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Estimate of Effluent Limitations to be Expected from Properly Operated and Maintained Treatment Works

ESTIMATION OF EFFLUENT LIMITATIONS TO BE EXPECTED FROM PROPERLY OPERATED AND MAINTAINED TREATMENT WORKS

by

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PART 1

CONTENTS

PART 1

FIGURES

PART 1

TABLES

ACKNOWLEDGEMENTS

This manual and the two accompanying manuals were prepared by Culp/Wesner/Culp (CWC) for the U.S. Environmental Protection Agency, Office of Water Enforcement, Washington, D.C. under Contract Number 68-01-4329 as directed by Mr. Jim Grafton, project officer.

Data were collected at several locations throughout the country with the assistance of several state and EPA offices as well as the operating agencies. The list below shows those offices who provided operating information. Considerable data were taken from other projects in progress by CWC.

Agencies Contacted

1. U.S. EPA, Kansas City, Kansas, Office of Surveillance and Analysis
2. U.S. EPA, Kansas City, Missouri, Office of Water Enforcement
3. Iowa Department of Environmental Quality, Region 1, Manchester, Iowa
4. Wisconsin Dept. of Natural Resources, Div. of Environmental Standards, Madison, Wisconsin
5. Neillsville, Wisconsin
6. Sun Prairie, Wisconsin
7. Stanley, Wisconsin
8. Cross Plains, Wisconsin
9. Mazomanie, Wisconsin
10. Adams, Wisconsin
11. Rockdale, Wisconsin
12. Colby, Wisconsin
13. Spencer, Wisconsin
14. California State Water Resources Control Board, Water Quality Division, Sacramento, California
15. Seaside, California
16. Gilroy, California
17. Santa Cruz, California
18. Pacific Grove, California
19. Watsonville, California
20. Santa Cruz County, California

21. San Diego County, California
22. Laguna Beach, California
23. Shellsburg, Iowa
24. Center Point, Iowa
25. Monticello, Iowa
26. Cascade, Iowa
27. Manchester, Iowa
28. Independence, Iowa
29. Georgia Dept. of Natural Resources, Environmental Quality Division, Atlanta, Georgia
30. U.S. EPA, Atlanta, Georgia, Office of Water Enforcement
31. College Park, Georgia
32. Atlanta, Georgia
33. Athens, Georgia
34. Cobb County, Georgia
35. Leominster, Massachusettes
36. Hampton County, Massachusettes
37. City of Westboro, Massachusettes
38. Nassau County, New York
39. Richmondville, New York
40. Athens, New York
41. Elmhurst, Illinois
42. Homewood, Illinois
43. Barrington, Illinois
44. Wooddale, Illinois
45. Addison, Illinois
46. Carpentersville, Illinois
47. Toledo, Oregon
48. Salem, Oregon
49. Gig Harbor, Washington
50. Sedro Wooley, Washington
51. Arlington, Washington
52. Massachusettes Dept. of Environmental Quality Engineering, Boston, Massachusettes
53. New York Dept. of Environmental Conservation, Albany, N. York
54. Illinois Environmental Protection Agency, Springfield, Illinois

55. Oregon Dept. of Environmental Quality, Portland, Oregon

56. Washington Dept. of Ecology, Olympia, Washington

SECTION 1

INTRODUCTION

There are a large number of municipal wastewater treatment plants that will be unable to comply with the legislatively mandated minimum secondary treatment requirements due to the lack of available funding. The intent and purpose of the 1972 Federal Water Pollution Control Act Amendments will be met when a municipality that is unable to finance capital improvements, unassisted, operates and maintains its existing facility to minimize the discharge of pollutants.

Since time and resources are unavailable to visit and examine every facility, a simplified screening procedure has been developed to establish effluent limitations considering the type of process and actual plant loading as related to the design loading. This loading relationship (normalized flow) is defined in this study as the ratio of actual flow to design flow. The developed procedure is designed to provide estimates of the expected effluent BOD_5 and suspended solids concentrations given the actual plant flow and design capacity. Operation and maintenance requirements for plants from .01 to 10 mgd were also developed to provide an estimate of the appropriate effort required by the owner to meet expected plant performance.

SECTION 2

PURPOSE

The purpose of this project is to provide U.S. Environmental Protection Agency regional staffs with a necessary documented method for establishing effluent limitations for unfunded, publicly owned treatment works. This method will provide a means of screening out facilities that are apparently not being operated and maintained at a level of effort necessary to achieve optimum performance. Those facilities that are screened by this process will require further review to determine the cause of inadequate performance. This method will not provide a means for determining whether the lack of optimum performance is due to inadequate operator skill, inadequate design, poor construction or addition of or lack of control of high strength industrial waste.

The following screening method is proposed to provide a rapid means of reviewing and issuing NPDES permits to a large number of applicants.

SECTION 3

DESCRIPTION OF MANUALS

This document consists of 3 parts. Part 1 describes the development and data sources as well as the use and limitations of the user manuals. Parts 2 and 3 each consist of a user manual. One manual was developed for determining effluent limitations (Part 2) and the other for determining operation and maintenance requirements (Part 3). The effluent limitations manual was developed to provide a reviewer with information necessary to predict expected unit process performance in terms of BOD_5 and suspended solids concentrations. The main premise used is that the plant was properly designed and constructed and that there are no major pieces of equipment that are inoperable. In other words, the unit process should meet design standards until the actual flow exceeds design flow. This manual is intended mainly for plants of less than 10 mgd flow. When the actual flow exceeds design flow, the effluent quality or constituent removal efficiency should decrease as predicted by the curves. Good operational control can provide better than predicted performance. With these performance curves, overloaded plants can be issued interim permits until plant expansion can be completed. If a facility does not meet the performance indicated by the curve for its unit process type, then further investigation is necessary.

The second manual provides operation and maintenance requirements information. Tables are provided to show labor hours, electrical energy consumption, chemical costs (mainly chlorine) and maintenance material costs (spare parts, replacement equipment, etc.). A unit labor cost (including fringes) of $9/hour and an electricity cost of 3.0¢/kwh were assumed to determine the total annual operation and maintenance costs shown on the figures for the various unit processes. The costs were first computed for plants operating at design capacity or at a normalized flow equal to 1.0. The tables and figures are then adjusted to show additional operation and maintenance costs due to overloaded conditions. The purpose of this approach is to provide guidance as to the necessary operation and maintenance cost to attain the effluent standards or removel efficiencies presented in the effluent limitations manual.

Unit process types and size ranges were selected based on data sources available through the U.S. Environmental Protection Agency "Needs Survey" and "Storet" programs. Unfortunately, some states provided less thorough information than others. There was also some confusion as to the proper category for certain modifications of activated sludge. For example, should contact stabilization be counted as activated sludge or as "other".

The predominant processes were primary, trickling filter, and activated sludge. Stabilization ponds or lagoons were eliminated due to the change in regulations, in that a 30 mg/l suspended solids effluent concentration is no longer required. As of this date, new standards have not been set. The various data sources failed to show numbers of package plant systems of the activated sludge type. Since most activated sludge systems smaller than 1 mgd will normally be more economical to operate and maintain if designed as package plants - extended aeration or contact stabilization, or as oxidation ditches, these categories were included.

The 1976 needs survey has just been completed. This survey differs from the 1974 survey in that a private contractor compiled data rather than the individual states. Details of this survey have not yet been published. However, there are some bits of data that are available and are applicable to this project. Based on the 1976 needs survey, 8,571 plants of 16,000 existing plants will not meet secondary treatment standards (30 mg/l BOD_5/30 mg/l suspended solids) by July 1, 1977. This fact shows the necessity of this project. Previous data from both "STORET" and the 1974 Needs Survey, although having some minor differences in inventories, show less than 3% of the treatment plants with existing flows greater than 10 mgd. The 1976 needs survey data show that over one half of the treatment plants in the United States have less than 0.1 mgd of flow. Thus, the flow ranges used for this study were chosen for less than 10 mgd. Processes where applicable are shown at capacities as low as 0.01 mgd. Some process types are not available for flows less than 0.1 mgd.

An effort was made to categorize plants by age or "flow age". Flow age is defined as the total gallons of flow having been treated by a facility. This results in a measure of the time that a plant has been operating at a relatively high flow rate. Unfortunately, records were not available or accurate enough to determine this parameter. Several plants were visited that had been built prior to 1950 but most mechanical equipment had been replaced several times since. A good example of this situation (although this example was not part of the study for the manual) is the City of Los Angeles Hyperion wastewater treatment plant. The primary sludge pumps were originally manufactured before 1930. Replacement parts are no longer available so the City's machine shop fabricates its own replacement parts. The result of this and other examples is that enterprising local agencies can maintain equipment to meet requirements regardless of plant or flow age.

The normal average pollutant effluent constituent concentration for each type of process when operated at or below design flow, i.e., normalized flow of 1.0 or less are summarized as follows:

Expected Plant Performance

	BOD_5	Suspended Solids
	Effluent Concentration mg/l	Effluent Concentration mg/l
Primary	130	70
Trickling Filter	30	30
Activated Sludge (including contact stabilization, extended aeration, oxidation ditch)	30	30

For flows exceeding design flow (or normalized flow greater than 1.0) the expected constituent concentrations will increase according to the effluent limitations manual.

SECTION 4

BACKGROUND THEORY AND DATA SOURCES

The effluent limitations manual shows expected performance for primary, trickling filter, activated sludge plants, and modified activated sludge processes. These process modifications include contact stabilization, extended aeration, and oxidation ditch processes. The oxidation ditch process may be operated as a one-pass system or as an extended aeration process. This report reviews oxidation ditches that are operated in the extended aeration mode.

Primary treatment is normally not affected by cold weather conditions. Therefore, one curve is shown for primary plants. The basis for the curve is suspended solids removal. This curve was developed based on a family of curves presented by Fair & Geyer (1). The curve was then verified by actual plant data. Removal of suspended solids can be improved by the use of chemicals such as polymers, ferric chloride, alum, or lime as described in the EPA manual Upgrading Existing Wastewater Treatment Plants (2) and as practiced in the primary plants visited in California cities with ocean discharges.

The primary plant BOD_5 removal performance curve was estimated based on an assumed 50% soluble BOD_5 fraction in the effluent. This curve was also verified by data obtained during plant visits.

Primary plants visited to verify the performance curves are listed in Table 1. The performance of each plant is summarized in Table 2. Figure 1 shows the performance curve with actual annual average data plotted on the curve.

The trickling filter BOD_5 effluent limitations curve was developed by first assuming a design of a system having a raw sewage influent BOD_5 concentration of 200 mg/l and a final effluent BOD_5 concentration of 30 mg/l. A 35% BOD_5 removal efficiency was assumed for primary clarification. In order to reduce the remaining BOD_5 to 30 mg/l, a 77% removal efficiency must be attained by the trickling filter (includes final clarification). Using the EPA Process Design Manual for Upgrading Existing Wastewater Treatment Plants (2), Figure 4-2 a hydraulic loading rate of 0.35 gpm/sq ft was determined for a 77% removal efficiency. The decrease in performance for overloaded facilities was then computed by adjusting the removal efficiencies for primary sedimentation (as developed in this project) and trickling filters (as shown in the Process Design Manual Figure 4-2).

TABLE 1. PRIMARY PLANTS VISITED

1. San Elijo, CA
2. Encina, CA
3. Laguna Beach, CA
4. Durham, N. H.
5. Bangor, MA
6. Gilroy, CA
7. Aptos, CA
8. Pacific Grove, CA
9. Seaside, CA
10. Watsonville, CA
11. Santa Cruz, CA
12. Junction City, KS
13. Lawrence, KS
14. Wamego, KS
15. Weiser, ID

TABLE 2. PRIMARY PLANT DATA SUMMARY

Wastewater Treatment Plant	Average In Pri. Effl., mg/l		Maximum In Pri. Effl., mg/l		Ave. Removal In Primary, Percent	
	BOD	SS	BOD	SS	BOD	SS
So. Tahoe P.U.D., CA	90	85	145	800	36	56
Bangor, MA	91	72	152	329	36	48
Gilroy, CA	-	90	-	112	-	-
Laguna Beach, CA*	160	100	-	-	-	-
Encina, CA	143	75	-	-	31	62
San Elijo, CA	111	67	-	-	32	71
Aptos, CA*	-	76	-	96	-	-
Pacific Grove, CA*	-	59	-	64	-	69
Seaside, CA*	-	49	-	275	-	76
Watsonville, CA*	208	74	406	153	53	80
Santa Cruz, CA*	209	118	-	-	29	60
Weiser, ID	25	20	60	34	36	50
Lawrence, KS	181	86	-	-	32	60
Junction City, KS	172	228	-	-	42	40
Wamego, KS	266	120	-	-	26	53
Average	150	88	191	266	34	60

*Polymers used

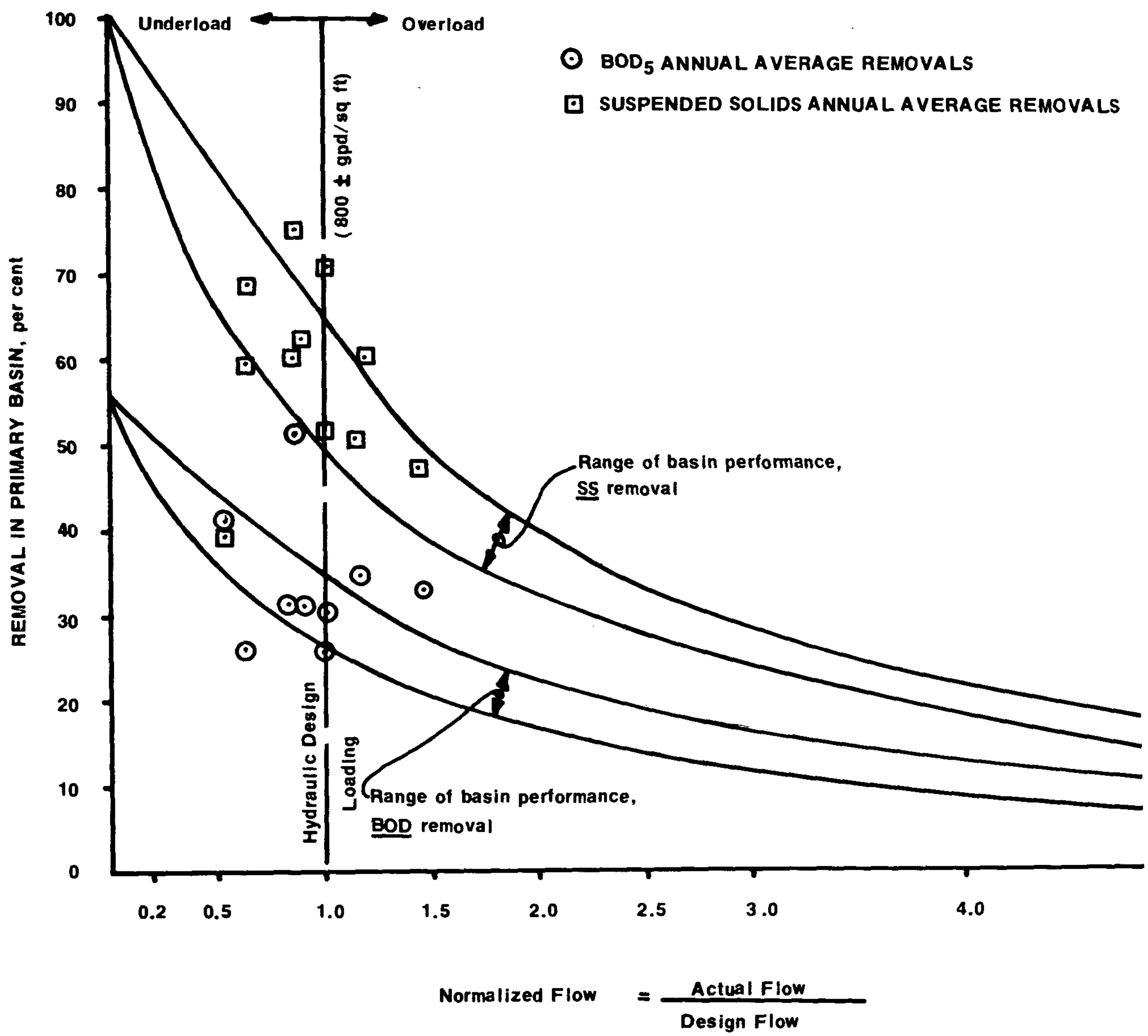

Figure 1. Estimated Removals of Suspended Solids and BOD in Primary Basins at Various Hydraulic Loadings

A specific set of criteria was chosen to develop the curve. However, this curve would be applicable for any loadings since the performance was calculated using a percent removal which varies linearly with variation in hydraulic loading rate. For example, a high strength waste would require a lower hydraulic loading rate to obtain a 30 mg/l but the same degradation rate would apply. By using the normalized flow parameter differences between loading rates do not change the performance result. An exception to this rule is a situation where an actual waste loading has changed in character from the design loading. For example, a system may have been designed to treat domestic waste only. If a high strength industrial waste was added to the system after it was constructed, then the overload performance protion of the curve would not apply.

The most complete available summary on temperature effects on effluent BOD_5 concentration was developed by Culp/Wesner/Culp as part of a study for the EPA on attached growth systems (3). The following discussion on temperature effects is an excerpt from that study report.

The temperature effects on effluent quality and system design requiements for trickling filters are usually critical for cold weather conditions. For a year-around effluent quality criteria, the cold weather conditions will determine the size of the trickling filter because of the lower biological reation rate. An extensive evaluation of data which assesses temperature effects was made by Galler-Gotaas (4). In their formula, temperature affects on effluent quality may be stated:

$$\frac{Le_T}{Le_{20}} = \left(\frac{20}{T}\right)^{0.15}$$

Where T = temperature, celcius

Le_T = effluent BOD mg/l at temperature T

Le_{20} = effluent BOD mg/l at temperature 20C

For example: To obtain an effluent BOD at 30 mg/l at a temperature of 10C, the effluent BOD at 20C would need to be 21.2 mg/l

Eckenfelder (5) states the effect of temperature as

$$E_T = E_{20} \times \theta^{(T-20)} \qquad \text{where } \theta = 1.035 \text{ to } 1.040$$

In a presentation of actual data, Benzie, et al (6) provided a basis to evaluate θ. Of the 17 plants reported, 6 plants had a θ over 1.01 which would exceed that predicted by Galler-Gotaas (1.011). Of these 6 plants, 5 plants employed recirculation, whereas, of the eleven plants having a calculated θ value below 1.01, only two plants employeed a 1:1 recirculation.

A comparison of plants employing recirculation from different sources by Culp (7) indicates that the location of the source of recirculation effects the results. The Webster City data and the calculated θ value is as follows:

	Warm Weather		Cold Weather		
	T-C	E	T-C	E	θ
Direct Filter Recirculation	18.3°	60.5	10.4	56.2	1.009
Recirculation From Final Effluent	18.6	51.4	9.4	38.6	1.032

The effect of temperature cannot be defined conclusively with the data collected for this report; however, temperature appears to play a less significant role than previously believed by many investigators. The reduced effect of temperature supports conclusions by Williamson and McCarty (8) that the role of biological reaction rates (drastically affected by temperature) must be tempered by the limitations imposed by diffusion of organics and oxygen through the bulk liquid and biofilm.

Operating data for trickling filters often reflect temperatures of raw sewage. The application of the sewage to trickling filters has a cooling effect, the extent of which is dependent upon the air temperature. Where high recirculation rates are employed, the cooling effect will be of greater significance on the operation of the trickling filter. Therefore, reported temperature and plant performance data may not be readily correlated since the trickling filter will experience cooler temperatures than reflected by the raw sewage temperature".

First the Galler-Gotaas equation is used. Assuming a system is designed to attain 30 mg/l BOD_5 at 20°C and the cold weather sewage temperature is 5°C, then the effluent BOD_5 will be 37 mg/l.

Applying the Eckenfelder equation, using the same assumptions as above and $\theta = 1.035$, the effluent BOD_5 will be 40 mg/l.

A comparison of these two equations shows increases in BOD_5 concentration of 23% and 33%. Benzie, et al (6), show decreasing BOD_5 removal efficiencies due to cold weather operation of 17 trickling filter plants in Michigan. The loss in efficiency varied considerably depending on recirculation practices. Averaging the data of all 17 plants, the loss in BOD_5 removal efficiency was 12%. The decrease in efficiency for those plants employing recirculation was 21%. Those plants without recirculation showed a 6% decrease in efficiency. Their analyses show the 21% difference to be statistically significant but the 6% difference was not.

Based on the Benzie work and CWC analysis, the temperature equations appear to be more conservative than actual operating data. However, the operating data are monthly averages and the plants reviewed in cold weather climates were usually designed to account for cold weather conditions. Generalizations made for a study such as this one can be misleading since the equations apply to specific temperatures and resulting BOD_5 concentrations. The formulae do not show the effect in extreme temperature variation or effects of freezing distributor arms. Obviously, there will not be effective treatment if the distributor is frozen. The monthly average effluent BOD_5 concentration will be raised due to the freezing condition and the time required for the filter organisms to recover. Conversely, a temperature drop that is brief in time may not have the impact of a long term temperature drop.

The performance curves developed consist of two situations representing extreme conditions. Curve 1 shows the predicted performance of plants operating under design conditions. If a plant was designed for cold weather conditons, the resulting BOD_5 effluent concentration should be less than or equal to that predicted by the curve. In other words, the plant designed for $5^{o}C$ temperatures should meet performance curve 1 when operated at $5^{o}C$.

If a particular system is designed for an effluent concentration greater than 30 mg/l, the curves are still valid. The user will simply change the vertical scale. For example, if the system was designed for 40 mg/l, then 30 mg/l should be changed to 40 mg/l and the remaining values increased by 10 mg/l.

There are no theoretical relationships for trickling filter loadings and resulting suspended solids removals. The suspended solids effluent concentration/removal efficiency curves were determined based on final clarifier removal and adjusted by an expected soluble BOD_5 percentage of 50%. This curve was then compared with actual data and adjusted accordingly.

Both of the trickling filter curves are subject to error due to recirculation constraints, due to design, and practices of the individual operator. The method presented herein can account for variations in organic loading and performance using a normalized flow unless the recirculation was limited by the original design.

The trickling filter plants visited for performance curve verification are listed in Table 3. Data obtained are summarized in Table 4. Figures 2 and 3 show data plotted on the performance curves. Winter data (December-March), summer data (June-September), and other months are plotted separately.

BOD_5 and suspended solids effluent quality performance curves shown for conventional activated sludge (Figures 4 and 5) and extended aeration, oxidation ditch, and contact stabilization modes of operation (Figures 6 and 7). Equal performance should be attained by any of these modes of operation but the conventional activated sludge process showed less reliability than the other modes of operation (see Tables 5 and 6). Based on plant visits made in the progress of this study, the conventional process was generally given inadequate attention by operating personnel. The other activated sludge modifications seemed to be less subject to variability in influent quantity and quality typically found in small plants. They also seemed to be less affected by operator error or

TABLE 3. TRICKLING FILTER PLANTS VISITED

1. Shellsburg, IA
2. Center Point, IA
3. Monticello, IA
4. Cascade, IA
5. Manchester, IA
6. Independence, IA
7. Lakeview, IA (by Kansas City, KS, EPA)
8. College Park, GA
9. Atlanta, GA
10. Cobb County, GA (three plants)
11. Athens, GA (two plants)
12. Cedartown, GA (data obtained w/o visit)
13. Newman, GA (Snake Creek plant, data obtained w/o visit)

$$\text{NORMALIZED FLOW} = \frac{\text{ACTUAL FLOW}}{\text{DESIGN FLOW}}$$

CURVE 1 shows performance of plants at 20°C temperature or plants designed for cold weather operation.

CURVE 2 shows cold weather (5° C) operation results for plants designed for 20° C operation.

(1) See text for explanations of terms.

- ● SUMMER (JUNE–SEP)
- ■ WINTER (DEC–MAR)
- ▲ OTHER MONTHS

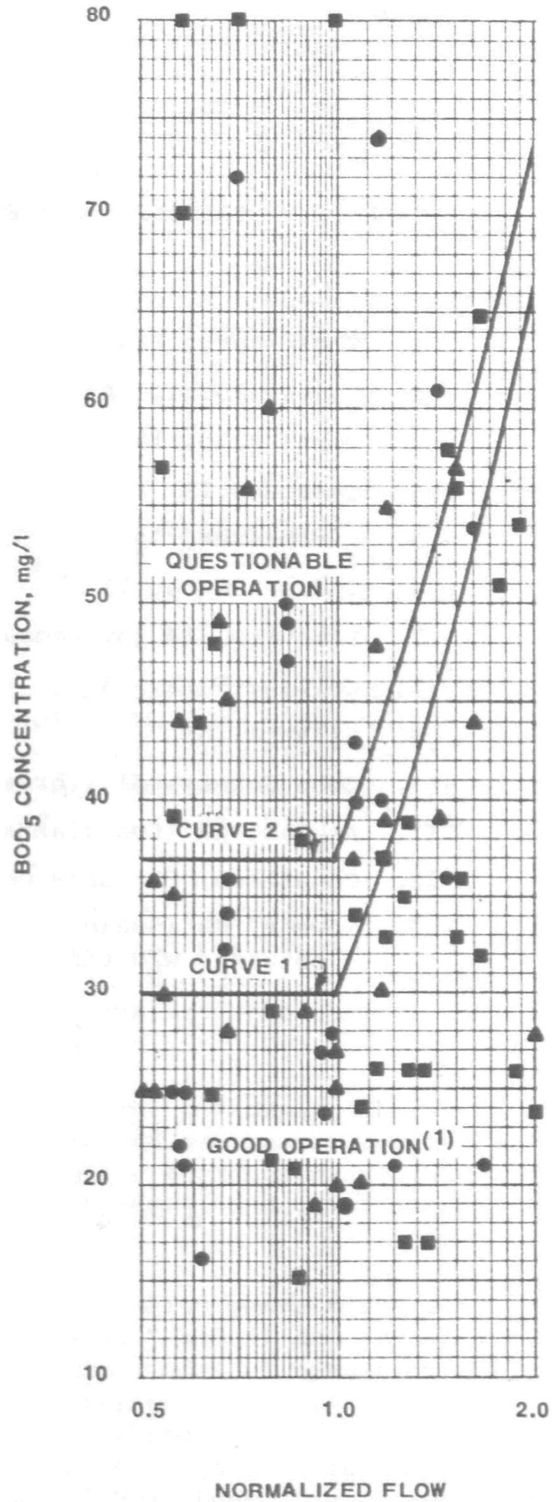

Figure 2. Trickling Filter Performance, BOD_5 Effluent Concentration

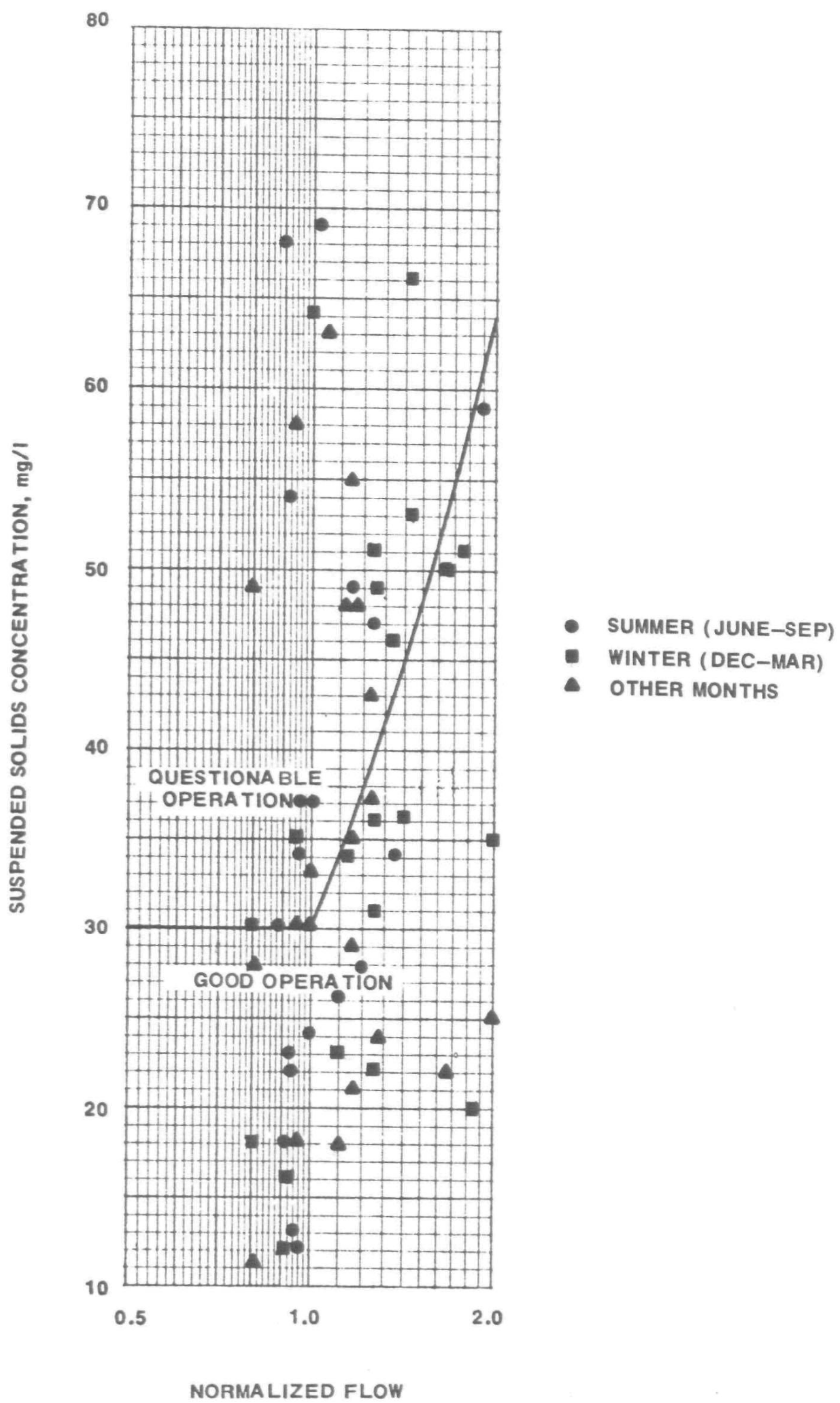

Figure 3. Trickling Filter Performance, Effluent Suspended Solids

TABLE 4. TRICKLING FILTER VISITATION DATA SUMMARY

Location or Plant Name	Design Flow mgd	Actual Flow mgd (annual average)	Normalized Flow (3) ÷ (2)	Effluent BOD_5 Conc. mg/l	BOD_5 % Removal %*	Effl. Susp. Solids Conc. mg/l	Susp. Solids % Removal*
Iowa:							
Shellsburg	0.0825	0.0609	0.74	47	70	-	-
Center Pt.	0.200	0.141	0.70	43	72	-	-
Monticello	0.800	0.412	0.51	39	80		
Cascade	0.220	0.081	0.37	48	76		
Independence	0.750	0.889	1.18	85	87		
Lakeview	0.175	0.153	0.87	69	69		
Georgia:							
Westside, 1975	1.00	1.059	1.059	25	75	30	70
Westside, 1976	1.00	0.971	0.971	35	72	38	68
Kennesaw, 1974	0.30	0.27	1.423	24	85	28	87
Sandtown, 1976	1.00	1.222	1.222	51	70	50	60
Newman, 1975	0.40	0.328	0.820	30	88	28	88
Newman, 1976	0.400	0.346	0.865	23	88	29	86
Intr. Cr., 1975	20.0	13.9	0.695	40	82	26	78
Intr. Cr., 1976	20.0	13.1	0.655	35	83	31	74
College Pk., 1976	1.2	1.36	1.13	43	90	35	76
Athens #1, 1975	5.00	5.60	1.12	80	69	64	73
Athens #1, 1976	5.00	5.14	1.028	64	73	47	80
Athens #2, 1975	2.00	2.90	1.45	46	73	58	68
Athens #2, 1976	2.00	2.60	1.30	47	75	40	78
Cedartown, 1974	1.00	0.82	0.82	46	77	40	80
Cedartown, 1975	1.00	0.92	0.92	17	89	18	90
Cedartown, 1976	1.00	1.06	1.06	23	88	22	88

*Removal over all of plant
Note: Manchester, Iowa data not used due to sampling problems

TABLE 5. BOD_5 REMOVAL RELIABILITY

	Percent of Time Less Than or Equal to 30 mg/l	Percent of Time Less Than or Equal to 40 mg/l
Conventional Activated Sludge	73	89
Contact Stabilization	96	99
Extended Aeration	93	98

TABLE 6. SUSPENDED SOLIDS REMOVAL RELIABILITY

	Percent of Time Less Than or Equal to 30 mg/l	Percent of Time Less Than or Equal to 40 mg/l
Conventional Activated Sludge	79	94
Contact Stabilization	77	88
Extended Aeration	94	97

inattention.

The performance curves for all of these processes were determined by assuming that those plants visited would show better performance than an average operation. Average data or "best-fit" lines were not used to determine the performance curves. The objective of the plant visitations was to show that a well-operated plant could meet the performance curves. Actual data are plotted on Figures 4-9 to show a comparison between actual data and the curves. These data are shown by season of the year for demonstration of possible effluent deterioration due to cold weather.

There was no significant difference between summer and winter operation results (June, July, August, September vs December, January, February, March). Use of a normalized flow concept, as presented in this report, should allow for special design requirements for those plants located in cold climates. Obviously, the extreme cold conditions will adversely affect process performance. However, on an average monthly or annual basis, an activated sludge process should be capable of performing according to the performance curves shown. (Assuming conservatively designed clarifiers with adequate sludge return and wasting equipment).

Activated sludge plants that are hydraulically overloaded, but not organically overloaded should still meet design effluent BOD_5 levels. Performance in terms of suspended solids will be adversely affected unless clarifiers were designed for excessive flow variations. Therefore, the performance curves will not directly apply to an overload condition if the overload is due to a hydraulic overload, e.g., excessive infiltration/inflow.

Conventional activated sludge, contact stabilization, and extended aeration plant data sources are listed on Tables 7, 8, and 9 respectively.

The user manual for estimating O & M requirements contains the assumptions used for preliminary treatment and sludge handling. The smallest plant capacities are 0.01 mgd and the largest are 10.0 mgd. The capacity range varies with the type of process used. There are 5 tables and 5 figures (primary plants having 4 variations) showing O & M requirements and total O & M costs respectively. Each process is shown for operation at design flow, 50% overload, and 100% overload (normalized flows of 1.0, 1.5, and 2.0).

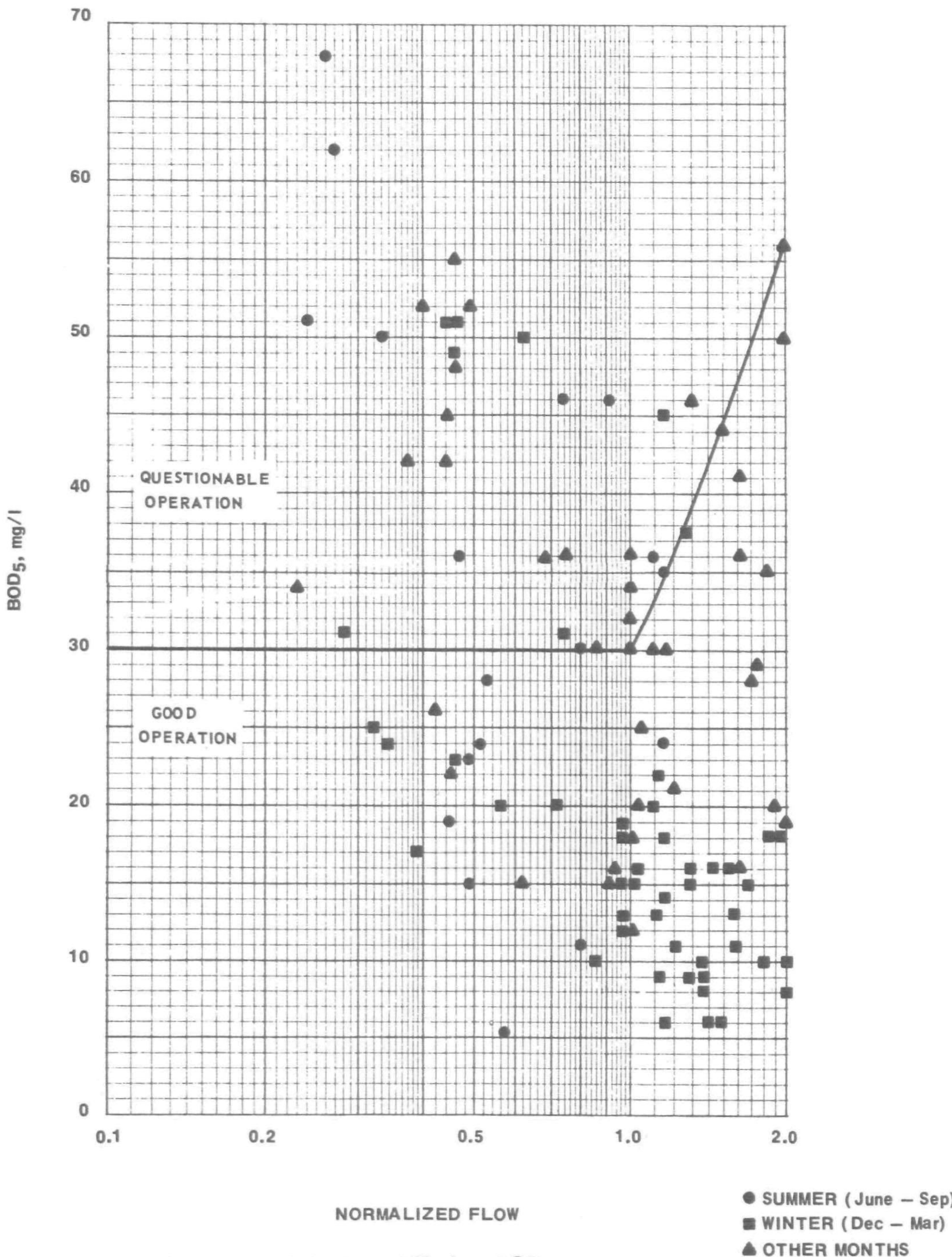

Figure 4. Conventional Activated Sludge, BOD_5

	NORMALIZED FLOW				
	<1.0				>1.0
	Total	Summer	Winter	Annual Ave.	
<60 mg/l BOD_5	98%	83%	99%		
< 50 mg/l	91%	83%	83%	99%	–
< 40 mg/l	78%	67%	67%	75%	–
< 30 mg/l	64%	50%	50%	75%	–

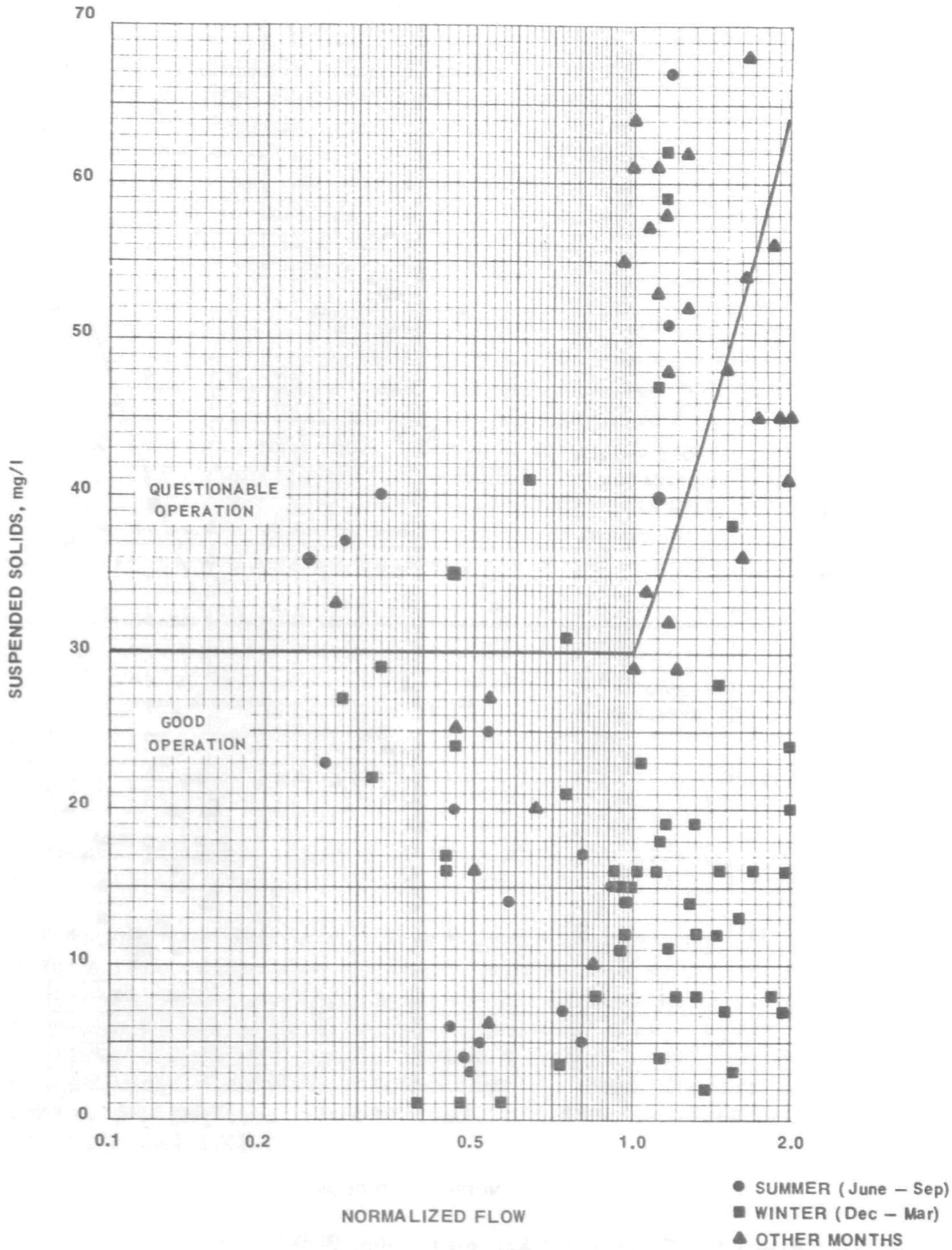

Figure 5. Conventional Activated Sludge, Suspended Solids

	NORMALIZED FLOW				
	<1.0				>1.0
	Total	Summer	Winter	Annual Ave.	
<60 mg/l BOD_5	99%				60%
< 55 mg/l				99%	
< 50 mg/l	97%		99%		20%
< 40 mg/l	94%	99%	93%	91%	
<30 mg/l	79%	75%	79%	82%	

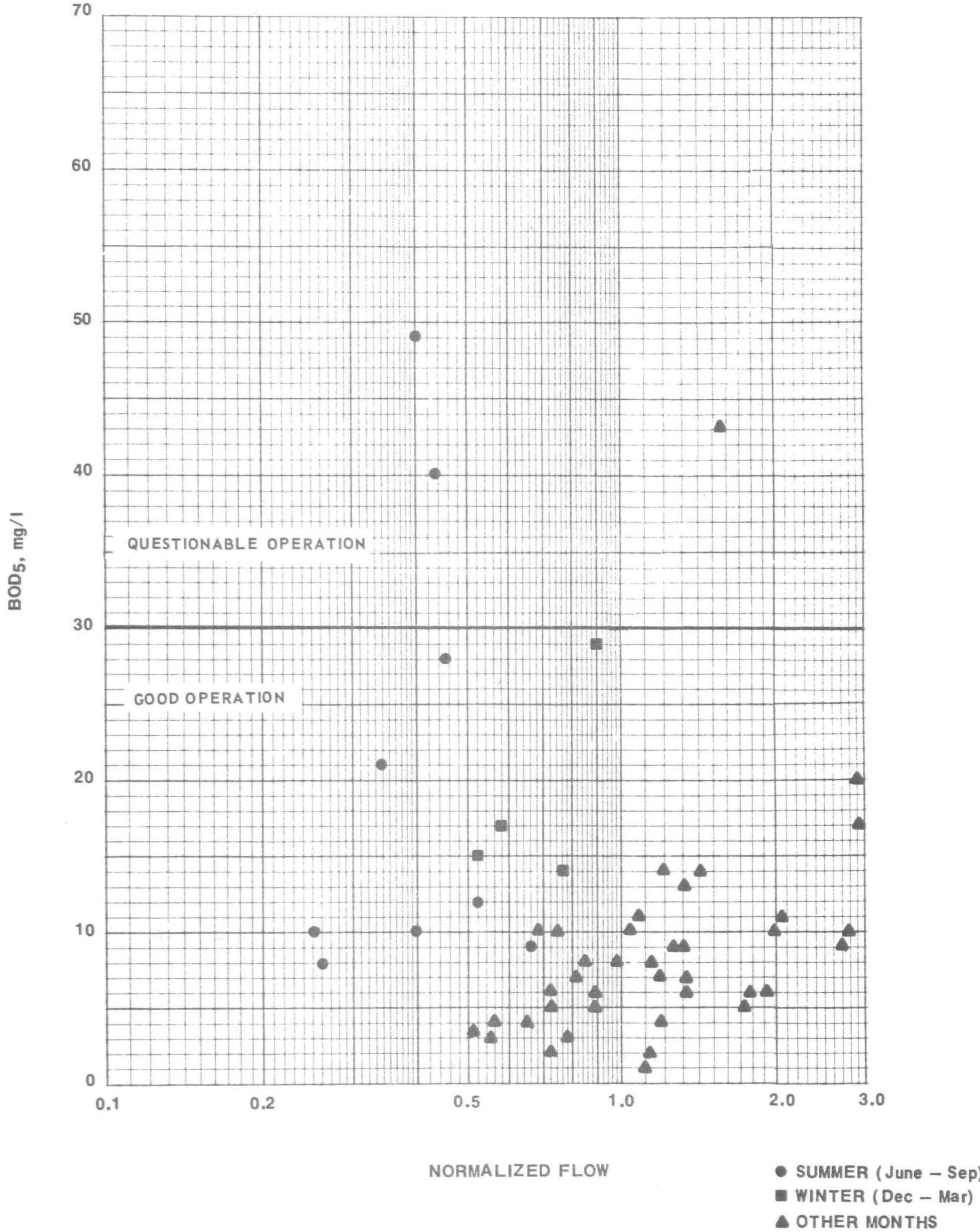

Figure 6. Extended Aeration, BOD_5

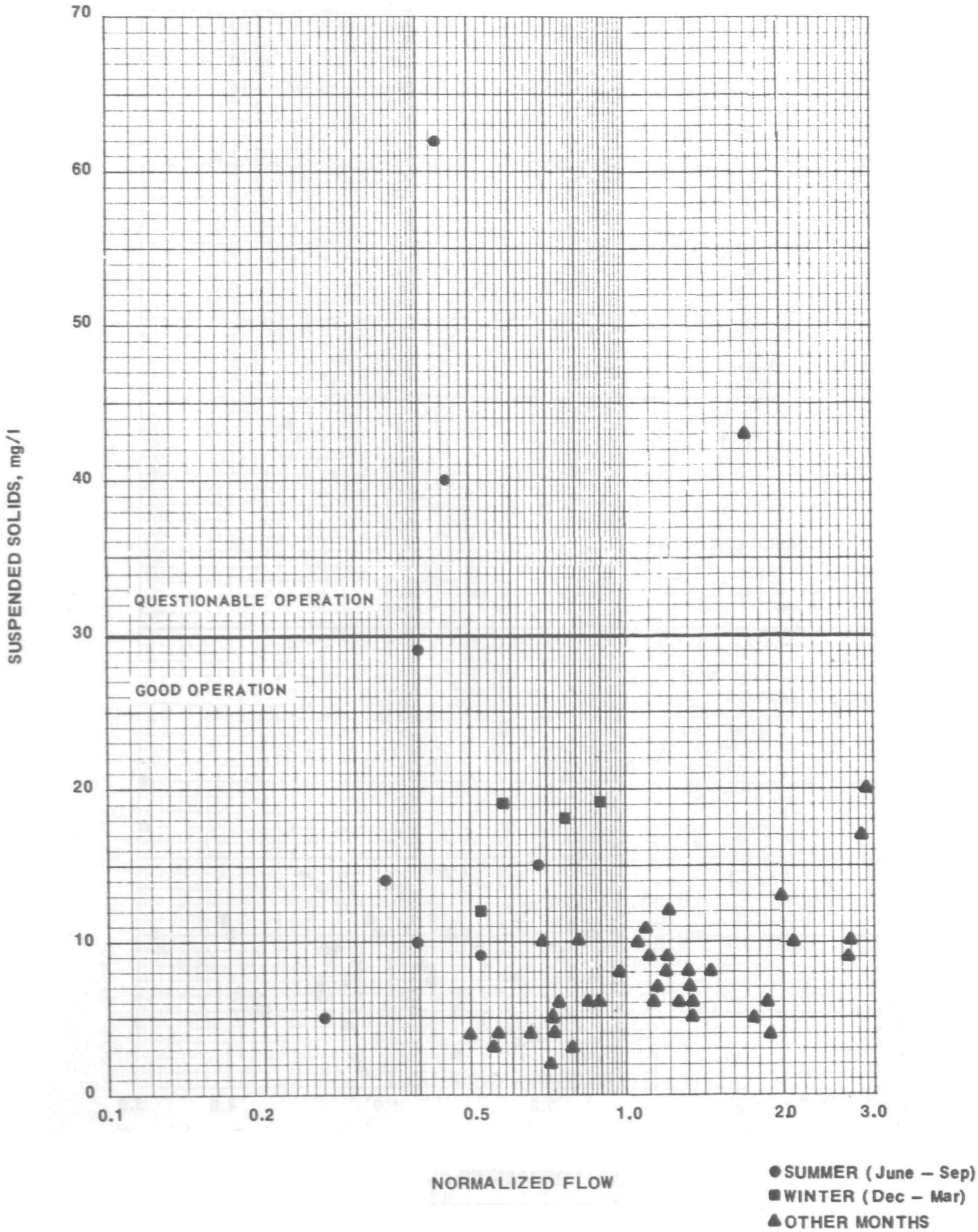

Figure 7. Extended Aeration, Suspended Solids

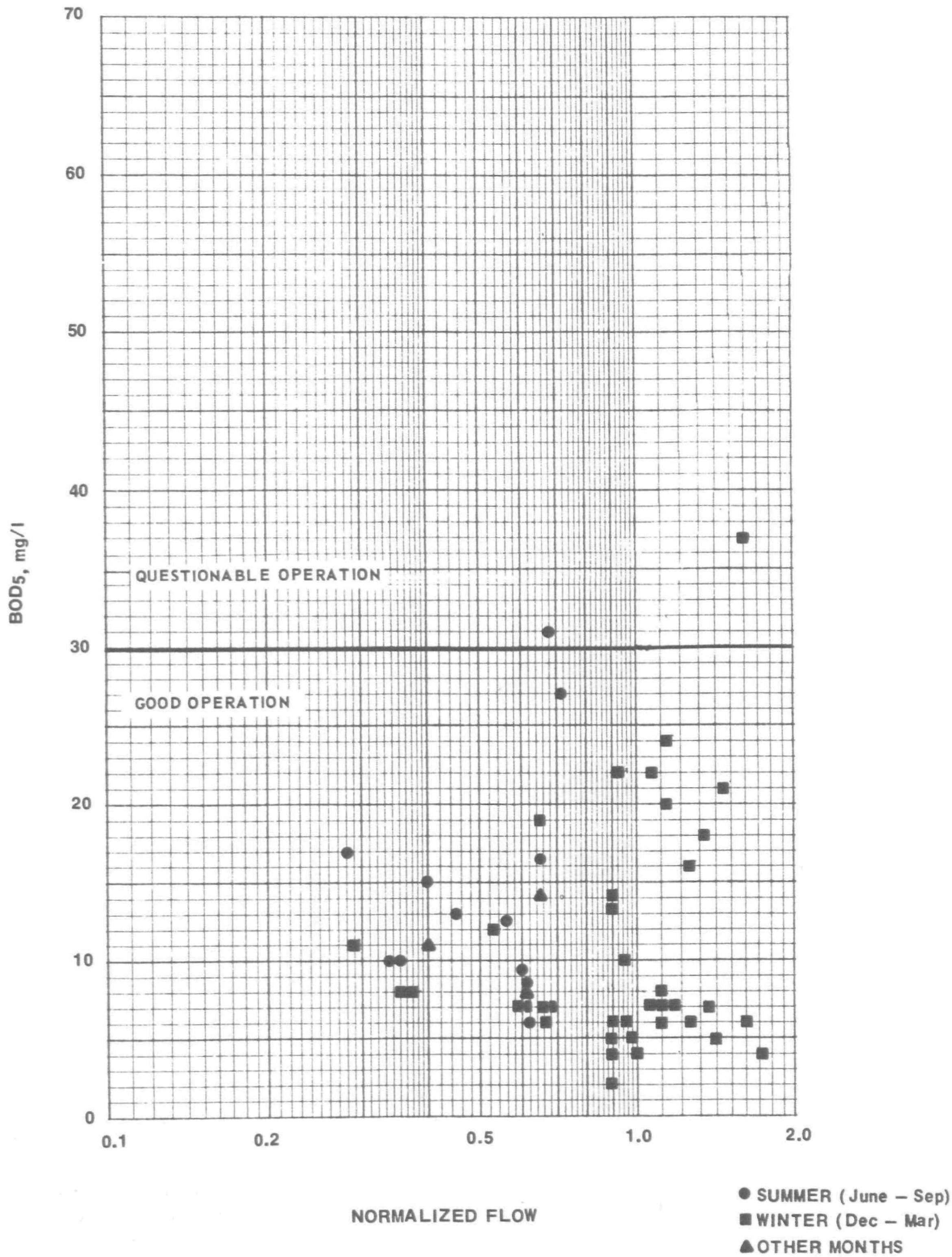

Figure 8. Contact Stabilization, BOD_5

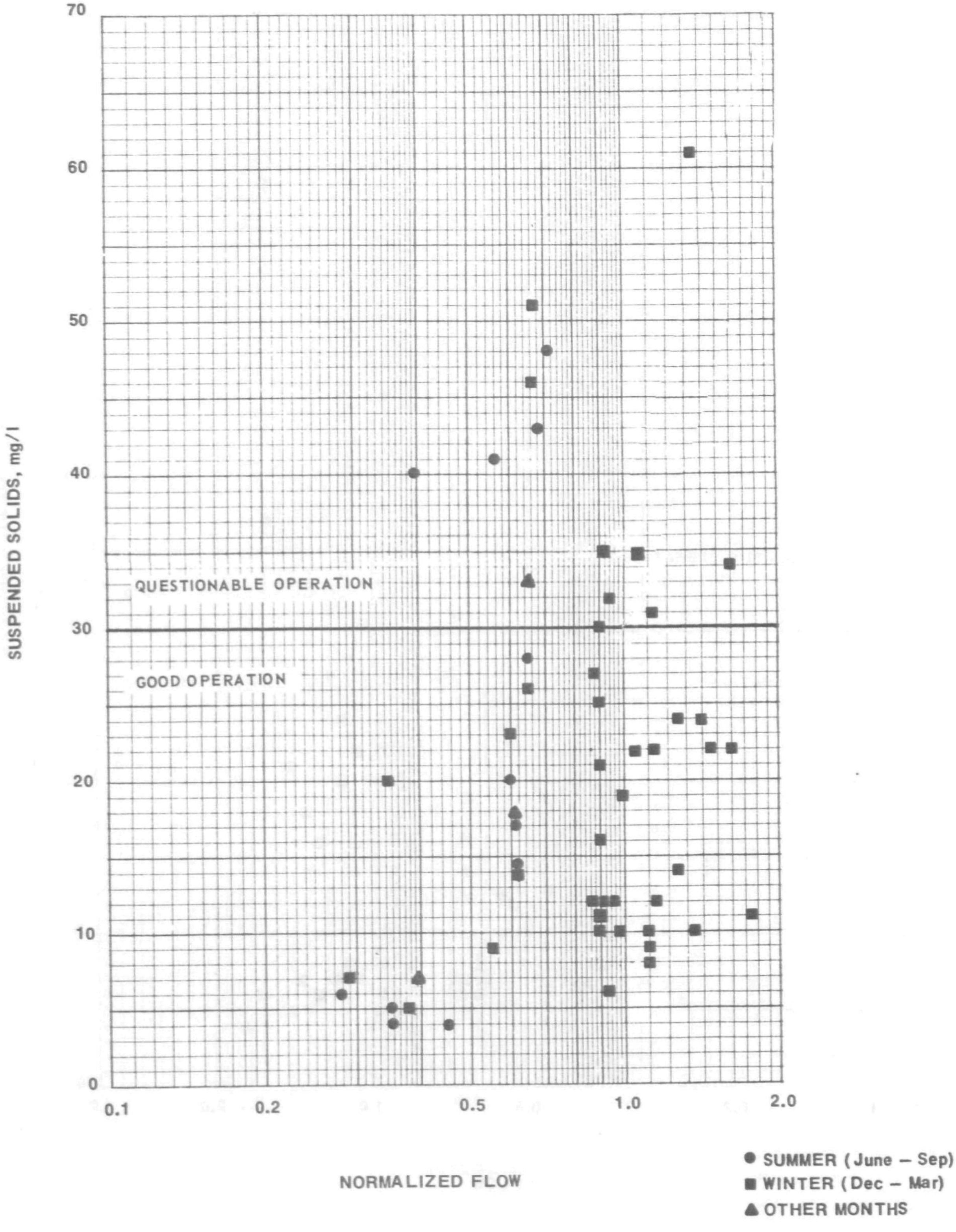

Figure 9. Contact Stabilization, Suspended Solids

TABLE 7. CONVENTIONAL ACTIVATED SLUDGE - PLANTS VISITED OR PLANTS WHOSE MONTHLY DATA WERE OBTAINED FROM STATE ENVIRONMENTAL OFFICES

Wisconsin

1. Neillsville Sewage Treatment Plant
   118 W. 5th Street
   Neillsville, WI 54456

2. Sun Prairie Sewage Treatment Plant
   Miller Drive
   Sun Prairie, WI 53590

3. Stanley Sewage Treatment Plant
   c.o City Hall
   Stanley, WI 54768

4. Cross Plains Sewage Treatment Plant
   1627 Cross Street
   Cross Plains, WI 53528

5. Mazomanie Sewage Treatment Plant
   Village Hall c/o City Clerk
   Mazomanie, WI 53560

Massachusetts

6. Leominster STP
   City of Leominster
   Leominster, MA

New York

7. Bay Park Sewage Treatment Plant
   Nassau County
   240 Old Country Road
   Mineola, New York 11501

Illinois

8. Elmhurst STP
   625 South Route 83
   Elmhurst, IL 60126

9. Homewood STP
   2020 Chestnut Rd.
   Homewood, IL 60430

Illinois (continued)

10. Barrington Plant
    300 N. Raymond Ave.
    Barrington, IL 60050

Oregon

11. Toledo Wastewater Treatment Plant
    Oregon

12. Salem Sewage Treatment Plant
    Oregon

Washington

13. GIG Harbor
    Washington

TABLE 8. CONTACT STABILIZATION PLANTS VISITED

---

1. City of Adams Sewage Treatment Plant
   c/o City Clerk
   Adams, WI 53910

2. Village of Rockdale
   Sewage Treatment Plant
   c/o Village Clerk Route 2
   Carbridge, WI 58523

3. Colby Sewage Treatment Plant
   c/o City Clerk
   Colby, WI 54421

4. Wooddale North Sewage Treatment Plant
   269 W. Irving Park Road
   Wooddale, IL 60191

5. Village of Addison
   233 S. Villa
   Addison, IL

6. Carpentersville Main Treatment Plant
   Lamerac Avenue
   Carpentersville, IL

TABLE 9. EXTENDED AERATION PLANTS VISITED

---

1. Spencer Sewer Utility
   117 E. Clark St.
   Spencer, WI 54479

2. Russell Sewage Treatment Plant
   Town of Russell
   Hampden County, MA 01071

3. Westboro Sewage Treatment Plant
   Westboro, MA 01581

4. Village of Richmondville
   Box L
   Richmondville, N.Y. 12149

5. Village of Athens
   Market Street
   Athens, N.Y.

6. Sedro Wooly Plant
   Washington

7. Arlington
   Washington

USER INSTRUCTIONS

The influent limitations manual requires an actual average flow and a design flow for prediction of constituent concentrations. The abscissas show the normalized flow. The normalized flow is computed as follows:

$$\text{normalized flow} = \frac{\text{actual average flow}}{\text{average design flow}}$$

Example: For a plant with an average design flow of 1.5 mgd and an actual average monthly flow of 1.7 mgd the normalized flow is:

$$\text{normalized flow} = \frac{1.7}{1.5} = 1.13$$

The normalized flow, of course, is a unitless quantity.

Once the normalized flow is determined, the curve for the appropriate process shows the effluent constituent concentration to be expected with questionable or good operation. Monthly or annual averages should be used for these since day-to-day values cannot be predicted accurately with this method.

These curves should not be used for plants that are hydraulically overloaded but not organically overloaded. Similarly, plant data that are influenced by a high strength waste not accounted for in the original design would not be applicable to the performance curve prediction. If a secondary plant is designed for an effluent constituent concentration other than 30 mg/l, then the vertical scale should be changed by the difference between the design value and 30 mg/l.

The performance curves are applicable to all sizes of treatment plants.

The O & M requirements manual shows total O & M costs for each process type as well as a tabular breakdown of the various components of labor, power, chemical, and maintenance material costs. To determine the operation and maintenance cost, use the figures. If a plant is operating at design capacity or slightly below, use the "design" cost curve. If the plant is operating at greater than design flow, determine the percent overload and interpolate between the "design" cost curve and "50 or 100% overloaded" cost curves.

The cost curves for secondary processes include primary treatment so the primary treatment cost should not be added in.

If a particular area has labor rates or power rates substantially different from those assumed, then the tables should be used to calculate the appropriate O & M cost.

REFERENCES

1. Fair, G. M. and C. G. Geyer. Water Supply and Wastewater Disposal. John Wiley & Sons, New York, 1959.

2. U. S. Environmental Protection Agency, Technology Transfer. Upgrading Existing Wastewater Treatment Plants. October, 1971.

3. Benjes, H. H., Jr. Attached Growth Biological Wastewater Treatment, Estimating Performance and Construction Costs and Operation and Maintenance Requirements. Draft submitted to the U. S. Environmental Protection Agency, Contract No. 68-03-2186. January, 1977.

4. Galler, W. S., and H. B. Gotaas. Analysis of Biological Filter Variables. Journal of the Sanitary Engineering Division, ASCE, 90, No. 6. pp. 59-79. 1964.

5. Eckenfelder, W. W. Trickling Filter Design and Performance. Transactions of the American Society of Civil Engineers. 128 Part III. pp. 371-398 . 1963.

6. Benzie, W., et al. Effects of Climatic and Loading Factors on Trickling Filter Performance. Journal Water Pollution Control Federation. 35, No. 4. pp. 445-455. 1963.

7. Culp, Gordon. Direct Recirculation of High Rate Trickling Filter Effluent. JWPCF, 35, 6. p. 742. 1963.

8. Williamson, K., and P. L. McCarty. A Model of Substrate Utilization by Bacterial Films. JWPCF, 48, No. 1. p. 9. January, 1976.

PART 2

USER MANUAL FOR ESTIMATING EFFLUENT LIMITATIONS FOR SEVERAL TYPES OF WASTEWATER TREATMENT PROCESSES

USER MANUAL FOR ESTIMATING EFFLUENT LIMITATIONS

INTRODUCTION

This manual provides a graphical means of estimating effluent limitations for several types of wastewater treatment systems. Included are primary, trickling filter, and activated sludge. These curves are designed to be used where there are limited data available.

In order to accurately evaluate the effluent capability of a particular treatment plant, the plant should be visited, unit process sizes determined, operation and maintenance practices analyzed in terms of personnel time and skill, and condition of mechanical equipment and structures analyzed. Generally speaking, there is not enough time or manpower to accomplish this task. Usually, the only data available are from periodic NPDES permit reports and from EPA 7500-5 forms. Data from these sources include actual flow quantities, effluent BOD_5 and suspended solids concentrations, removal efficiencies, design flow, operation and maintenance budgets and personnel inventories and skill levels. The following user manual requires data on design flow, actual flow (average), and effluent suspended solids and BOD_5 concentrations.

Each of the following curves shows an effluent constituent concentration related to a normalized flow or a percent removal related to normalized flow. Normalized flow is the actual flow divided by the design flow.

Primary Plants

Estimated removals of suspended solids and BOD_5 are shown on Figure 1. The design loading was assumed to be 800 gpd/sq ft. The suspended solids curve envelope was developed based on information by Fair & Geyer*. Data points from individual plants that are above the curve are indicative of good operation, use of chemical aids, or some other specialized means of improving performance. The BOD_5 removal curve was derived based on an assumed 50% insoluble BOD_5 fraction which would be removed as suspended solids. These curves are applicable to conventional primary sedimentation plants.

*Fair, G.M. & Geyer, J.C., Water Supply & Waste Water Disposal, John Wiley & Sons, 1954

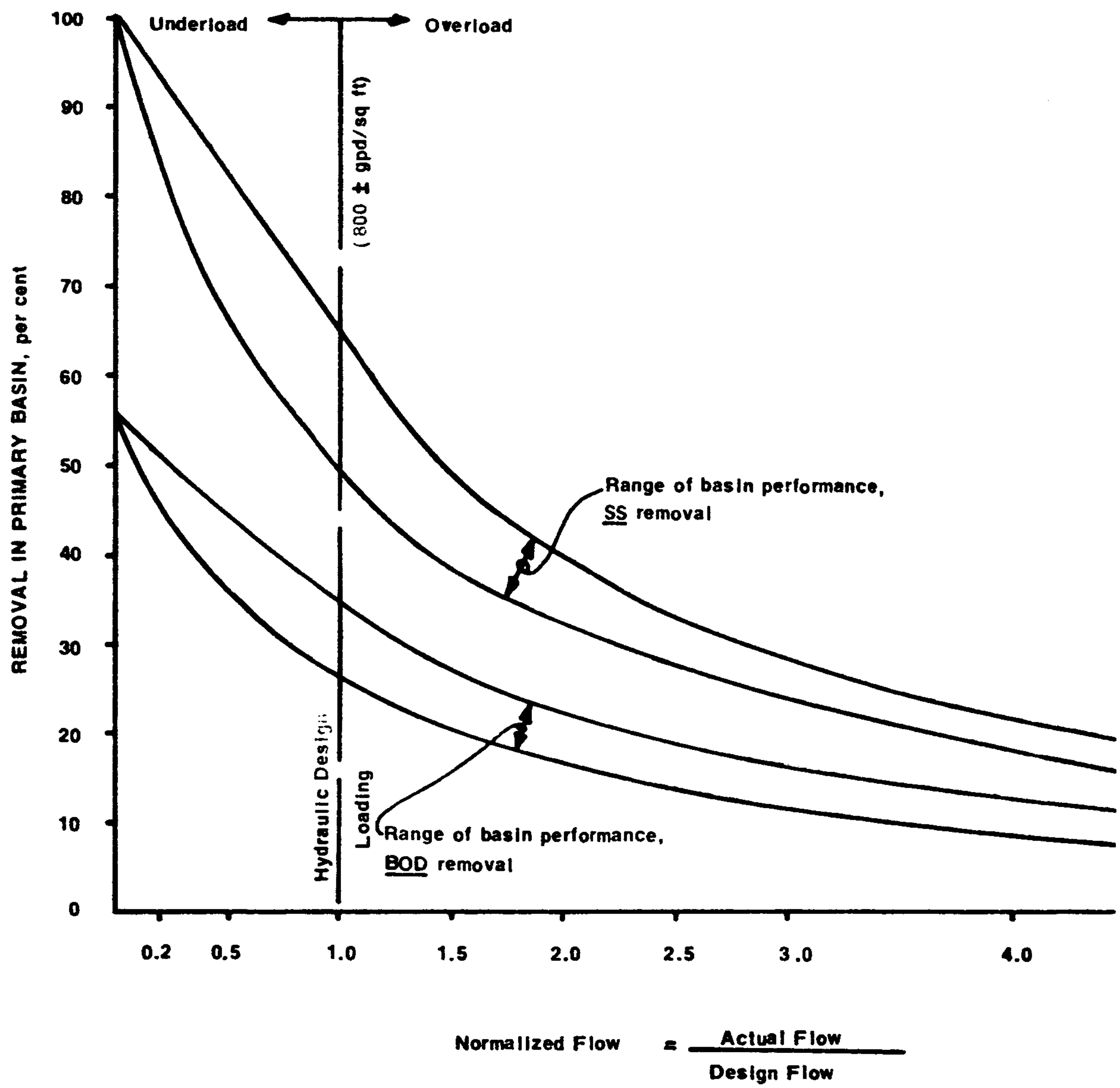

Figure 1. Estimated Removals of Suspended Solids and BOD in Primary Basins at Various Hydraulic Loadings

Trickling Filter Plants

Expected BOD_5 and suspended solids concentrations for trickling filter plants are shown on Figures 2 and 3, respectively. Suspended solids removal efficiency is more dependant on clarifier loading. Therefore, the suspended solids curve is a function of clarifier hydraulic loading. The design loading is assumed to be 800 gpd/sq ft. Data were obtained from a published report by Benzie, et al**, on Michigan plants, operating data from five Iowa plants, operating and field test data from the EPA Kansas City, Kansas, Office of Surveillance, and Analysis, and eight Georgia plants. Selection of these geographical locations enabled review of cold weather effects on treatment efficiency.

Curve 1 on Figure 2 shows the expected BOD_5 effluent concentration for those plants that are operating under the same conditions as were assumed by the designer. In other words, if a plant was designed for cold weather operation, then cold weather should not cause a deteriation in performance. Curve 2 on Figure 2 shows the expected performance of plants operating at $5^{o}C$ influent temperatures that were designed for $20^{o}C$ influent temperature. The performance curves obviously cannot account for situations where filter distributors freeze.

Activated Sludge Plants

Activated sludge plants include conventional, extended aeration (oxidation ditch considered as an extended aeration process) and contact stabilization. Effluent concentrations for BOD_5 and suspended solids for the conventional plants are shown on Figures 4 and 5 respectively. BOD_5 and suspended solids effluent concentrations for the other process modifications are shown on Figures 6 and 7. A comparison of these figures shows that the overload conditions impact the conventional plants but not the modified activated sludge processes. The BOD_5 effluent concentration values for overloaded plants were determined by the Eckenfelder equation as described in the first section of this manual. Theoretically, the modified process should behave similarly, but the field data showed that these processes still produced design effluent concentrations even at flows twice the design flow. Therefore, the extended aeration, oxidation ditch, and contact stabilization plants are shown with 30 mg/l effluent concentrations up to normalized flows of 2.0.

The suspended solids results were estimated based on performance of those plants visited. The performance curve was drawn to include the data from those plants that were judged to be well-operated facilities. This curve is not an average of the data collected nor is it a "best fit" line.

**Benzie, et al, "Effects of Climatic and Loading Factors on Trickling Filter Performance", JWPCF, April, 1963, Vol. 35, No. 4, pp. 445-455.

NORMALIZED FLOW = $\frac{\text{ACTUAL FLOW}}{\text{DESIGN FLOW}}$

CURVE 1 shows performance of plants at 20°C temperature or plants designed for cold weather operation.

CURVE 2 shows cold weather (5° C) operation results for plants designed for 20° C operation.

(1) See text for explanations of terms.

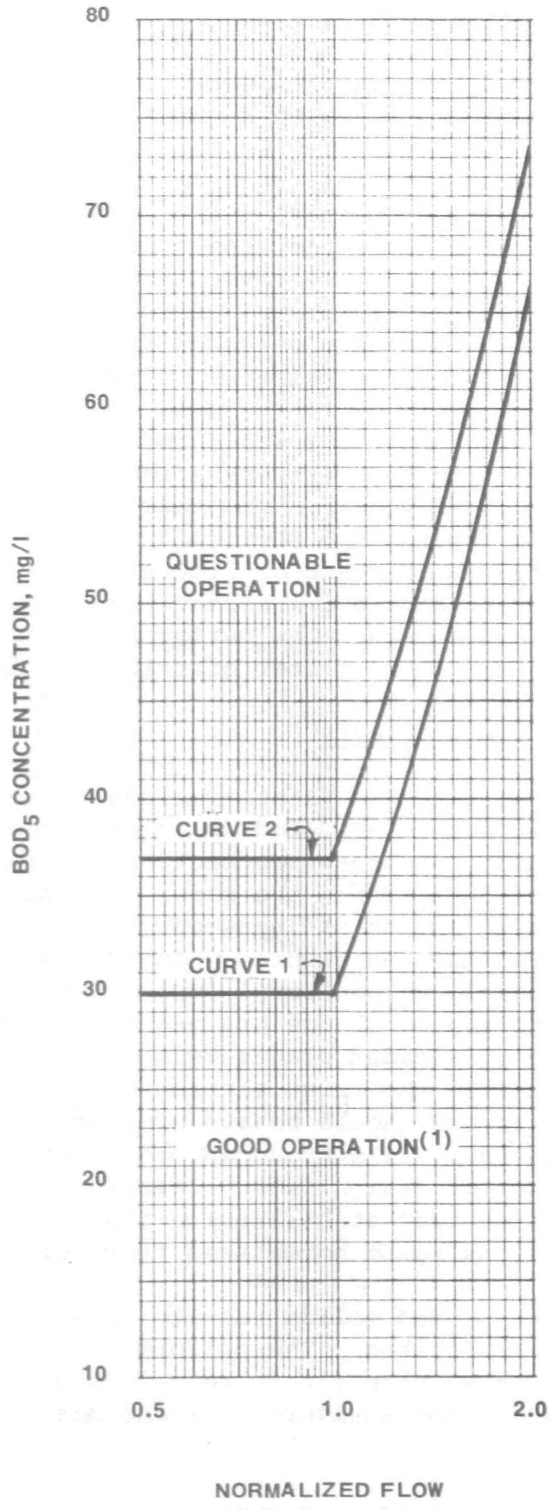

Figure 2. Trickling Filter Performance, BOD_5 Effluent Concentration

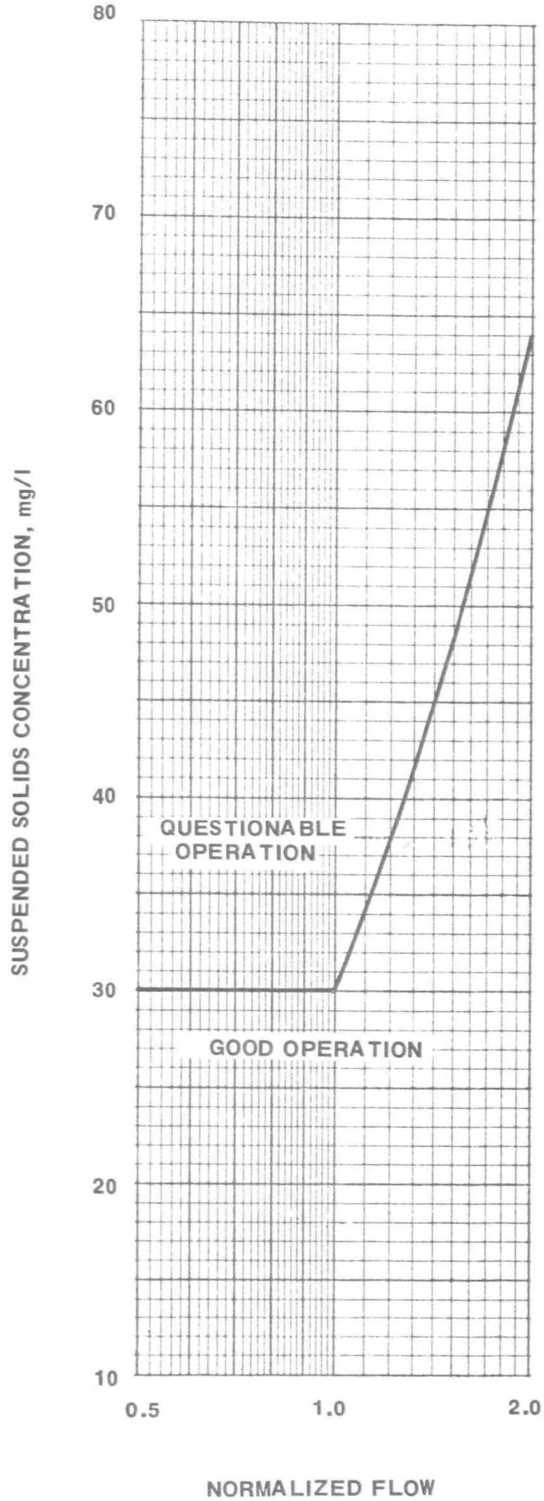

Figure 3. Trickling Filter Performance, Effluent Suspended Solids

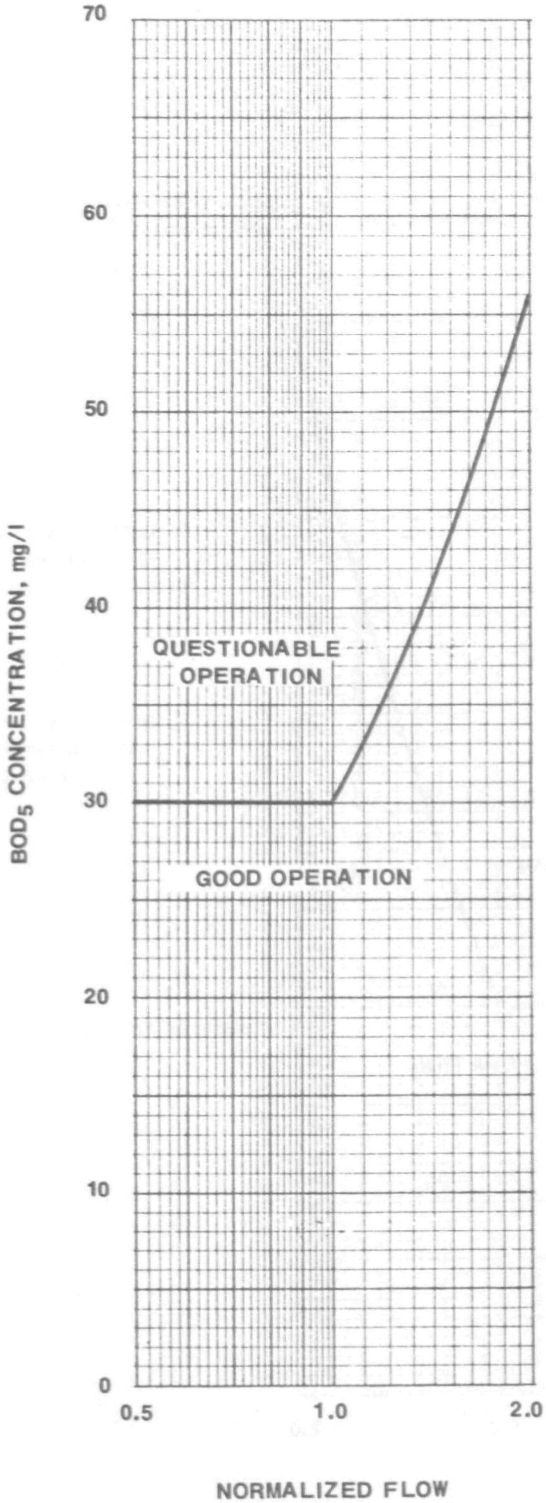

Figure 4. Conventional Activated Sludge, Effluent BOD_5

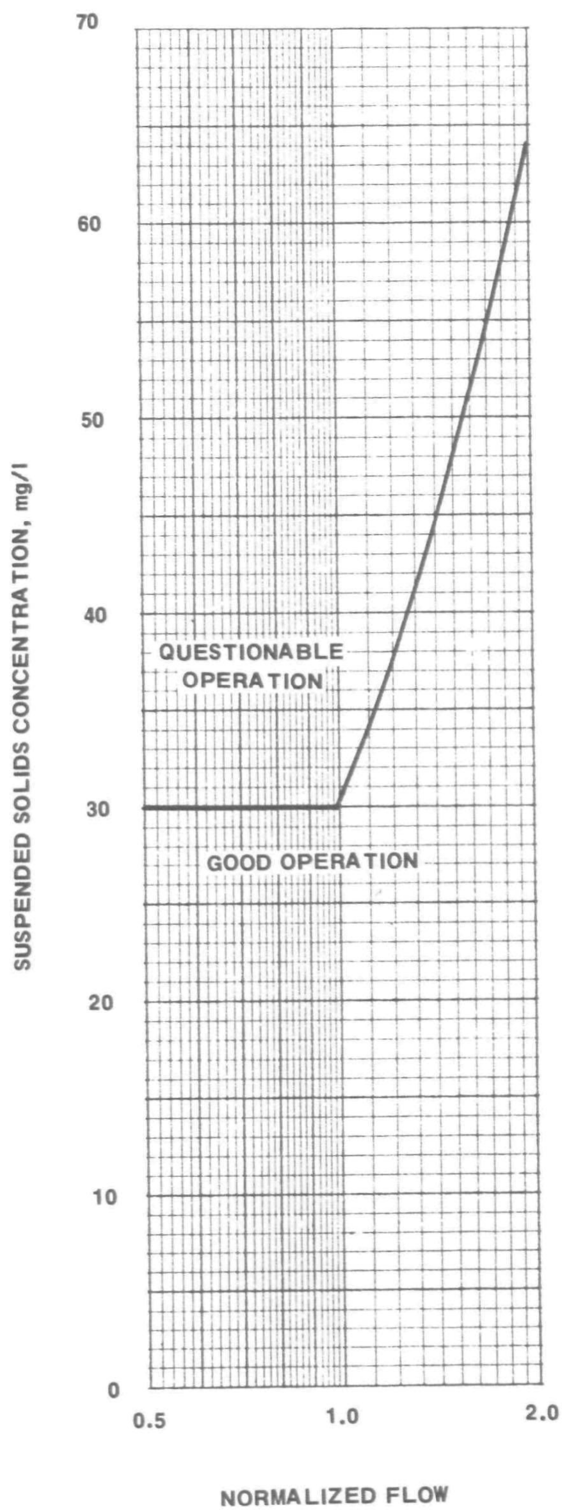

Figure 5. Conventional Activated Sludge, Effluent Suspended Solids

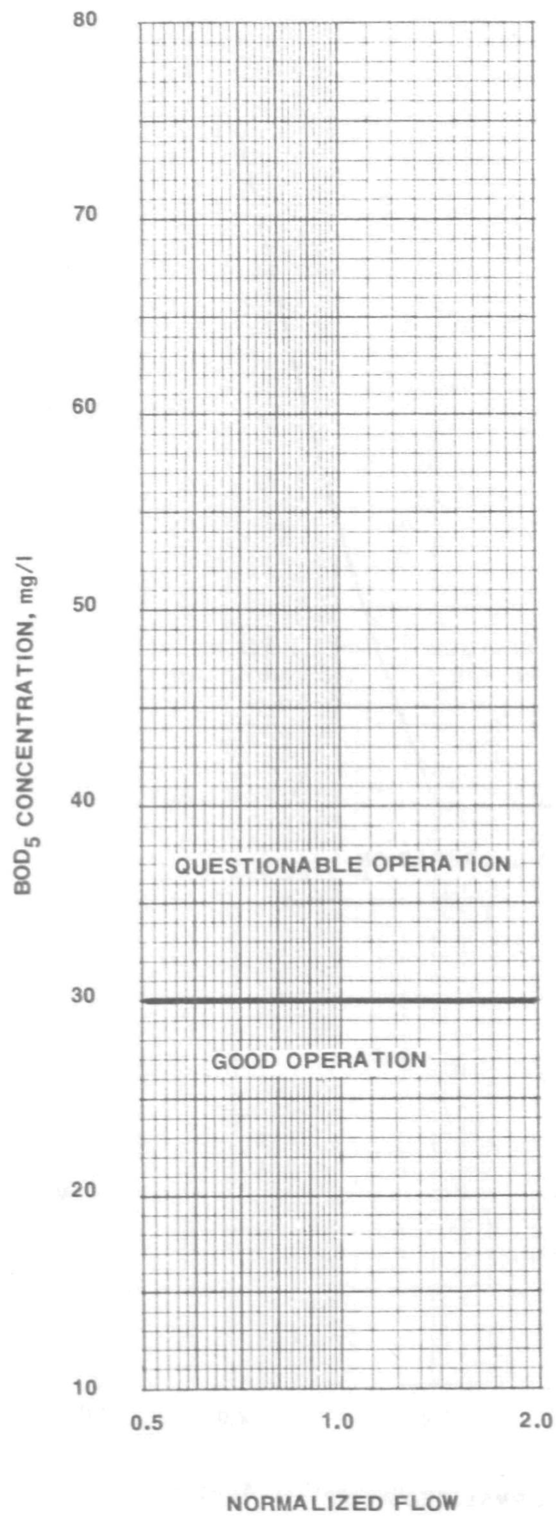

Figure 6. Extended Aeration, Oxidation Ditch, or Contact Stabilization Performance Effluent BOD_5

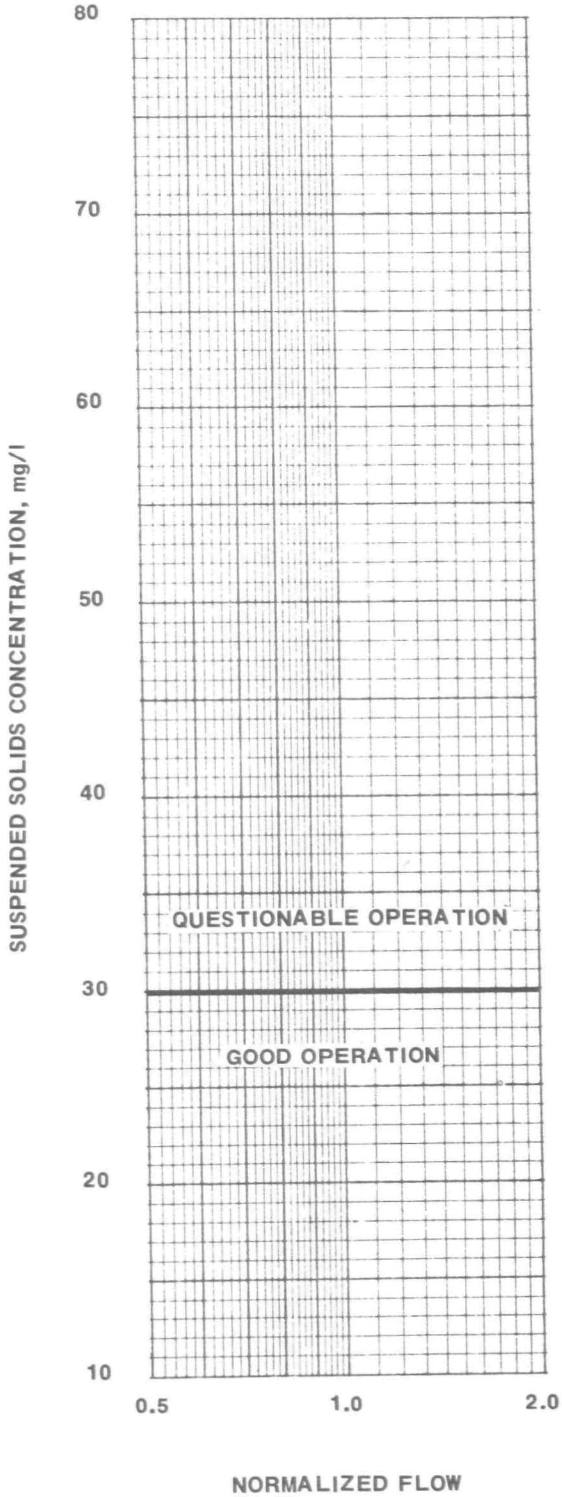

Figure 7. Extended Aeration, Oxidation Ditch, or Contact Stabilization Performance Effluent Suspended Solids

PART 3

USER MANUAL FOR ESTIMATING
OPERATION AND MAINTENANCE REQUIREMENTS

USER MANUAL FOR ESTIMATING OPERATION AND MAINTENANCE REQUIREMENTS

INTRODUCTION

This manual provides information and methods for estimating operation and maintenance requirements and costs for publicly owned primary and secondary wastewater treatment plants. It is aimed specifically at plants which are not scheduled to receive federal construction grants in the near future. Most plants in this category are in the capacity range of .01 to 10.0 mgd. The operation and maintenance requirements are estimated at a level which should allow such plants to achieve optimum performance with the facilities available.

These operation and maintenance requirements are based, to the extent possible, on experiences at actual operating facilities. Such requirements will vary between similar facilities depending upon the exact unit processes within that facility. The facilities and unit processes upon which these stated requirements are based are outlined hereinafter. More complex unit processes than those assumed may require additional operation and maintenance requirements and less complex unit processes somewhat lesser operation and maintenance. The assumptions made herein should result in information applicable to the average plant of the particular type of facility.

Operation and maintenance costs were also determined for overloaded treatment facilities.

USE OF MANUAL

The manual is designed to provide guideline operation and maintenance requirements for various types of treatment processes. The requirements can be determined by personnel having only a limited amount of information from the facility. The guideline requirements determined from this manual can then be used to evaluate the level of operation and maintenance at the particular facility. The actual operation and maintenance requirements will vary widely from facility to facility, but the requirements in this manual should be adequate for satisfactory operation of the specific types facilities. The requirements in the tables for facilities operating at design capacity are broken down into several categories for cases where more detail is needed while the figures indicate total requirements.

TREATMENT PROCESSES

Plants are classified according to treatment processes and design flow capacity for estimating purposes.

The facility classifications and design flow ranges are outlined hereafter.

FACILITY	FLOW RANGE, MGD
Primary Plant	0.5 to 10
Trickling Filter Plant	0.5 to 10
Contact Stabilization Plant	0.1 to 1.0
Extended Aeration Package Plant	0.01 to 0.1
Oxidation Ditch Plant	0.05 to 5.0
Conventional Activated Sludge Plant	1.0 to 10

Primary Plant

The assumed basic primary plant consists of headworks typical for the flow, raw sewage pumping, primary sedimentation, chlorination, anaerobic digestion, outdoor sand drying beds and laboratory. Information is provided for analysis of primary plants with vacuum filtration for sludge dewatering (rather than sludge drying beds) and for primary plants with chemical addition to aid the sedimentation process.

Trickling Filter Plant

The assumed trickling filter plant consists of headworks, raw sewage pumping, primary sedimentation, trickling filtration, (rock media), recirculation, final clarification, chlorination, anaerobic digestion, outdoor sand drying beds, and laboratory.

The operation and maintenance information applies to both covered and open trickling filters.

Contact Stabilization Plant

Contact stabilization plants include complete package type including tankage or those designed for installation into on-site tankage as appropriate to the size. Contact stabilization plants include raw sewage pumping, comminutor, contact zone, settling zone, reaeration zone, chlorination, aerobic digestion, outdoor sand drying beds, and laboratory.

Extended Aeration Package Plant

The assumed plant is a standard package plant as supplied by a number of manufacturers. Tankage is typically steel or fiberglass. The plants include raw sewage pumping, comminutor, aeration, final clarification, sludge return and wasting, sludge storage, blowers and blower housing, chlorination, and a small laboratory space.

Oxidation Ditch Plant

The assumed plant includes headworks, raw sewage pumping, oxidation ditch, final clarification, sludge return and wasting, outdoor sludge drying beds, chlorination, and laboratory facilities. The operation and maintenance requirements are based on information from 20 operating plants. These plants are operated in the extended aeration mode.

Conventional Activated Sludge Plant

The assumed plant consists of headworks, raw sewage pumping, primary sedimentation, aeration, secondary clarification, chlorination, sludge return and wasting, anaerobic digestion, vacuum filtration, and laboratory. Operation and maintenance requirements were developed by unit process from published information and experiences of actual operating plants.

OPERATION AND MAINTENANCE REQUIREMENTS

Operation and maintenance requirements were determined, to the extent possible, from experiences of actual operating facilities of similar type and complexity. This field information was augmented and cross checked by calculations, information from published literature, and other sources of O & M information. The information should be typical for average facilities of the specified type.

Operation and maintenance information is developed in four categories; labor (operation and maintenance), energy, chemicals, and maintenance materials.

Labor

Labor requirements include all operation, maintenance, administration, sampling, and laboratory work required for the facility. Sampling and laboratory requirements vary depending on local regulatory agency permit programs. Generally speaking, 5-15 man-hours per week are devoted to sampling and laboratory analysis for plants less than 3 mgd. For 3-10 mgd capacities, this workload increases to 30-40 man-hours per week. The lower values apply to primary and trickling filter plants. The higher values apply to activated sludge plants. Labor rates vary widely and are generally lower for small plants; however, a uniform rate of $9.00 per hour is used herein. This rate includes the cost of all fringe benefits and training.

Energy

The energy requirements are all converted to equivalent electrical units and include lighting, heating, controls, and electric drives. A unit cost of $0.03 per kwh is assumed.

Chemicals

Chemical requirements include chlorine, chemicals required for sludge conditioning, and chemicals for other uses in the plant. Chemical unit prices are based on recent quotations related to type and quantity.

Maintenance Materials

Maintenance materials include all parts and supplies used in the normal operation and maintenance of the facility. These requirements are based on recent experiences of operating facilities and vary widely.

Presentation

The operation and maintenance information is presented in tabular and graphical form for easy use as follows. The tabular information is broken down by O & M category and the graphical information shows total requirements.

TYPE FACILITY	TABLE NO.	FIGURE NO.
Primary	1	1
Trickling Filter	2	2
Contact Stabilization	3	3
Extended Aeration Package	4	4
Oxidation Ditch	5	5
Conventional Activated Sludge	6	6

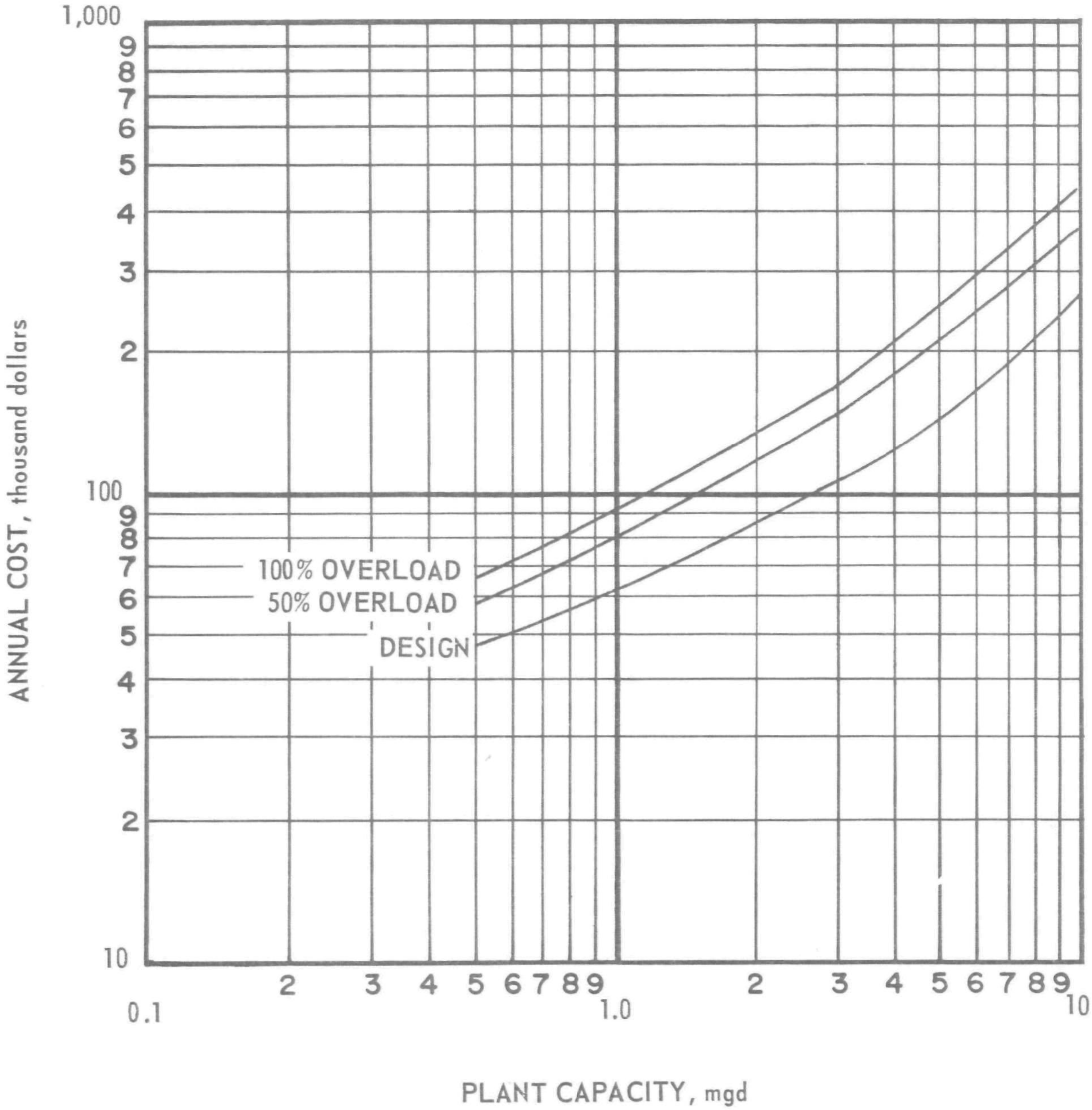

Figure 1a. Total Annual Operation and Maintenance Cost
Primary Plants With Drying Beds
February 1977

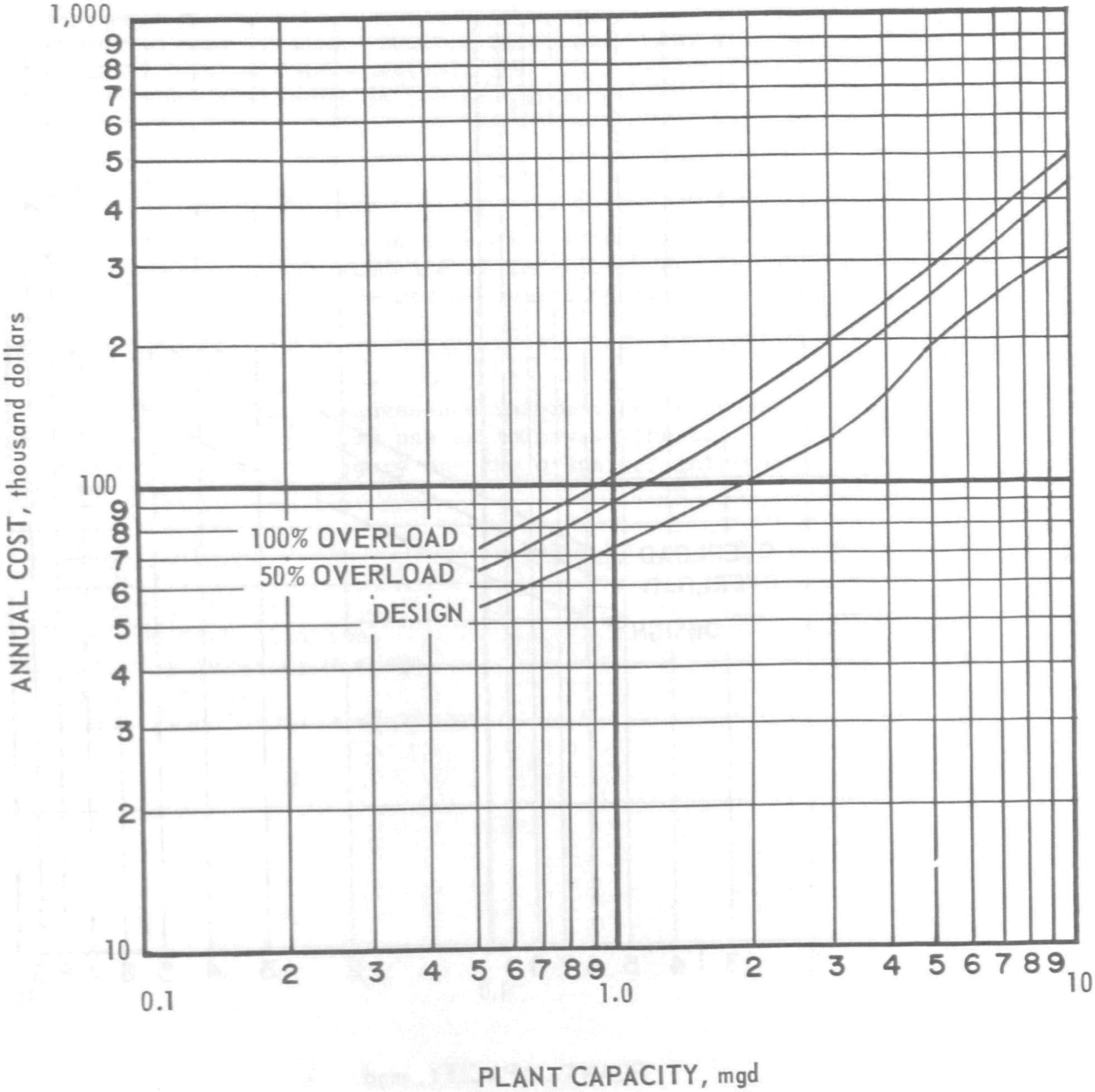

Figure 1b. Total Annual Operation and Maintenance Cost
Primary Plants Chemical Addition and Drying Beds
February 1977

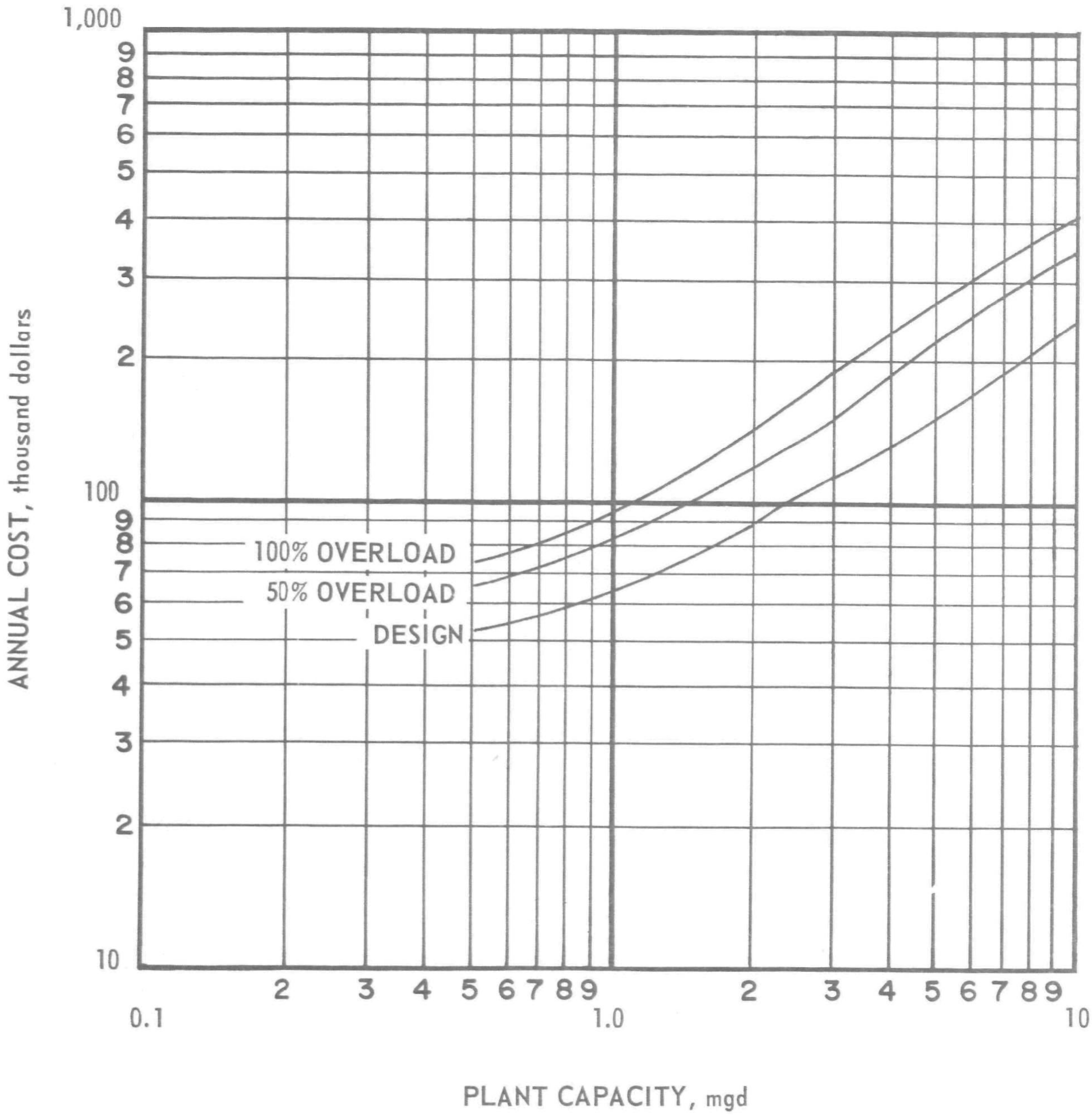

Figure 1c. Total Annual Operation and Maintenance Cost
Primary Plants With Vacuum Filtration
February 1977

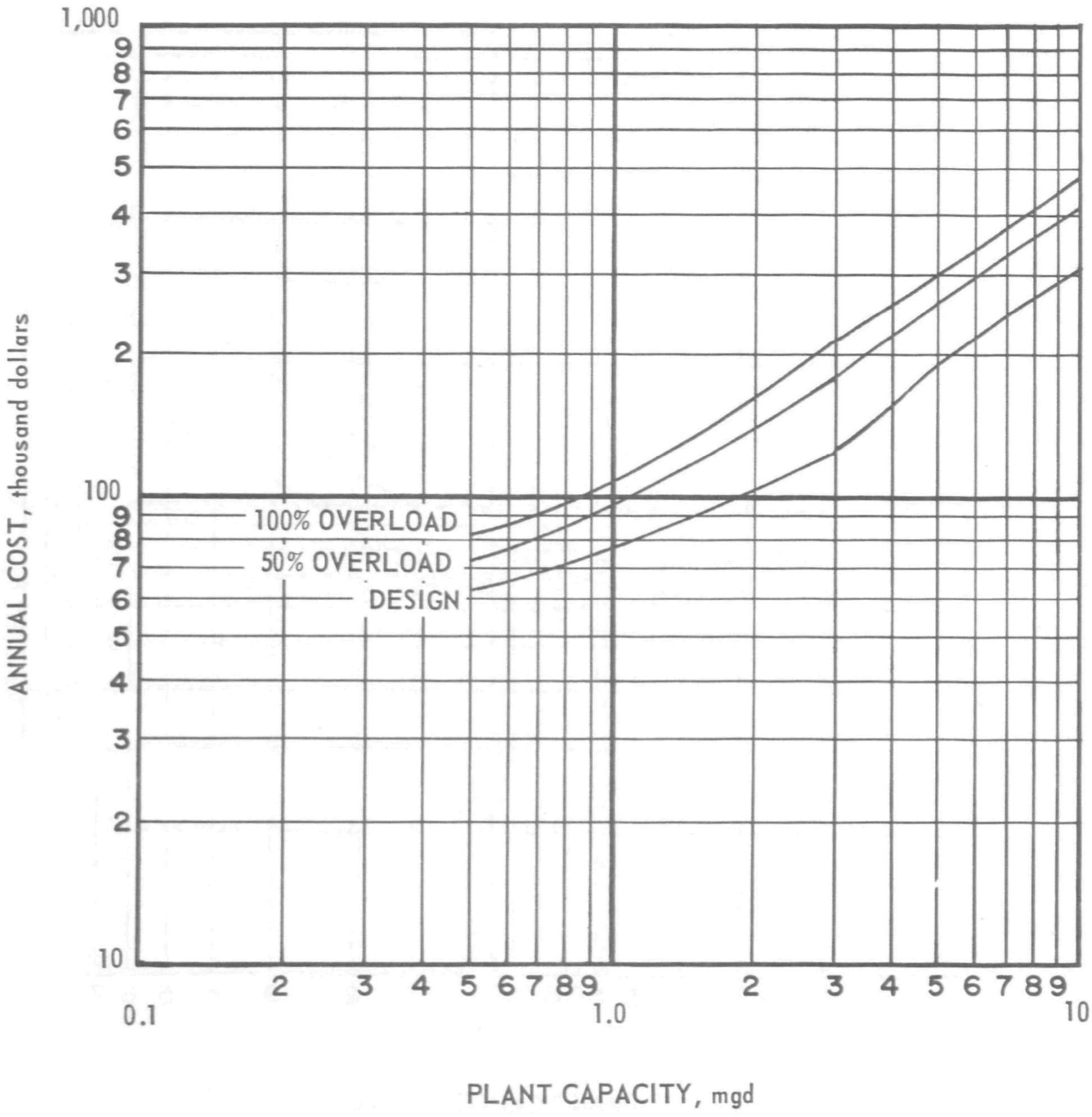

Figure 1d. Total Annual Operation and Maintenance Cost
Primary Plants With Chemical Addition and Vacuum Filtration
February 1977

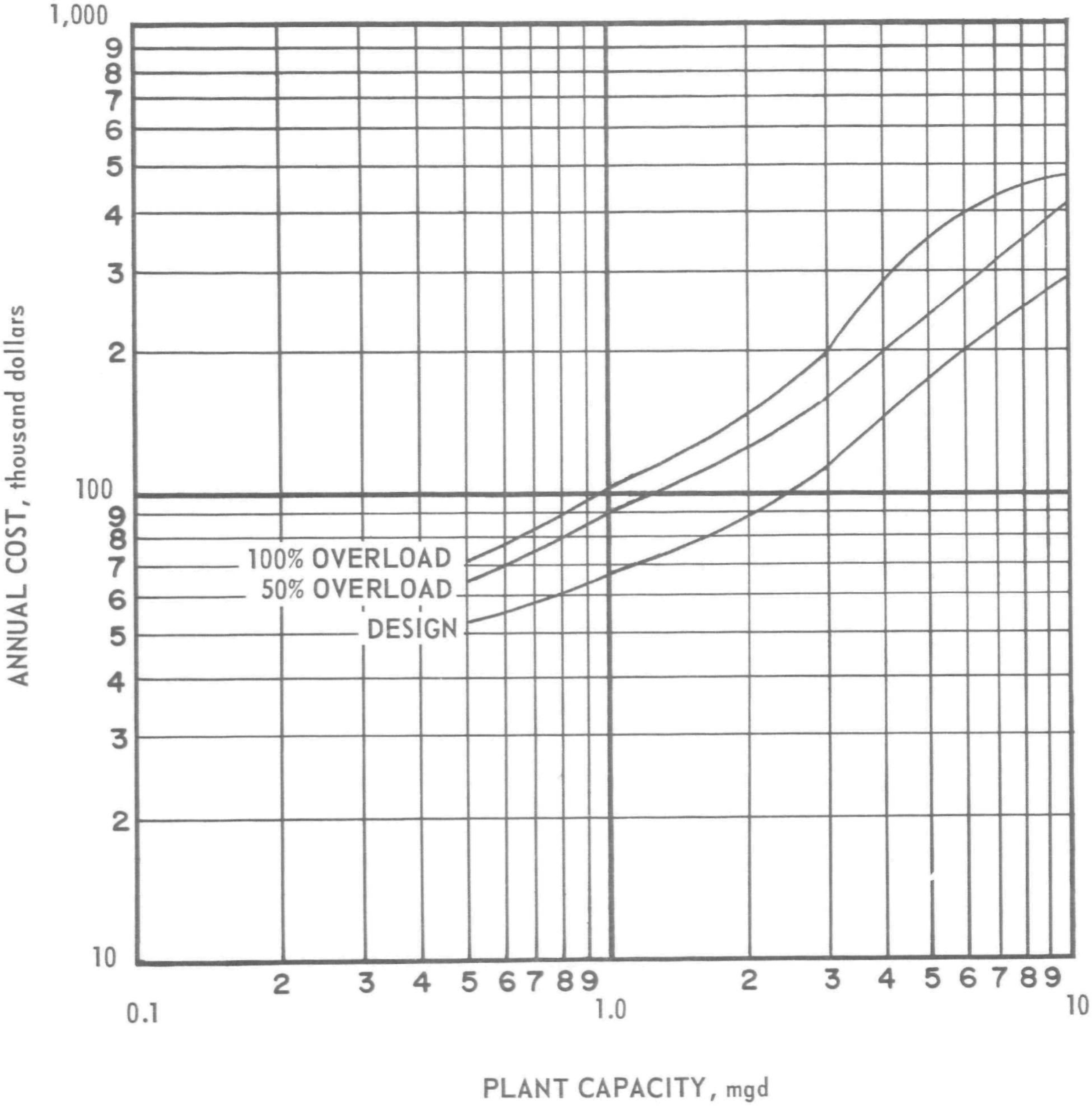

Figure 2. Total Annual Operation and Maintenance Cost
Trickling Filter Plants
February 1977

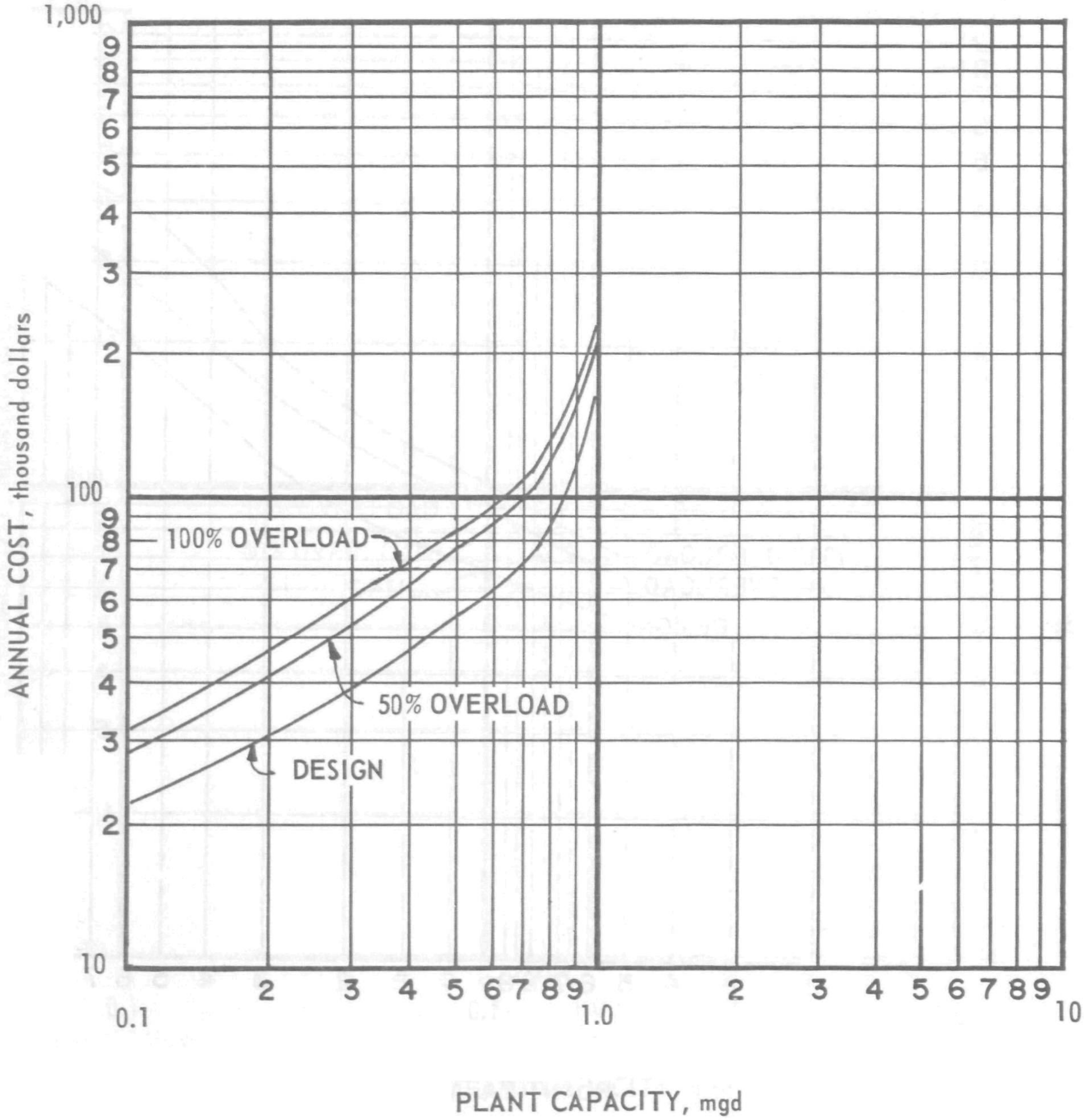

Figure 3. Total Annual Operation and Maintenance Cost
Contact Stabilization Plants
February 1977

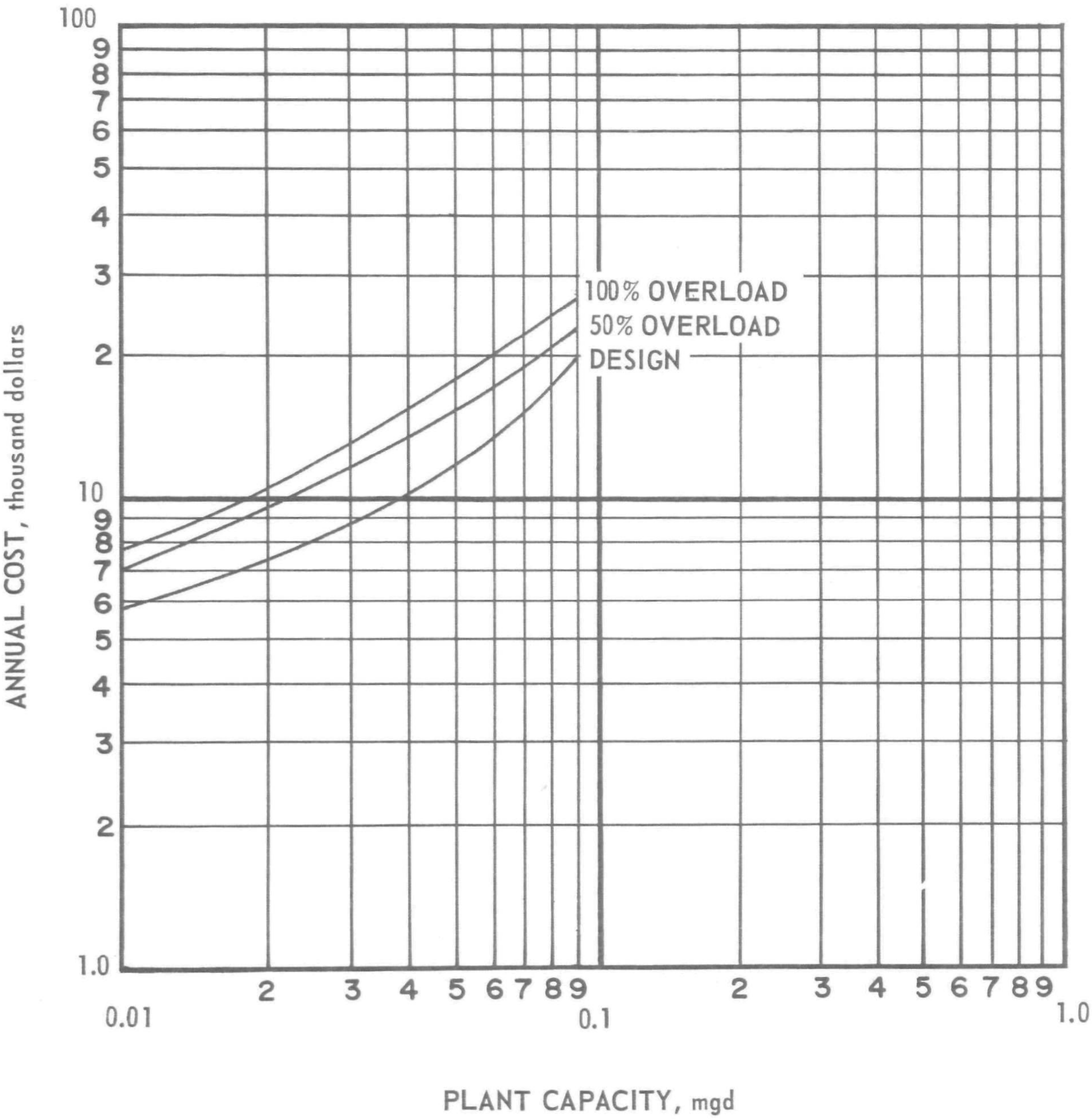

Figure 4. Total Annual Operation and Maintenance Cost
Package Extended Aeration Plants
February 1977

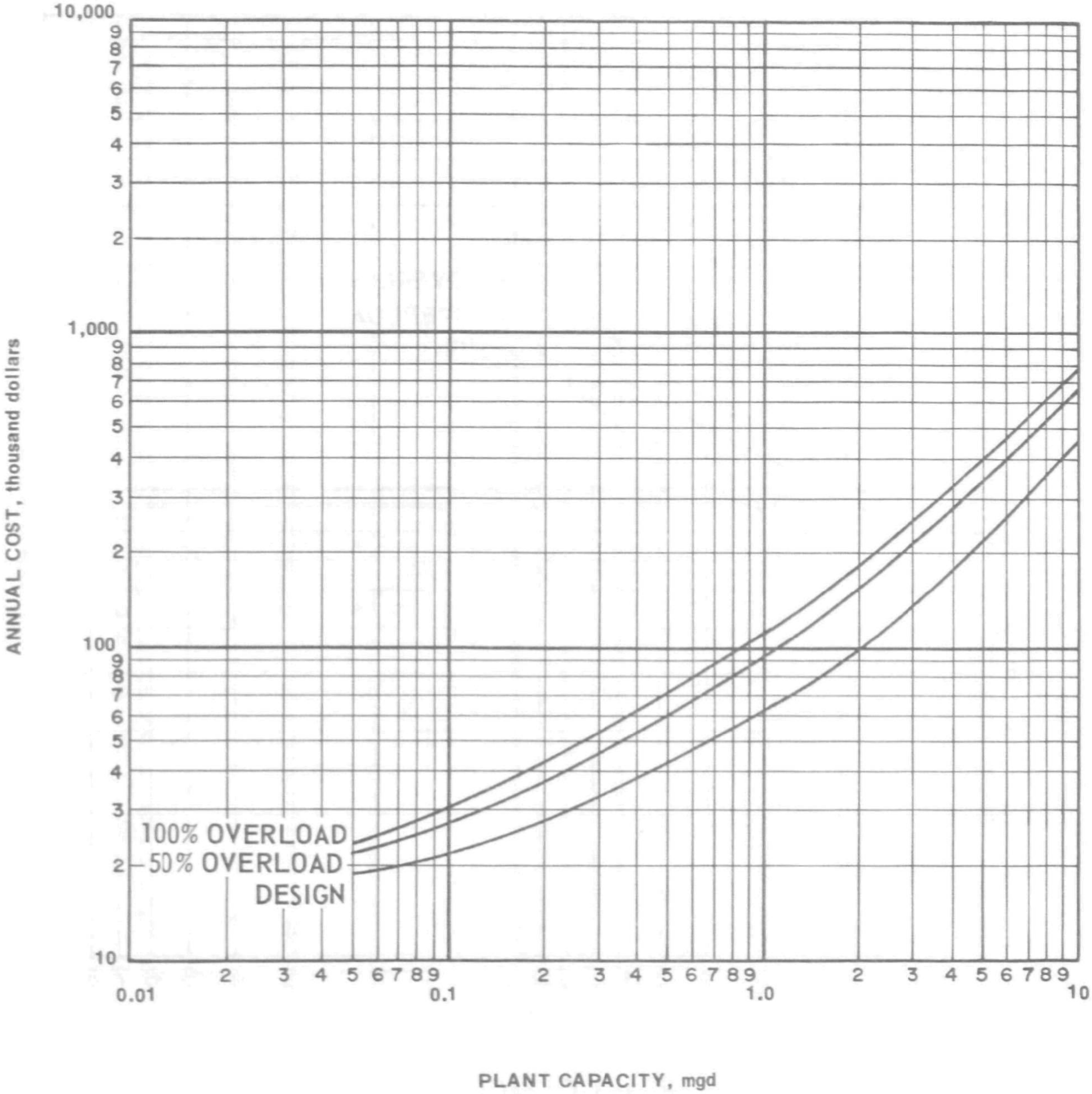

Figure 5. Total Annual Operation and Maintenance Cost
Oxidation Ditch Plants
February 1977

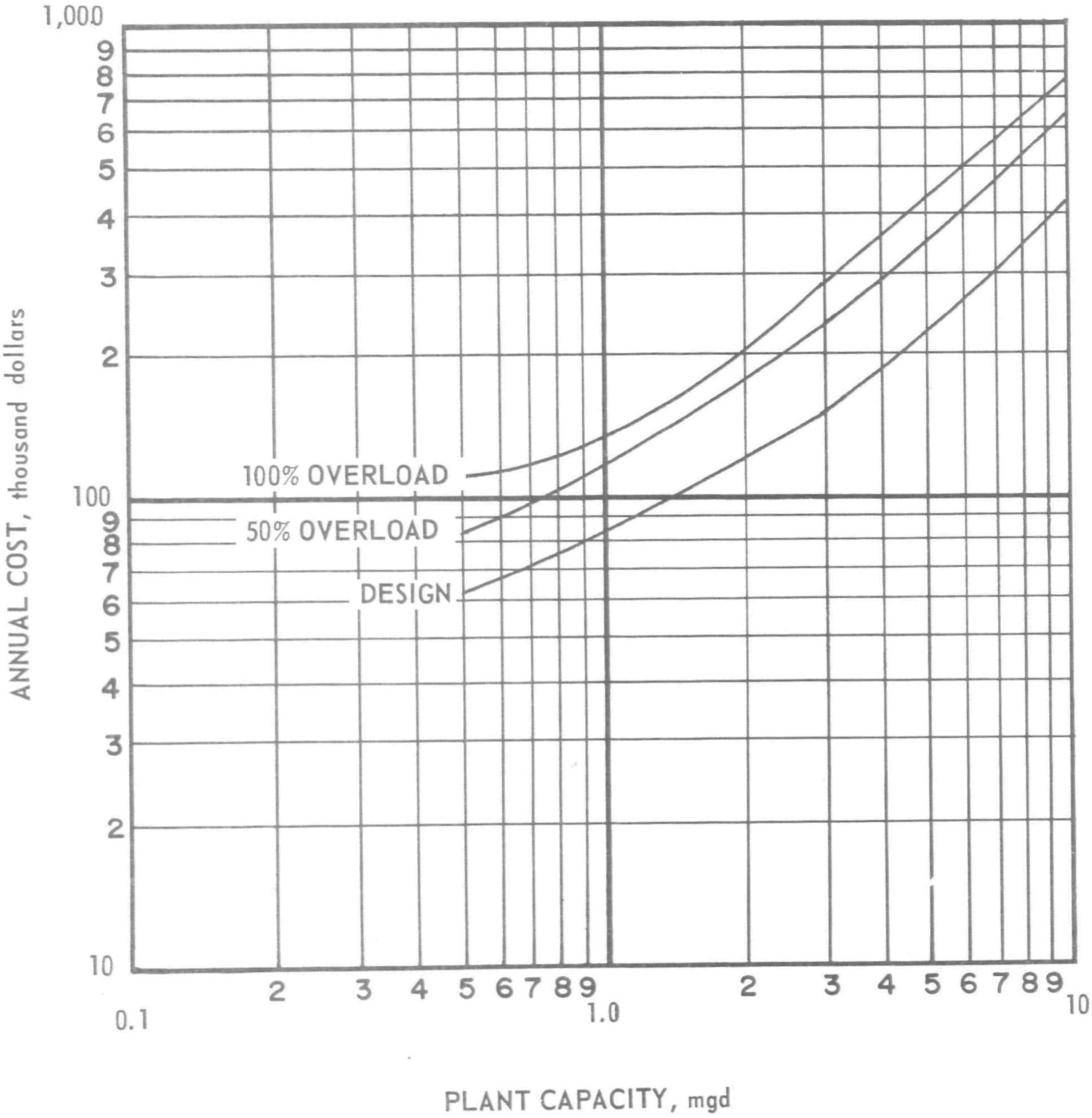

Figure 6. Total Annual Operation and Maintenance Cost
Conventional Activated Sludge
February 1977

TABLE 1. PRIMARY PLANTS - ANNUAL OPERATION AND MAINTENANCE REQUIREMENTS, 1976

Plant Capacity, MGD	LABOR Hours	LABOR $1000 (*)	ENERGY 1000 KWH	ENERGY $1000 (+)	Maint. Mat., $1000	Chemicals, $1000	Total, $1000 Normal Load	Total, $1000 50% Overload (±)	Total, $1000 100% Overload (±)
WITH DRYING BEDS									
0.5	3,800	34.2	104.3	3.1	7.4	3.0	47.7	59.5	67.6
1.0	4,700	42.3	142.4	4.3	10.6	5.0	62.2	81.7	94.1
3.0	8,000	72.0	228.5	6.9	17.9	10.0	106.8	149.8	176.4
5.0	11,000	99.0	311.0	9.3	24.7	18.0	151.0	213.6	251.0
10.0	20,000	180.0	481.6	14.4	38.0	33.0	265.4	373.3	434.8
WITH CHEMICAL ADDITION AND DRYING BEDS									
0.5	4,100	36.9	108.2	3.2	7.7	5.8	53.6	65.4	73.5
1.0	5,200	46.8	146.5	4.4	10.9	10.7	72.8	92.3	104.7
3.0	9,000	81.0	233.1	7.0	18.2	24.9	131.1	174.1	200.7
5.0	12,000	108.0	315.8	9.5	25.0	40.8	183.3	245.9	283.3
10.0	21,000	189.0	486.7	14.6	38.4	78.6	320.6	428.5	490.0
WITH VACUUM FILTRATION									
0.5	5,580	50.2	8.7	0.3	0.2	3.6	54.3	66.1	74.2
1.0	6,670	60.0	17.4	0.5	0.5	6.0	67.0	86.5	98.9
3.0	11,540	103.9	26.1	0.8	1.2	12.5	118.4	161.4	188.0
5.0	15,050	135.5	34.8	1.0	2.0	22.0	160.5	223.1	260.5
10.0	22,350	201.2	43.5	1.3	3.7	41.0	247.2	355.1	416.6
WITH CHEMICAL ADDITION AND VACUUM FILTRATION									
0.5	6,020	54.2	12.6	0.4	0.5	6.4	61.5	73.3	81.4
1.0	7,160	64.4	21.5	0.6	0.8	11.7	77.5	97.0	109.4
3.0	12,170	109.5	30.7	0.9	1.5	27.4	139.3	182.3	208.9
5.0	15,730	141.6	39.6	1.2	2.3	44.8	189.9	252.5	289.9
10.0	23,180	208.6	48.6	1.5	4.1	86.6	300.8	408.7	470.2

(*) At $9.00 Per Hour

(+) At $0.03 Per KWH

(±) Costs for overloaded plant include extra raw sewage pumping, solids handling, and chemicals.

TABLE 2. TRICKLING FILTER PLANT - ANNUAL OPERATION
MAINTENANCE REQUIREMENTS, 1976

Plant Capacity, MGD	LABOR Hours	LABOR $1000(*)	ENERGY 1000 KWH	ENERGY $1000(+)	Maint. Mat., $1000	Chemicals, $1000	Total, $1000 Normal Load	Total, $1000 50% Overload(±)	Total, $1000 100% Overload(±)
0.5	3,900	35.1	158.3	4.7	8.9	3.0	51.7	64.4	72.8
1.0	5,000	45.0	222.4	6.7	12.7	5.0	69.4	90.4	103.3
3.0	8,700	78.3	402.5	12.1	22.0	10.0	122.4	169.2	196.8
5.0	12,000	108.0	573.0	17.2	30.3	18.0	173.5	242.6	351.0
10.0	20,000	180.0	915.6	27.5	47.3	33.0	287.8	405.2	470.4

(*) At $9.00 Per Hour

(+) At $0.03 Per KWH

(±) Costs for overloaded plant include extra raw sewage and recirculation pumping, solids handling, and chemicals.

TABLE 3. CONTACT STABILIZATION PLANTS - ANNUAL OPERATION AND MAINTENANCE REQUIREMENTS, 1976

Plant Capacity, MGD	LABOR		ENERGY		Maint. Mat., $1000	Chemicals, $1000	Total, $1000		
	Hours	$1000 (*)	1000 KWH	$1000 (+)			Normal Load	50% Overload (±)	100% Overload (±)
0.10	1,800	16.2	80	2.4	4.0	0.7	23.3	29.0	32.4
0.25	2,600	23.4	190	5.7	6.0	1.5	36.6	48.3	54.2
0.50	3,900	35.1	380	11.4	7.5	2.2	56.2	76.4	87.5
0.75	5,000	45.0	600	18.0	9.0	4.0	76.0	103.7	117.6
1.00	6,000	54.0	800	24.0	10.6	5.3	169.9	204.4	222.5

(*) At $9.00 Per Hour

(+) At $0.03 Per KWH

(±) Costs for overloaded plant include extra raw sewage pumping and aeration energy, solids handling and chemicals.

TABLE 4. PACKAGE EXTENDED AERATION PLANTS - ANNUAL OPERATION MAINTENANCE REQUIREMENTS, 1976

Plant Capacity, MGD	LABOR Hours	LABOR $1000 (*)	ENERGY 1000 KWH	ENERGY $1000 (+)	Maint. Mat., $1000	Chemicals, $1000	Total, $1000 Normal Load	Total, $1000 50% Overload (±)	Total, $1000 100% Overload (±)
0.01	500	4.5	13	0.4	0.9	0.1	5.9	7.0	7.6
0.02	650	5.8	20	0.6	1.2	0.2	7.8	9.5	10.7
0.05	1,000	9.0	40	1.2	2.7	0.4	13.3	16.7	18.8
0.07	1,200	10.8	70	2.1	3.1	0.5	16.5	20.8	23.5
0.09	1,400	12.6	90	2.7	3.5	0.6	19.4	24.7	27.9

(*) At $9.00 Per Hour

(+) At $0.03 Per KWH

(±) Costs for overloaded plant include extra raw sewage pumping and aeration energy, solids handling and chemicals.

TABLE 5. OXIDATION DITCH PLANT - ANNUAL OPERATION MAINTENANCE REQUIREMENTS, 1976

Plant Capacity, MGD	LABOR		ENERGY		Maint. Mat., $1000	Chemicals, $1000	Total, $1000		
	Hours	$1000 (*)	1000 KWH	$1000 (+)			Normal Load	50% Overload (±)	100% Overload (±)
0.05	1,756	15.8	46	1.4	0.7	0.5	18.4	21.8	23.9
0.10	2,000	18.0	72	2.2	1.0	0.7	21.9	27.6	31.0
0.50	3,044	27.4	280	8.4	2.7	2.2	40.7	60.9	72.0
1.00	4,156	37.4	500	15.0	4.2	4.7	61.3	95.8	113.9
3.00	9,200	82.8	1,200	36.0	10.0	13.0	141.8	223.8	265.4
5.00	15,200	136.8	2,000	60.0	17.5	25.0	239.3	362.9	423.3
10.00	30,400	273.6	3,200	96.0	30.0	50.0	449.6	665.5	769.0

(*) At $9.00 Per Hour

(+) At $0.03 Per KWH

(±) Costs for overloaded plant include extra raw sewage pumping and aeration energy, solids handling and chemicals.

TABLE 6. CONVENTIONAL ACTIVATED SLUDGE - ANNUAL OPERATION MAINTENANCE REQUIREMENTS, 1976

Plant Capacity, MGD	LABOR Hours	LABOR $1000 (*)	ENERGY 1000 KWH	ENERGY $1000 (+)	Maint. Mat., $1000	Chemicals, $1000	Total, $1000 Normal Load	Total, $1000 50% Overload (±)	Total, $1000 100% Overload (±)
0.5	4,300	38.7	433	13.0	9.0	2.0	62.7	82.9	114.0
1.0	5,498	49.5	548	16.4	11.7	4.0	81.6	116.1	134.2
3.0	10,000	90.0	1,200	36.0	18.0	11.0	155.0	237.0	278.6
5.0	15,000	135.0	1,875	56.2	24.7	20.0	235.9	358.5	419.9
10.0	25,000	225.0	3,653	109.6	36.1	45.0	415.7	631.6	751.1

(*) At $9.00 Per Hour

(+) At $0.03 Per KWH

(±) Costs for overloaded plant include extra raw sewage pumping and aeration energy, solids handling and chemicals.

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