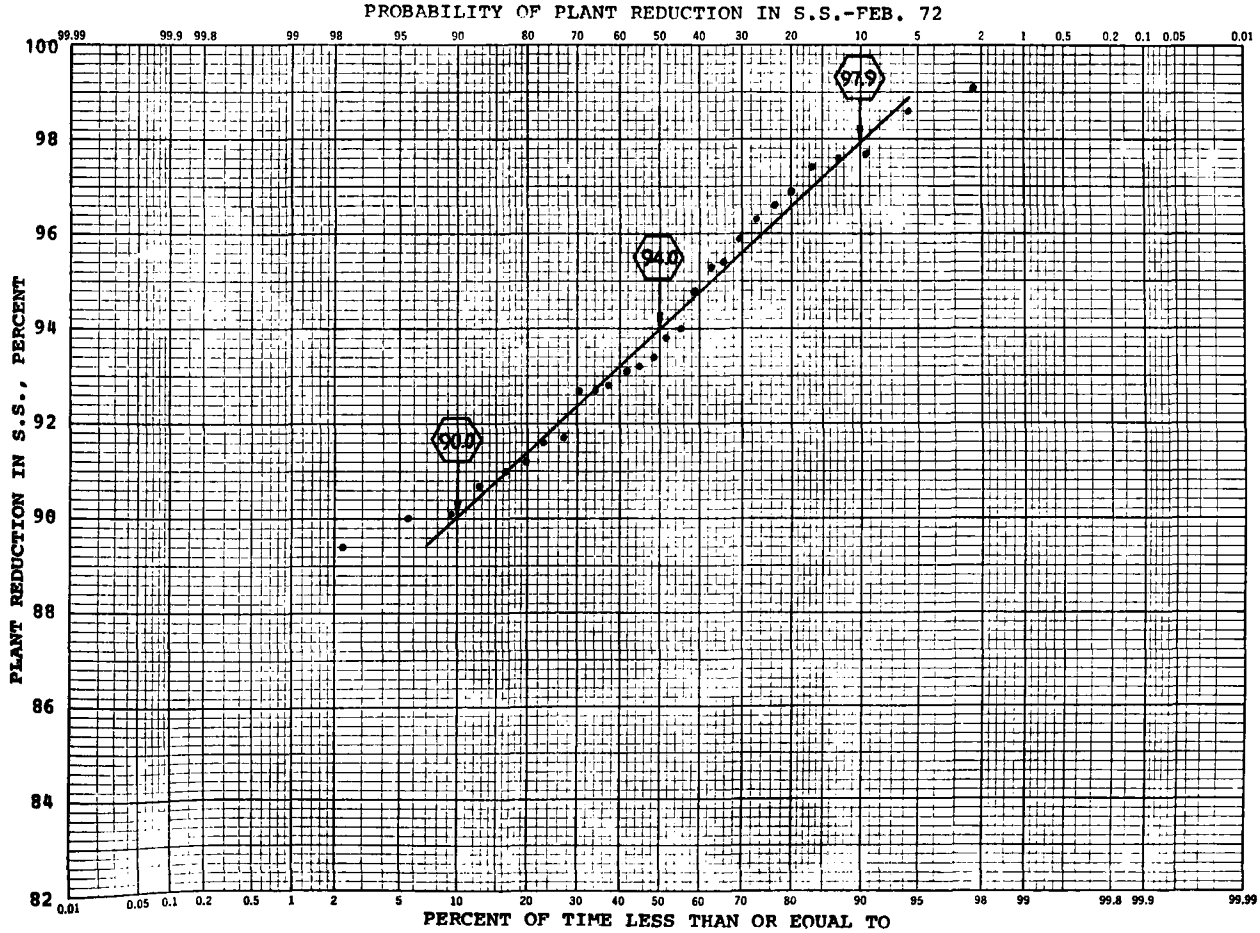

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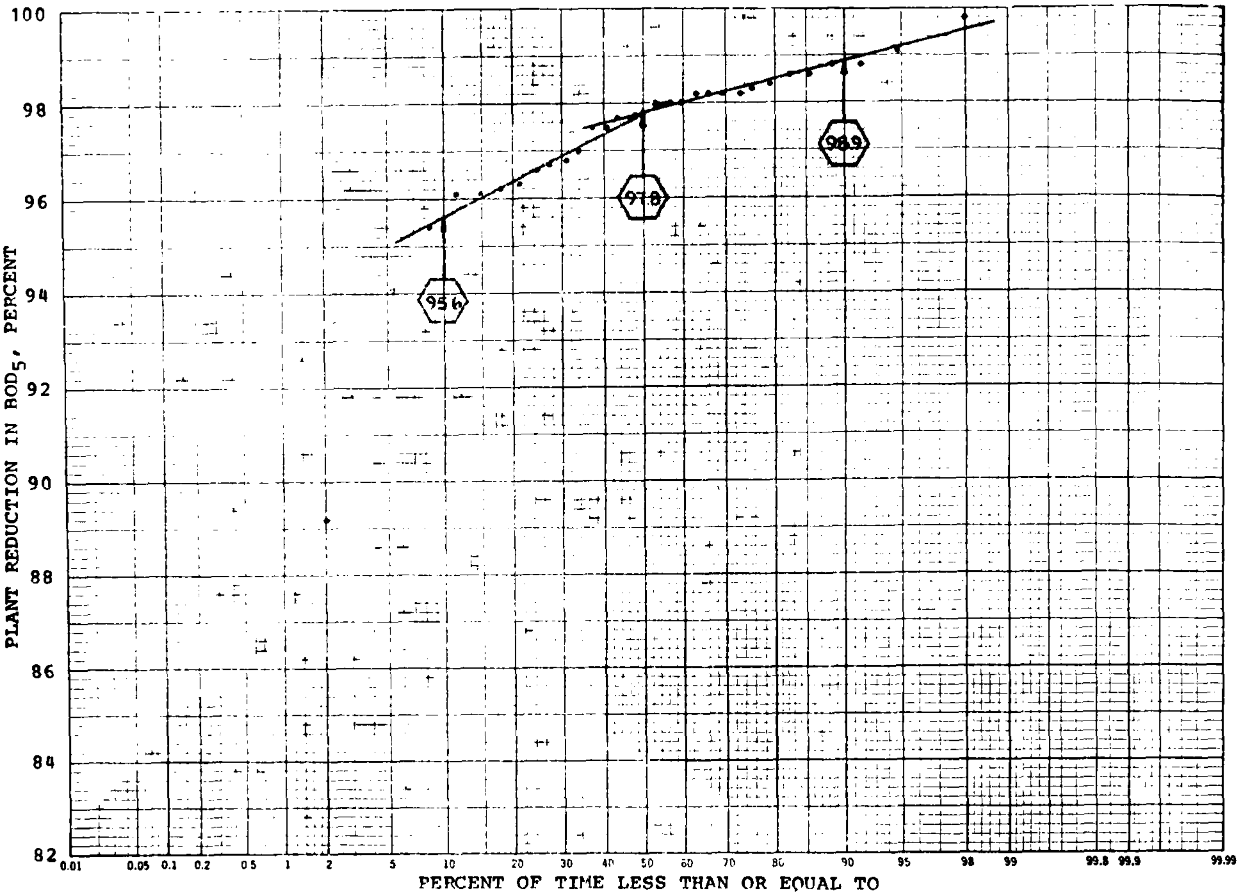

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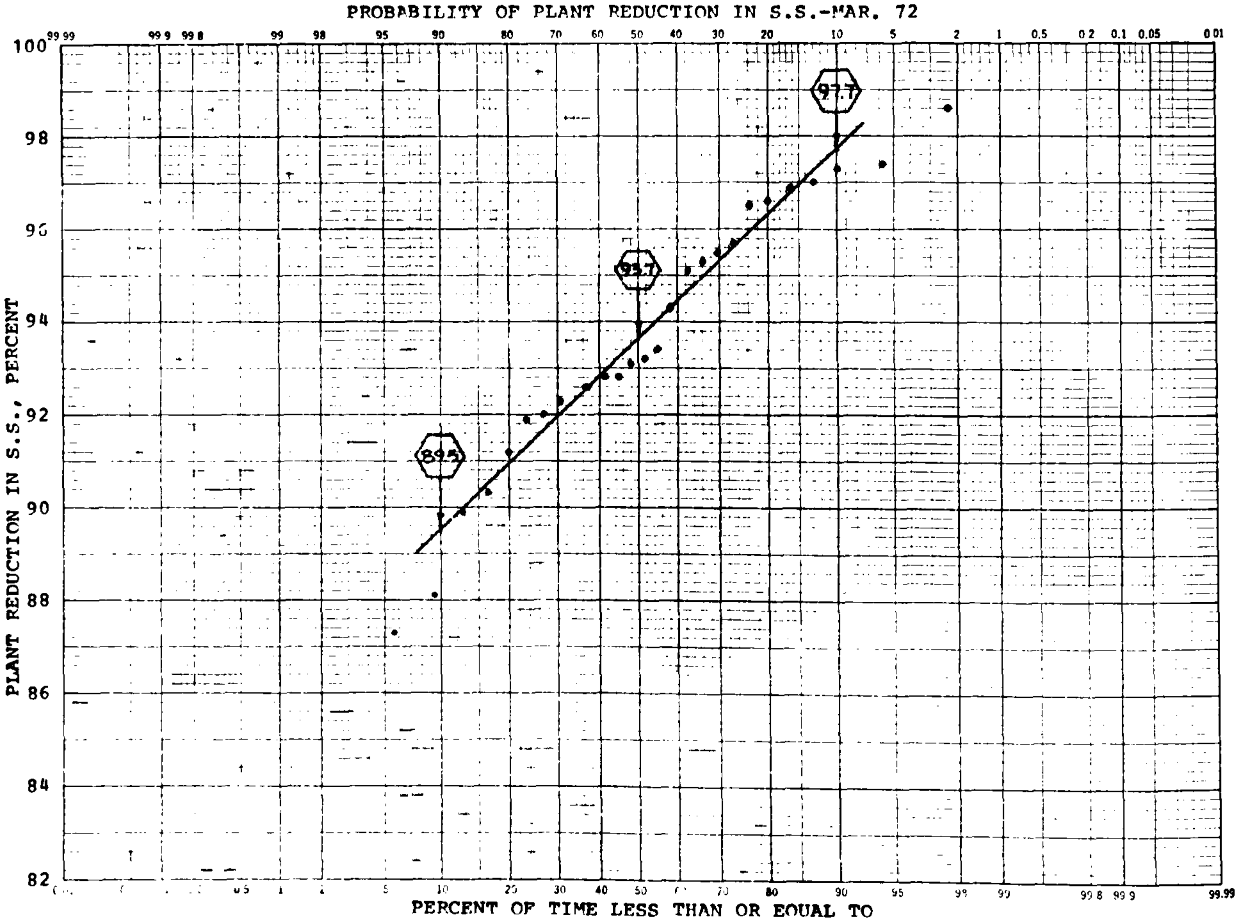

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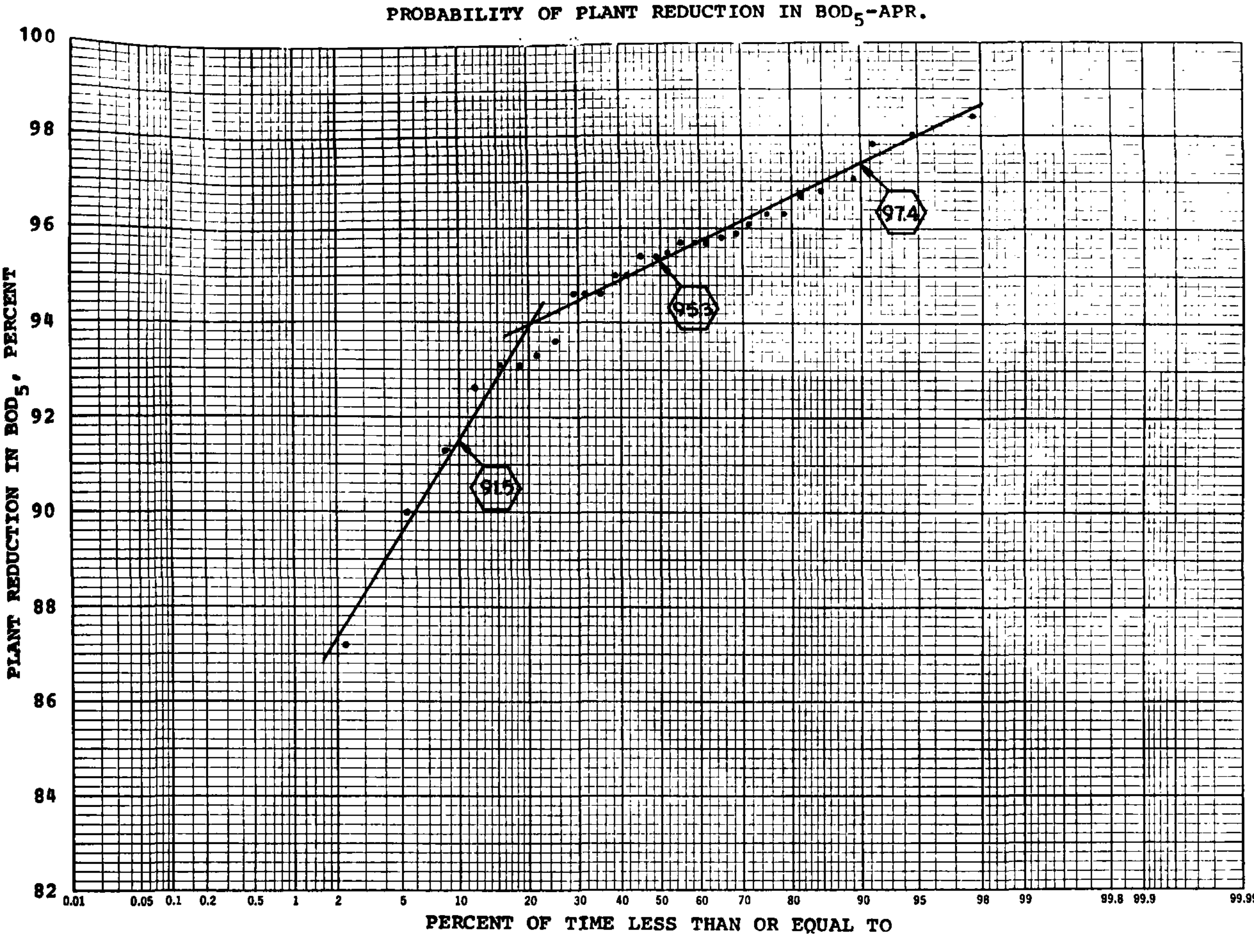

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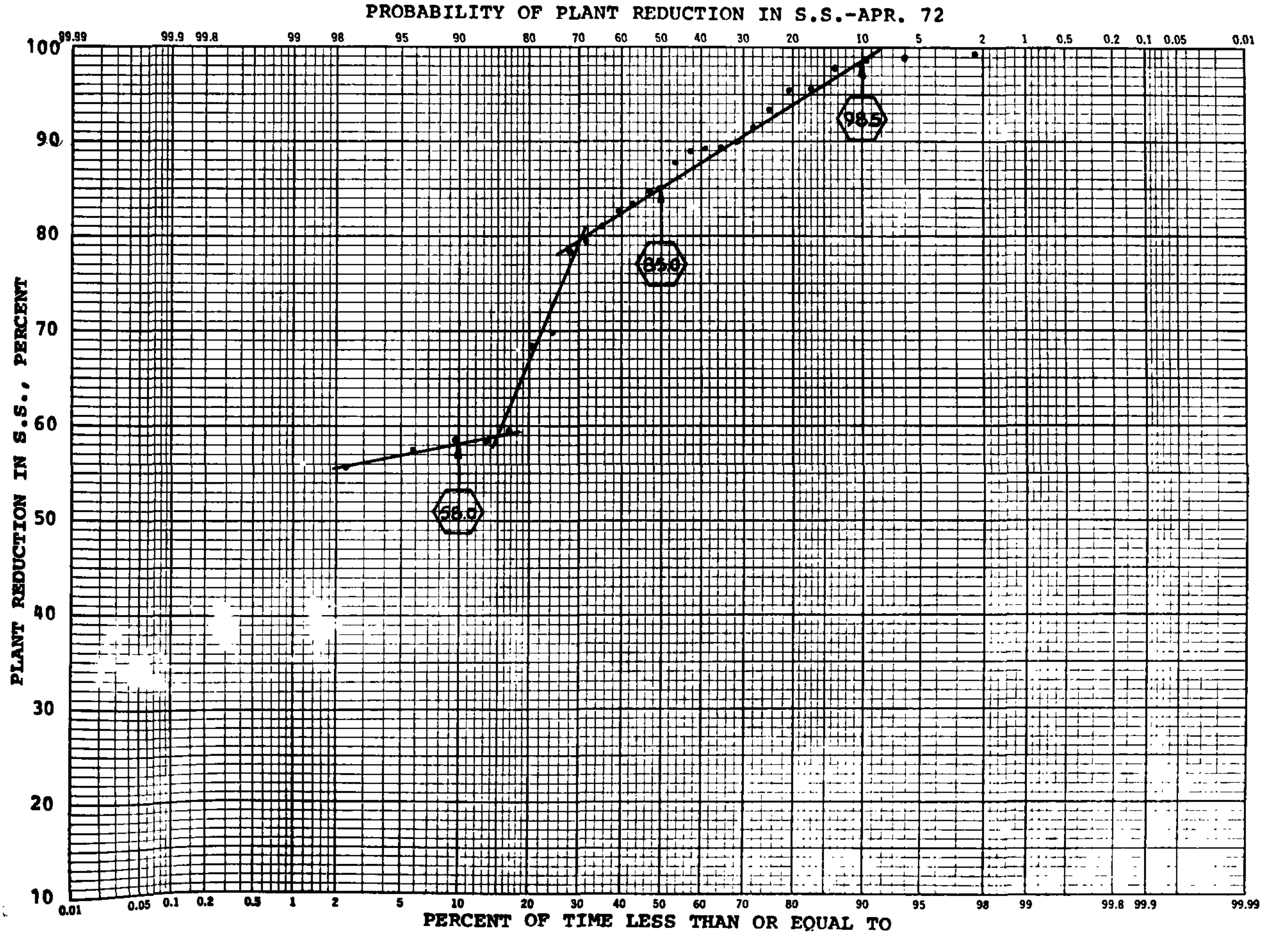

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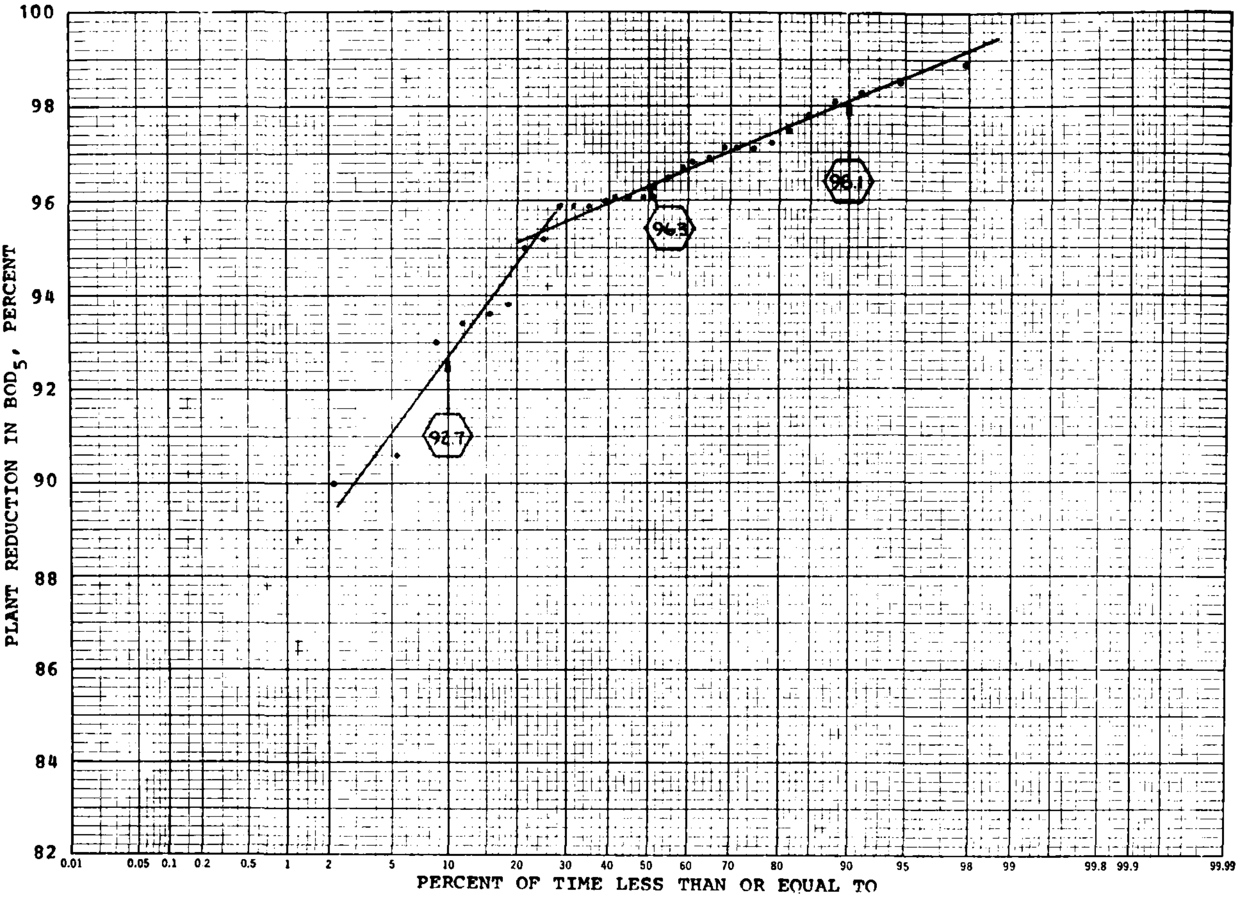

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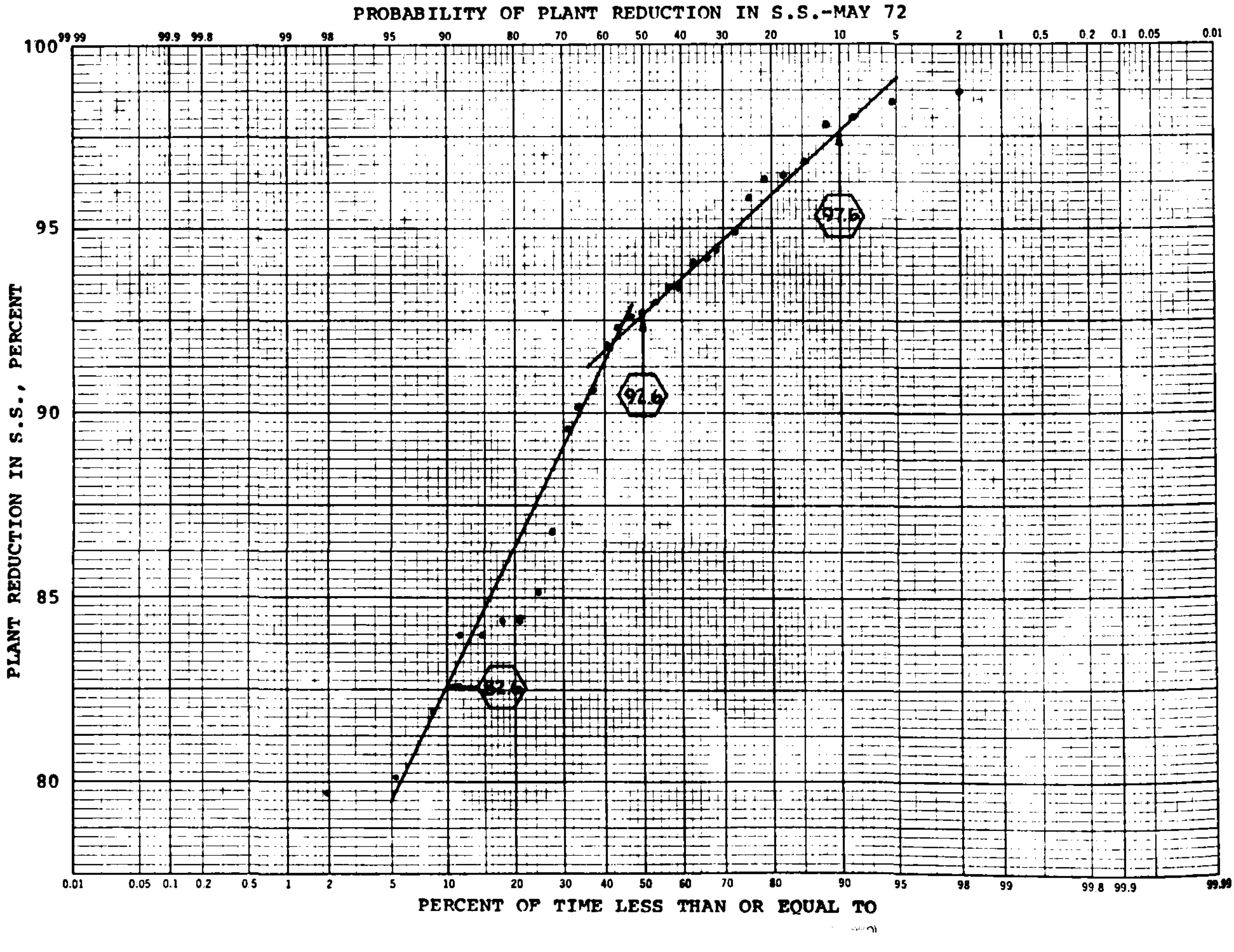

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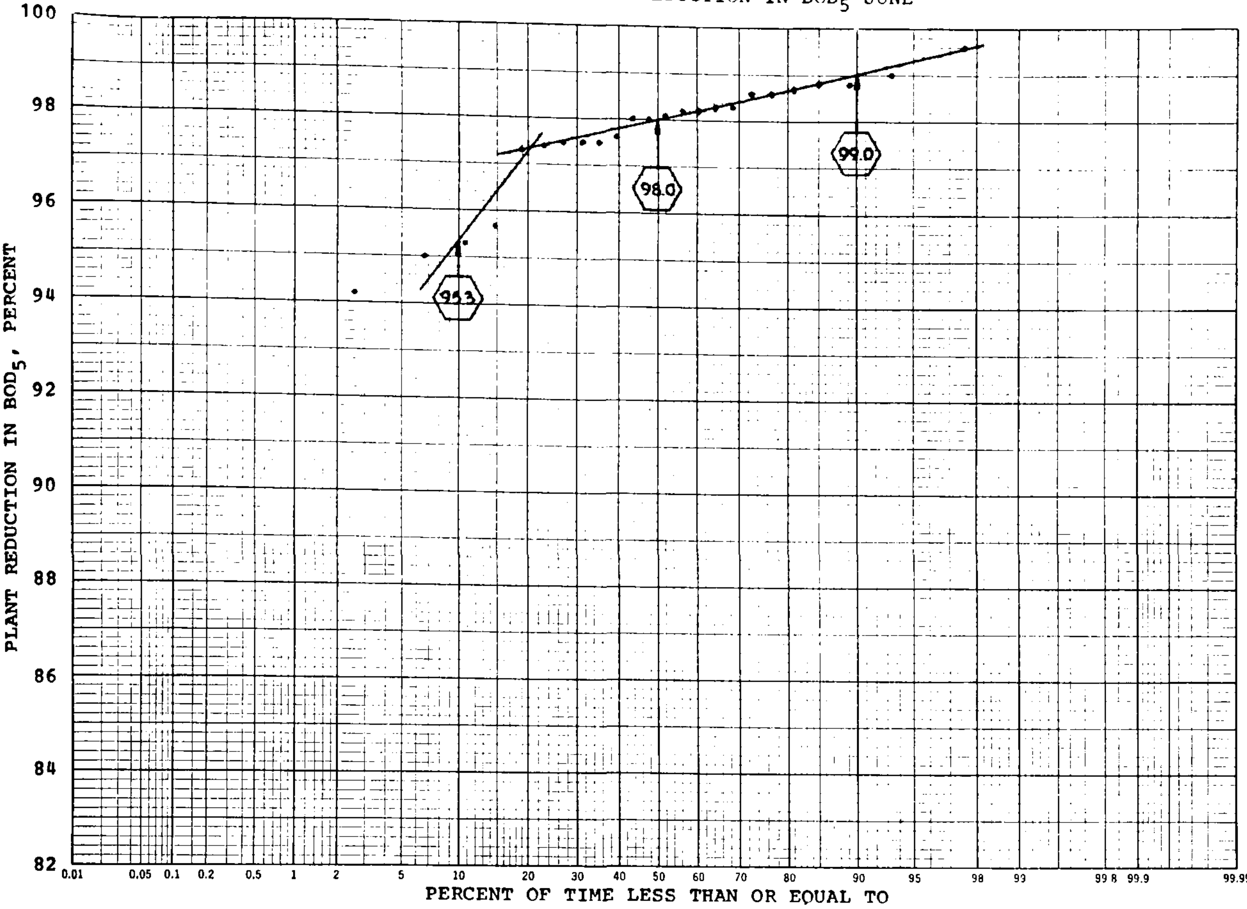

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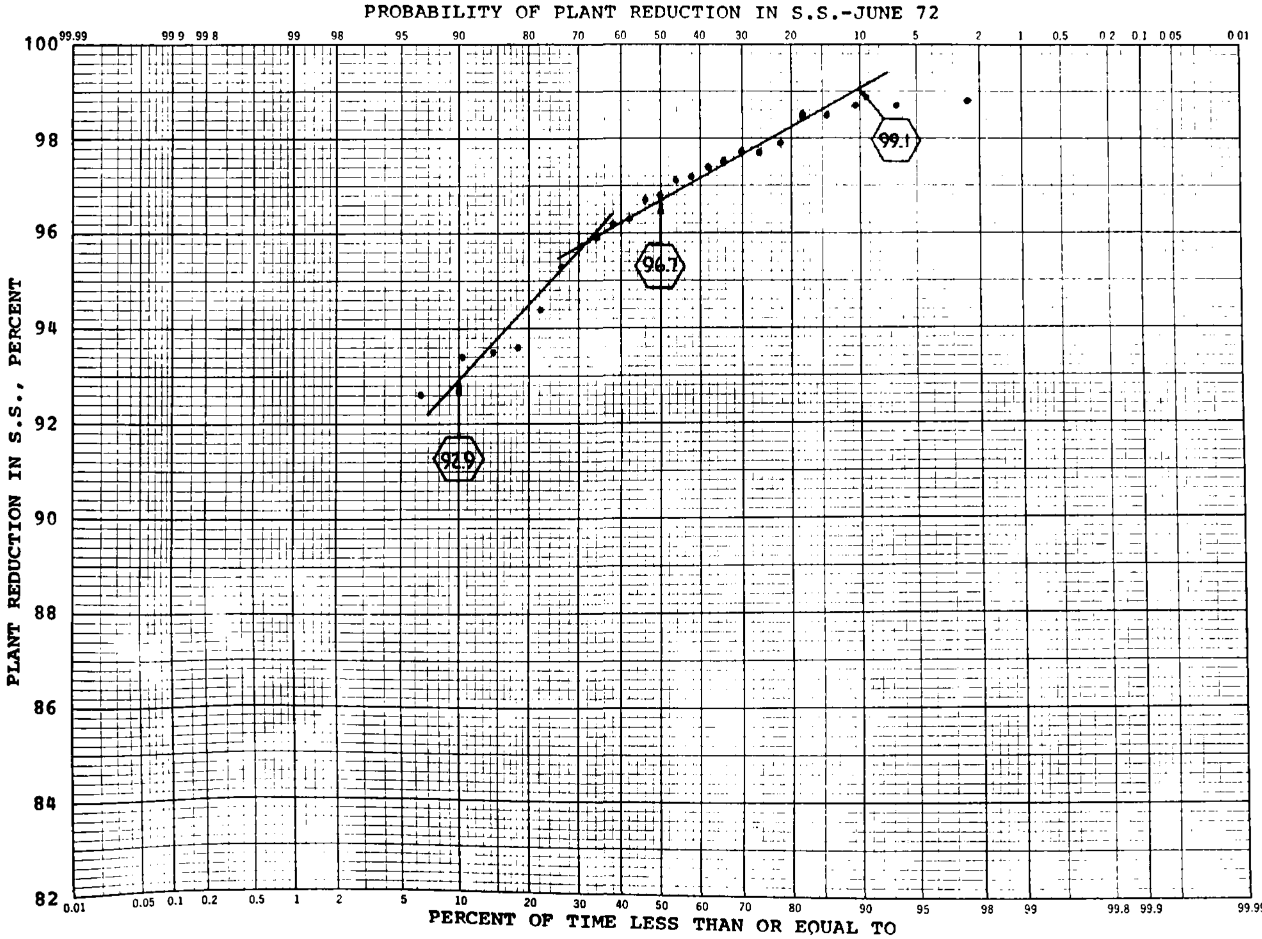


APPENDIX B

SYMBOLS AND TERMINOLOGY

USED IN

ACTIVATED SLUDGE PROCESS CALCULATIONS

APPENDIX B

SYMBOLS AND TERMINOLOGY USED IN ACTIVATED SLUDGE PROCESS CALCULATIONS

AAG	Aerator Age (Days sludge under aeration)
ADT	Aeration Detention Time (Hours - based on AIF + RSF) (Sludge ADT will differ from Sewage ADT in "STEP" operation)
AFI	Aerator Flow - Influent (MGD of Waste Water)
AGE	Calculated Sludge Age (Days)
ASU	Aerator Sludge Units
ATC	Aeration Tank Concentration (% by Centrifuge)
AVF	Aeration Tank Volume (Cu. Ft.)
AVG	Aeration Tank Volume (Gallons)

BLT	Clarifier Sludge Blanket Thickness (Either in feet, or fraction of CWD)
BLV	Clarifier Sludge Blanket Volume (Either in gallons or fraction of CVG)
BLX	Clarifier Sludge Blanket Index
BOD	Biochemical Oxygen Demand (5-day - Unless stated otherwise)
CDT	Clarifier Detention Time (Hours based on TFL)
CET	Clarifier Effluent Turbidity (in JTU)
CFI	Clarifier Flow - Influent (TFL - XMF in MGD)
CFO	Clarifier Flow - Out (CFI - CSF in MGD)
CMC	Clarifier Mean Sludge Concentration $\left(\frac{ATC + RSC}{2}\right)$
CSA	Clarifier Surface Area (Square Feet)
CSD	Clarifier Sludge Flow Demand
CSF	Clarifier Sludge Flow (RSF + XRF in MGD)
CSP	Clarifier Sludge Flow Percent (RSF + XRF as a % of CFI)
CSU	Clarifier Sludge Units (In sludge blanket)
CVF	Clarifier Volume (Cubic Feet)
CVG	Clarifier Volume (Gallons)
CWD	Clarifier Mean Water Depth (Feet)

DOB	Depth Of Sludge Blanket (Feet from Water Surface)
ESU	Final Effluent Sludge Units (Total Suspended Solids lost in Final Effluent - expressed as SLU)
FEC	Final Effluent Concentration (Suspended Solids converted to % by Centrifuge)
FET	Final Effluent Turbidity (JTU)
FLI	Raw Flow - Into Plant (MGD)
FLO	Effluent Flow - Out of Plant (MGD)
JTU	Jackson Turbidity Units
LOD	Load (Lbs. BOD/Day to Aerator)
Lod	Load (mg/l BOD to Aerator)
MLTSS	Mixed Liquor Total Suspended Solids (mg/l)
MLVSS	Mixed Liquor Volatile Suspended Solids (mg/l)

OFR	Clarifier Overflow Rate (Gal./Sq. Ft./Day based on CFO)
OIX	Oxidation Index (Based on Optimum SSV)
PET	Primary Effluent Turbidity (JTU)
PFI	Primary Flow Into Primary Sedimentation Tank (MGD)
PFO	Primary Flow Out of Primary Sedimentation Tank (MGD)
PSF	Primary Sludge Flow (MGD)
RFD	Return Sludge Flow Demand (MGD)
RFP	Return Sludge Flow Percentage (RSF as a % of AFI by meter)
RSC	Return Sludge Concentration (% by Centrifuge)
RSF	Return Sludge Flow (MGD)
RSP	Return Sludge Percentage (% of AFI - Usually calculated from ATC and RSC)
RSTSS	Return Sludge Total Suspended Solids (mg/l)
RSU	Return Sludge Units (To aerators)
RSVSS	Return Sludge Volatile Suspended Solids (mg/l)

SAH	Sludge Aerator Hours (Hours per day in aerator)
SAP	Sludge Aerator Hours in Percent of Day (Either % or decimal fraction)
SCO	Settled Sludge Concentration - at Optimum (Optimum SSC - % by Centrifuge)
SCR	Sludge Concentration Ratio (SSC/RSC)
SCY	Sludge Cycles (per day)
SDR	Solids Distribution Ratio (Between aerators and clarifiers = ASU/CSU)
SDT	Sludge Detention Time (Hours in clarifiers)
SLR	Sludge Ratio (RSC/ATC)
SLU	Sludge Units (Volume in gallons x % concentration as a decimal fraction)
SSC	Settled Sludge Concentration (Calculated % by Centrifuge)
SSV	Settled Sludge Volume (cc/l in Settleometer)
SVO	Settled Sludge Volume at Optimum (cc/l in Settleometer)
TDT	Total Sludge Detention Time (ADT + SDT in Hours)
TFI	Thickner Flow Into (MGD)
TFL	Total Flow (MGD out of aeration tanks)
TFO	Thickener Flow Out (MGD)
TKR	Tank Ratio (AVG/CVG)

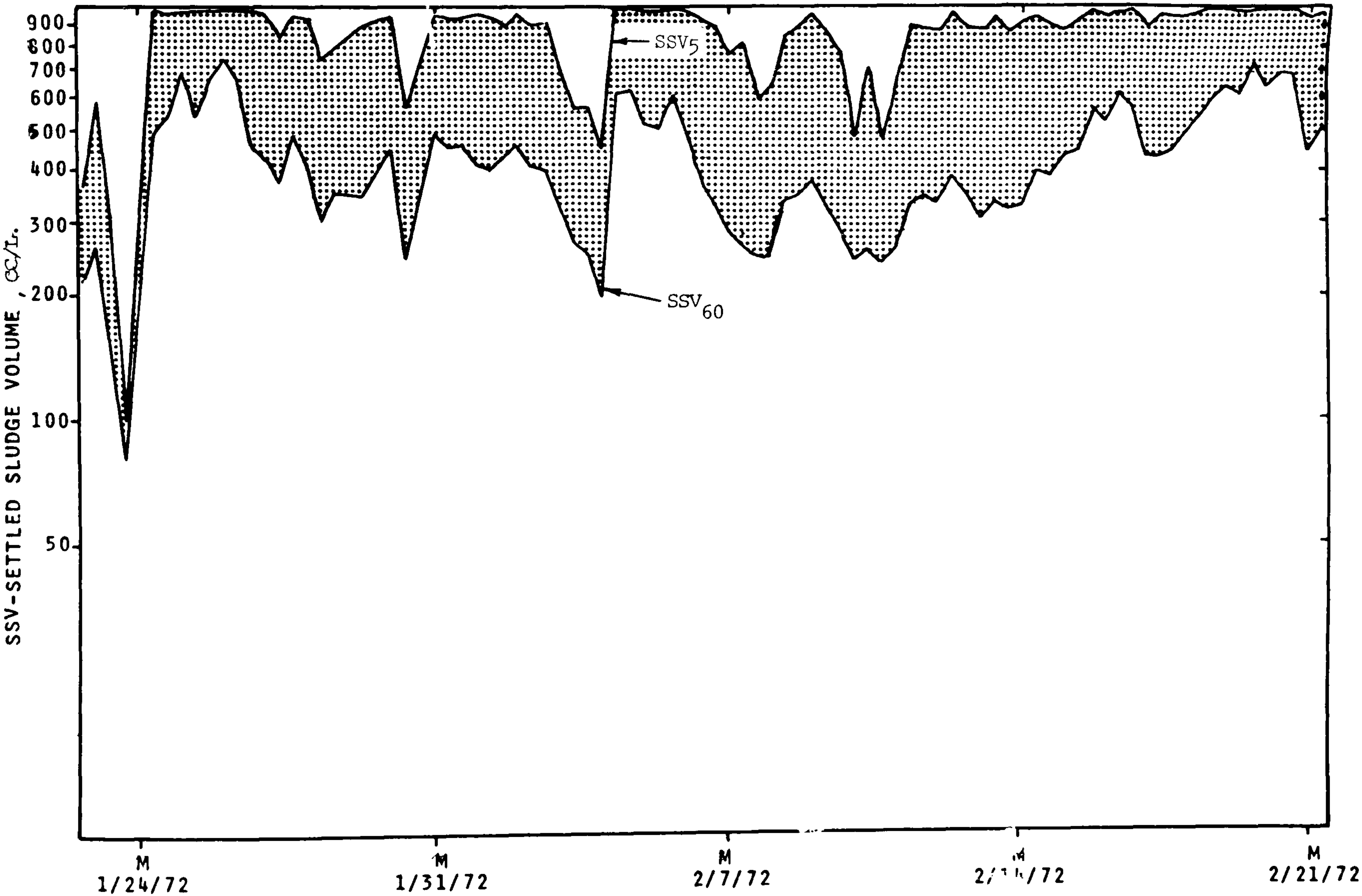
TSF	Thickener Sludge Flow (MGD)
TSS	Total Suspended Solids (MG/L)
TSU	Total Sludge Units (ASU + CSU)
TXU	Total Excess Sludge Units To Waste (XSU + ESU)
XFP	Excess Sludge Flow (As Percent of Sewage Flow)
XMF	Excess Mixed Liquor Sludge Flow To Waste (MGD)
XRF	Excess Return Sludge Flow To Waste (MGD)
XSF	Total Excess Sludge Flow To Waste (MGD)
XSU	Excess Sludge Units To Waste

APPENDIX C

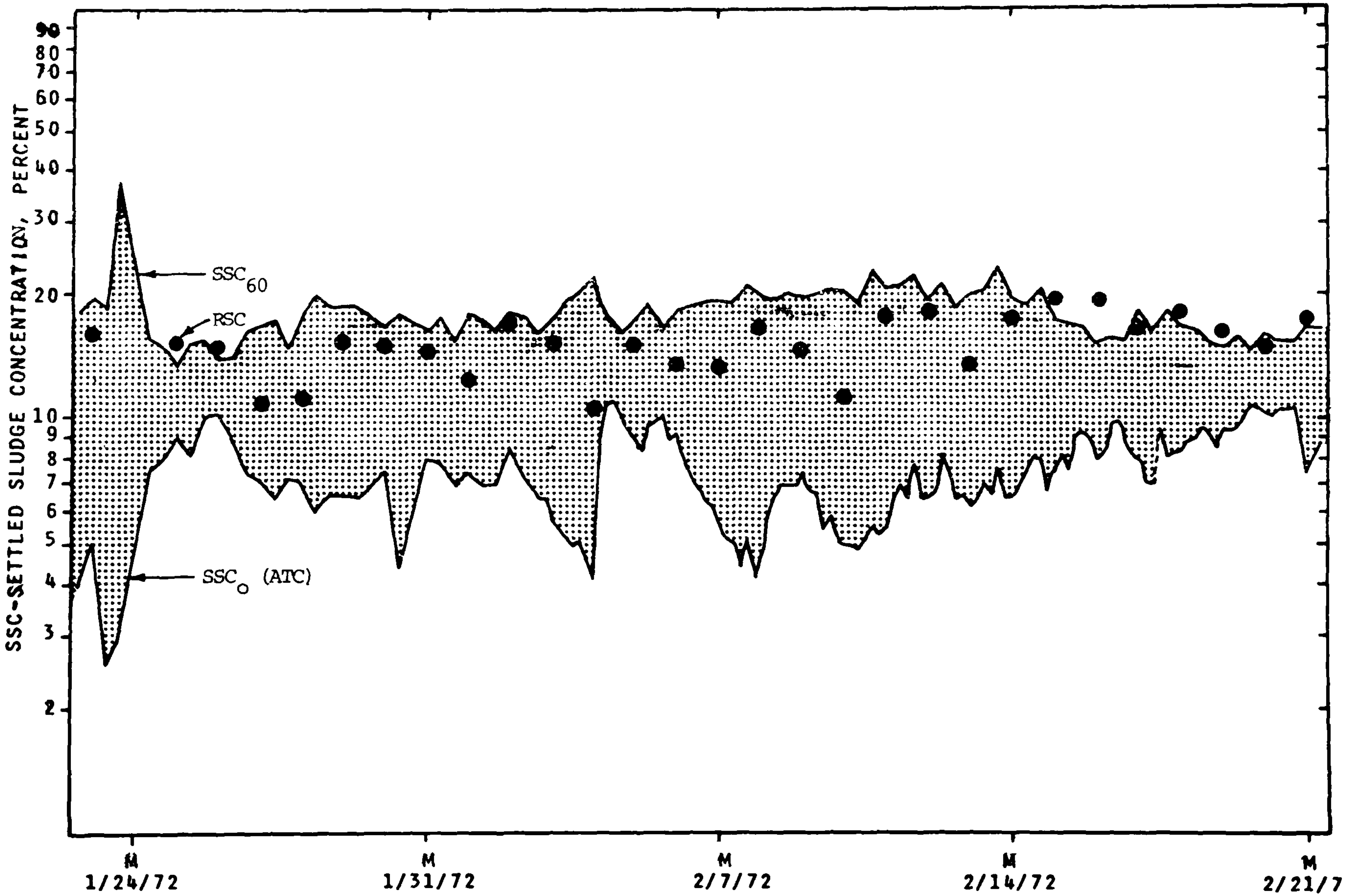
OPERATIONAL CONTROL TREND CHARTS

C-1

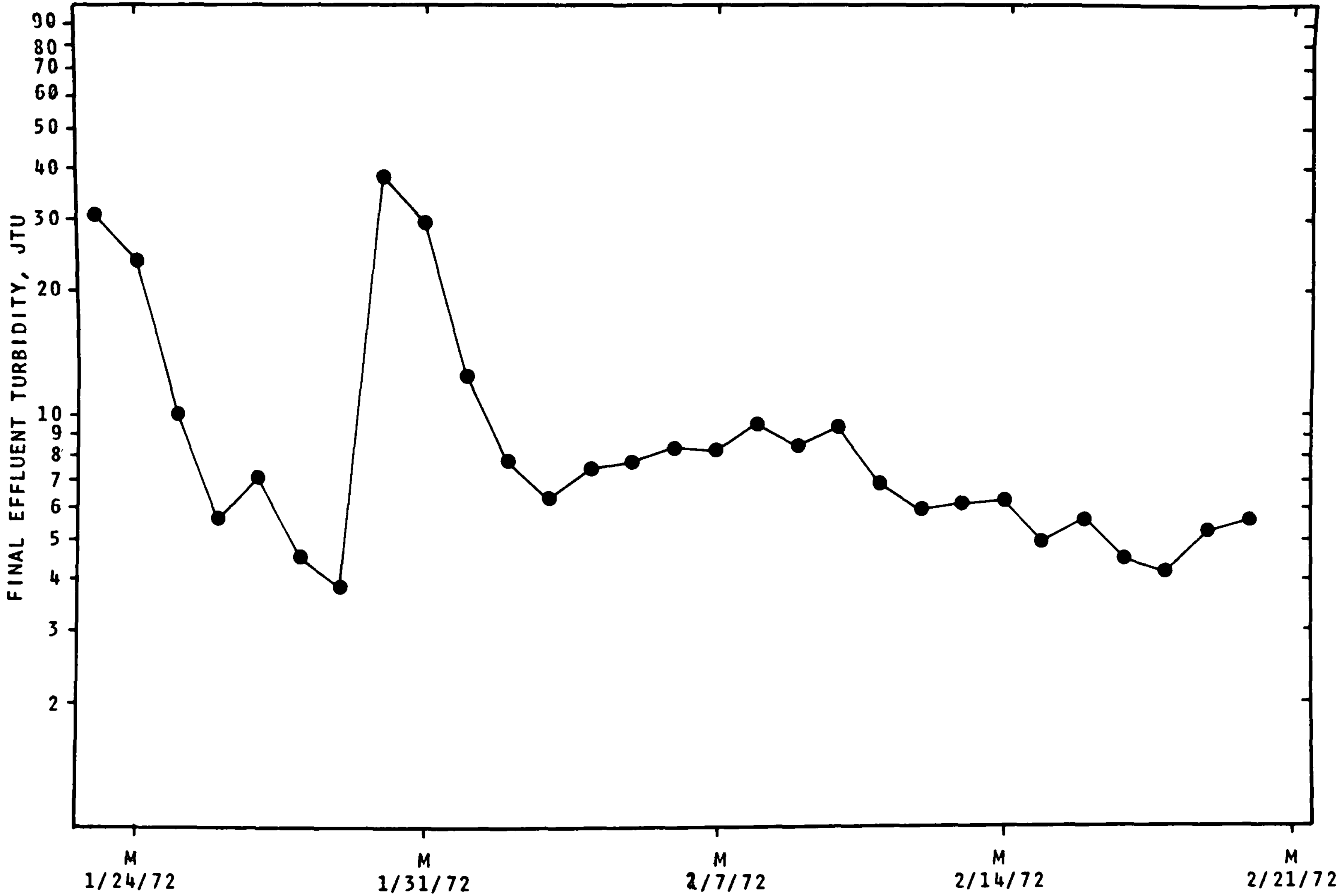
SETTLED SLUDGE VOLUME - SSV



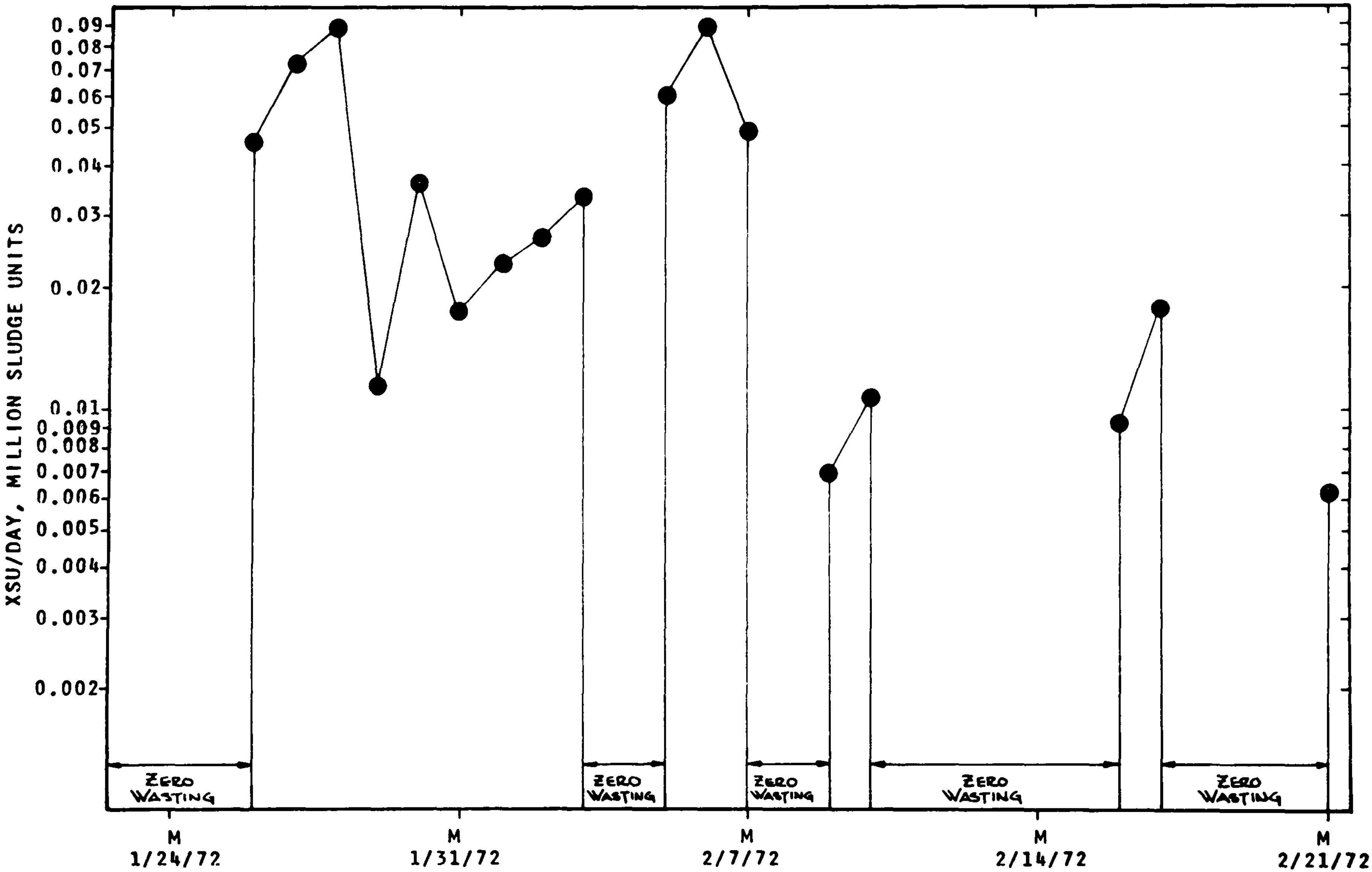
SETTLED SLUDGE CONCENTRATION - SSC



FINAL EFFLUENT TURBIDITY

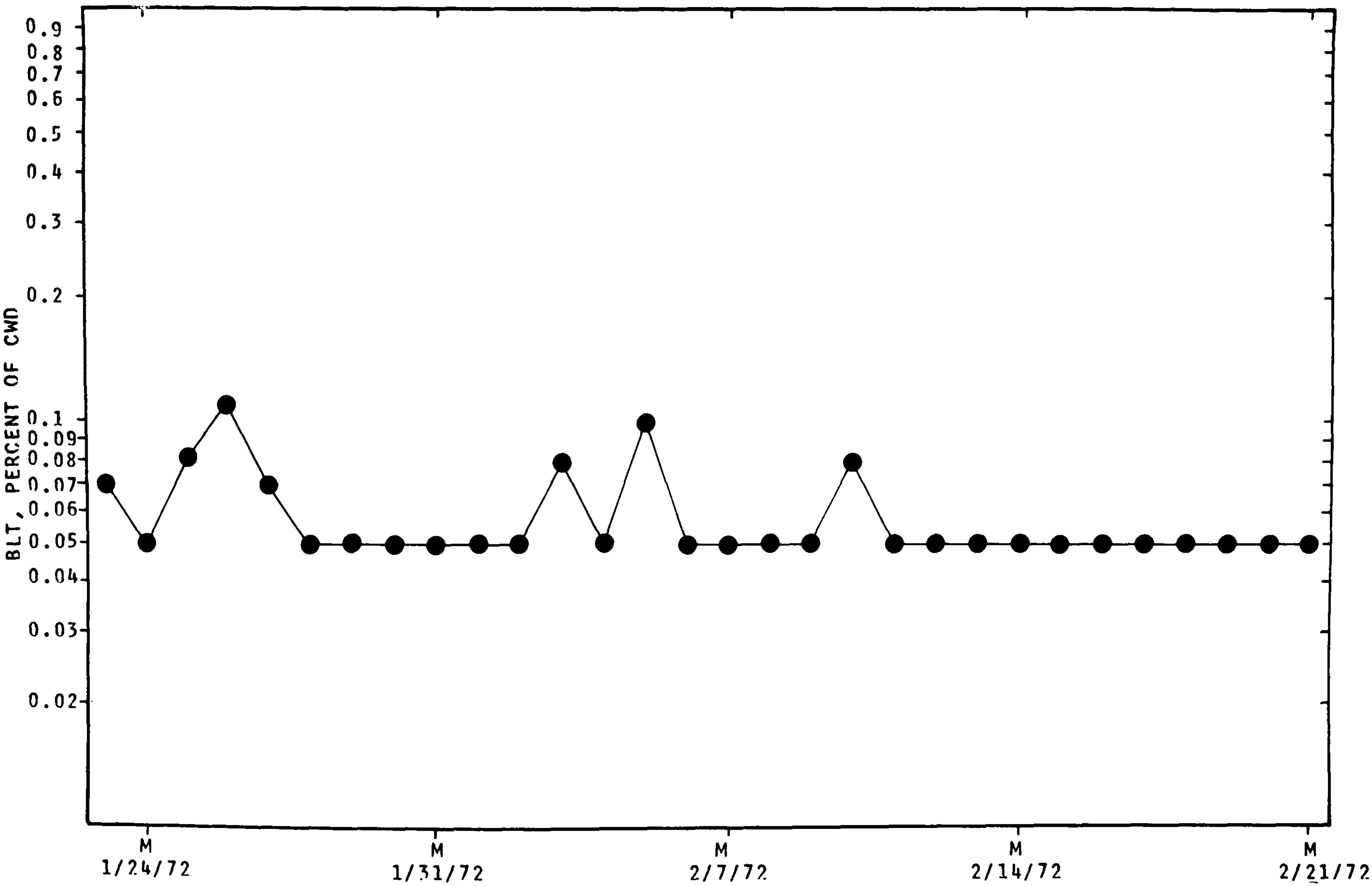


EXCESS SLUDGE UNITS WASTED/DAY - XSU/DAY

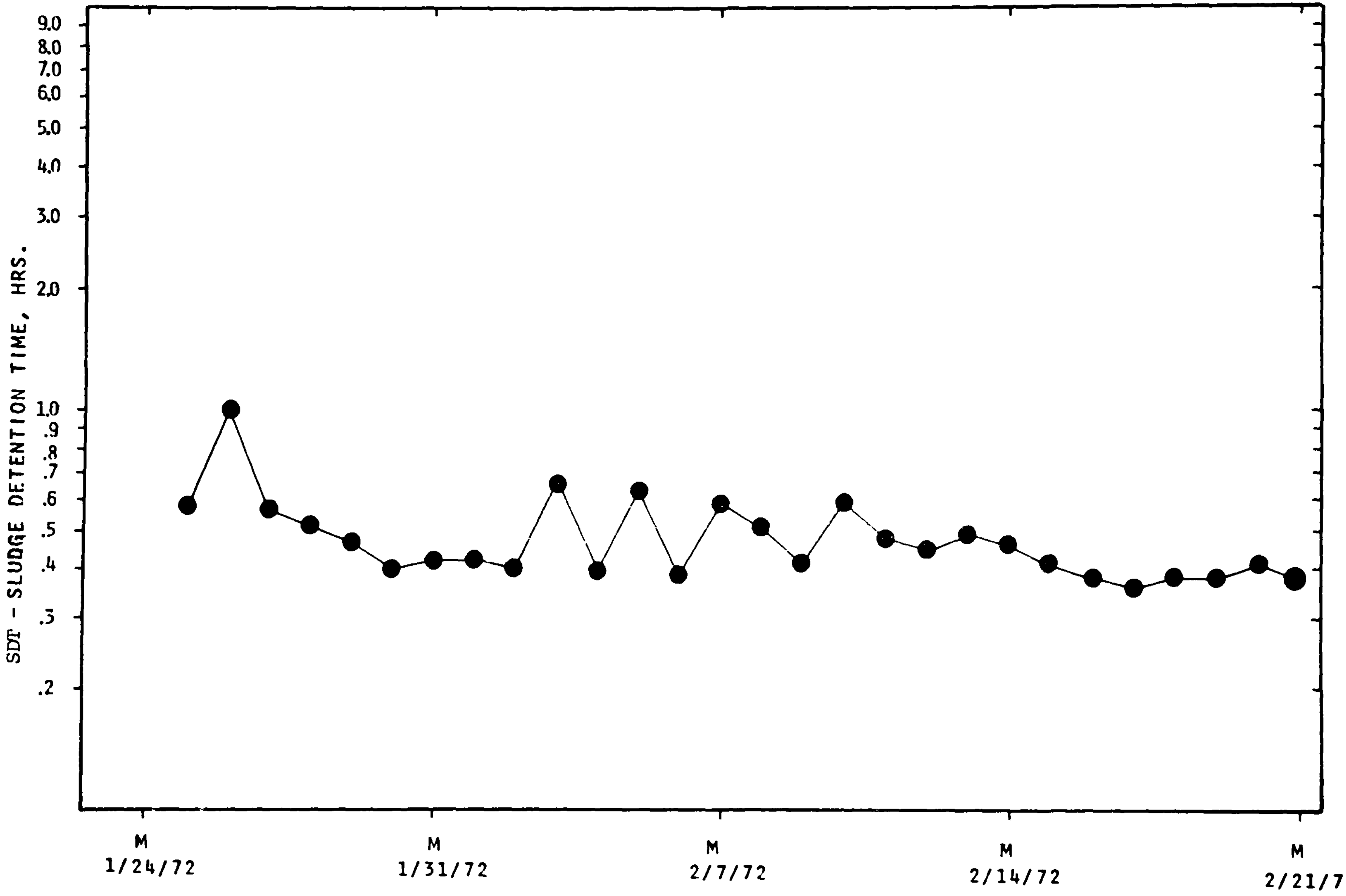


C-5

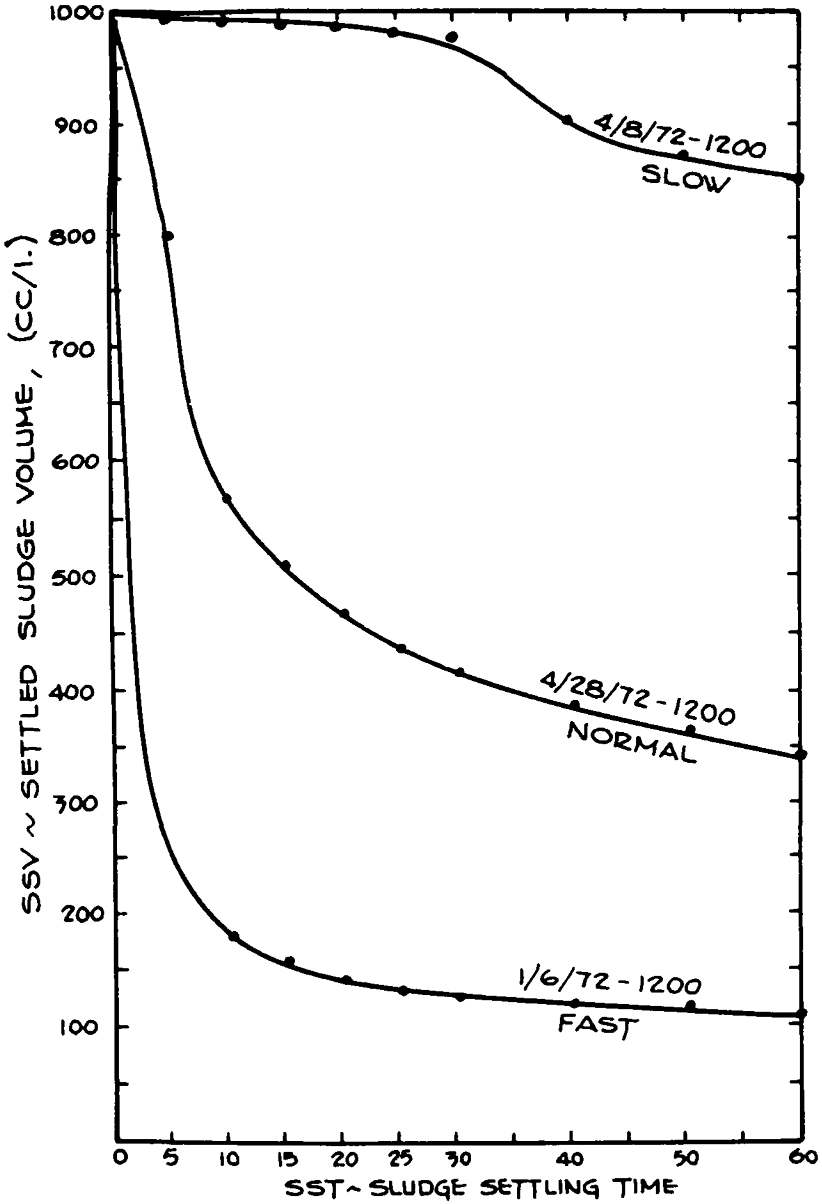
BLANKET THICKNESS-BLT



SLUDGE DETENTION TIME - SDT



SSV CURVES ~ HRSD



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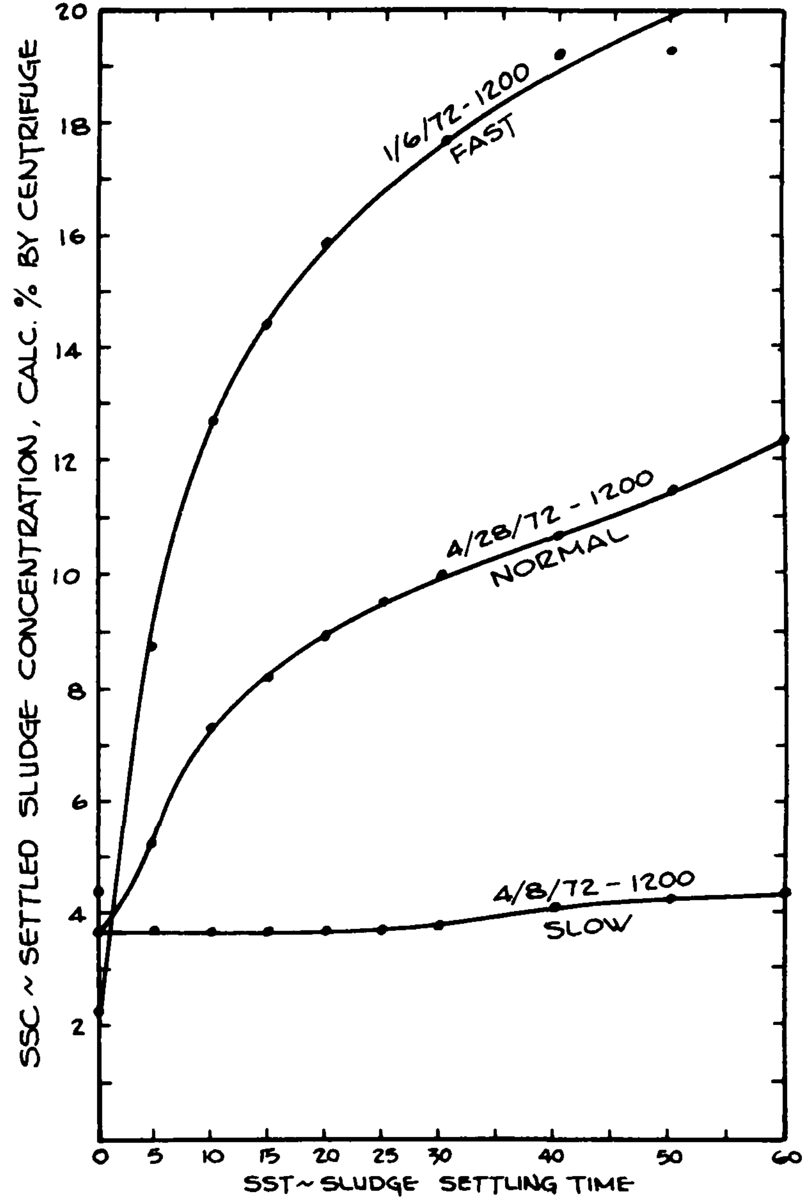

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